living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

Earth Observation Data Cubes to monitor land degradation processes in South Africa

I. Otte*, S. Hill, A. Hirner, M. Urban, C. Pathe, M. Kganyago, N. Mashiyi, A. Mlisa, M. Schwinger, M. Thiel, U. Geßner, C. Schmullius, J. Baade

*Department of Remote Sensing, Institute of Geography and Geology, University of Würzburg

24.05.2022

SALDi Background

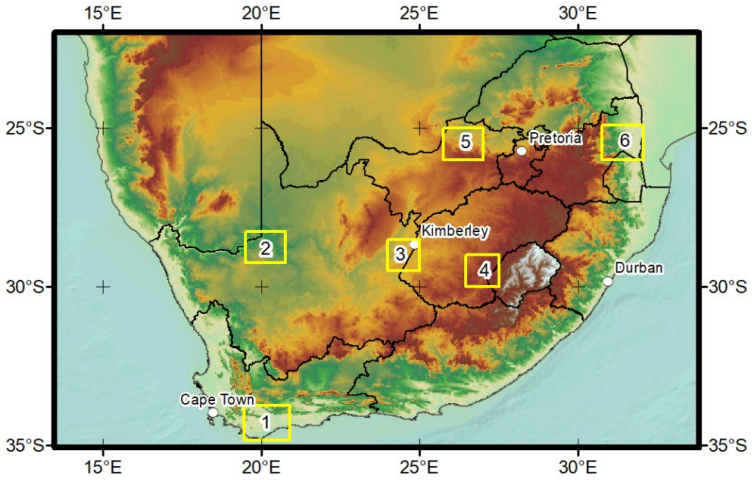
Land degradation deteriorates ecosystem functioning and services and causes loss of biodiversity. Thus it poses a threat to a number of Sustainable Development Goals (SGDs), including provision of clean water, food production, etc.

Gully erosion and badlands on communal land in the Free State

SALDi Background

SALDi: South African Land Degradation Monitor

1. Development of a permanent observation system (monitor) for ecosystem changes and degradation by means of satellite remote sensing.
2. Modeling the interactions between surface changes, weather and climate.
3. Improvement of the procedures for assessing soil degradation, especially soil erosion by water.
4. Consideration of the socio-economic dimensions and effects of land degradation as well as evaluation of SALDi products by local actors



→ Sub-project 4.2: Set-up EO Data Cube for analysis ready data and methods

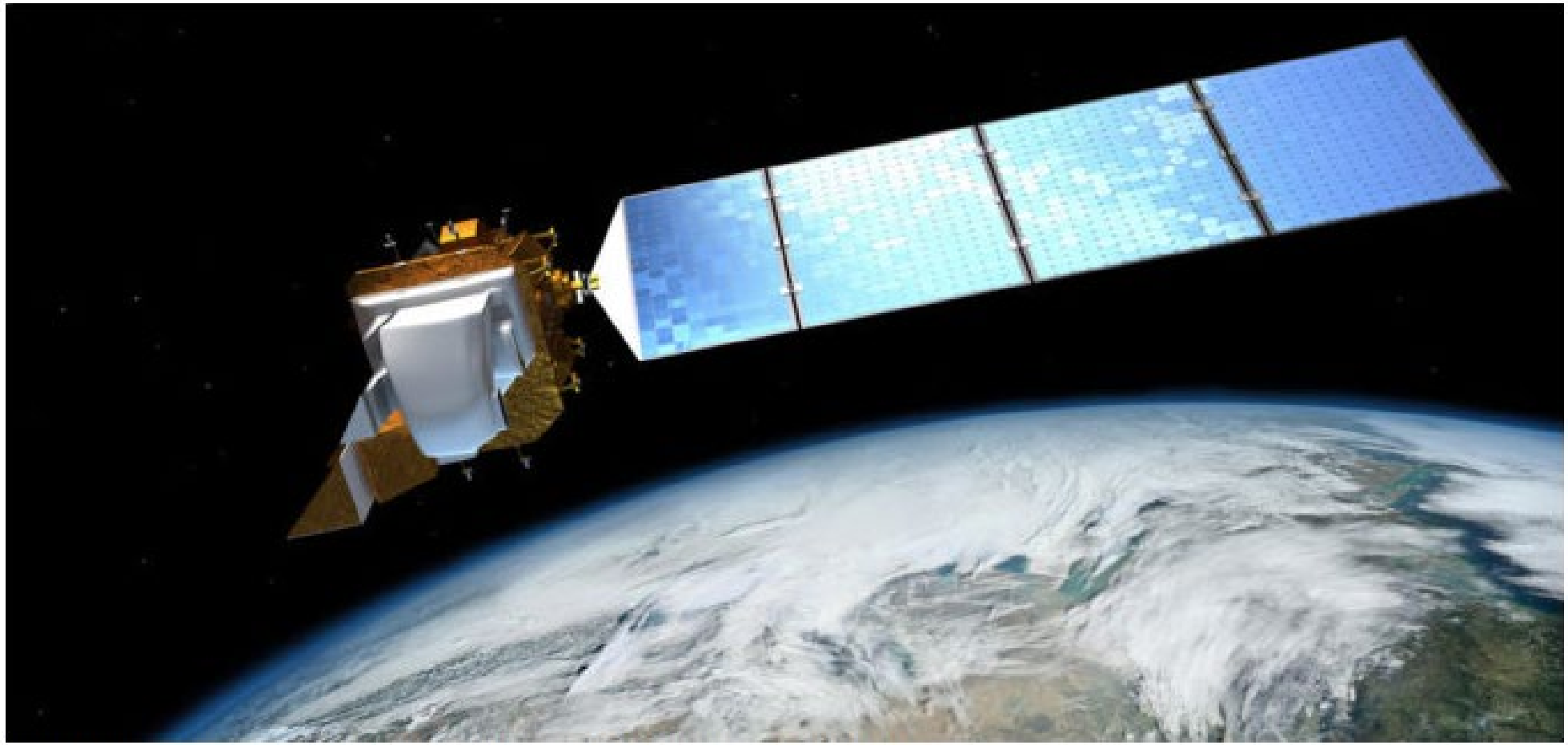
SALDi Background

The aim of the SALDi DataCube is to establish an **earth observation infrastructure for land degradation processes** providing

- uncomplicated EO data access for method development (analysis ready data)
- flexibility and standardization in EO data management
- dynamic working EO tools for research teams and users
- decision-ready EO products
- highly spatio-temporal resoluted time-series

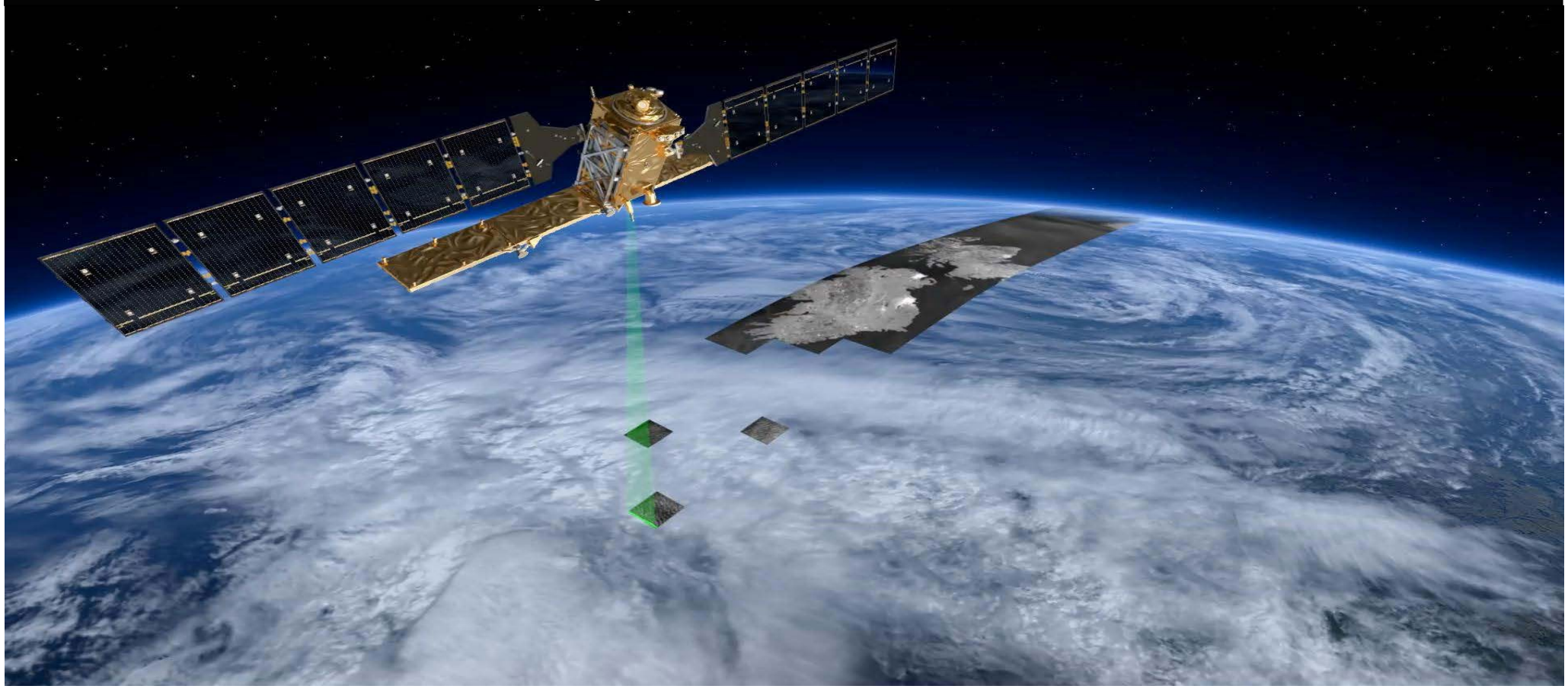
for 6 SALDi research sides from 2016 to 2022.

Landsat has already taken more than 7.5 million images of the Earth surface



Credit: United States Geological Survey (Landsat-8 Illustration Above Earth)

... and this number will continue to increase with the increasing number of satellites!
ESA Sentinel 1 & 2: 5-10TB / day !



Source: esa.int

Why do so few people use satellite data?

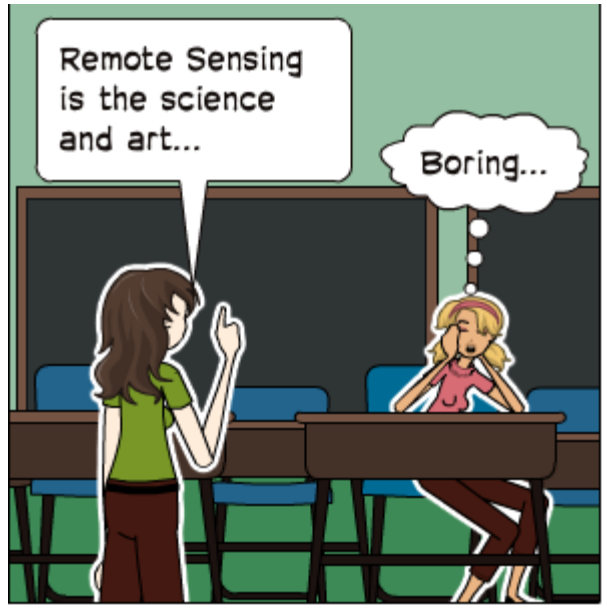
- Scientific knowledge is required to understand... (what kind of data? / resolution? / what type?)

- Difficult to access and download

- Difficult to prepare... atmospheric corrections, alignment, formats

- Challenging analysis

- Need for training and capacity building



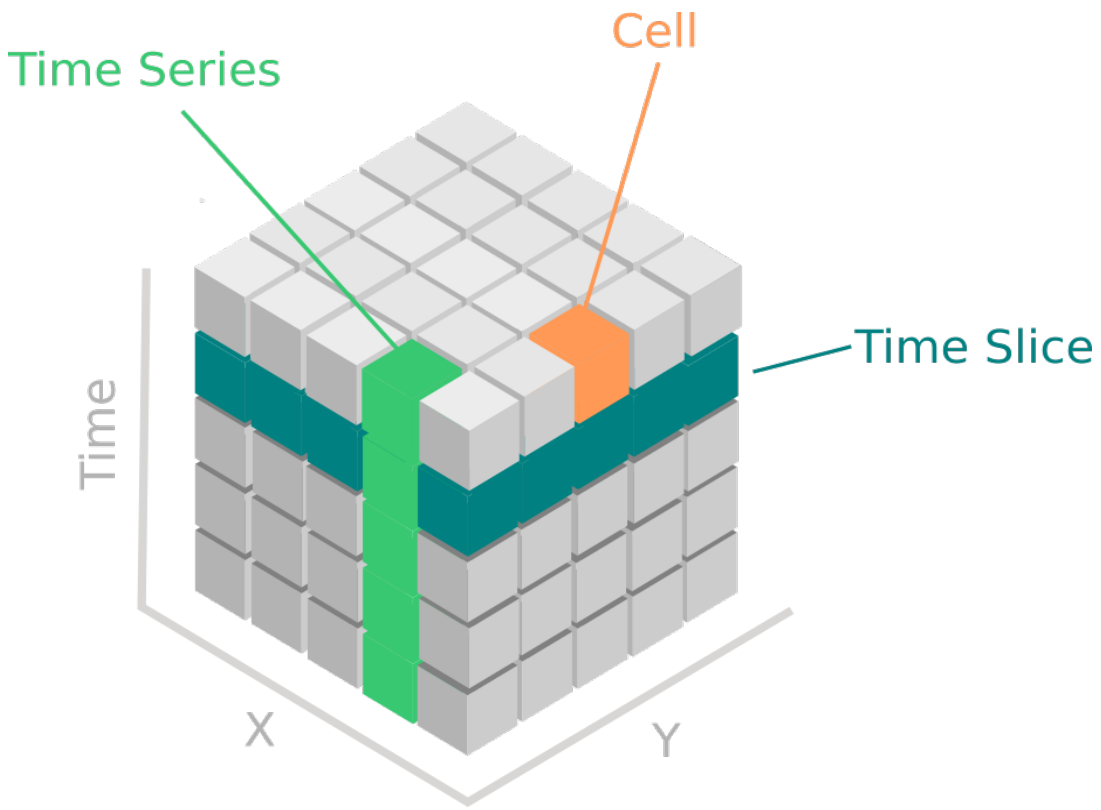
https://www.kejoyce.com/blog/

Innovative data analysis infrastructure for the analysis of earth observation data in order to support decision making

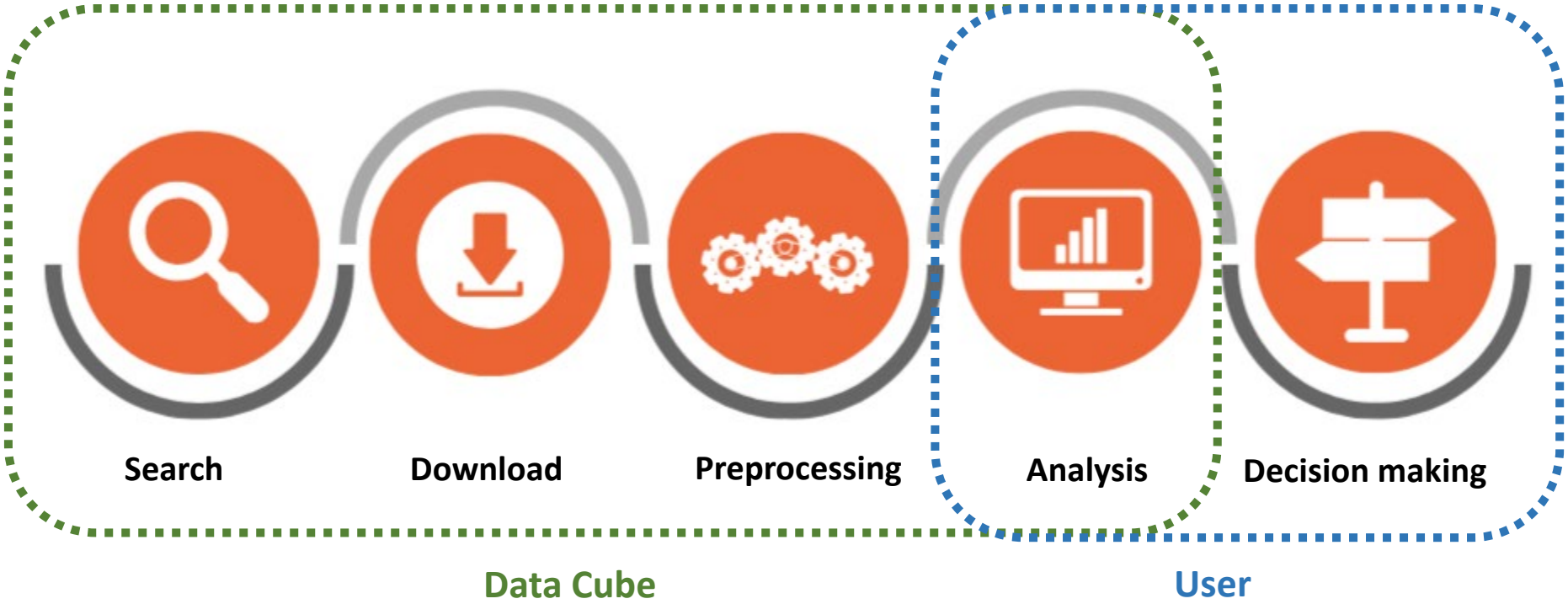
A new solution... **DATA CUBES?**

What is a data cube?

- Used to represent data along some measure of interest
- Can be 2-dimensional, 3-dimensional, or higher-dimensional
- Each dimension represents some attribute in the database
- Each cell in the data cube represents the measure of interest

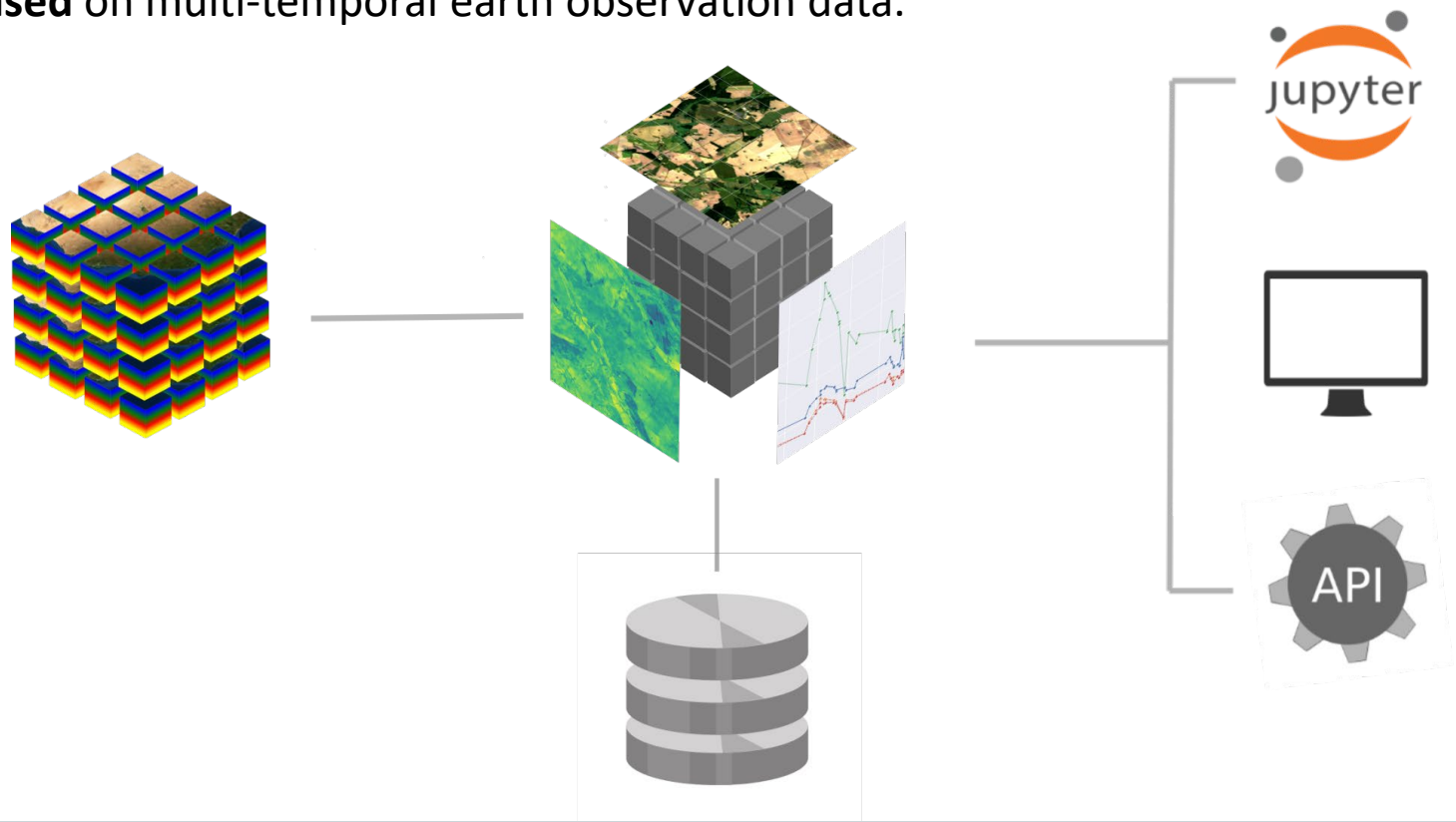


Workflow data cube



The idea of the SALDi data cube is …

to **increase the value and impact of global Earth observation satellite data for all SALDi sites** by providing an accessible exploitation architecture for an **efficient and user-oriented analysis based** on multi-temporal earth observation data.



Status quo: What is already inside SALDiCube?

Remote Sensing Datasets [2016-2022]

- ✓ Sentinel-1
- ✓ Sentinel-2
- ✓ DEMs (30 m)

Preprocessing

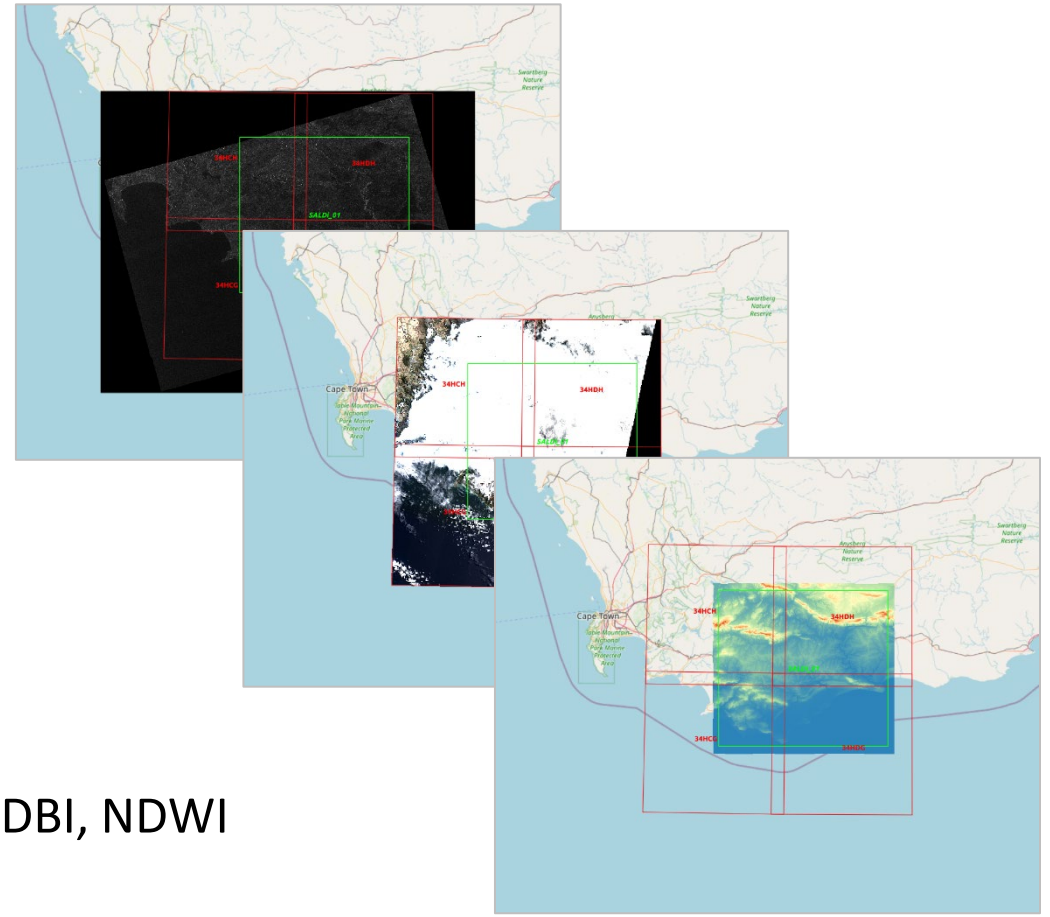
- ✓ Atmospheric correction: sen2cor
- ✓ Cloud mask: sen2cor

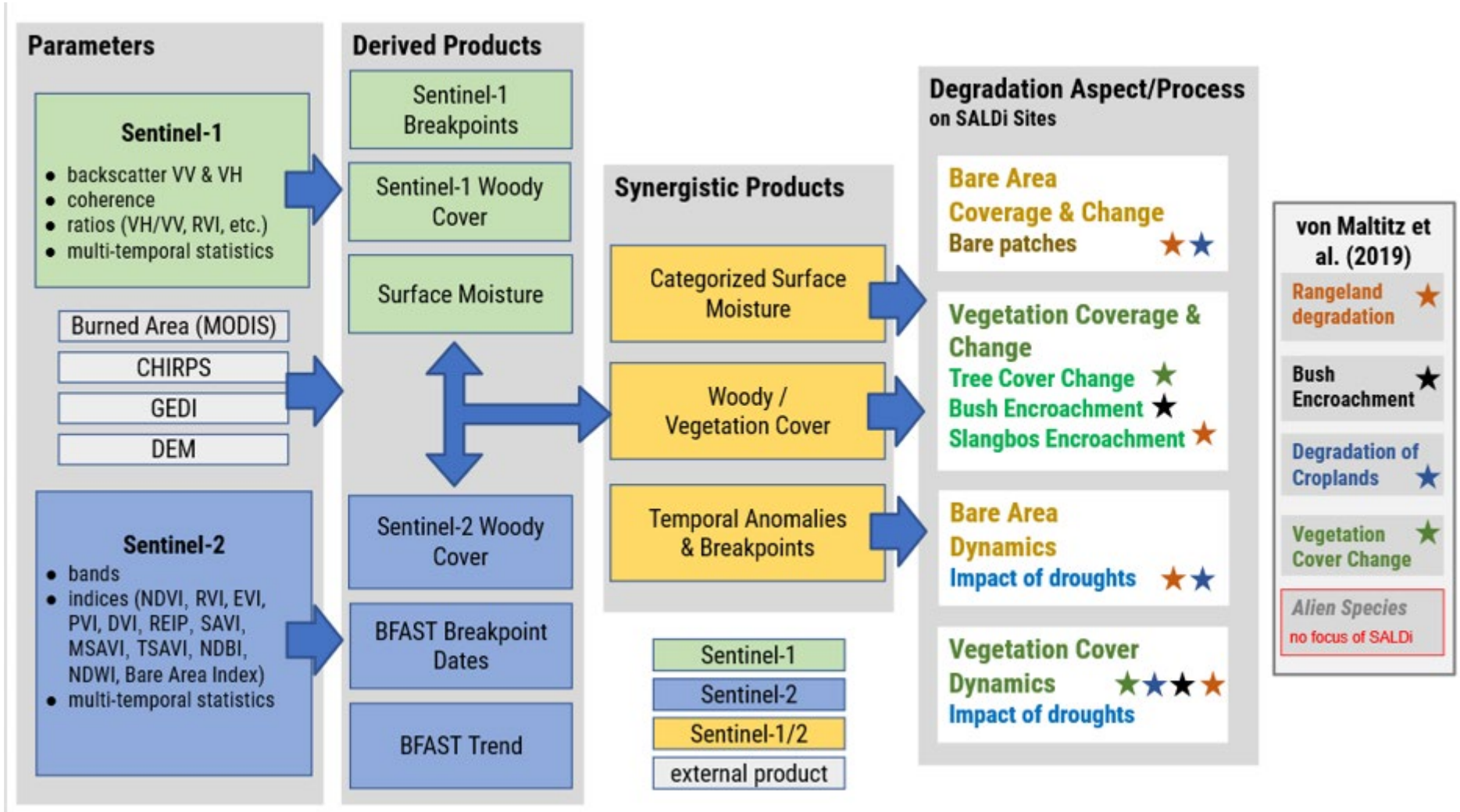
Analysis

- ✓ Various spectral indices [11; bundle product]:

  NDVI, RVI, EVI, PVI, DVI, REIP, SAVI, MASVI, TSAVI, NDBI, NDWI

- ✓ BSI (bare soil index) [single product]




Parameters
Sentinel-1
backscatter VV & VH
coherence
ratios (VH/VV, RVI, etc.)
multi-temporal statistics
Burned Area (MODIS)
CHIRPS
GEDI
DEM
Sentinel-2
bands
indices (NDVI, RVI, EVI, PVI, DVI, REIP, SAVI, MSAVI, TSAVI, NDBI, NDWI, Bare Area Index)
multi-temporal statistics
Derived Products
Sentinel-1 Breakpoints
Sentinel-1 Woody Cover
Surface Moisture
Sentinel-2 Woody Cover
BFAST Breakpoint Dates
BFAST Trend
Synergistic Products
Categorized Surface Moisture
Woody / Vegetation Cover
Temporal Anomalies & Breakpoints
Sentinel-1
Sentinel-2
Sentinel-1/2
external product
Degradation Aspect/Process
on SALDi Sites
Bare Area
Coverage & Change
Bare patches
Vegetation Coverage & Change
Tree Cover Change
Bush Encroachment
Slangbos Encroachment
Bare Area
Dynamics
Impact of droughts
Vegetation Cover
Dynamics
Impact of droughts
von Maltitz et al. (2019)
Rangeland degradation
Bush Encroachment
Degradation of Croplands
Vegetation Cover Change
Alien Species
no focus of SALDi

Methods Sentinel-2 data

Vegetation and Woody Cover

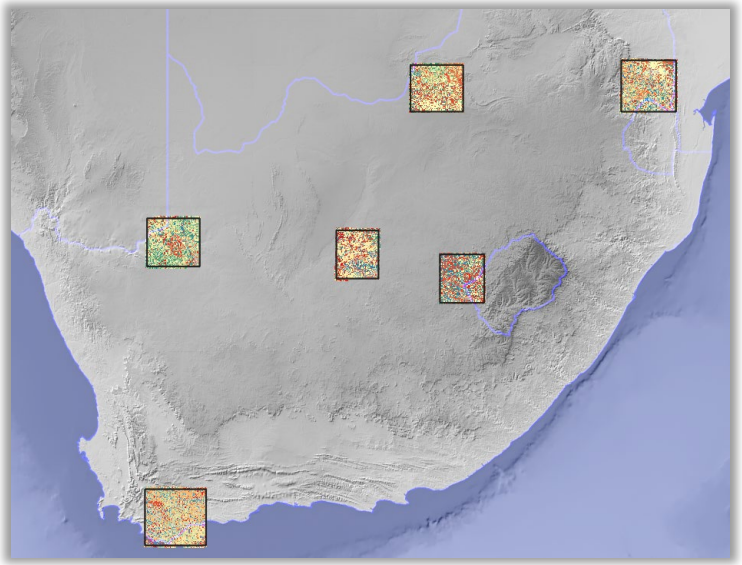
Input data:

Full time series Sentinel-2 (and Sentinel-1)

GEDI

Random Forest Regression

10m, seasonal or annual outputs



Breakpoint Detection

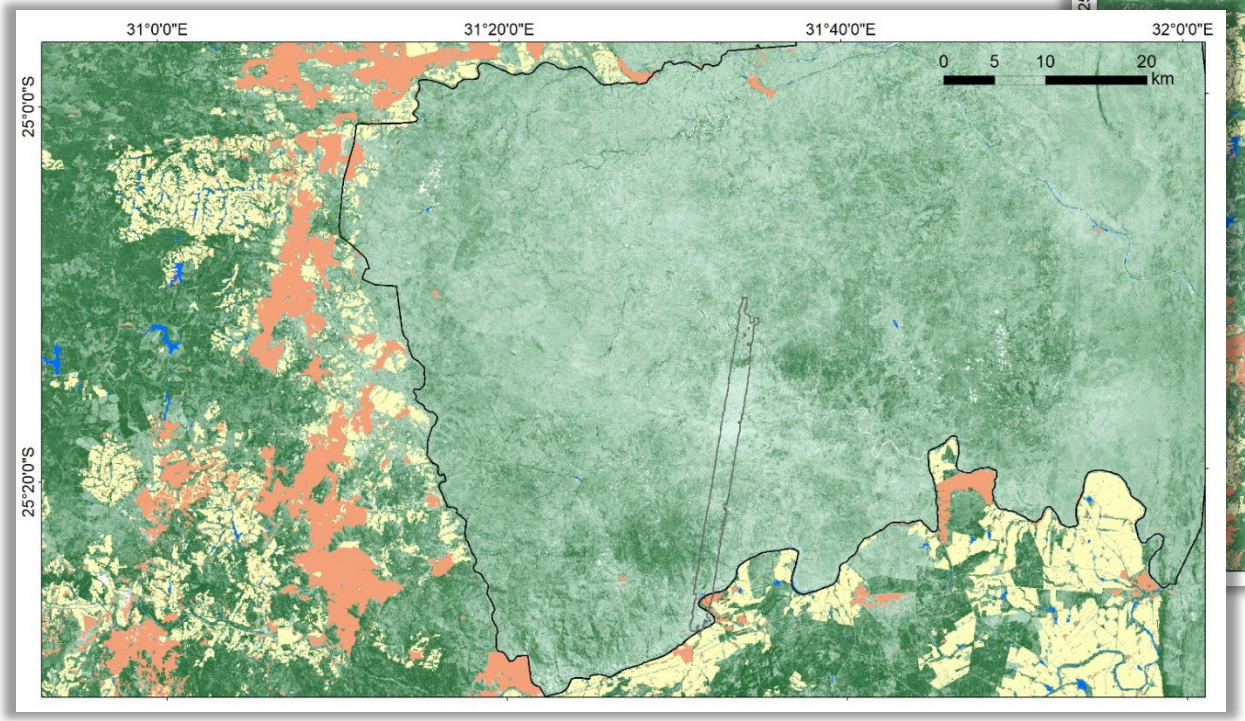
Input data: Full time series Sentinel-2 (BSI and NDVI)

BEAST

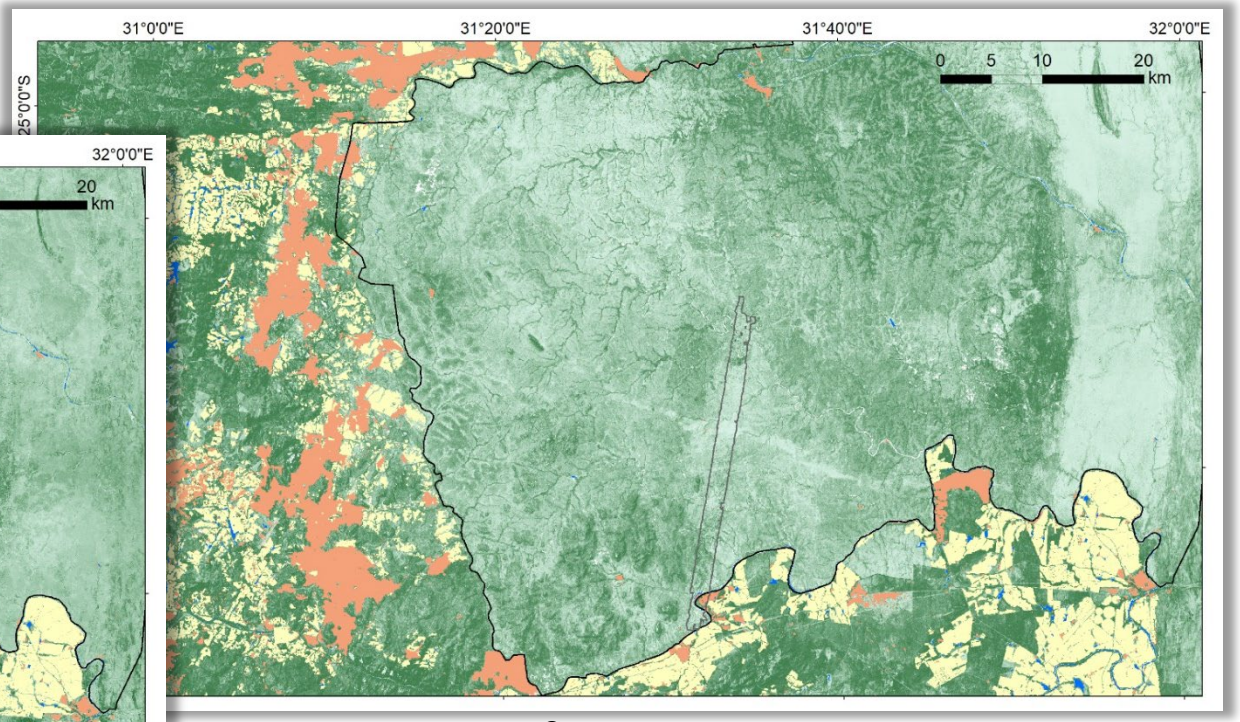
10m

Vegetation and Woody Cover

Woody Cover
combining airborne LIDAR, Sentinel-1 and Sentinel-2 data



Sentinel-2: R^2=0.6, RMSE 17.5%, MAE 10.0%

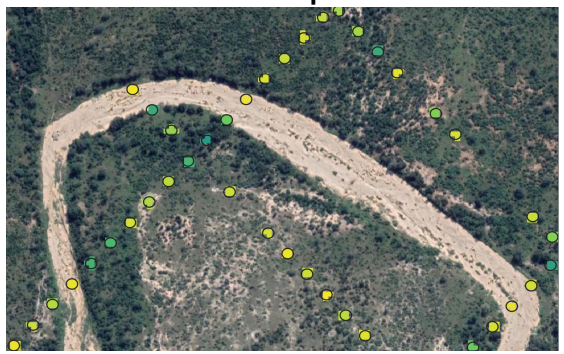


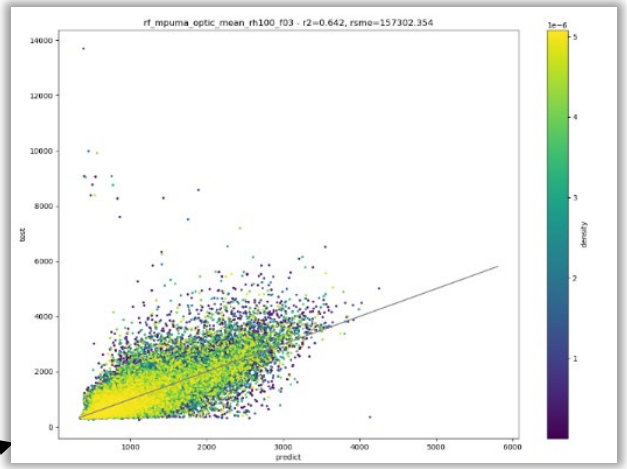
Sentinel-1: R^2=0.3, RMSE 22.8%

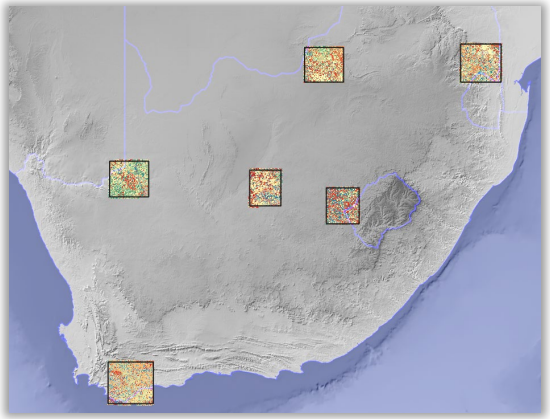
Breakpoint detection

Vegetation Cover & Height combining GEDI and Sentinel-2 data

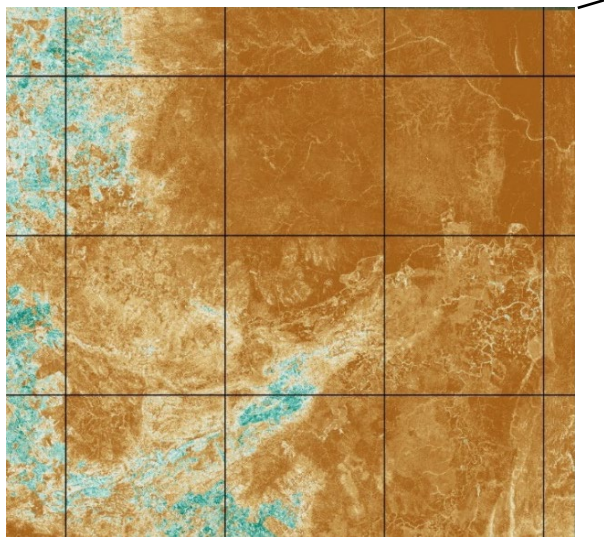
GEDI Footprints



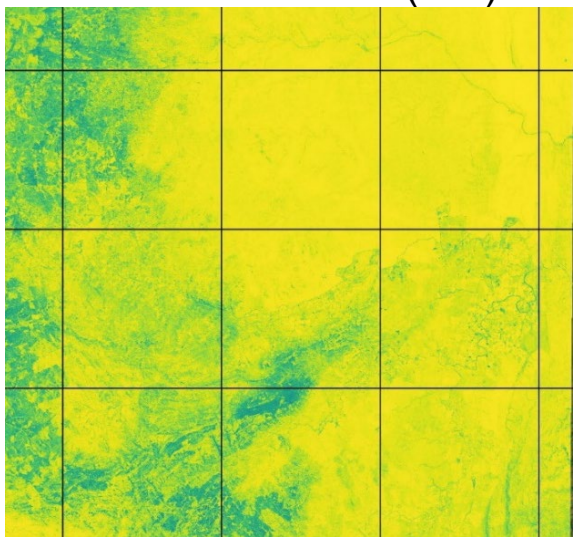




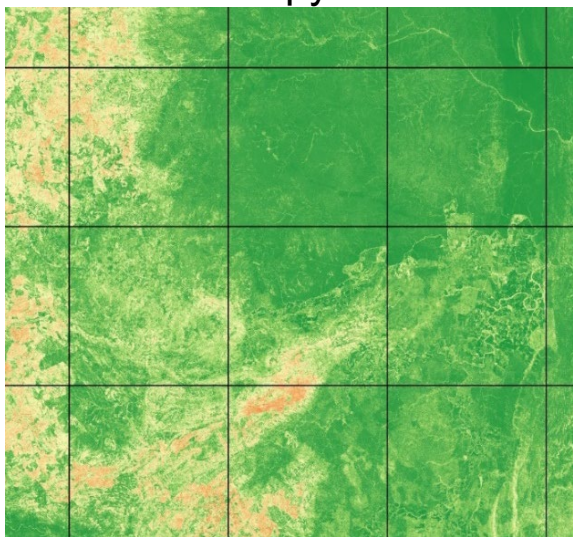
Canopy Height (rh100)



Plant Area Index (PAI)

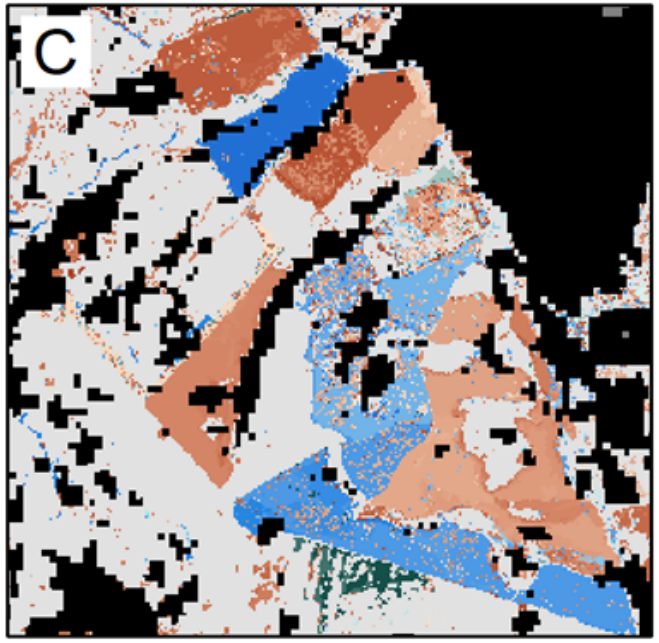


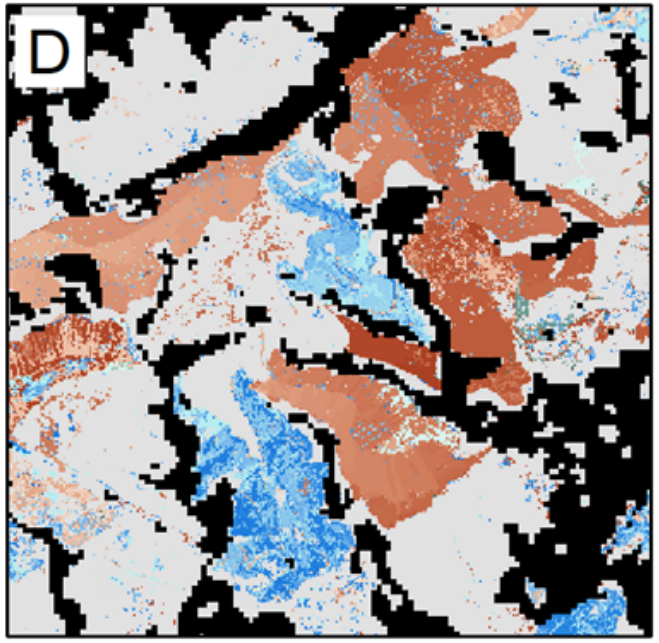
Total Canopy Cover

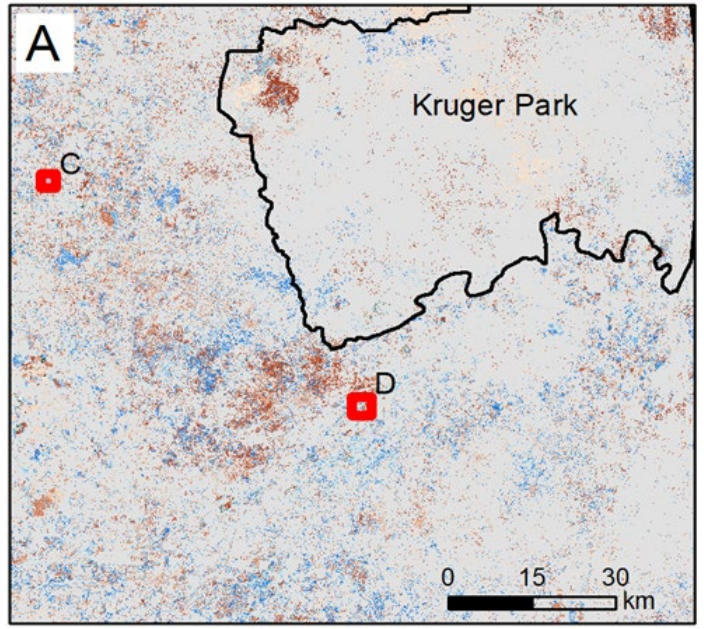


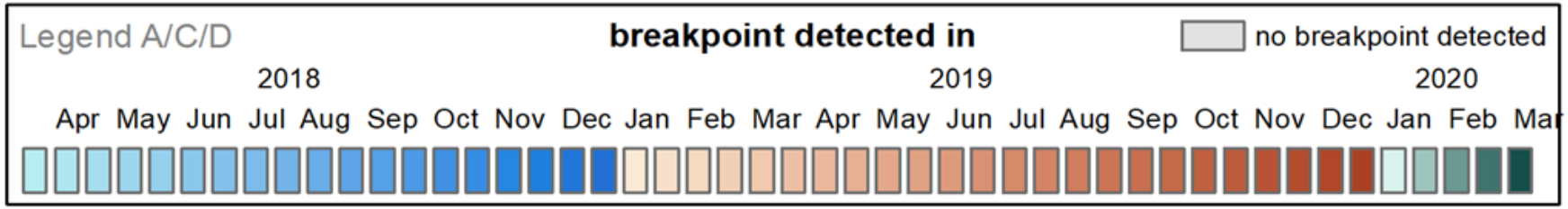
Breakpoint detection

Break Point Detection **(BEAST)**
Sentinel-2 BSI and NDVI time series - Ehlanzeni forest logging







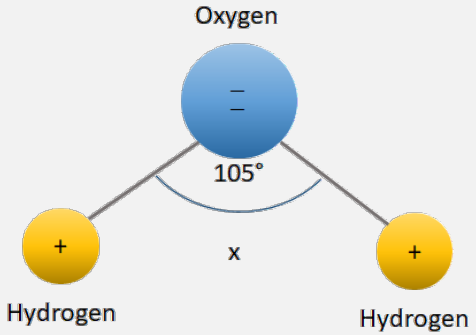


Surface Soil Moisture Retrieval in SALDi using Change Detection

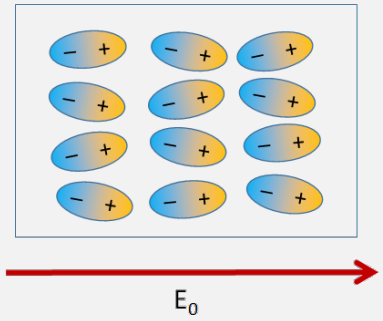
Surface Soil Moisture (SSM) mapping

- Focus on soil erosion and land degradation
- Several Earth Observation products used as proxies to detect and monitor these processes
- **Sentinel-1A and 1B** used for SSM mapping

Water molecule H_2O is a polar molecule and therefore acts as electric dipole



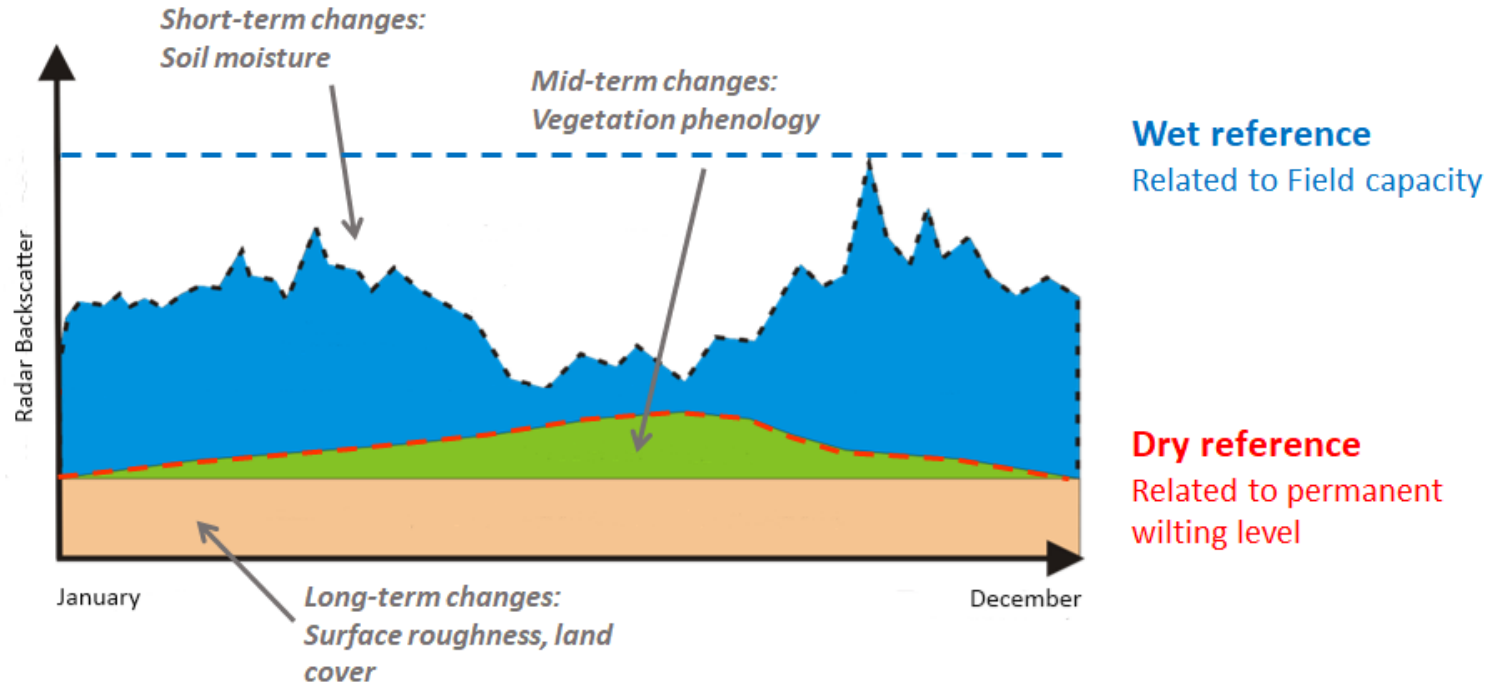
When an external electric field in microwave domain is applied, the molecules partially align with the field.



Surface Soil Moisture

Idea behind multi-temporal Surface Soil Moisture (SSM) mapping approach in the SALDi project:

- Processes controlling **surface soil moisture** act on **different time scales** from **short term changes** to **long term changes**
- Not the relation of pixel values to each other in one image is analysed – instead **the backscatter history of each pixel** – independent from it‘s neighbours is analysed



Take away & Outlook

Analysis ready data sets are key to reduce the burden on EO data users

Data cubes can provide the long baseline required to determine trends, define present and inform future

Visit our website eo2cube (http://datacube.remote-sensing.org/)

Thanks for listening!!