SCOPE MODEL INVERSION FOR SENTINEL-3 DATA RETRIEVAL

S3.5
PLANT TRAITS AND BIOCHEMICAL CYCLES

ICEI 2018, Jena

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ITC – University of Twente

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Speaker:
Egor Prikaziuk
Sentinel-3 is waiting for...

2 instruments
> 30 bands
revisit time 1 day

spatial resolution 300-500m

http://www.esa.int/spaceinimages/Images/2016/01/Sentinel-3

The FLuorescence EXplorer Mission 2022

Drusch et al., 2017
User-available Sentinel-3 products (Level-2)

<table>
<thead>
<tr>
<th>#</th>
<th>products</th>
<th>abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>fAPAR</td>
<td>OGVI</td>
</tr>
<tr>
<td>2</td>
<td>chlorophylls</td>
<td>OTCI</td>
</tr>
<tr>
<td>3</td>
<td>reflectance @681, 865</td>
<td>RC681, RC865</td>
</tr>
<tr>
<td>4</td>
<td>water vapor</td>
<td>IWV</td>
</tr>
<tr>
<td>5</td>
<td>aerosols</td>
<td>AOD</td>
</tr>
<tr>
<td>6</td>
<td>surface temperature</td>
<td>LST, WST</td>
</tr>
<tr>
<td>7</td>
<td>fire radiative power</td>
<td>FRP</td>
</tr>
</tbody>
</table>

ESA uses a couple of bands to produce each product
Can we use all bands of Sentinel-3 to get more products?
Introduction

Plant Traits

- Leaf Area Index (LAI)
- Efficiencies
  - Carboxylation rate ($V_{cmax}$)

Ecosystem Functional Properties

- UP-scaling
- DOWN-scaling

individual plant

ecosystem

Leaf Area Index (LAI)
Efficiencies
Carboxylation rate ($V_{cmax}$)
Objectives

To test an algorithm for the retrieval of plant traits from Sentinel-3 data
## Methods

<table>
<thead>
<tr>
<th></th>
<th>Ocean and Land Colour Instrument</th>
<th>Sea and Land Surface Temperature Radiometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>abbreviation</td>
<td>OLCI</td>
<td>SLSTR</td>
</tr>
<tr>
<td>bands</td>
<td>21</td>
<td>9 x 2</td>
</tr>
<tr>
<td>spatial resolution</td>
<td>300m</td>
<td>500-1000m</td>
</tr>
</tbody>
</table>

http://www.esa.int/spaceinimages/Images/2016/01/Sentinel-3
Methods

Direct irradiance

TOC reflectance

wavelength, nm

500 1000 1500 2000 2500

sensor

OLCI 21 bands

SLSTR 6 bands
S6 atmospheric model (Vermote et al., 1997)

- Aerosols (aerosol profile)
  - the nearest weather station
- Atmospheric profile
  - “us standard 62”
- Water and Ozone
  - satellite products
- Geometry
  - satellite products

Second Simulation of a Satellite Signal in the Solar Spectrum

Py6S (Wilson, 2013)
# Methods

## SCOPE model

### Soil
- Observation, Photochemistry and Energy fluxes (Van der Tol et al., 2009)

### Radiative Transfer
- Module optical part – **RTMo** – Simulation of top of a canopy reflectance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
<th>Unit</th>
<th>Min</th>
<th>Max</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leaf traits</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cab</td>
<td>Chlorophylls</td>
<td>µg cm(^{-2})</td>
<td>0</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Cca</td>
<td>Carotenoids</td>
<td>µg cm(^{-2})</td>
<td>0</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>Cdm</td>
<td>Dry matter</td>
<td>g cm(^{-2})</td>
<td>0</td>
<td>0.02</td>
<td>0.0012</td>
</tr>
<tr>
<td>Cw</td>
<td>Water thickness</td>
<td>cm</td>
<td>0</td>
<td>0.2</td>
<td>0.009</td>
</tr>
<tr>
<td>Cs</td>
<td>Senscent fraction</td>
<td>-</td>
<td>0</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Cant</td>
<td>Antocyanins</td>
<td>µg cm(^{-2})</td>
<td>0</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>N</td>
<td>Mesophyll structure</td>
<td>-</td>
<td>1</td>
<td>3.5</td>
<td>1.4</td>
</tr>
</tbody>
</table>

| **Canopy traits** |                          |            |     |     |         |
| LAI         | Leaf area index         | m\(^2\) m\(^{-2}\) | 0   | 7   | 3       |
| hc          | Canopy height           | m          | 0.1 | 2   | 1       |
| LIDFa       | Leaf Inclination        | -          | -1  | 1   | 0.35    |
| LIDFb       | Distribution Function parameters | -       | -1  | 1   | -0.15   |
| leafwidth   | Leaf width              | m          | 0.01| 0.1 | 0.1     |
Methods

Sentinel-3

OLCI
SLSTR

nadir
nadir
oblique
thermal

TOA radiance measured

6S atmospheric model
RTMo

atmospheric parameters
TOC reflectance

aggregation

numerical optimization

TOA radiance simulated

plant traits
SCOPE
GPP

low cost

YES

NO
Example of a curve fitting
Methods

Study site – Majadas
(39.9415, -5.7734)

field data collection from 2009
tree-grass ecosystem
Methods

Sentinel-3

OLCI
SLSTR
nadir
nadir
oblique
thermal

TOA radiance measured

numerical optimization

low cost

YES

plant traits

SCOPE

GPP

NO

6S atmospheric model

RTMo

atmospheric parameters

TOC reflectance

TOA radiance simulated

aggregation
Plant traits retrieved from a collection of Sentinel-3 images over Majadas site with the RTMo module of the SCOPE model from April 2017 to April 2018

<table>
<thead>
<tr>
<th>instrument</th>
<th># pixels</th>
<th>not measured</th>
<th>clouded</th>
<th>valid pixels</th>
<th>exceptions</th>
<th>high NRMSE</th>
<th>fitted pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLCI + SLSTR</td>
<td>214</td>
<td>12</td>
<td>42</td>
<td>168</td>
<td>9</td>
<td>13</td>
<td>146</td>
</tr>
</tbody>
</table>

![Graphs showing Cab and LAI over time](image)

- Cab, µg cm⁻²
- LAI, m² m⁻²
- Dates: April 2017 to April 2018
- Smoothing highlights trends start of a year
- Exceptions and high NRMSE identified in fitted pixels
Results

Gross Primary Productivity (GPP) calculated in a forward simulation of the SCOPE model with the parameters retrieved from Sentinel-3 images from April 2017 to April 2018.
1. Validation with ground measurements of:
   • atmospheric correction with 6S model
   • retrieved plant traits (chlorophylls, LAI)
   • simulated ecosystem property (GPP)

2. Improve of the retrieval algorithm
   • addition of “close to the previous” constraint
   • look-up table approach

3. What is the uncertainty of our retrieval?

4. Shall we use higher resolution of the Sentinel-2 satellite (20-60m)?
Sentinel-3 is waiting for...

- 2 instruments (OLCI, SLSTR)
- > 30 bands
- revisit time 1 day
- spatial resolution 300-500m

http://www.esa.int/spaceinimages/Images/2016/01/Sentinel-3

https://pixabay.com/p-49909/?no_redirect
TRUSTEE project
www.trusteennetwork.eu
Training on remote sensing for ecosystem modelling

• 12 PhD students
  1. identification of plant traits and ecosystem functional properties
  2. assessment of photosynthetic activity by fluorescence
  3. integration of multisource remote sensing data into ecosystem models
  4. upscaling: plant traits -> ecosystem functional properties
The project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 721995.