A Light-Weight Hyperspectral Mapping System for Unmanned Aerial Vehicles – The First Results

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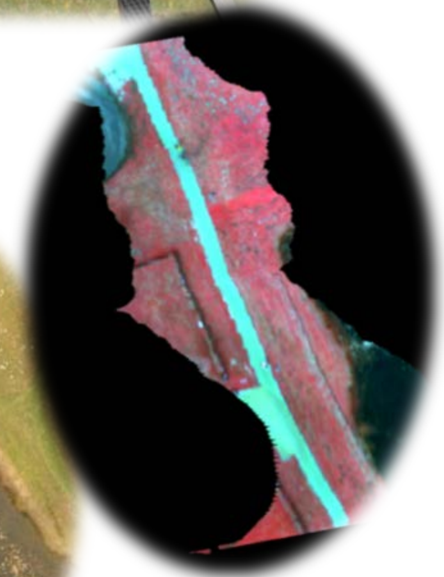
Contents

- *WUR Hyperspectral Mapping System*
  - Custom lightweight system
  - Concept + hardware
- Processing chain
  - Exploits photogrammetry
  - No external data needed
- First result
- Conclusions



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Motivation

- *Acquire high resolution hyperspectral datacube maps using a small Unmanned Aerial Vehicle*
  - By *high resolution* we mean from a 10 centimeters to one meter
  - By *small* we mean 2kg payload
- We developed our own system because such commercial solutions were not available (last autumn)

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Mapping Concept

- Aerialtronics Altura AT8
  - Programmable autonomous flight
  - 2kg payload
  - 5-10 min flight time
- Pushbroom spectrometer
  - 450-950nm
  - FWHM 9nm
  - 20 lines/s
- Consumer RGB camera
- GPS/Inertia navigation System
  - Accuracy: 4m / 0.25°

Sensor system main components

- Spectrometer:
  - Smart Camera: Photonfocus SM2-D1312
  - Spectrograph: Specim ImSpector V10 2/3“
  - Optics: Specim OT-12 (f=12mm)
- GPS/INS: XSens MTi-G-700
- Camera: Panasonic GX1 + 14mm obj.
- Data storage: RaspberryPI
- Total: 2.0kg, 12k€

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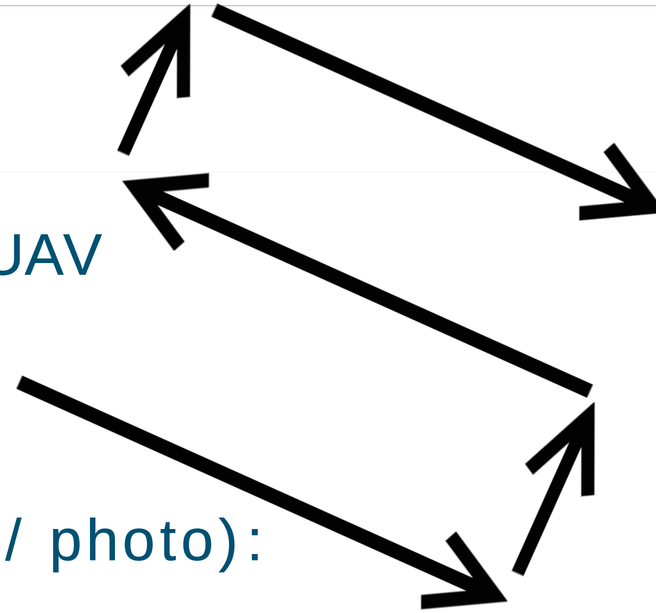
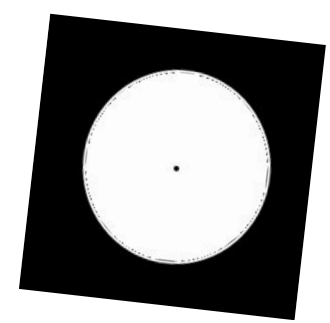
Data acquisition



- Programmed block flight with the UAV
  - Up to 1km flight path
  - Speed 2-10 m/s
- Ground Sampling Distance (hyper / photo):
  - @30m: 9cm / 1.7cm
  - @120m: 36cm / 7cm
- Typical in-flight raw data set:
  - 5-10 000 spectrometer lines
    (328 cross pixels, 200 spectral pixels)
  - 125-250 photos (16 Mpix 12bit RAW)
  - GPS/INS data
  - Optional: *RTK GPS Ground Control Points*



Overview of processing chain

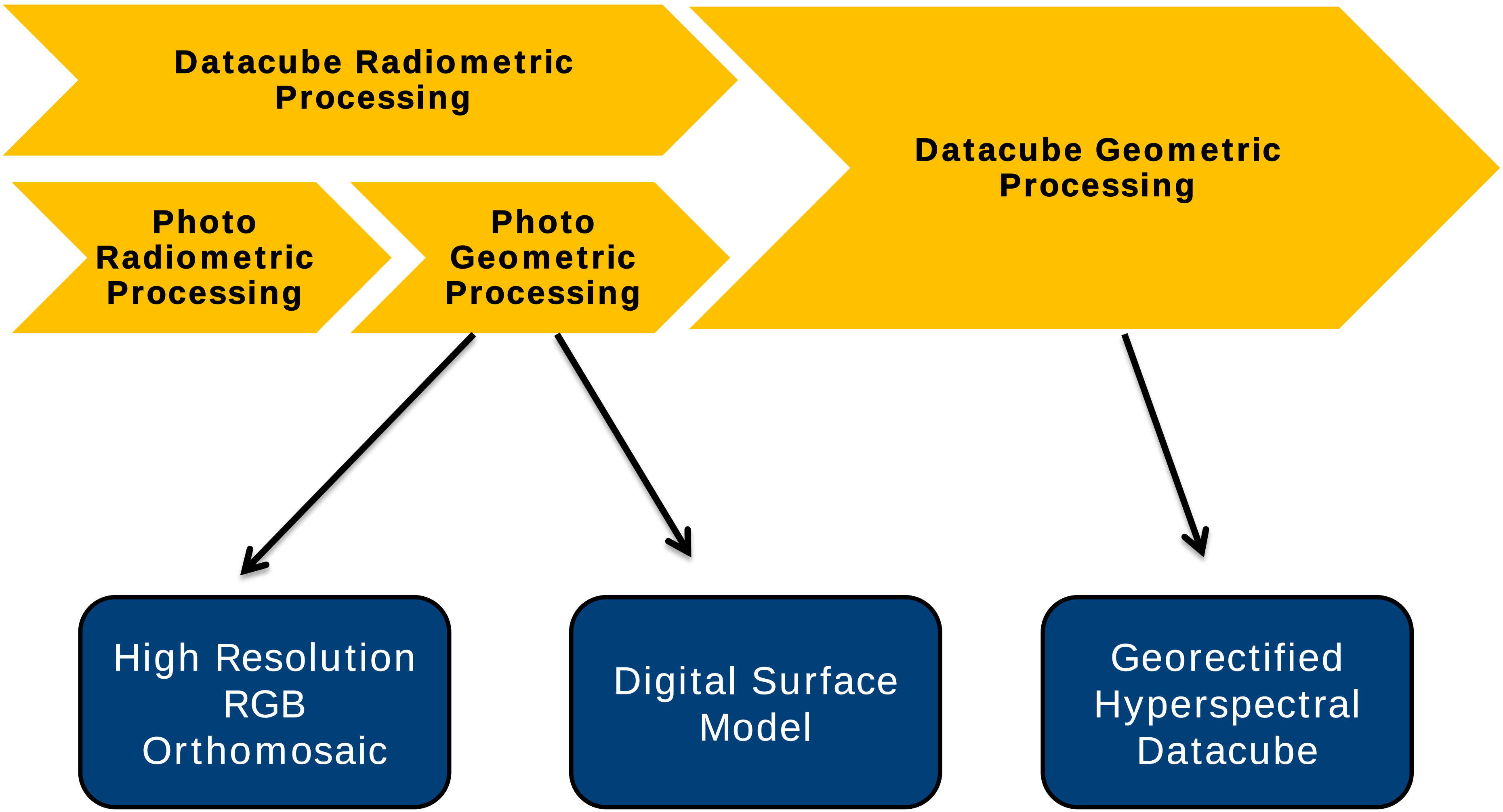


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Photo radiometric processing

Custom Matlab script

As in field spectroscopy:

1. The raw images are loaded
2. Converted to radiance images using dark and flat field calibrations
3. Converted to reflectance factor images using empirical line correction
4. Stored as 16bit TIFFs

No atmospheric modelling.

DN

DN

Reflectance factor

Datacube radiometric processing

Custom Matlab script

Same as with photos:

1. The raw spectrometer data are loaded
2. Converted to radiance spectra using dark and flat field calibrations
3. Converted to reflectance factor spectra using empirical line correction
4. Stored as 16bit ENVI BSQ

Unrectified datacube (false color)

Digital Surface Model?

- To georecitify airborne data a Digital Elevation/Surface Model is needed.
- For 10cm resolution data we need one that…
    - …describes the **surface** detailed enough
    - …is co-register accurately to GPS/INS data

» Generate co-registered DSM using photogrammetry

Photogrammetry

- Photogrammetry produces a 3D model by analysing overlapping images
  - Works as our eyes do
- Iterative workflow:
  - Align images
  - Find tie points
  - Generate DSM

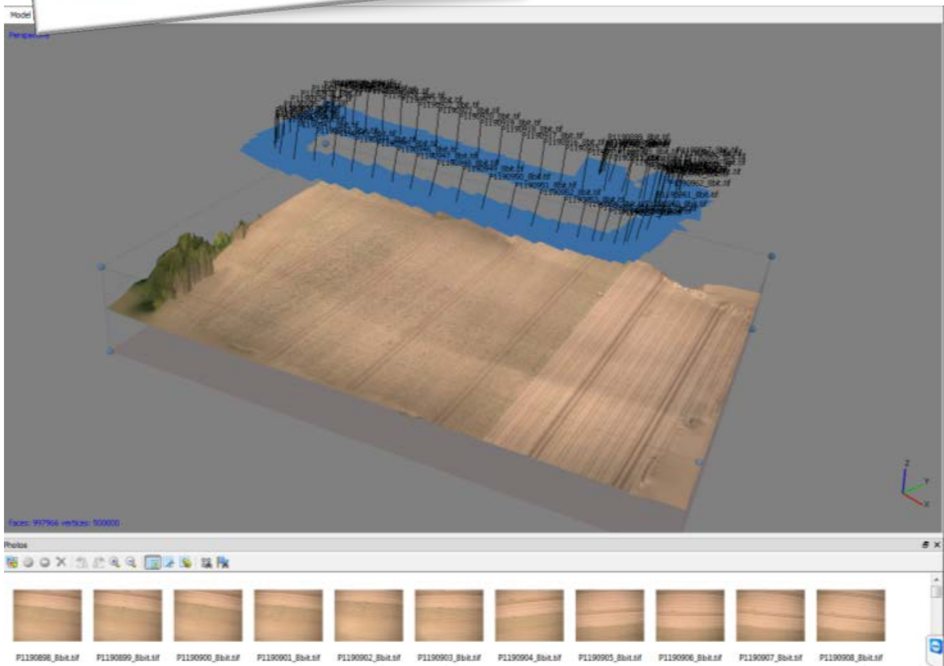

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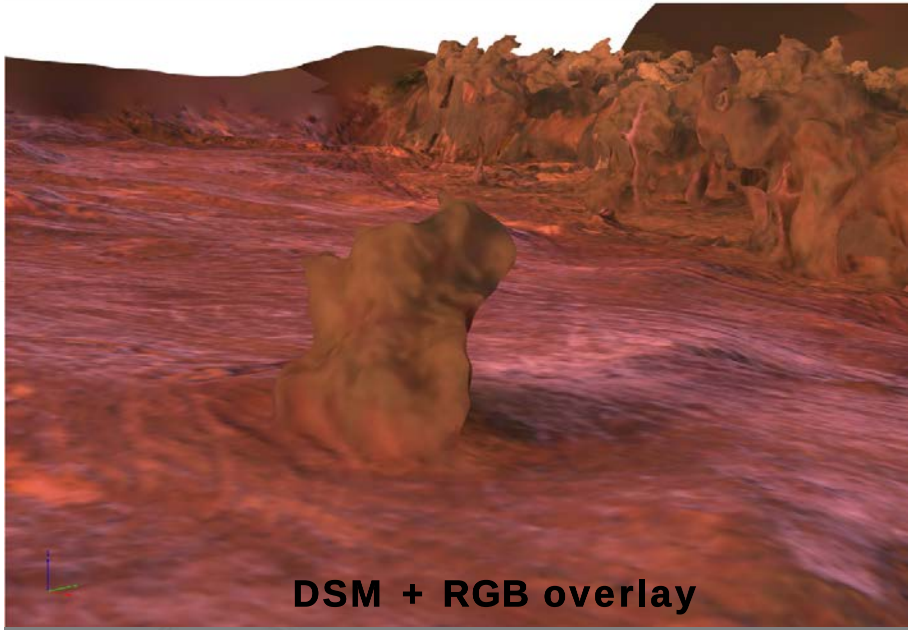
Photo Geometric Processing

- *Agisoft PhotoScan Pro*
- Geolocated with
  - GPS/INS data
  - *RTK GPS Points*
- Outputs
  - Digital Surface Model
  - Orthomosaic
  - Point cloud
  - Camera positions
  - *3D Model*



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Datacube Geometric Processing

Custom Matlab script

- We have **photogrammetric camera positions** with accuracy of a few centimeters relative to the DSM!
- Photogrammetric camera positions are used to **calibrate/stabilize the GPS/INS data** relative to DSM
- The **enhanced GPS/INS data** provides spectrometer flight path with a few centimeter accuracy.

ReSe PARGE

- Datacube is georectified using the photogrammetric DSM and the enhanced GPS/INS data

Mapping campaigns summer 2013

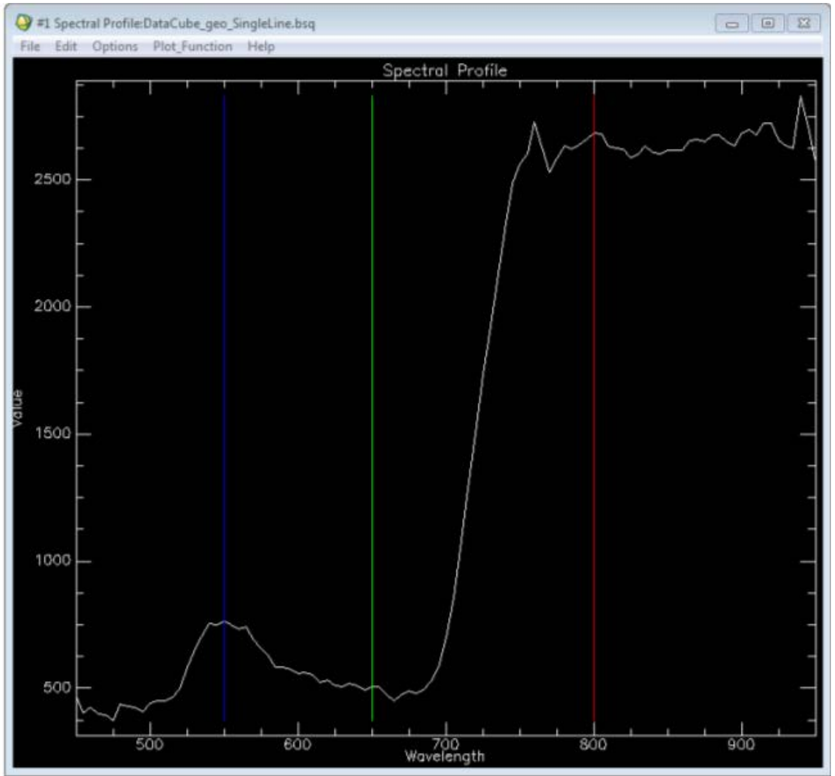
- First summer of operation
- ~100 campaign mapping flights
  - vdBorne (Varying fertilizers on potatoes)
  - Dronten (Time series on agricultural crops)
  - Bonaire (Status of coral reefs)
  - Unifarm(Wageningen), Soestduinen, Haus Riswick, Lisse, …

Main experiment 2013

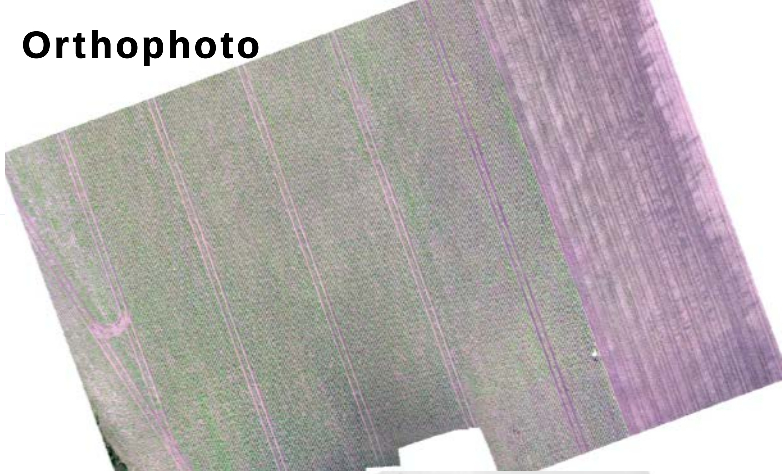
- Collecting time-series over potato field
- Varying nitrogen fertilizer: 167%, 100%, 56%, and 0% of the normal level
- Airborne and ground data on weekly basis
  - SPAD
  - LAI-2000
  - Cropscan

Results

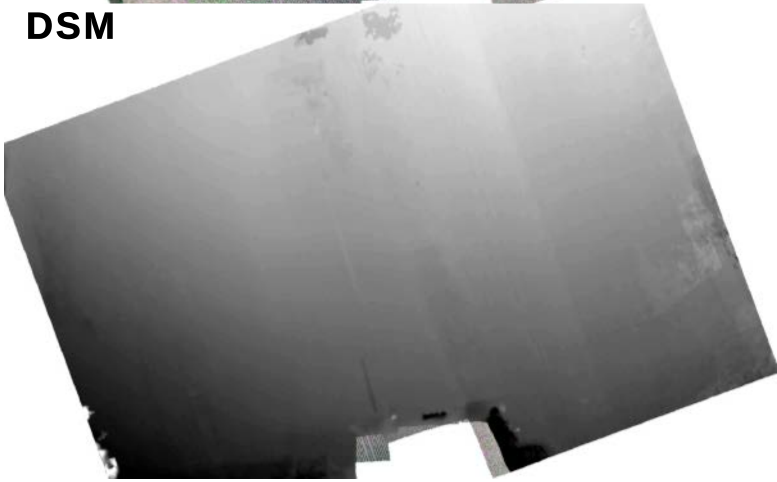
- Flights at 100m altitude
- Pixel size
  - Orthophoto 0.05m
  - Hyperspectral 0.50m



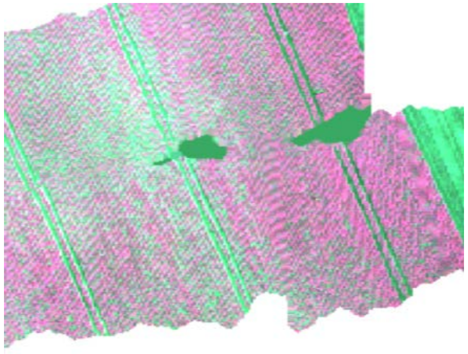
Orthophoto



DSM



Datacube (false color extract)

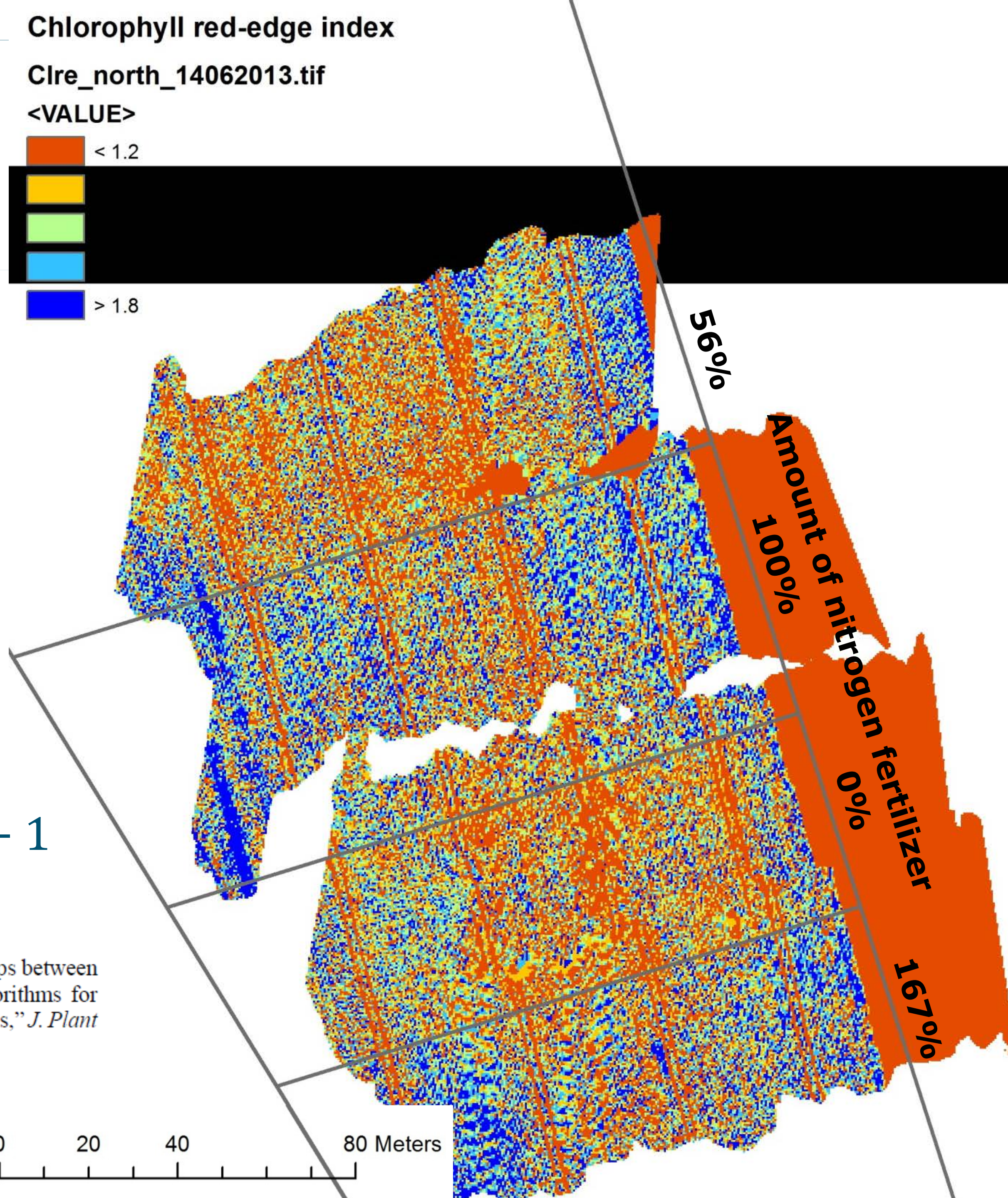


Chlorophyll mapping

- Potato fields on June 14th 2013
- Chlorophyll red-edge index:

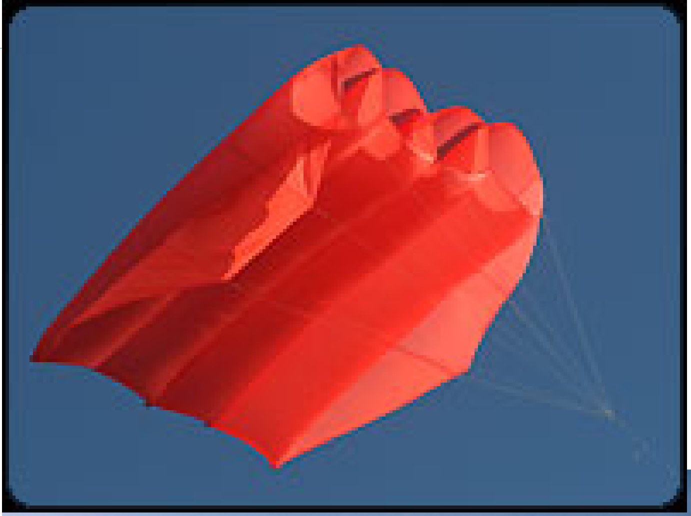
$$CI_{red\ edge} = (R_{780}/R_{710}) - 1$$

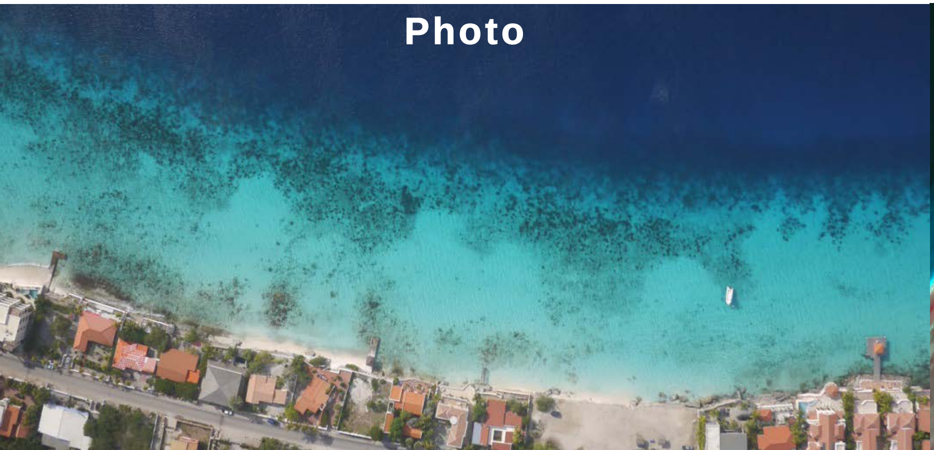
A. A. Gitelson, Y. Gritz, and M. N. Merzlyak, "Relationships between leaf chlorophyll content and spectral reflectance and algorithms for non-destructive chlorophyll assessment in higher plant leaves," *J. Plant Physiol.*, vol. 160, pp. 271–282, 2003.



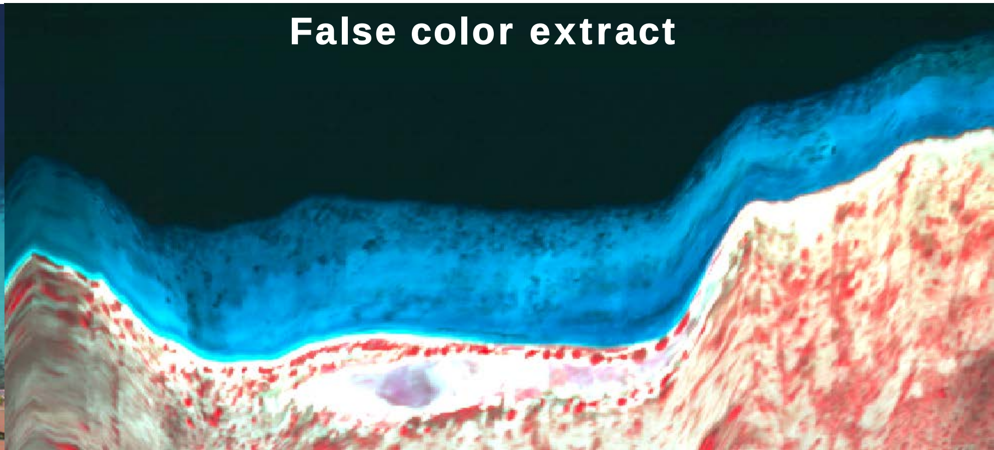
Bonaire

- Mapping status of coral reefs with IMARES
- Airplane:
  - 50km of coast line
  - 5m resolution
- Kite:
  - 15km of coast line
  - 1m resolution





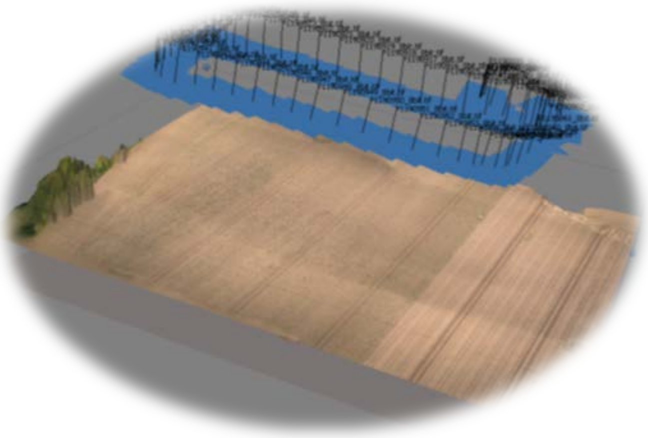
Photo



False color extract

Conclusions

- We have developed a lightweight hyperspectral mapping system
  - for small UAVs/light platforms
  - 2kg on ready-to-fly
  - Off-the-shelf components
- Novel processeing chain:
  - Cutting-edge combo of photogrammetry + traditional hyperspectral georectification
  - Internally produced DSM
  - enhanced GPS/INS data



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Thank you

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