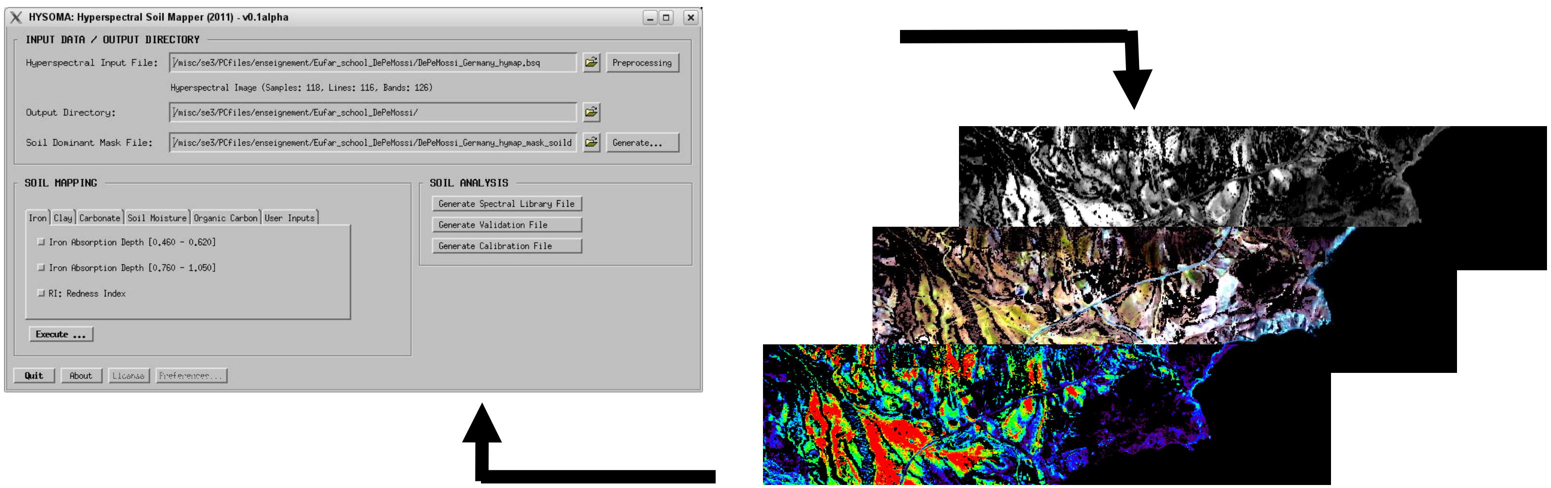
# The HYperspectral SOil MApper (HYSOMA)

*Sabine Chabrillat, GFZ*




***N4EWG12 - Hyperspectral Applications for Soil***

***DePeMossi Workshop - August 29-31, 2011 – GFZ Potsdam, Germany***

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# Agenda

- **Introduction**
  - Context
  - Litterature: Methods from soil spectroscopy to imaging spectroscopy
  - Development strategy

- **HYSOMA structure and methods**
  - Conceptual framework
  - Graphical User Interface
  - Overview of soil mapping methods
  - Overview of soil analyses tools
  - Software availability/terms of use

- **Some examples: Validation of the HYSOMA**

- **Exercises**

## Introduction

- **Increasing demand nowadays for the availability/ accessibility of hyperspectral soil products from „non-expert“ hyperspectral users**

- **Call for development of automatic toolboxes for the quantification of chemical and physical soil properties based on spectral reflectance**

- **High relevance**
  - EUFAR project
  - Preparation of the future satellite hyperspectral missions
  - ..

→ Can we develop automatic algorithms for soil mapping based on spectral reflectance?

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# EUFAR- European Facility for Airborne Research



## EUFAR

*Integrating Activity of the EC FP7*


***Budget 8 M€ Duration 4 years (2008-2012) 32 Partners***

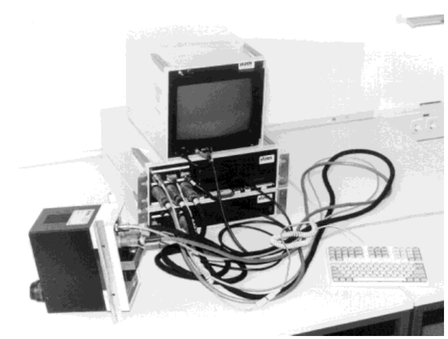
***6 instruments and 21 aircraft open to Trans-national Access***

***www.eufar.net***


Courtesy I. Reussen

# HyperSpectral Imaging sensors open to TA

| Operator | Instrument |
|---|---|
| VITO | APEX |
| DLR | ROSIS |
| NERC | Eagle/Hawk |
| INTA | AHS/CASI1500i |
| FUB | CASI2 |



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# EUFAR Activities

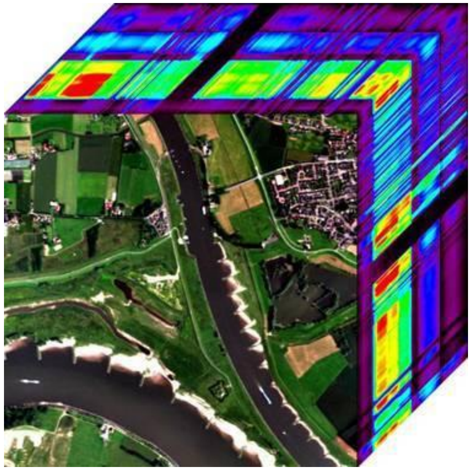
- **Networking Activities – 2 M€**
  - **N1.** Scientific Advisory Committee (N1SAC-CNRM)
  - **N2.** Transnational Access coordination (N2TAC-MetOffice)
  - **N3.** Future of the Fleet (N3FF-Jülich)
  - **N4.** Expert Working Groups (N4EWG-ULEI)
  - **N5.** Education and Training (N5ET-VITO)
  - **N6.** Standards and Protocols (N6SP-DLR)
  - **N7.** Airborne Data Base (N7DB-STFC)
  - **N8.** E-Communication (N8EC-CNRM)
  - **N9.** Sustainable structure (N9SST-CNRM)

- **Transnational Activities (TA) – 3 M€**

- **Joint Research Activities (JRA) – 2,4 M€**
  - **JRA1.** Development and evaluation of new and improved hygrometers for airborne research (DENCHAR-Jülich)
  - **JRA2.** Quality layers for airborne hyperspectral imagery and data products (HYQUAPRO-VITO)
  - **JRA3.** Airborne Laser Interferometric Drop Sizer (ALIDS-IRSN)

# JRA2 - Quality layers for airborne hyperspectral imagery and data products (HYQUAPRO)

- **Objectives**:
  - To develop quality indicators and quality layers for airborne hyperspectral imagery
  - To develop quality indicators and quality layers for higher level data products
  - To implement and to test quality layers in existing processing chains of airborne hyperspectral imagery
  - To develop higher performing water and soil algorithms as demonstrators for end-to-end processing chains with harmonized quality measures



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# Objectives

- **Complex processing and interpretation of imaging spectroscopy for geo-applications, little attractive to new users**

- **In task 4: Development higher performing soil algorithms as demonstrators for end-to-end processing chains with harmonized measures**
  - Delivery of soil products to users based on higher performing robust algorithms integrated in existing processing chains
  - As a demonstrator, further improvement and implementation of existing algorithms for soil products to provide standardized data products, attractive to new users who do not have expertise or software

- **GFZ: Expertise in hyperspectral applications in related geo-sciences and soil products**

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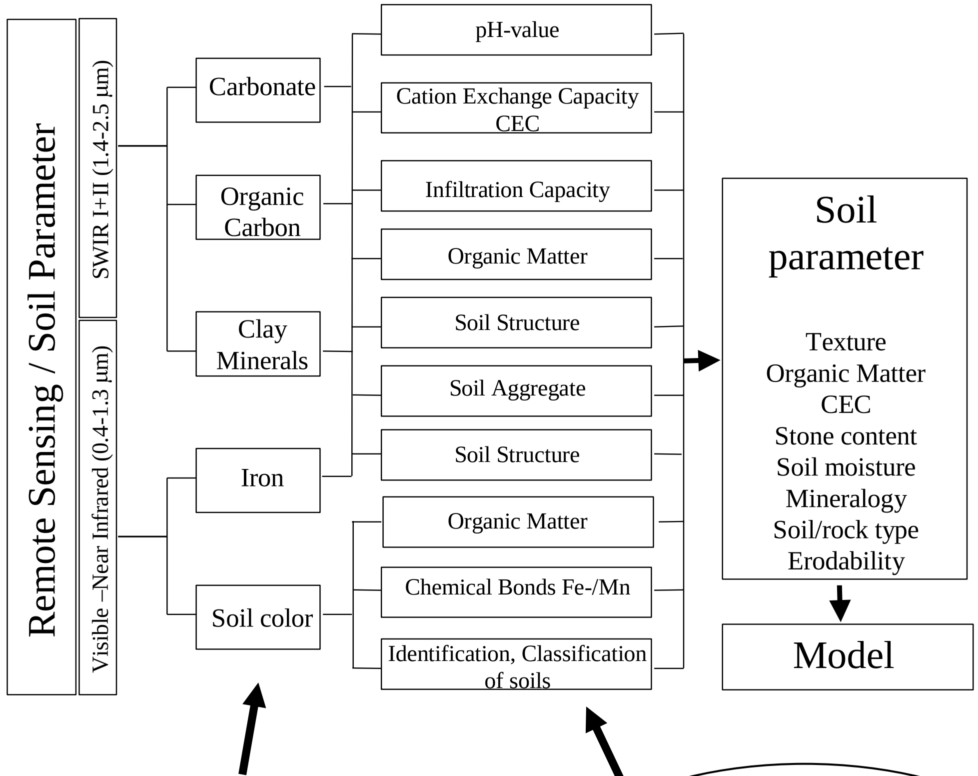
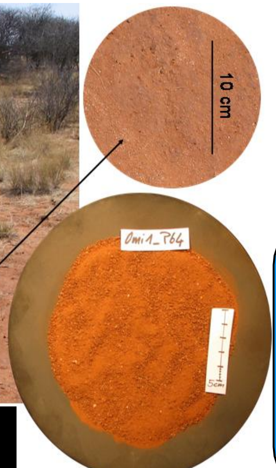
# Soil Parameters accessible with VNIR-SWIR spectroscopy

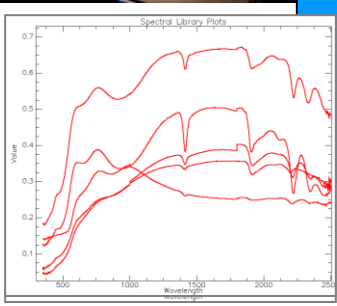



**Primary Properties; Directly linked; With a theoretical basis for prediction from spectroscopy**

**Secondary properties; Derived in a detour via the Correlation with one or more of the primary properties !!Even though they do not respond directly to VIS-NIR-SWIR wavelength!!**

# Literature review on existing methods for extraction of soil information



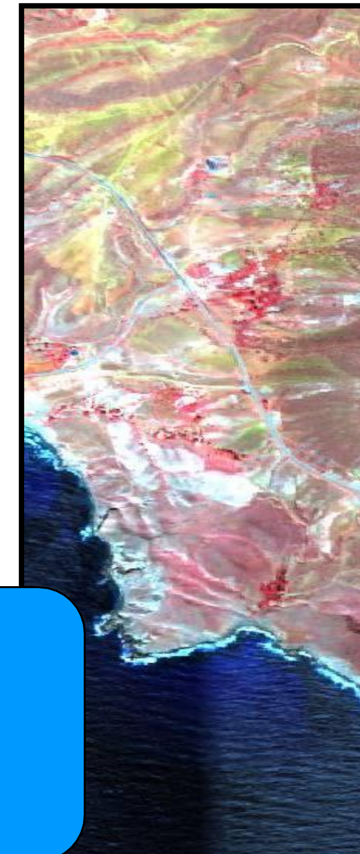

Methods in

A
Spectroscopy

B
Imaging
Spectroscopy

Coming from …

..going to …



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# Studies On Spectroscopy

A → Quantitative estimates on pedochemical parameters on the basis of **field and laboratory spectroscopic technique** have been demonstrated by many authors:

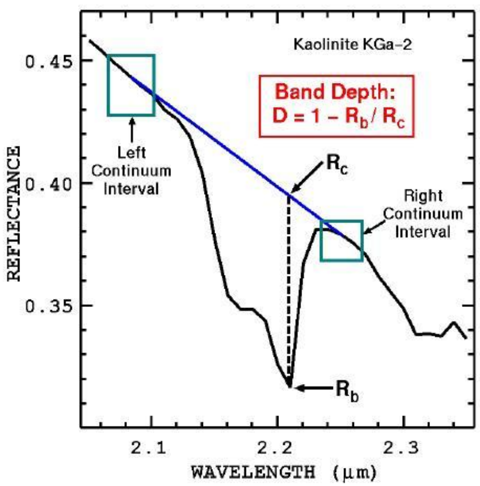
**Soil Parameters**

- **Clay**
  - Chabrillat et al (2002)
  - Goetz & Chabrillat (2001)
  - Duke, 1994
  - Ben-Dor
- **Carbonates**
  - Ben-Dor
  - Van der Meer, 1994
  - Kruse, 1988
- **Iron**
  - Richter et al (2009)
  - Ben-Dor & Banin (1990)
  - Escadafal (1994)
  - Sheperd and Walsh (2002)
  - Cloutis et al (1986)
- **Salt**
  - Ben-Dor (1999)
  - Ben-Dor (2002)
  - Metternicht&Zink (1997,2003)
  - Taylor et al (1994)
- **Organic Matter**
  - Ben-Dor et al (1997)
  - Vinogradov (1981
  - Schreier (1977)
- **Soil Moisture**
  - Whiting (2004)
  - Lobell & Asner (2002)
  - Weidong (2002,2003)

Courtesy A. Eisele

# Empirical relationship with samples

These techniques, after several spectral manipulation techniques, often make use of absorption feature characteristics (e.g., absorption-band wavelength position, depth and asymmetry), which are combined with geochemical analysis in a multi-linear regression to find empirical relationships with chemistry of a sample




Material

Shape

Position

**Identification**

Depth, area..

**Quantification**

# Studies on Imaging Spectroscopy

**B → There are various techniques to process hyperspectral imagery in order to obtain soil surface compositional information on a pixel by pixel basis:**

**Soil Parameters**

- **Clay**
  - Chabrillat & Goetz (2006)
  - Chabrillat et al (2002)
  - Ben-Dor et al (2002)
  - Bourguignon et al (2007)
  - Kariuki (1999)
- **Carbonates**
  - Ben-Dor ()
  - Jarmer (2005)
  - Jarmer et al (2007)
- **Iron**
  - Bartholomeus (2007)
  - Richter et al (2007)
- **Salt**
  - Taylor et al (2001)
  - Dehaan & Taylor (2002,2003)
  - Taylor (2004)
- **Organic Matter**
  - Jarmer et al (2005)
  - Stevens (2006)
- **Soil Moisture**
  - Whiting (2005)
  - Haubrock et al (2008)

# State of the art – Research

| | *Topic* | *Approach* | *Bio-, geochemical & physical Variables*<br>*Pre-product* | *End-Product* |
|---|---|---|---|---|
| G<br>E<br>O<br>S<br>P<br>H<br>E<br>R<br>E | Soils | - Spectral Feature Fitting based on empirical/(physic.) models – SFF (i, n)<br>– Linear/non-linear spectral mixture analyses - SMA (d, i, n)<br>– Multiple, non-linear regress. (a)<br>– Neural networks (i)<br>– Spectral matching (i) | – Soil mineral abundance<br>– Vegetation abundance<br>– Soil parent material type<br>– Dry matter (lignin/cellulose)<br>– Soil condition indices (e.g., clay/carbonate ratio)<br>– Mineral abundance<br>– Water content | – Top soil constituents maps (organic matter, minerals, texture classes<br>– Soil cover/vegetation maps<br>– Soil condition/degradation maps<br>– Degradation trend maps<br>– Land management decision support systems |

[1)] Approach: developed (d); to be adapted (a); to be improved (i); to be newly developed (n)

Source: EnMap

# Review of soil algorithms: Physical vs. Empirical modelling

- **Pure physical modelling**
  - Methods: BRDF-radiative transfert modeling, electronic and vibrational transitions theory
  - Output: soil-leaving reflectance, calculations of absorption features
  - Comment: limited, not available for whole soils and rocks

- **Empirical modelling**
  - Methods: PLS, MLR, SVM
  - Output: quantitative determination of pure mineral content
  - Comment: need pre-knowledge (in-situ soil data, training vectors)

- **Physical modelling (Analytical approaches)- selection**
  - Spectral mixture analyses
  - Spectrum modelling (MGM)
  - Spectral Band fitting (SFF/Tetracorder®), spectral matching (SAM, MTMF)
  - Spectral band analyses/modelling (cont. rem., Band depth/areas, ..)
  - Spectral indices

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# Review of soil algorithms

⇨ schematic ordering of methodologies in terms of development status and pre-knowledge needed

| Algorithm | Output | Status | Pre-knowledge needed |
|---|---|---|---|
| **BRDF-Radiative Transfer modeling** | Soil-leaving reflectance | n/a | Soil geometry, illumination, albedo |
| **Electronic and vibrational transitions theory** | Calculation of absorption features | n/a | Molecule structure, replacement ion, energy fields |
| **Spectral Mixture Analyses** | Abundance image fraction. Quantification of soil type | r | Endmember selection or spectral library |
| **Spectral Feature Fitting** | Mineral identification | r | Spectral library |
| **Modified Gaussian Modeling** | Quantification of soil biophysical properties | r-fdn | - |
| **ENVI classification techniques** | Mineral identification (SAM) or quantification (MF) | r | Endmember selection |
| **Spectral Indices** | Semi-quantification of soil minerals or soil biophysical properties | r | - |
| **Statistical Regression Analysis (LR, PLS)** | Quantification of soil type, soil minerals, soil biophysical properties | r | In-situ data |
| **Artificial Neural Network, SVM** | Quantification of soil minerals, soil types | r-fdn | Learning/traning vectors |

*n/a non available; r robust; fdn further development needed*
*Source: EUFAR Deliverable DJ241 March 2010*

# The HYperspectral Soil MApper (HYSOMA) (1)

## Main motivation

- To provide non-expert hyperspectral users with a suite of tools for soil applications

## Criteria of developments (literature review + expert workshop)

- Use of methodology where automation is possible
- Choice of multiple algorithms by the users
- Addition: Implementation of a user custom option to incorporate user-driven applications and more quantitative mapping

## Focus

- Identification and semi-quantification of key soil parameters
  - Soil moisture and soil organic matter
  - Mineral occurence mapping (iron oxide, clay minerals, carbonates)
- No need of user input data (e.g. spectral libraries, ground truth)

# The HYperspectral Soil MApper (HYSOMA) (2)

- **Software interface developed in IDL language**
  - IDL widely used in the hyperspectral community Cf ENVI
  - Can be executed without an IDL license as a binary version .SAV file using a free IDL virtual machine (Linux, MacOS, Windows..)
  - Easy implementation in DLR processing chain

- **Stand alone software**
  - GUI interface oriented for non-expert users
  - Block programmation for handling of large datafile
  - Multi-processor capabilities for fast calculations
  - Configuration as XML files

# The HYperspectral Soil MApper (HYSOMA) (3)

- **Incorporates**
  - Easy-to-use graphical interface based on simple menu-driven functions

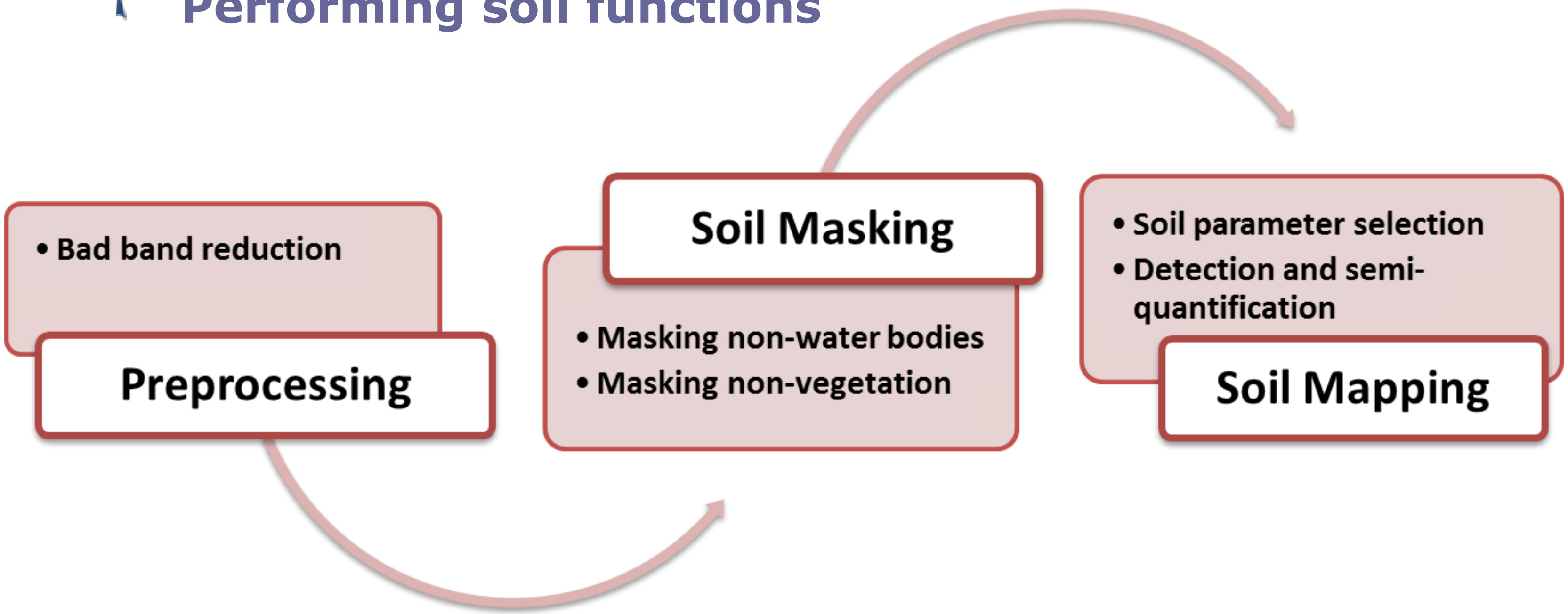
  - Soil functions based on analytical and empirical algorithms
    - Spectral feature analyses method (Continuum calculations, band depth, areas, ..)
    - Spectral indices from the literature
    - Gaussian modelling (Soil Moisture Gaussian Modelling method from Whiting)

  - User custom options for fully quantitative soil mapping (experts-request)
    - User-driven spectral feature analyses
    - Using users own spectral-based models (PLS equation)

    - Soil Analyses Tools
      - Input field measurements for calibration
      - Extraction of spectral library
      - Extraction of derived soil attributes

# HYSOMA conceptual framework

- Input: Basic image file import based on ENVI format
- Soil mask option removing water and vegetation pixels
- Performing soil functions

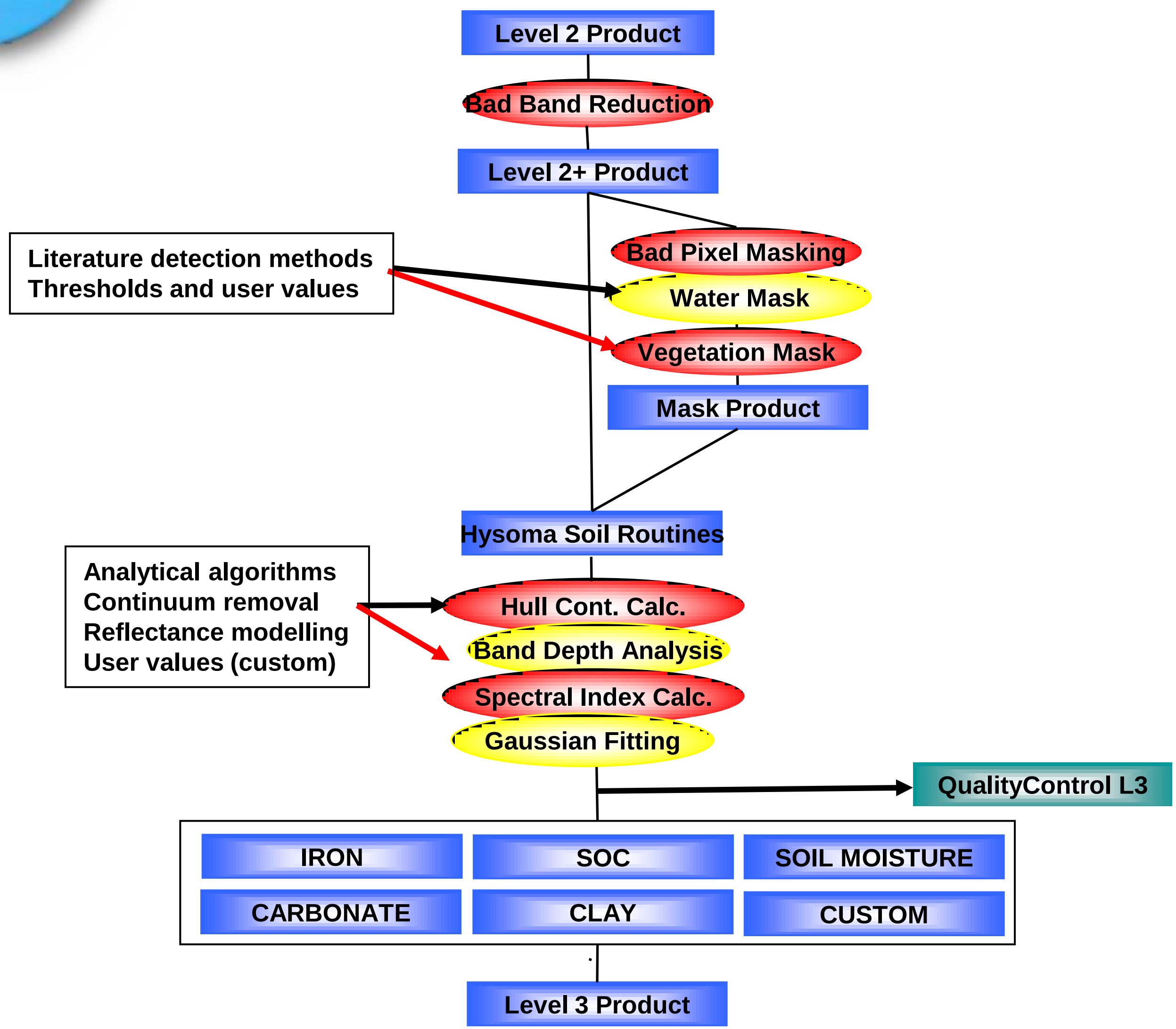


# HYSOMA: Data formats

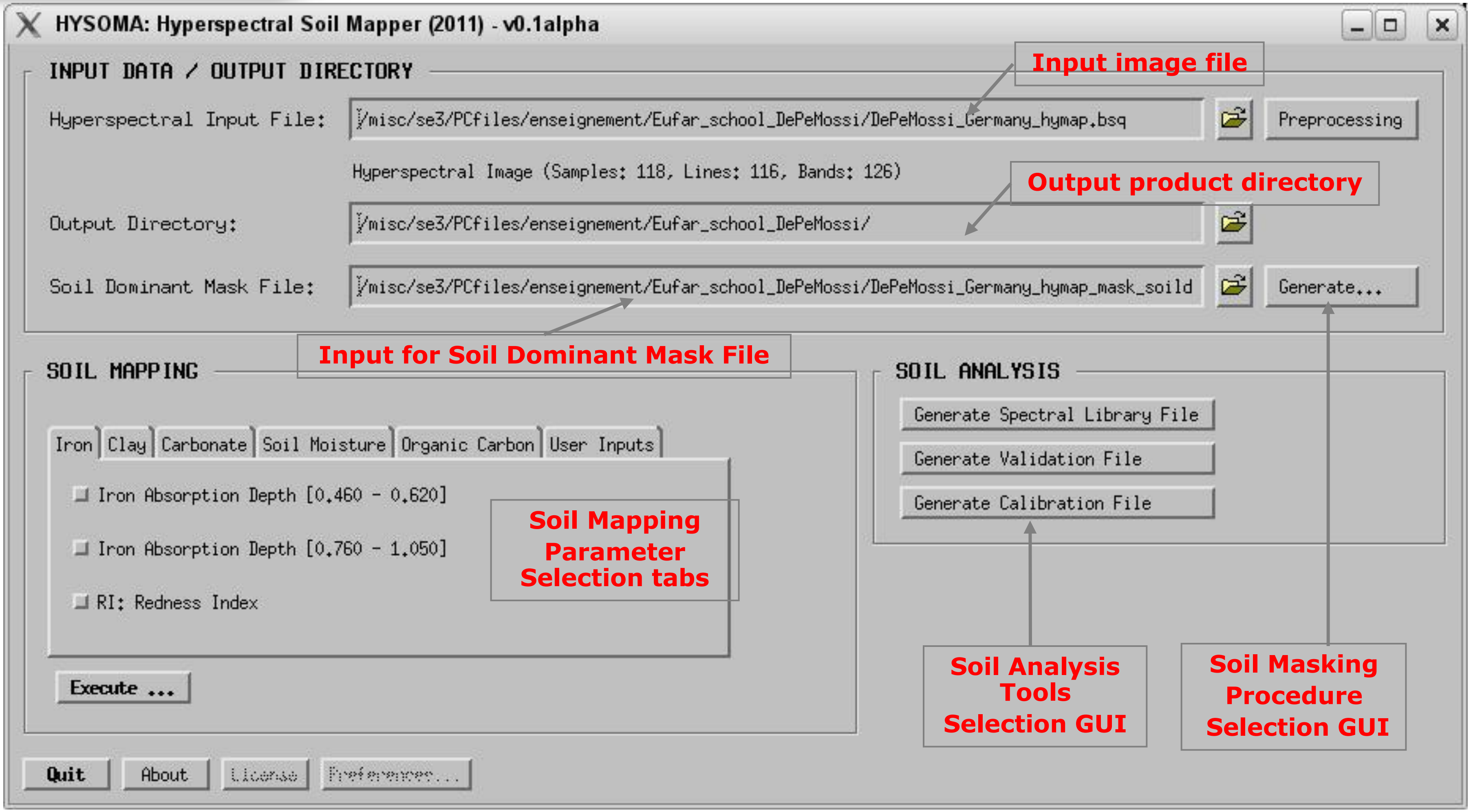
- **Input: L2 product**
  - Ortho-rectified ground reflectance, corrected for terrain illumination effects, as integer values, scaled to 10.000 (=100% reflectance), Flat binary BSQ format, ENVI header
  - Standard HDF5 format
  - Quality Layers according to harmonized EUFAR standard (QC_overall, QC_water)
  - Also possible: input spectral library (envi format)

- **Ouput: L3 products**
  - One file for each soil map
  - Format: ENVI, floating point
  - Automatic names based on image name+ Suffix
  - Quality Layers for soil product (QC_soil)

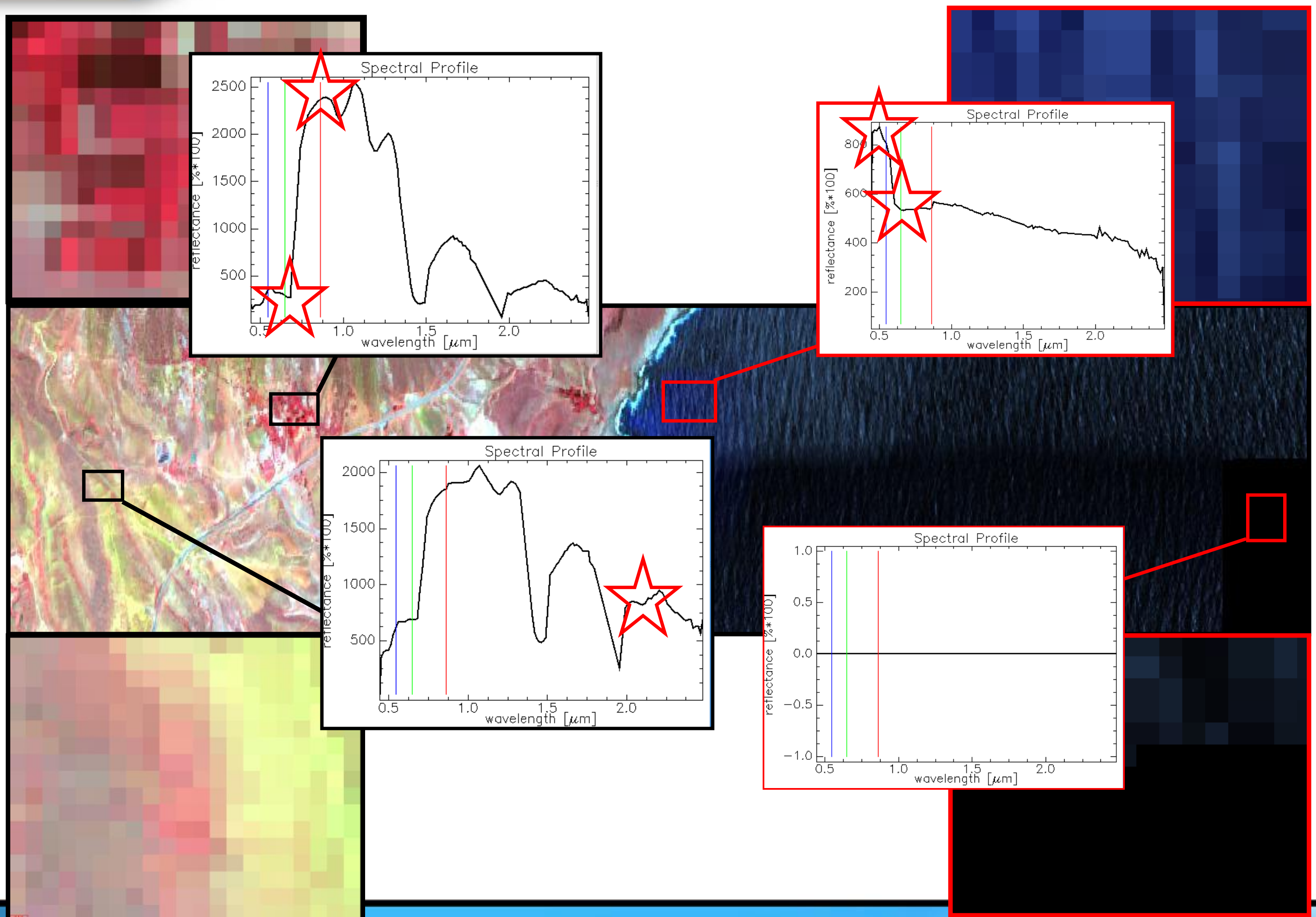
# HYSOMA: From ortho-rectified reflectance to soil attributes maps



# HYSOMA main GUI



# Workflow of getting spectrally soil dominant pixels (1)



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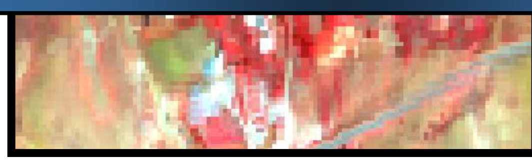
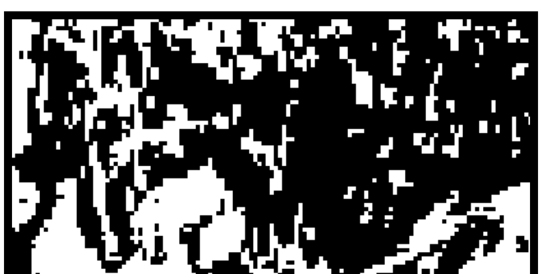
# Workflow of getting spectrally soil dominant pixels (2)

$$NDVI = \frac{(R_{800} - R_{670})}{(R_{800} + R_{670})}$$

$$ARVI = \frac{\rho_{NIR} - (2\rho_{RED} - \rho_{BLUE})}{\rho_{NIR} + (2\rho_{RED} - \rho_{BLUE})}$$

$$EVI = 2.5\left(\frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + 6\rho_{RED} - 7.5\rho_{BLUE} + 1}\right)$$





PIXEL

*Mask as „not a number!"*

No data / NaN mask

$$= \frac{1/2(R_{2000} + R_{2200}) - R_{2100}}{1/2(R_{2000} + R_{2200}) + R_{2100}}$$

Green Vegetation mask

Dry Vegetation mask

Merging masks

Spectrally soil dominant PIXELS

# HYSOMA soil functions: Overview

## Identification and semi-quantification

| Soil chromophores | Soil algorithm | Spectral Region (nm) | Estimated soil parameters |
|---|---|---|---|
| **Clay Minerals** Al-OH content | Clay index (SWIR FI) | 2209, 2133, 2225 | Clay mineral content (Levin et al., 2007) |
| | Clay absorption depth | 2120 - 2250 | Clay mineral content |
| **Iron Oxides** $Fe_2O_3$ content | Iron index (RI) | 477, 556, 693 | Hematite content (Madeira et al., 1997 ; Matthieu et al., 1998) |
| | Iron absorption depth 1 | 450 - 630 | Iron oxide content |
| | Iron absorption depth 2 | 750 - 1040 | Iron oxide content |
| **Carbonates** Mg-OH content | Carbonate absorption depth | 2300 - 2400 | Carbonate content |
| **Soil Moisture Content** | Moisture index (NSMI) | 1800, 2119 | Soil moisture content (Haubrock et al. 2008a, 2008b) |
| | Gaussian modelling (SMGM) | ~1500-2500 | Soil moisture content (Whiting et al. 2004) |
| **Soil Organic Carbon** | Band analysis SOC 1 | 400 - 700 | Organic matter content (Bartholomeus et al., 2008) |
| | Band analysis SOC 2 | 400 , 600 | Organic matter content (Bartholomeus et al., 2008) |
| | Band analysis SOC 3 | 2138 - 2209 | Indirect organic matter content (Bartholomeus et al., 2008) |

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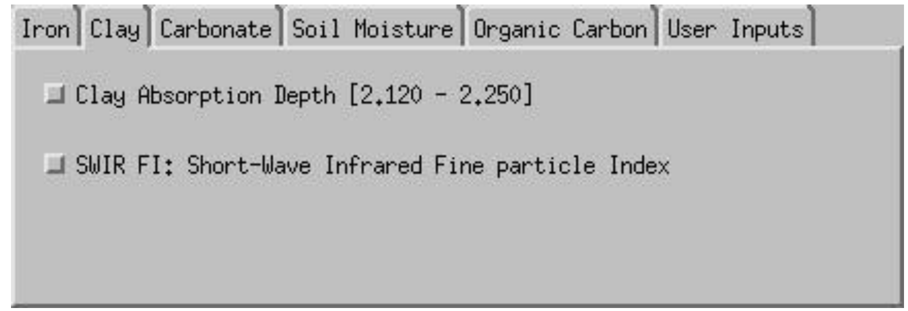
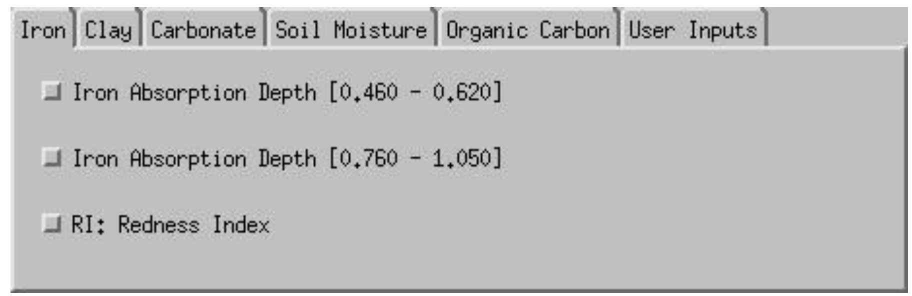
# HYSOMA soil functions

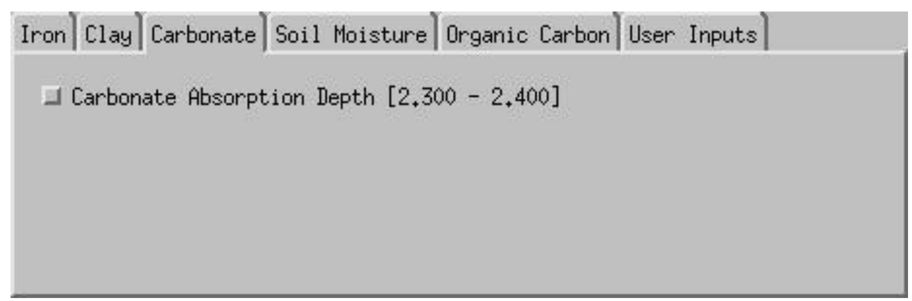
- **Clay Minerals - Al-OH content**
  - Clay CRAD 1 (2120 - 2250nm)
  - Clay Index (*Levin et al., 2007*)




- **Iron Oxides - $Fe_2O_3$ content**
  - Iron CRAD 1 (450 – 630nm)
  - Iron CRAD 2 (750 – 1040nm)
  - Iron Index (*Mathieu et al. 1998*)

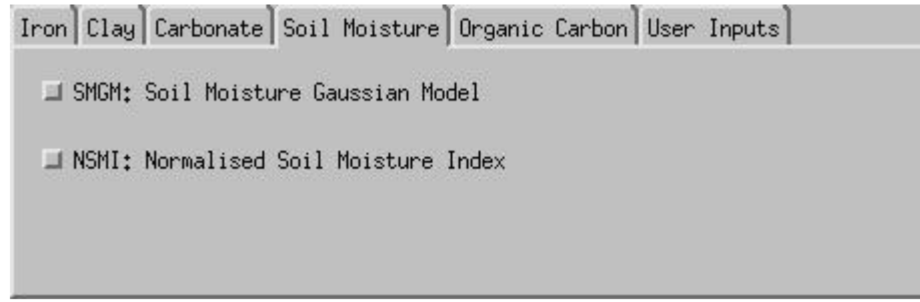



- **Carbonates - Mg-OH content**
  - Carbonate CRAD (2300 – 2400nm)

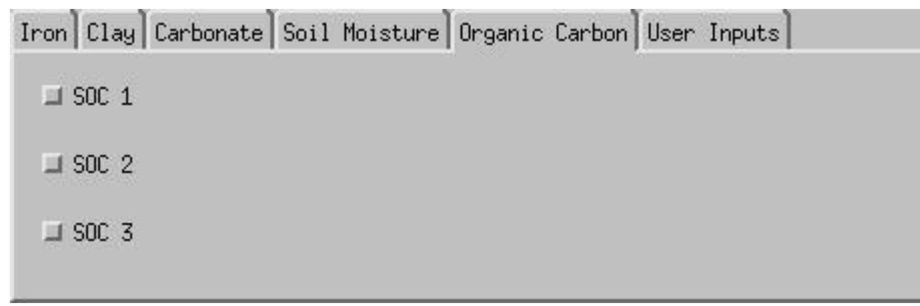


# HYSOMA soil functions

- **Soil Moisture content**
  - SMGM (Whiting et al. 2004)
  - NSMI (Haubrock et al. 2008)




- **Soil Organic Carbon**
  - SOC 1 (*Bartholomeus et. al., 2008)*
  - *SOC 2 (Bartholomeus et. al., 2008)*
  - *SOC 3 (Bartholomeus et. al., 2008)*



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# Soil Algorithms

## Spectral Soil Algorithms I

- Redness Index (RI)

$$Iron-Index = \frac{(R_{693})^2}{(R_{477})*(R_{556})^3}$$

- Clay Index (SWIR FI)

$$Clay-Index = \frac{(R_{2133})^2}{(R_{2225})*(R_{2209})^3}$$

- Normalized Soil Moisture Index (NSMI)

$$NSMI = \frac{(R_{1800}-R_{2119})}{(R_{1800}+R_{2119})}$$

- Surface Soil Moisture (SMGM)

after *Whiting et al. (2004)*

$$A = R_d \sigma \sqrt{\frac{\pi}{2}} * erf\left(\frac{\lambda_0 - \lambda_i}{\sqrt{2*\sigma}}\right)$$

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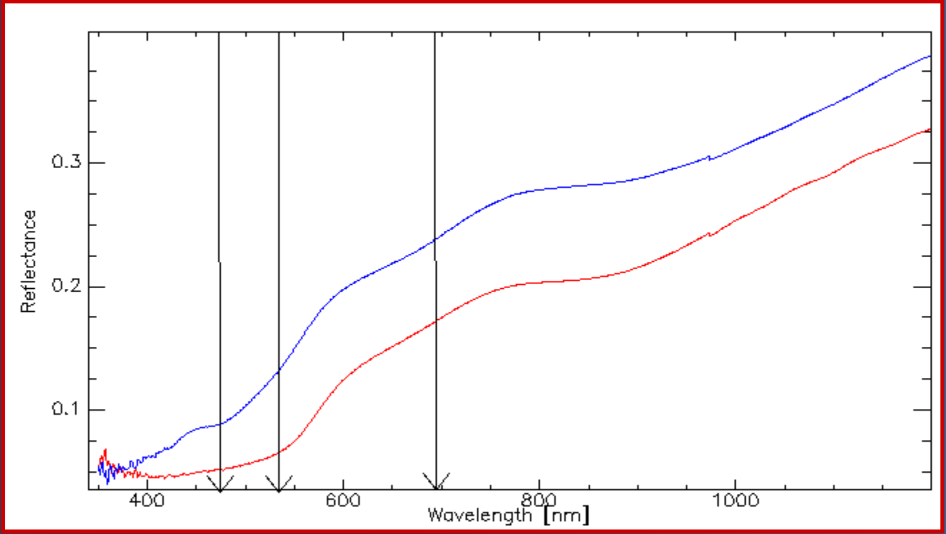

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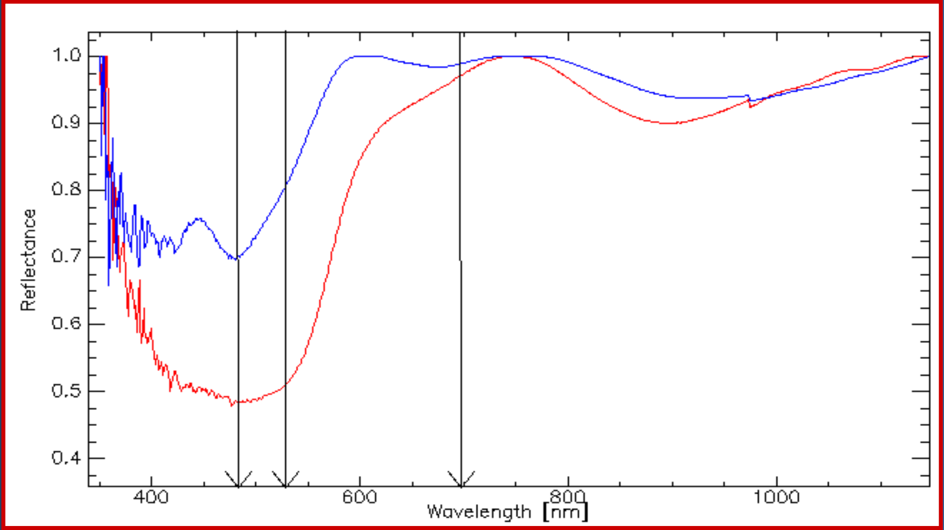

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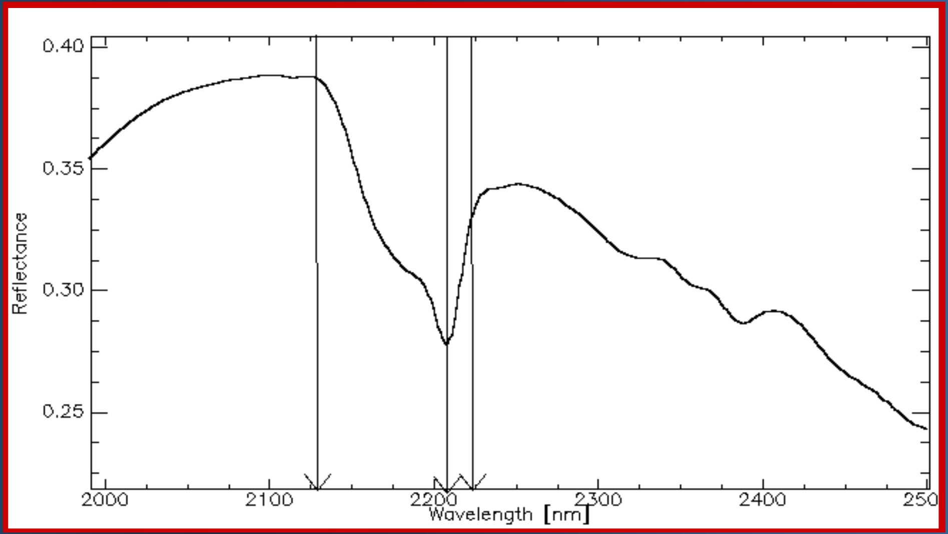

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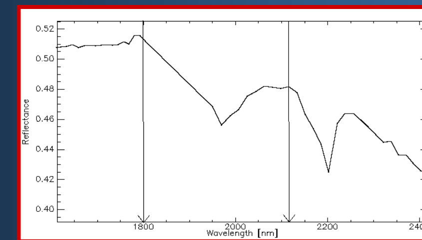


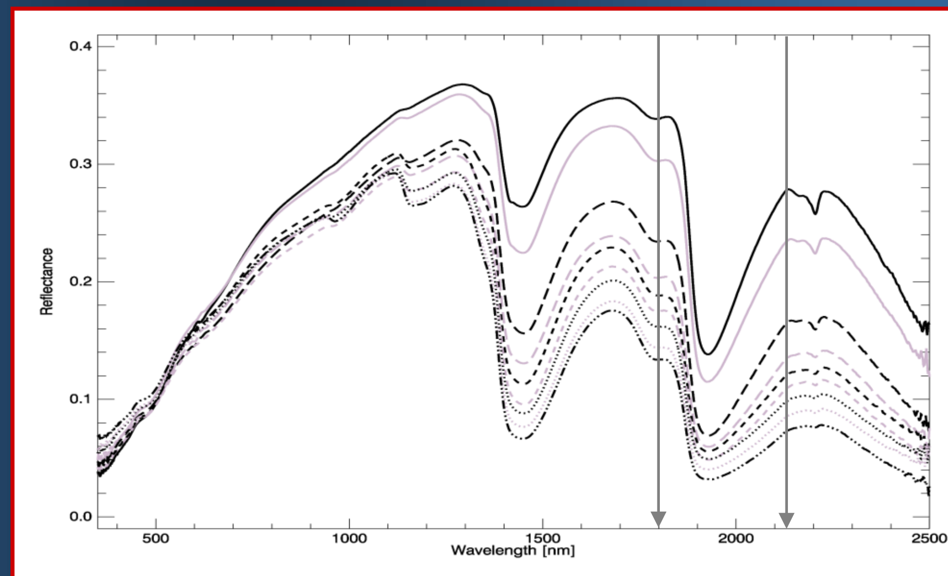

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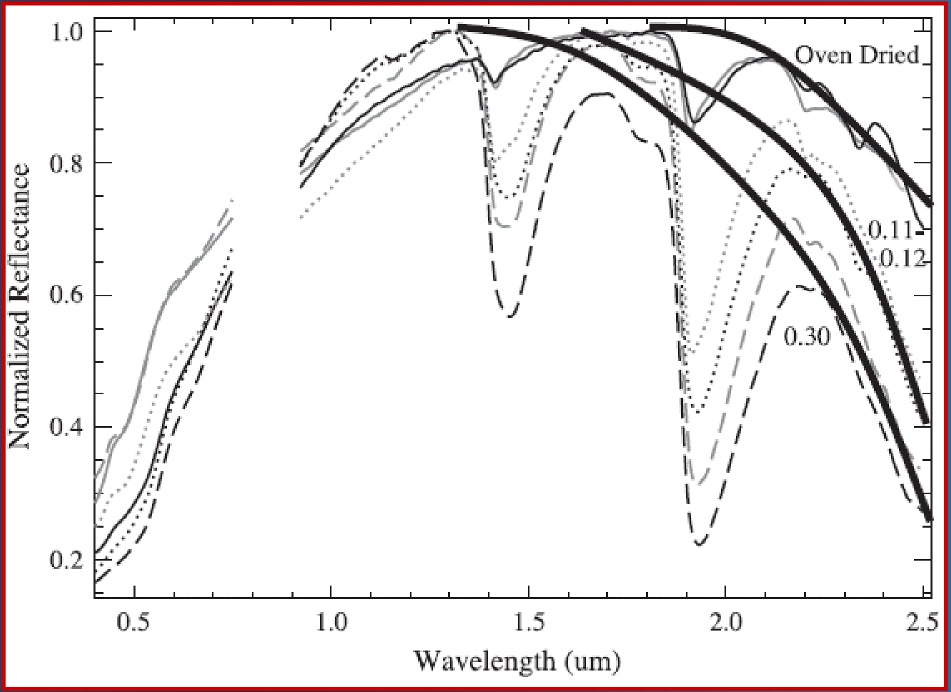
- Normalized Soil Moisture Index (NSMI)

$$NSMI = \frac{(R_{1800} - R_{2119})}{(R_{1800} + R_{2119})}$$

- Surface Soil Moisture (SMGM)

after *Whiting et al. (2004)*

$$A = R_d \sigma \sqrt{\frac{\pi}{2}} * erf\left(\frac{\lambda_0 - \lambda_i}{\sqrt{2*\sigma}}\right)$$



# Soil Algorithms

**Spectral Soil Algorithms I**

- Redness Index (RI)

$$Iron-Index = \frac{(R_{693})^2}{(R_{477}) * (R_{556})^3}$$

- Clay Index (SWIR FI)

$$Clay-Index = \frac{(R_{2133})^2}{(R_{2225}) * (R_{2209})^3}$$

- Normalized Soil Moisture Index (NSMI)

$$NSMI = \frac{(R_{1800} - R_{2119})}{(R_{1800} + R_{2119})}$$

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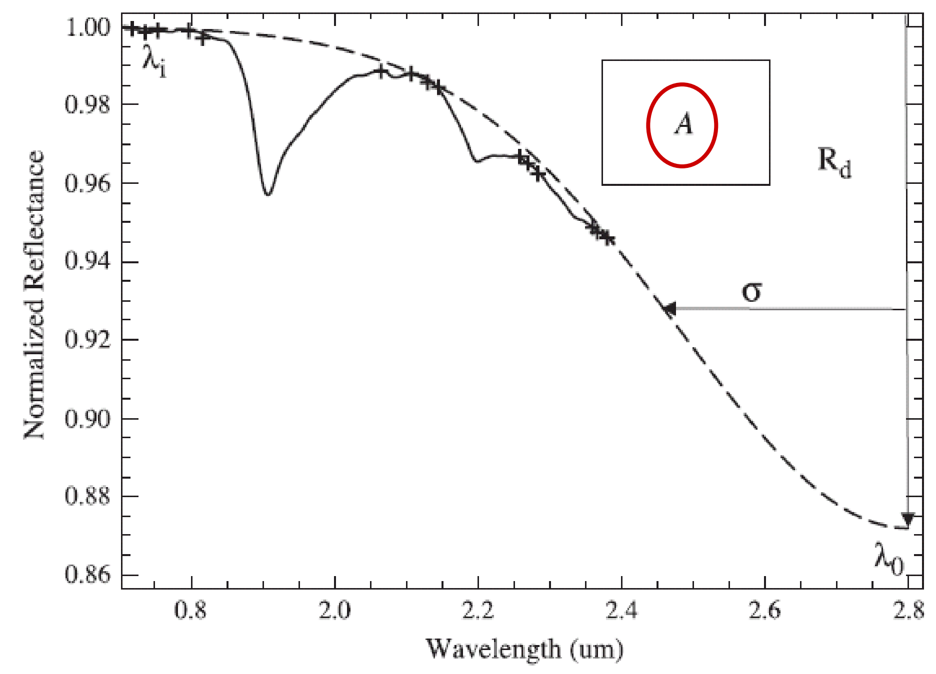


# Soil Algorithms

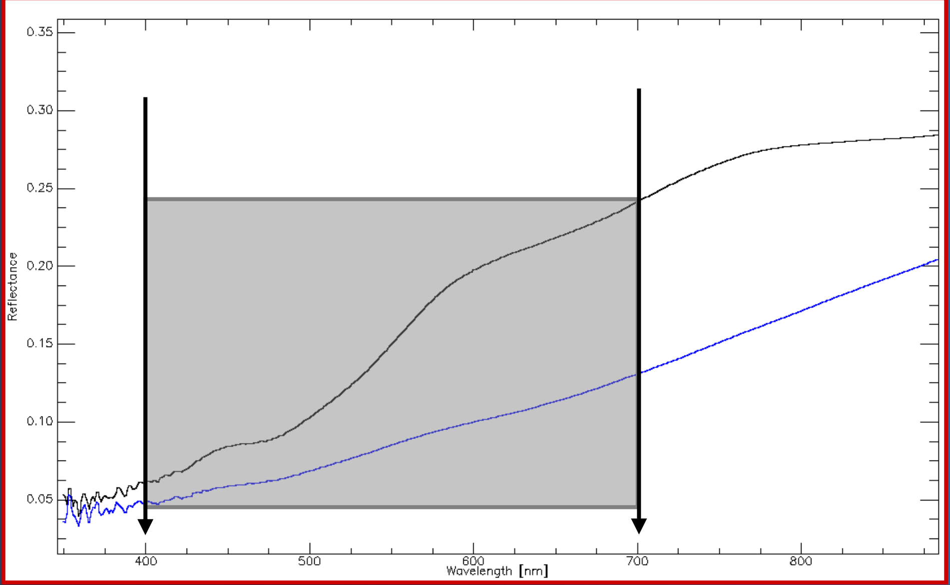
## Spectral Soil Algorithms II

- Soil Organic Carbon

$$SOC1 = \frac{1}{\sum_{400-700}(CR - R)}$$

$$SOC2 = \frac{1}{slope(R_{400-600})}$$

$$SOC3 = \frac{1}{slope(R_{2138-2209})}$$



# Soil Algorithms

## Spectral Soil Algorithms II

- Soil Organic Carbon

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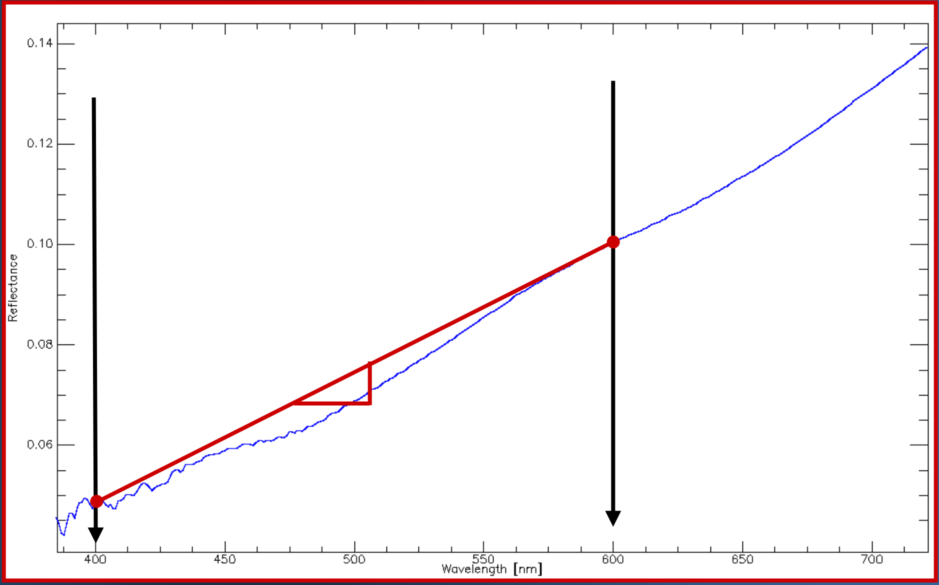

# Soil Algorithms

**Spectral Soil Algorithms II**

- Soil Organic Carbon

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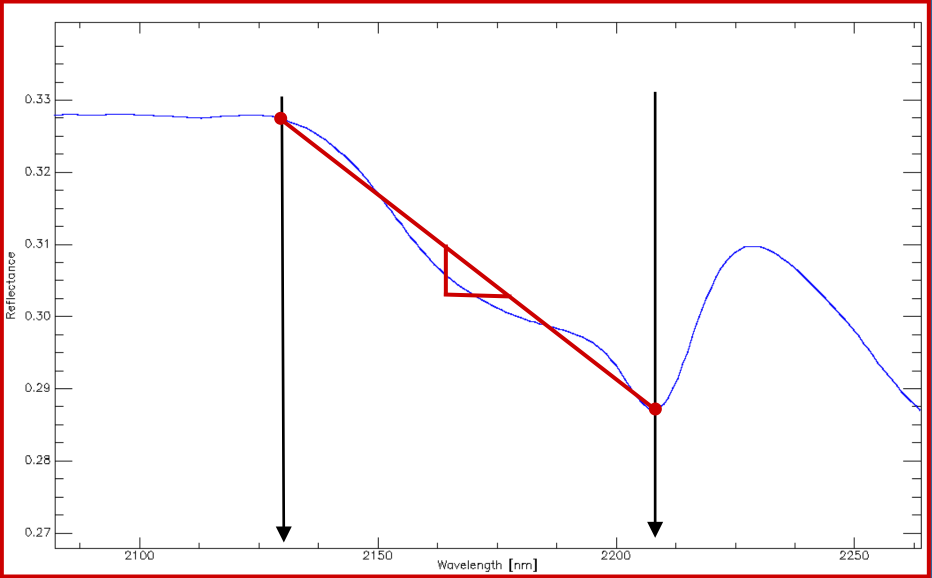
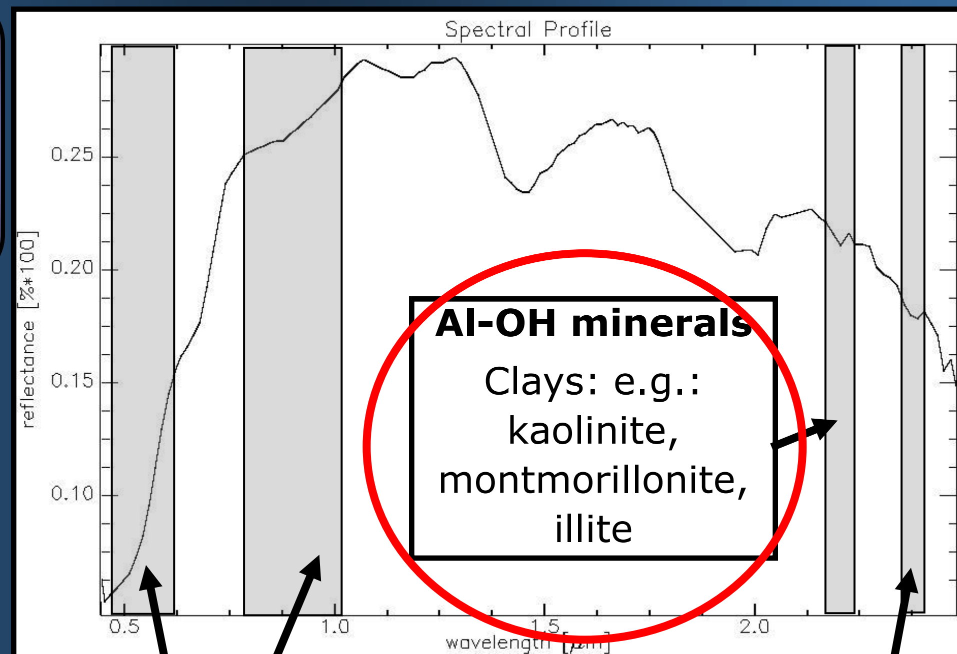


# Soil Algorithms

**HYSOMA Spectral Feature Analyses: Hull function Max Abs depth**




**$Fe^{3+}$(ferric) minerals**

Iron oxides:

e.g.: hematite, goethite, jarosite, “limonite”

**Mg-OH minerals**

Carbonates:

e.g.: calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$)

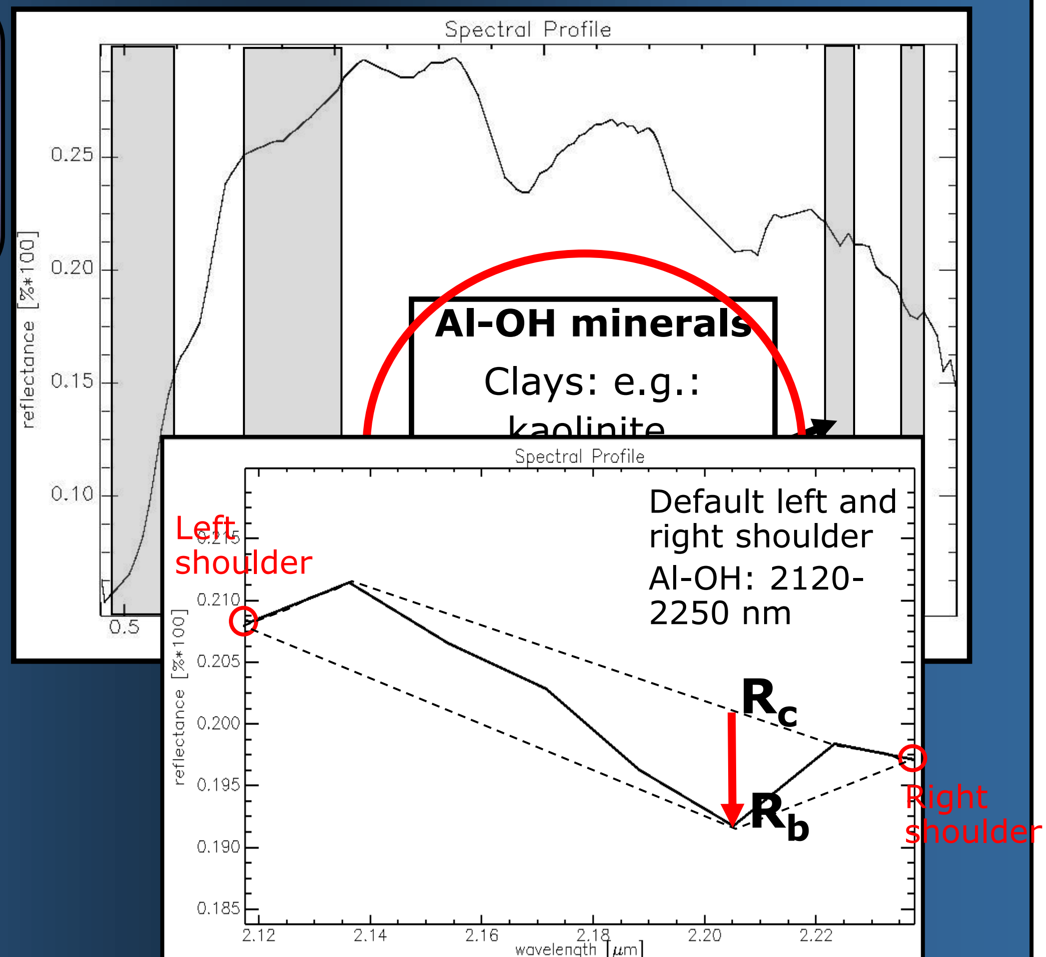
# Soil Algorithms

**HYSOMA Spectral Feature Analyses:**
**Hull function**
**Max Abs depth**

- Left/right shoulders: Define a <u>maximum</u> frame

- Cont. Removed Abs Depth – CRAD at the absorption maximum

$$\mathbf{CRAD_{\lambda} = 1 - R_b/R_c}$$



# Soil Quality Layer

**Determine range of error of soil mapping**

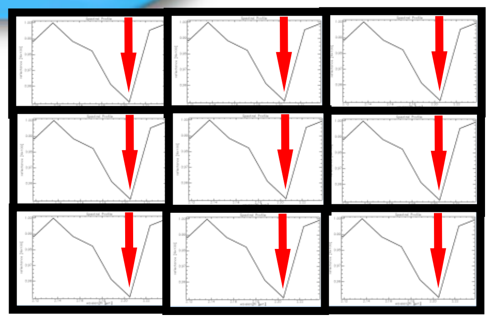
- Standard Format EUFAR quality layers: 3 levels of accuracy
  - Nominal accuracy
  - Reduced accuracy
  - Low accuracy
- Based on 4 parameters
  - Pre-processing overall quality layer (QC_overall, EUFAR standard) if available
  - Vegetation coverage (both green and dry vegetation)
  - Soil moisture content

# HYSOMA output files

| Soil chromophores | Soil algorithm | Spectral region (nm) | File name (Suffix)* |
|---|---|---|---|
| **Iron oxydes**<br>**$Fe_2O_3$ content** | RI (Redness Index) | 477, 556, 693 | *_Iron_RI* |
| | Iron CRAD 1 | 460 – 620 | *_Iron_CRAD_460_620* |
| | Iron CRAD 2 | 760 – 1050 | *_Iron_CRAD_760_1050* |
| **Clay Minerals**<br>**Al-OH content** | SWIR FI (Fine particule Index) | 2209, 2133, 2225 | *_Clay_SWIRFI* |
| | Clay CRAD | 2120 – 2250 | *_Clay_CRAD_2120_2250* |
| **Carbonates**<br>**Mg-OH content** | Carbonates CRAD | 2300 – 2400 | *_Carbonate_CRAD_2300_2400* |
| **Soil moisture content** | NSMI (Normalised Soil Moisture Index) | 1800, 2119 | *_Moisture_NSMI* |
| | SMGM (Soil Moisture Gaussian Modeling) | ~1500 – 2500 | *_Moisture_SMGM* |
| **Soil Organic Carbon content** | SOC 1 | 400 – 700 | *_SOC1* |
| | SOC 2 | 400, 600 | *_SOC2* |
| | SOC 3 | 2138, 2209 | *_SOC3* |
| **Soil Quality Layer** | Water mask, green/dry veg, soil moisture, pre-processing overall EUFAR quality layer | all | *_QC_Soil* |

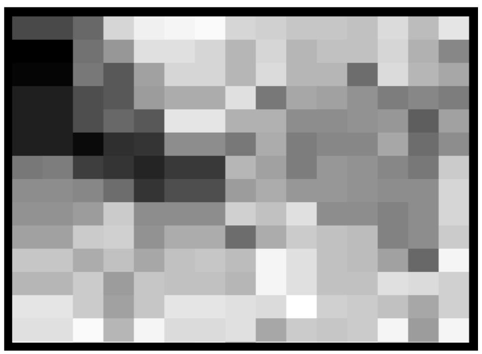
**Full file names: basename+suffix*

# Mapping the results



| | | |
|---|---|---|
| 0.138 | 0.789 | 0.003 |
| 0.222 | 0.265 | 0.987 |
| 0.789 | 0.878 | 0.333 |

**$CRAD_\lambda$ for relative Al-OH abundance**



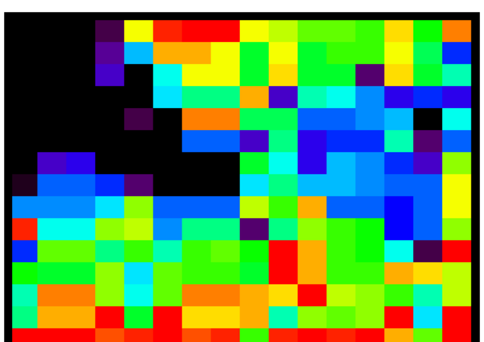
$CRAD_\lambda$

Min. Max.

Stretch CRADs to 8bit grey values to Visualize zB ENVI

Grey values

0 255



**Map of relative Al-OH abundance**

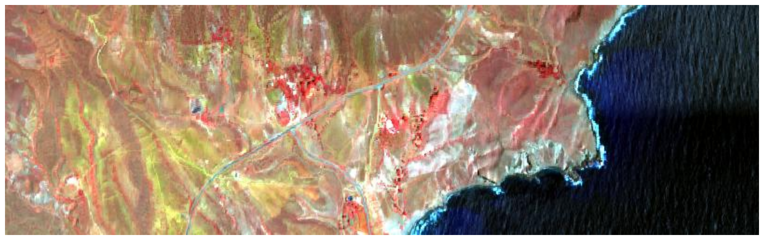
*Color Table*

0  1

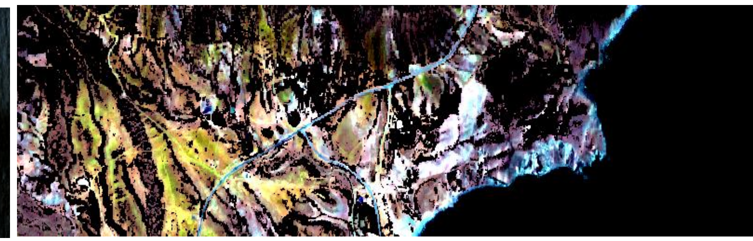
Courtesy A. Eisele

# Some screenshots from HYSOMA results

**Hyperspectral (HyMAP) color infrared scene**
**(Cabo de Gata)**

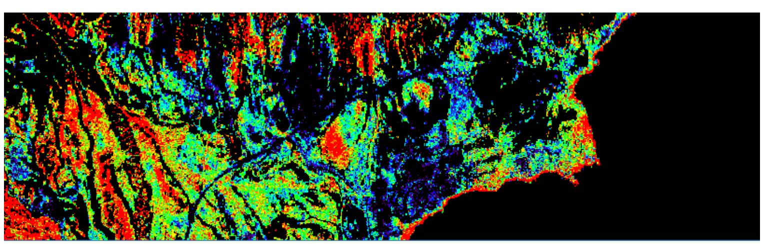


**Spectrally soil dominant pixels**



**Al-OH**

**relative abundance**

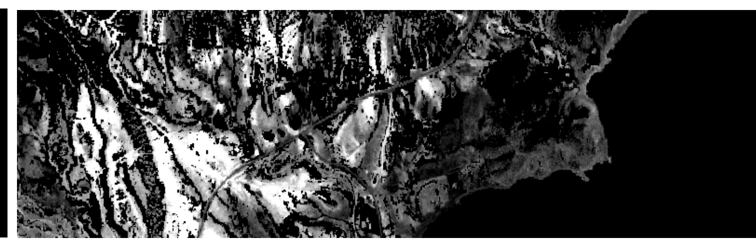


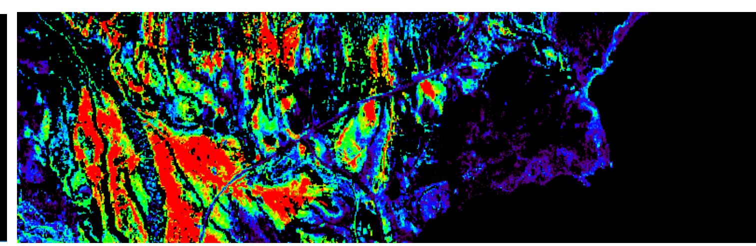
**CRAD$_\lambda$**

0 — 1

**Iron oxides**

**relative abundance**





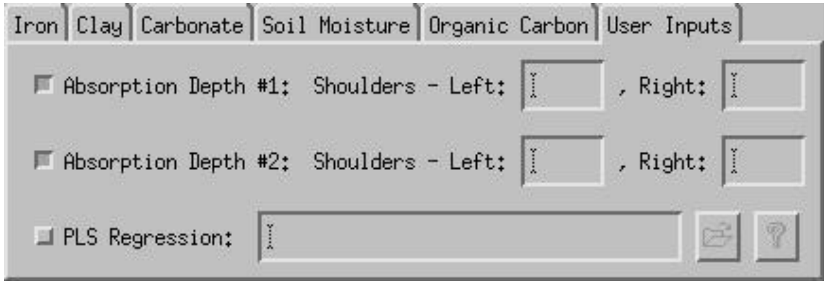
**CRAD$_\lambda$**

0 — 1

# Additional soil functions: User Inputs

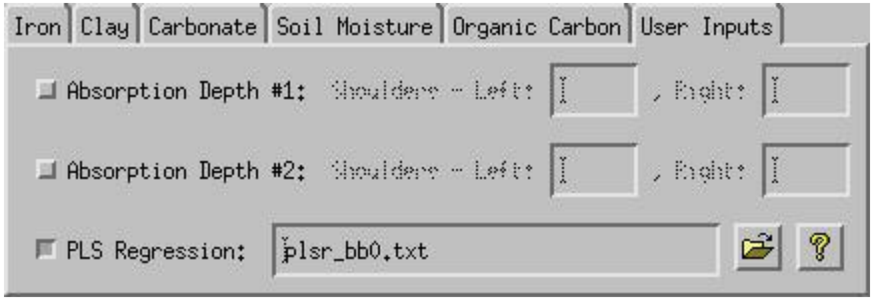
## User input

- Individual Spectral Feature Analyses
- Self defined left-right shoulder
- !! Shoulders are not real shoulder, but should enveloppe your spectral feature!!
- Output: relative abundance map




## Input PLS equation file

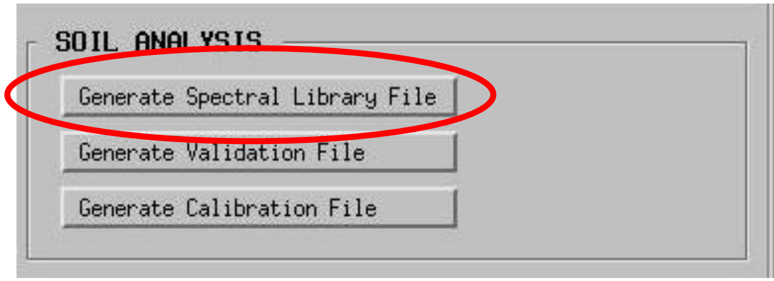
- File format: text (Parles software output)
- 3 columns: lambda, b, b0
- Ouput: Fully quantitative abundance soil maps

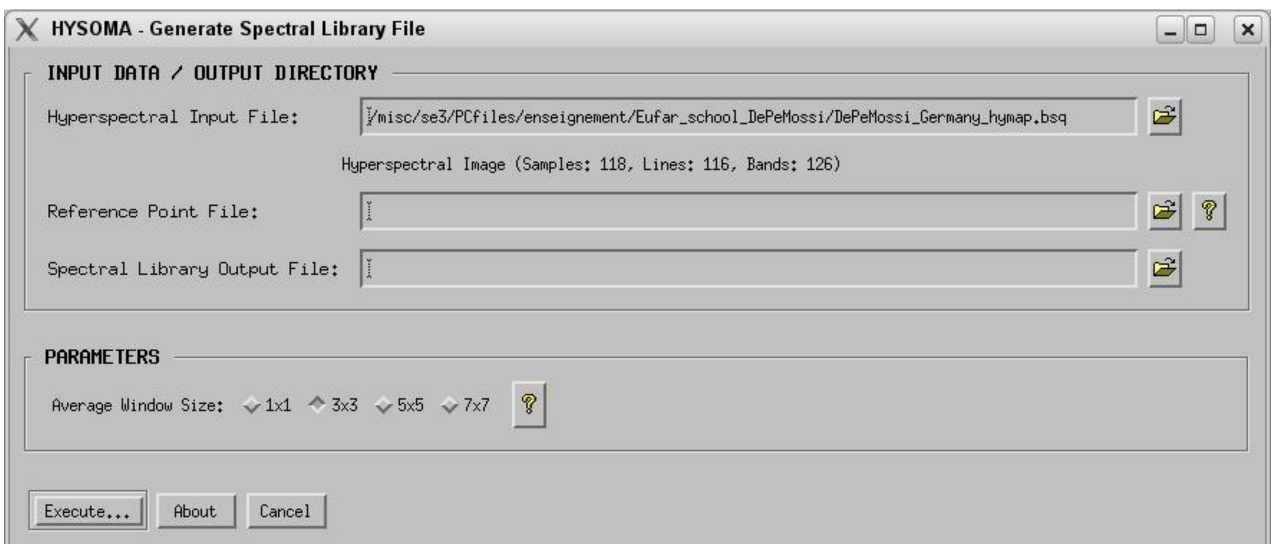


# Soil Analyses Tools

## Generate Spectral Library

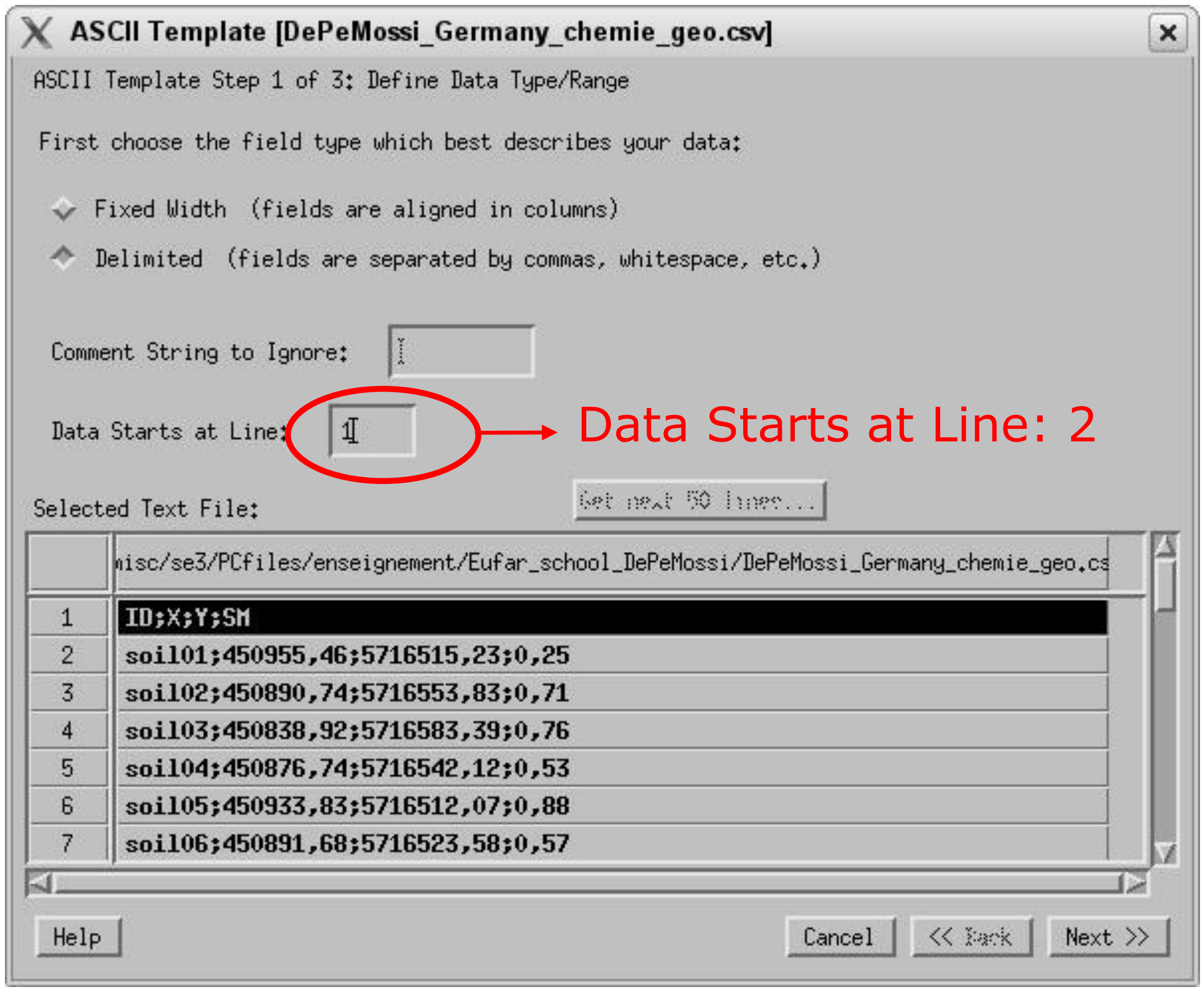
- Extract individual spectra from the image file
- Input: geographic coordinates
  - File format: csv
  - 3 columns: ID, X, Y
- Ouput: spectral library Envi format
- Option: window size



# Soil Analyses Tools

- **Import**



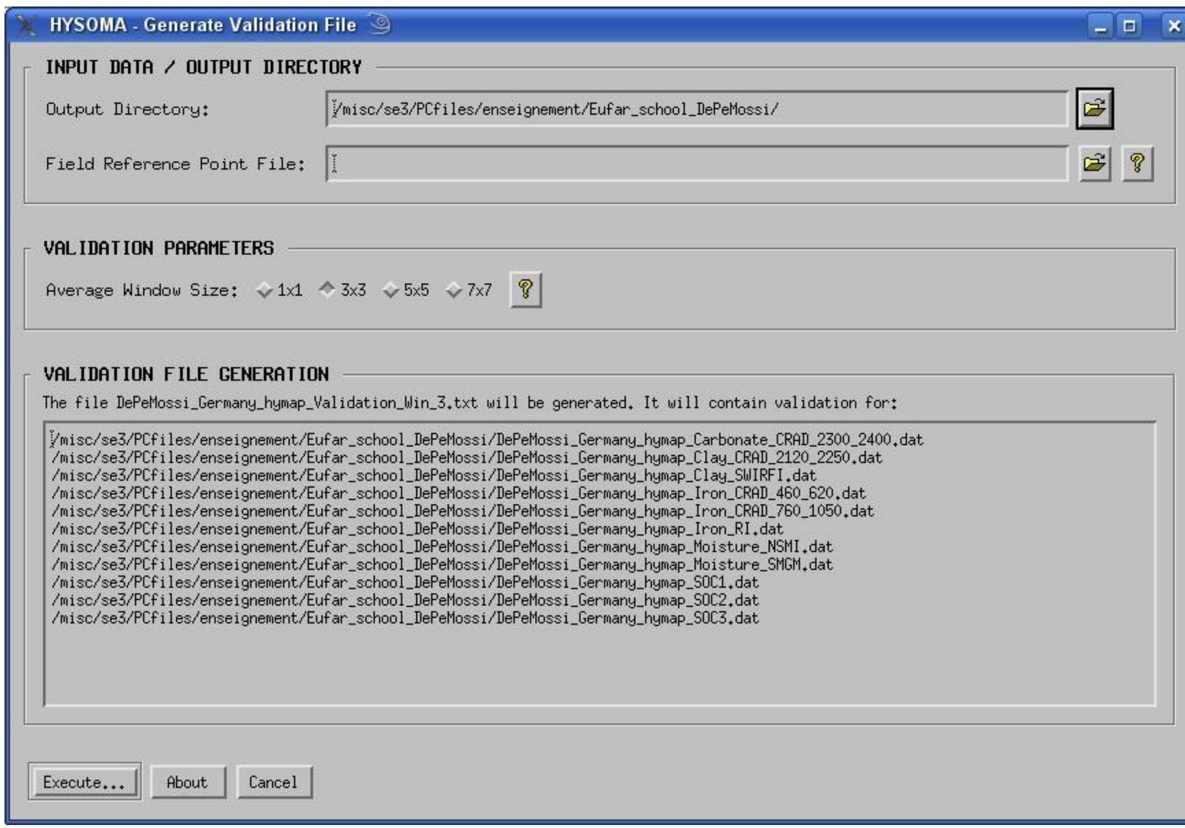
# Soil Analyses Tools

- **Generate Validation file**
  - Extract individual soil parameter values from HYSOMA ouput soil maps (automatic detection of already calculated HYSOMA output files)
  - Input: geographic coordinates of points
    - File format: csv
    - 3 columns minimum: ID, X, Y
  - Ouput: Excell table with Name, X, Y, soil parameters (as many as HYSOMA already calculated soil maps)
  - Option: window size for averaging the soil parameter value extracted

# Soil Analyses Tools

## Generate Validation file

- Extract individual soil parameter values from HYSOMA ouput soil maps (automatic detection of already calculated HYSOMA output files)




ny as

extracted

EUFAR.net European Facility For Airborne Research

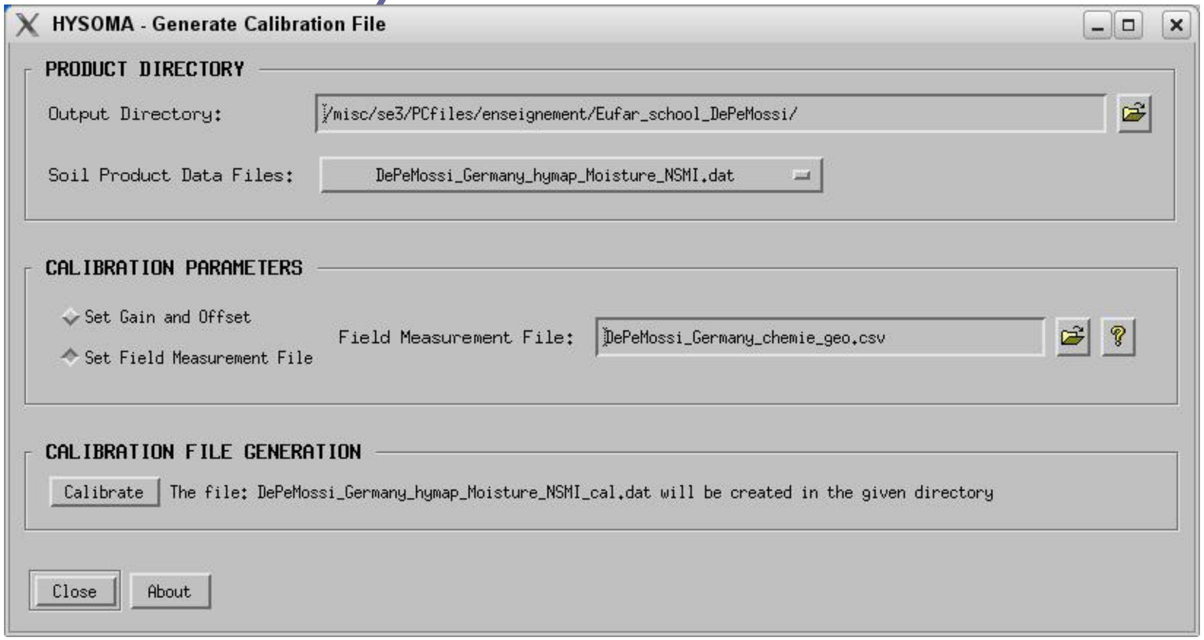
# Soil Analyses Tools

- **Generate Calibration file: Input field measurements for calibration**
  - Perform calibration of an HYSOMA output soil map with field measurements
  - Input: field measurements file or already calculated gain and offset
    - File format: csv
    - 4 columns: ID, X, Y, absolute value of soil parameter
  - Ouput: Fully quantitative abundance soil map file

# Soil Analyses Tools

## Generate Calibration file: Input field measurements for calibration

- Perform calibration of an HYSOMA output soil map with field measurements
- Input: field measurements file or already calculated gain and offset



# Soil Analyses Tools

- **Generate Calibration file: Input field measurements for calibration**
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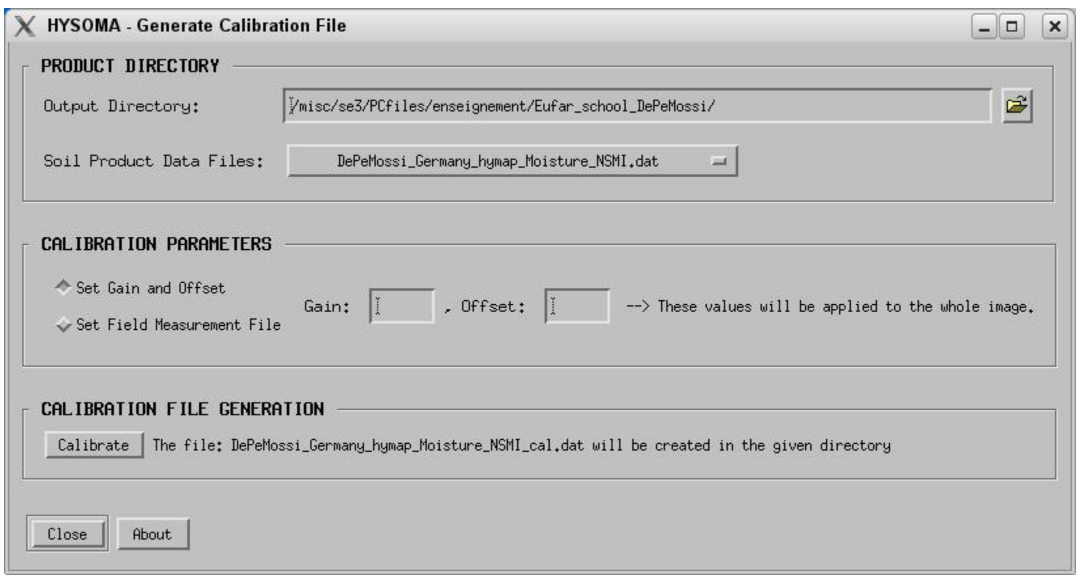
  - Input: field measurements file or already calculated gain and offset




Gain and offset

# Software availability/ Terms of use

## HYSOMA development

- Made at GFZ under the EU-FP7 EUFAR project
- Current prototype in last phase of development
- « HYSOMA_AUTO » integrated in DLR PAF: incorporates all automatic algorithms of HYSOMA

## Some limitations, notes for the future

- Read ENVI, HDF5
- Image visualisation deactivated
- Processing methods fixed

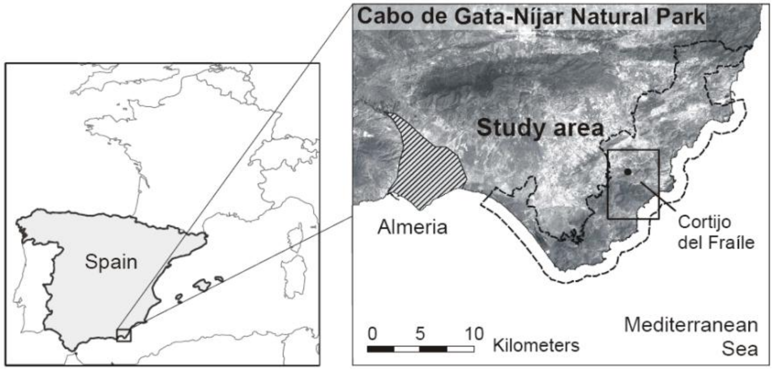
## Distribution

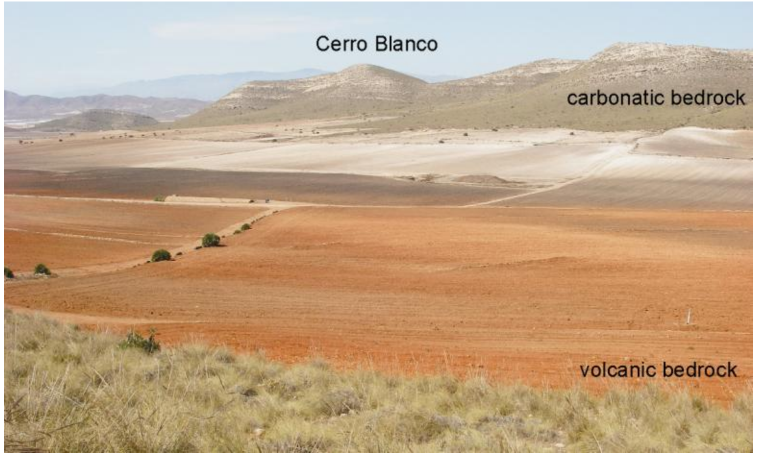
- As pre-compiled version (sav file). IDl license or freely available IDL virtual machine necessary (www.ittivs.com/idlvm)
- Provided free-of-charge via the internet on GFZ web site
- HYSOMA interface will be included in EUFAR toolbox in 2012
- Usage free for non-commercial and educational purposes

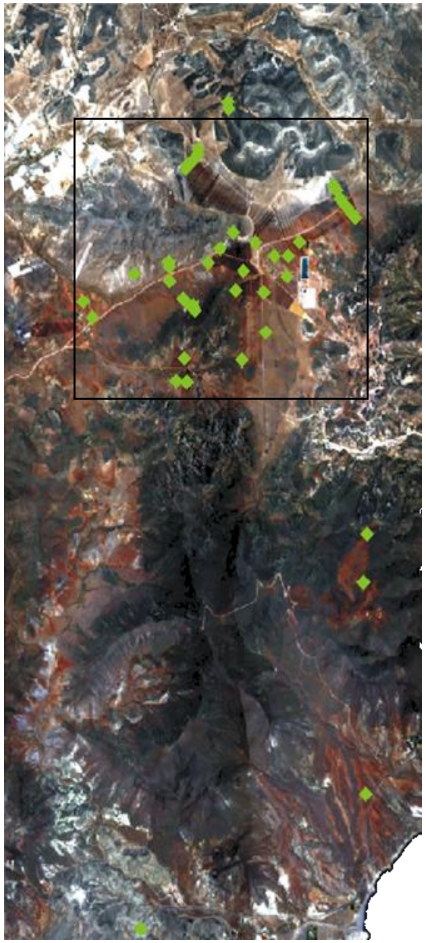
# Test and validation for clay, carbonates and iron estimation

## Cabo de Gata test site (Dr. Nicole Richter, GFZ, UAL, UPM)

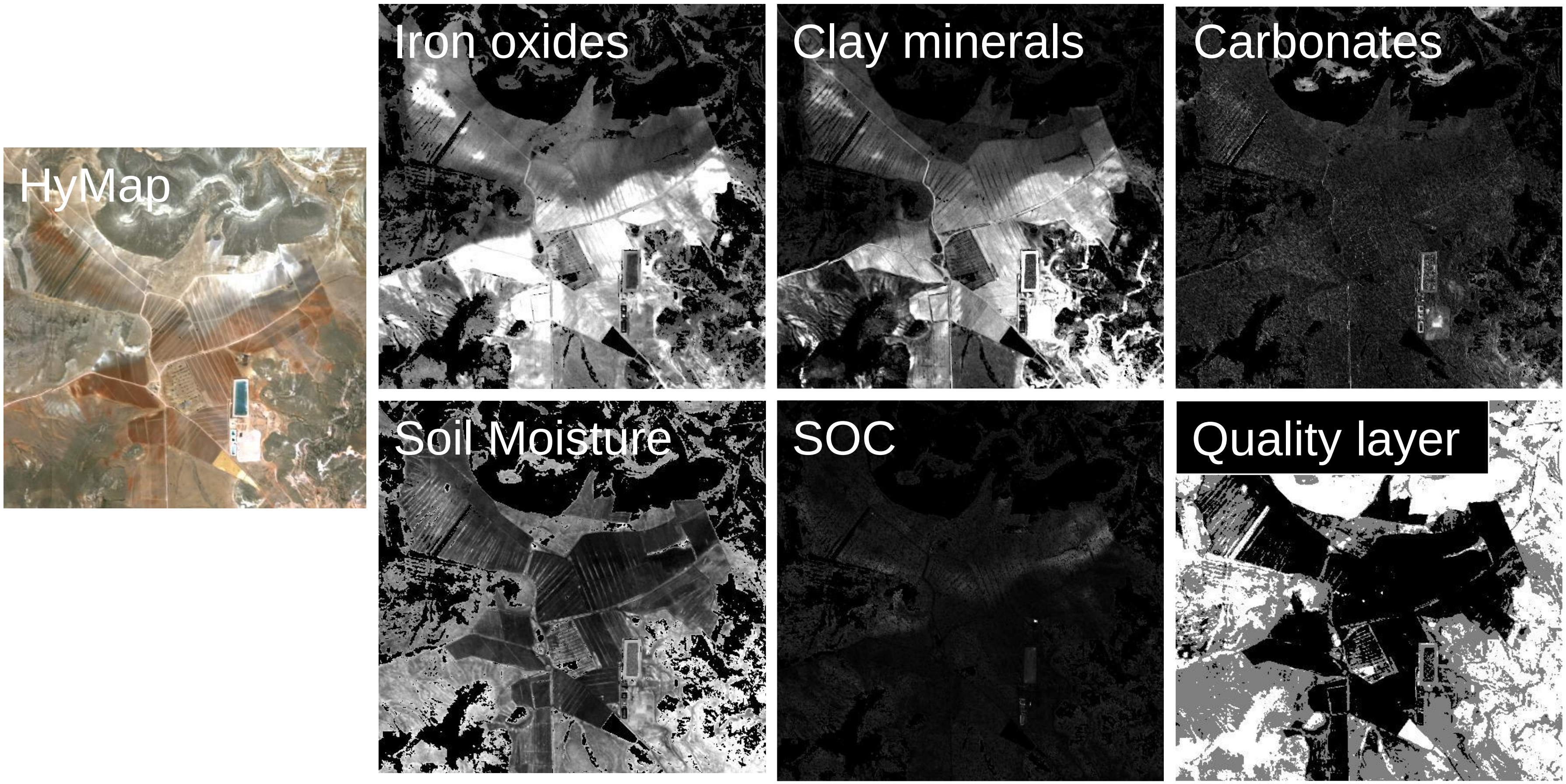
- 50 samples
  - Soil texture
  - CaCO3
  - OC
  - $Fe_d$
- HyMap imagery 20050624



# Some screenshots of HYSOMA soil maps



# HYSOMA: Conclusion (1)

- **Main motivation**
  - To provide non-expert hyperspectral users with a suite of tools for soil applications
- **Stand alone IDL software**
  - Easy implementation in hyperspectral and non-hyperspectral community (distribution under idl- virtual machine)
  - Choice of multiple algorithms for each soil parameter
- **Focus**
  - Fully automatic generation of semi-quantitative soil maps (no need of spectral library, ground truth)
  - Key soil parameters: soil moisture, soil organic matter, iron oxide, clay, carbonates content
  - Soil functions based on analytical and empirical algorithms
  - User custom option for fully quantitative soil mapping

# HYSOMA: Conclusion (2)

- **HYSOMA**
  - Is: Experimental platform for soil mapping applications of hyperspectral imagery
  - Is NOT: Image processing software incl. All methods

- **Results**
  - Hysoma handles well all sensors and input type (.bsq, hdf5)
  - All algorithms checked
  - Qualitative and quantitative in-situ validation of soil products: correlations from $R^2$ of 0.67 (SOC) up to >0.9 (NSMI & SMGM)
    - 3x3 window optimum for cal/val
    - Results consistent with literature
      - NSMI and SMGM both provide good results
      - SOC methods based on spectral indices are more limited – PLS regression mostly used for quantitative SOC mapping
      - Soil products based on spectral band analyses consistent with mineralogical maps
      - Some (inherent) limitations

# HYSOMA: Lessons learned

- **Always much more work to do….**
  - Final tests and validation
  - Add other approaches in the future
  - Software in development!

- **Does Automatisation mean No quantification ?**
  - Did we miss something?
    - → More physically based approaches
    - → Global models vs. local

- **Implementation and future development of soil toolboxes for easy access to L3 geoscience products**
  - Integration in EUFAR toolbox
  - Free distribution

# HYSOMA 2011 - THANK YOU!

- **HYSOMA team at GFZ and TU-Berlin**
  - Andreas Eisele
  - Stéphane Guillaso
  - Christian Rogass
  - Mathias Rösch


- **EUFAR HYQUAPRO partners**
  - Eyal Ben-Dor, TAU
  - Ils Reussen, VITO
  - Martin Bachmann, DLR
  - Steve Groom, PML

- **Collaborating scientists for validation data**
  - Antoine Stevens, UCL Belgium
  - Sören Haubrock, GNS science
  - Mike Whiting, UCLA California
  - Nicole Richter, Uni Bergen
  - Group of Eyal Ben-Dor, TAU