Estimation of spatial biomass distribution of a grassland using UAV based multispectral imagery

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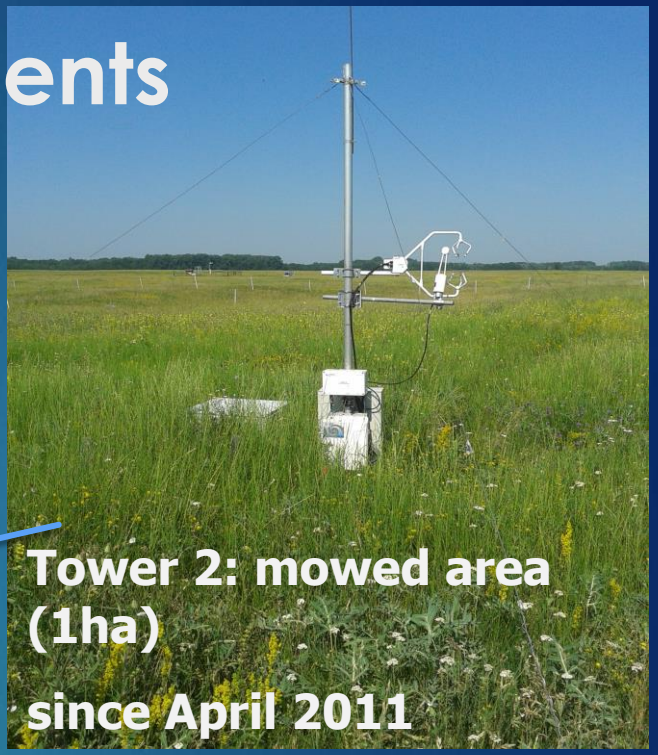
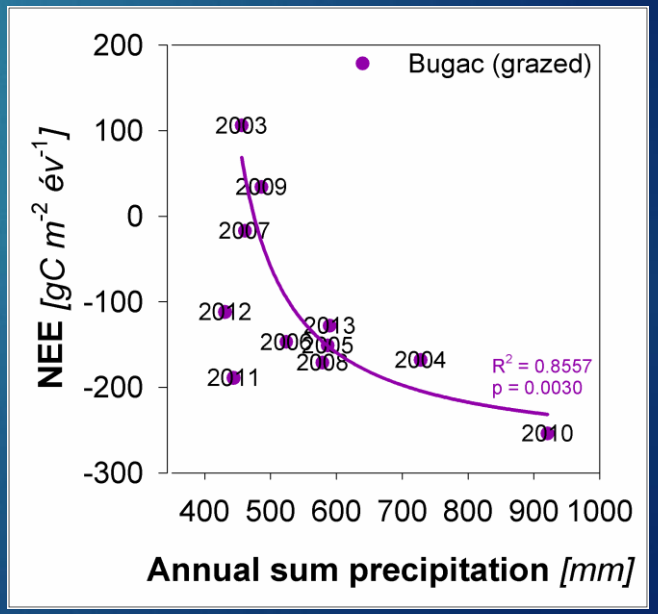
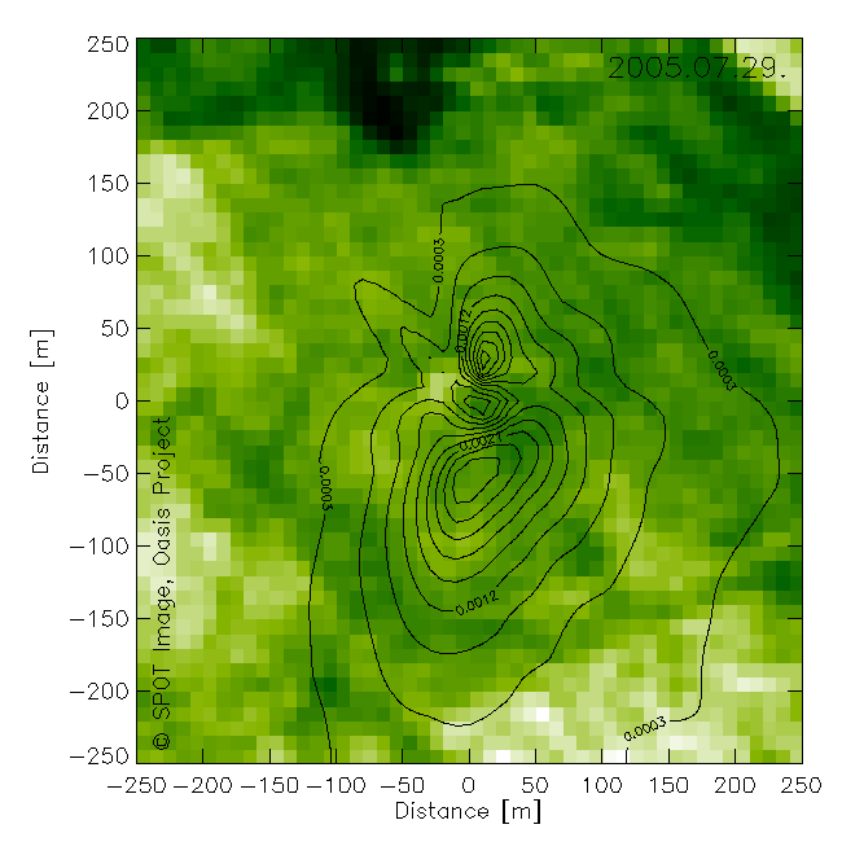
Eddy covariance measurements since 2002



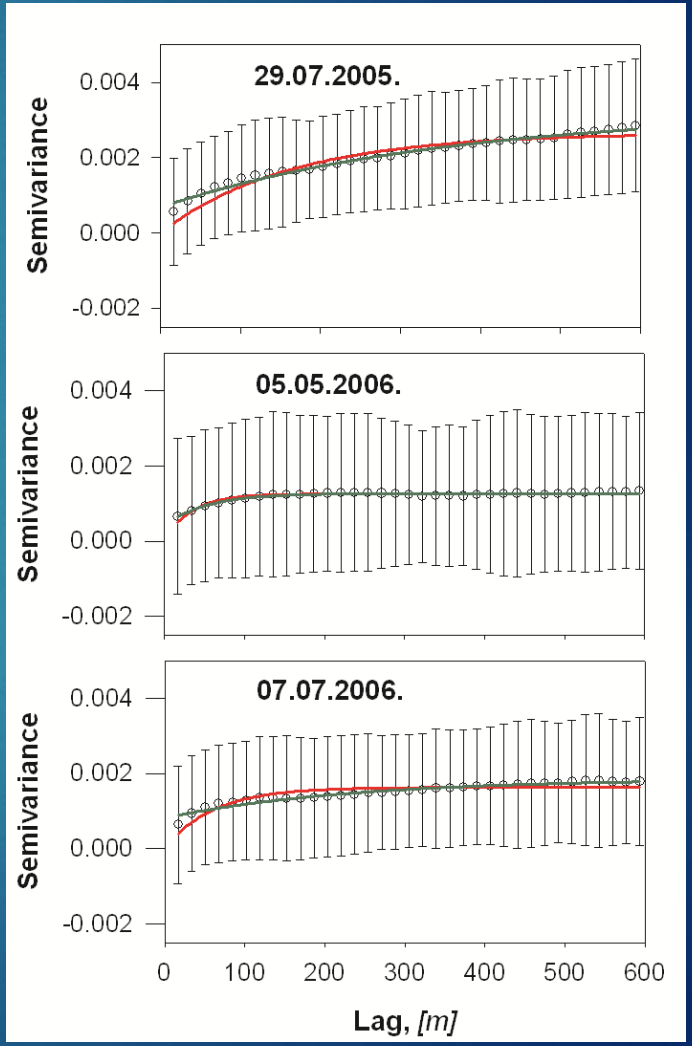


Highly diverse grassland: more than 100 species

Previous investigations…
spaceborn hyperspectral image



SPOT NDVI
1km x 1km area
10m pixel size



UAV based multispectral imaging 2014

14 flights in May-September 2014

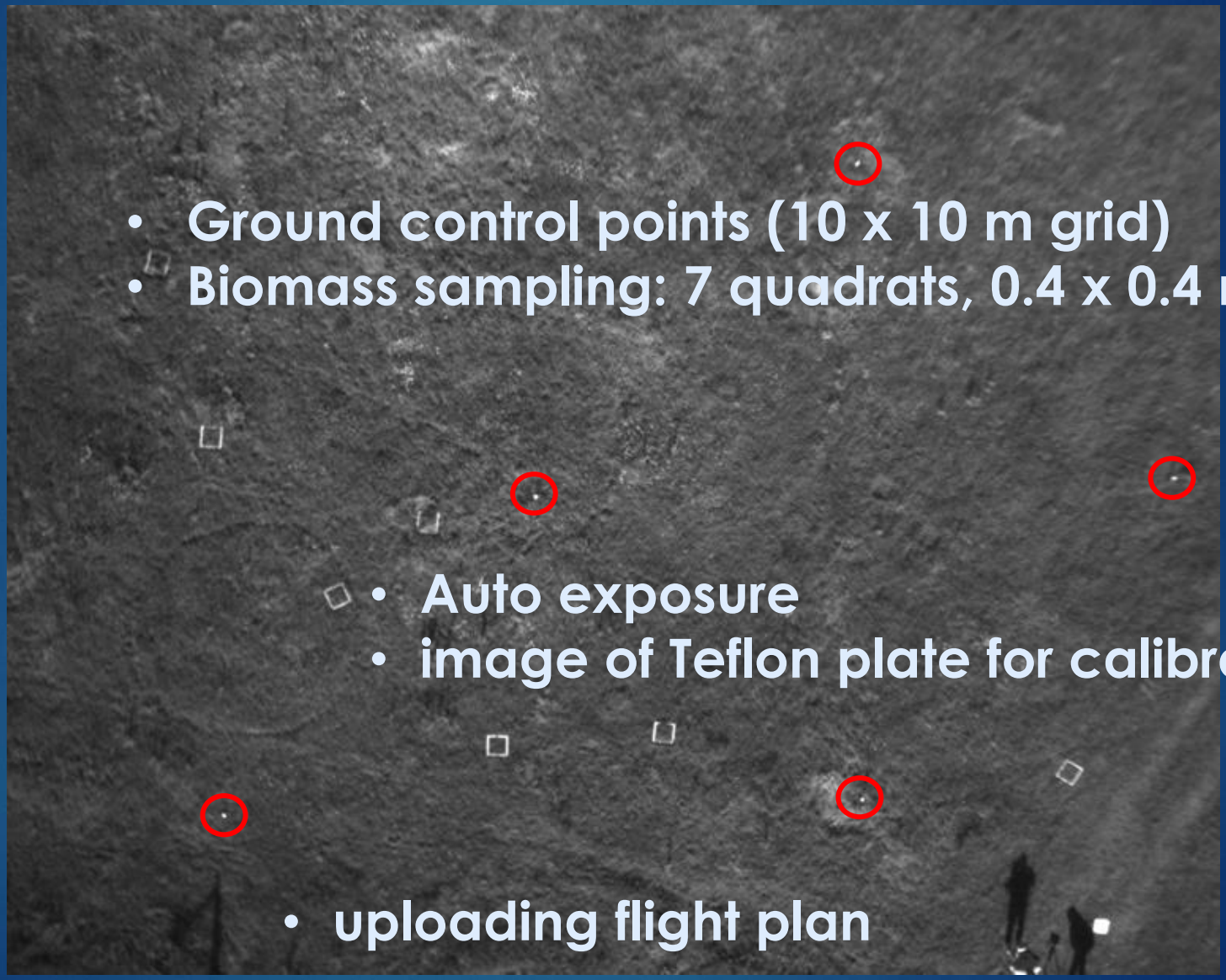
Tetracam, Mini MCA

- 550 nm
- 680 nm
- 800 nm
- 970 nm

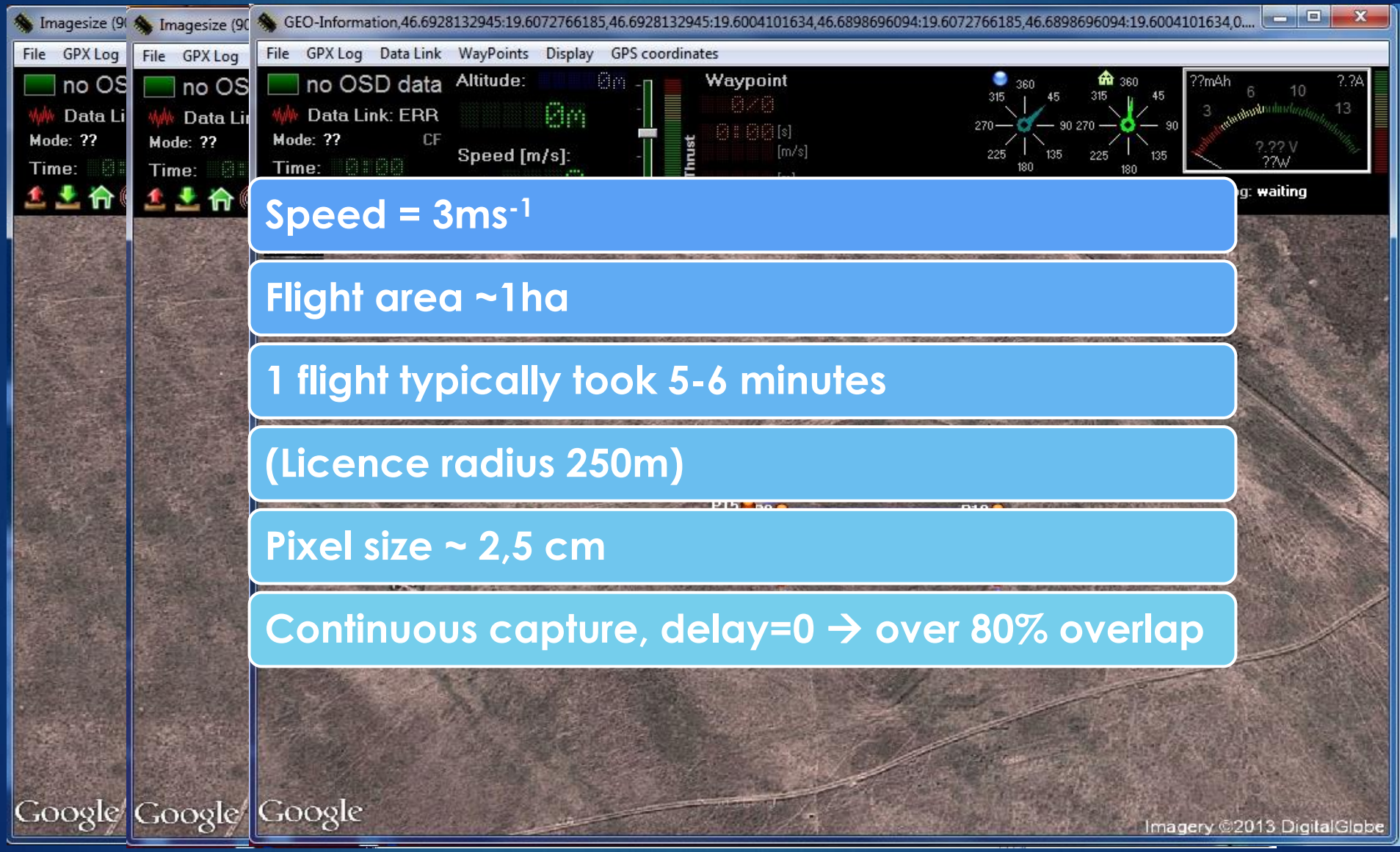
planned upgrade

- 740 nm
- ILS
- camera calibration

Prior to flight



Routes



Speed = 3ms^{-1}

Flight area ~1ha

1 flight typically took 5-6 minutes

(Licence radius 250m)

Pixel size ~ 2,5 cm

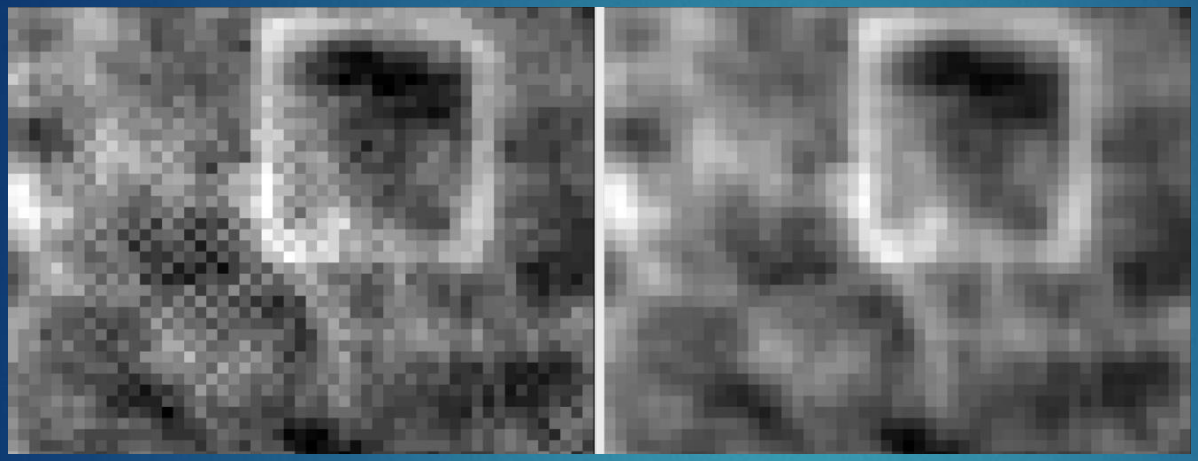
Continuous capture, delay=0 → over 80% overlap

Flights – 2014

DST (UTC+2)	grazed1		grazed2		mowed	
	Start	end	start	end	start	end
6 May 2014	11:36	11:39				
9 May 2014	13:23	13:27			12:17	12:22
28 May 2014	08:05	08:08	08:52	08:56	08:21	08:26
4 June 2014	08:53	08:57	14:27	14:36	09:06	09:11
19 June 2014	10:11	10:13	10:22	10:26		
2 July 2014	08:31	08:34	09:04	09:09	09:29	09:34
25 July 2014	09:02	09:06	09:26	09:31	10:30	10:35
12 August 2014	14:13	14:16				
18 August 2014	09:35	09:38	09:45	09:49	10:27	10:32
29 August 2014	10:03	10:06	10:13	10:17	10:55	11:01
9 September 2014	12:02	12:06	12:11	12:15	12:58	13:03
24 September 2014	10:45	10:49	10:56	11:00	11:36	11:45

Data processing

Noise reduction with convolution filter



0	1	0
1	3	1
0	1	0

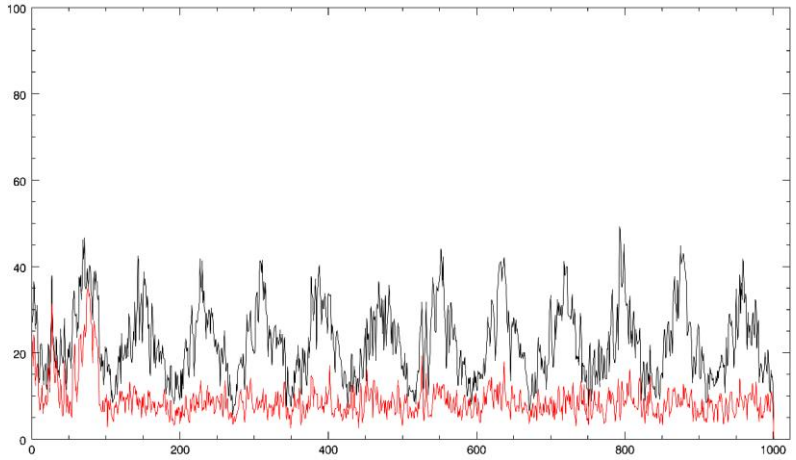
CONVOLUTION MATRIX:

$$New(x,y) = \frac{\sum_{i,j=1}^{3} CM(i,j) * Original(x+1-i, y+1-j)}{\sum CM}$$

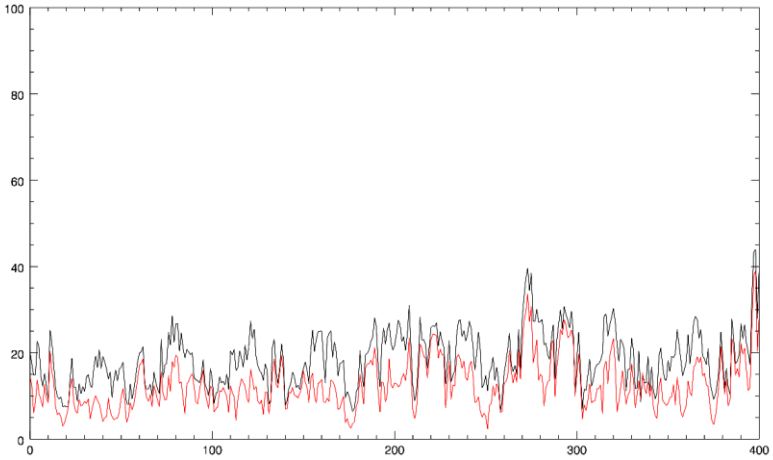
Data processing

Noise reduction with convolution filter

3x3 Standard deviation (teflon plate)



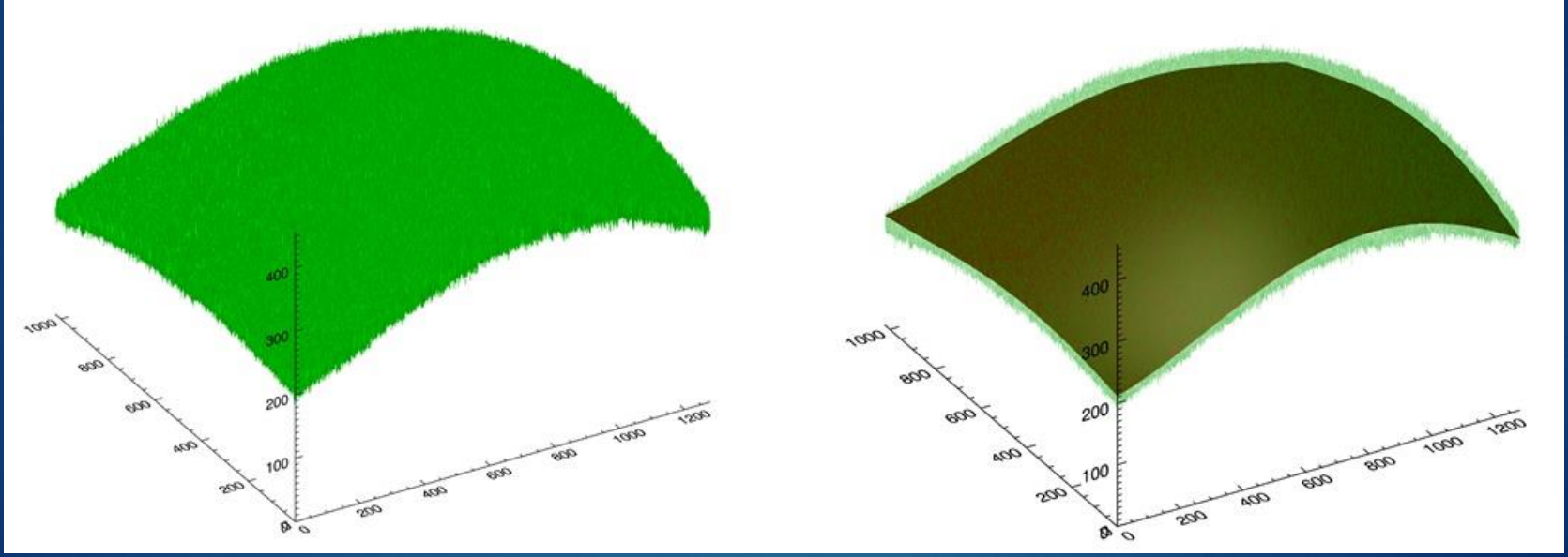
3x3 Standard deviation (vegetation)



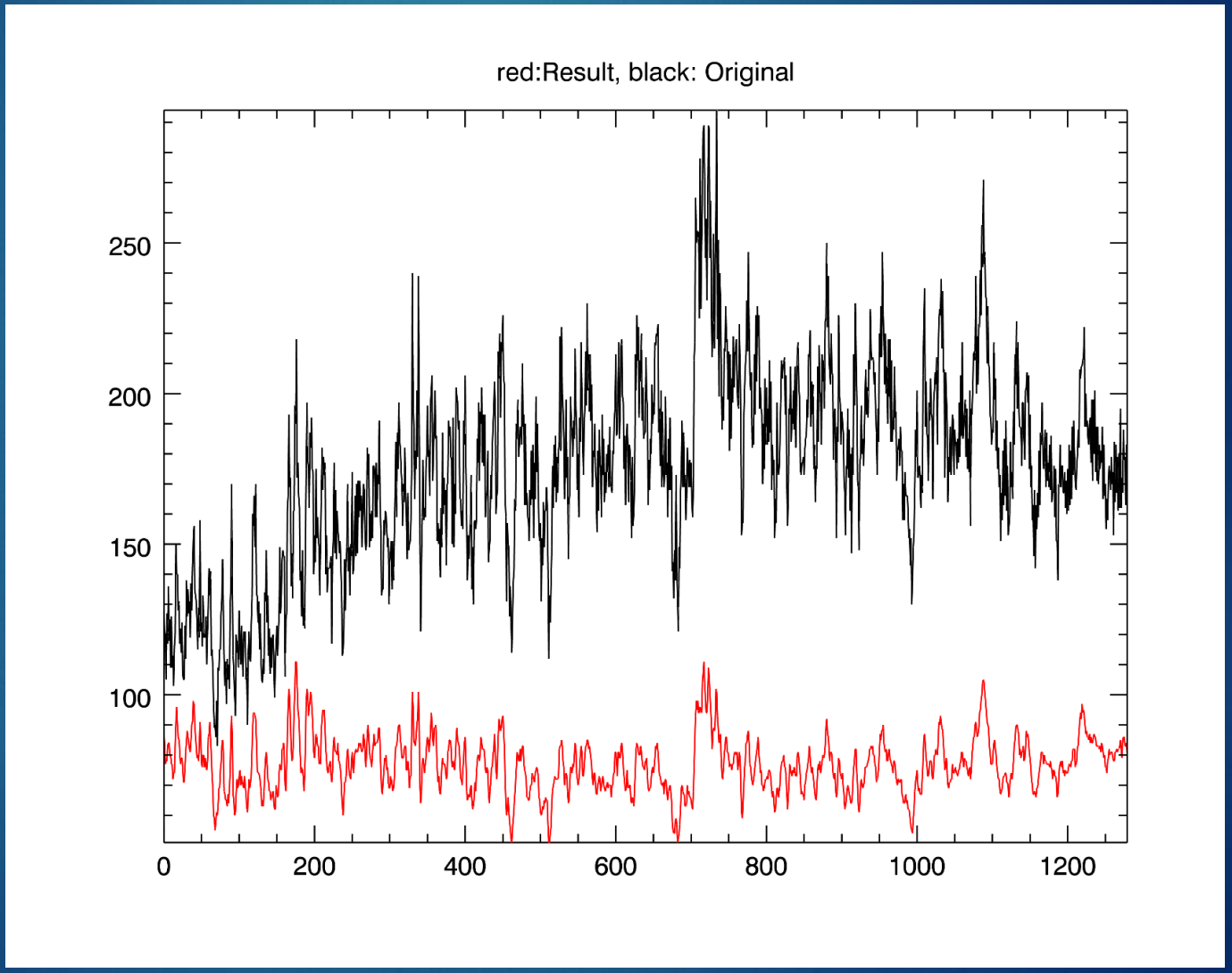
Black: original image **Red: filtered image**

Data processing
Vignetting

- 3D function surface
- Surface was calculated from a photo taken from a white surface



Data processing
Vignetting



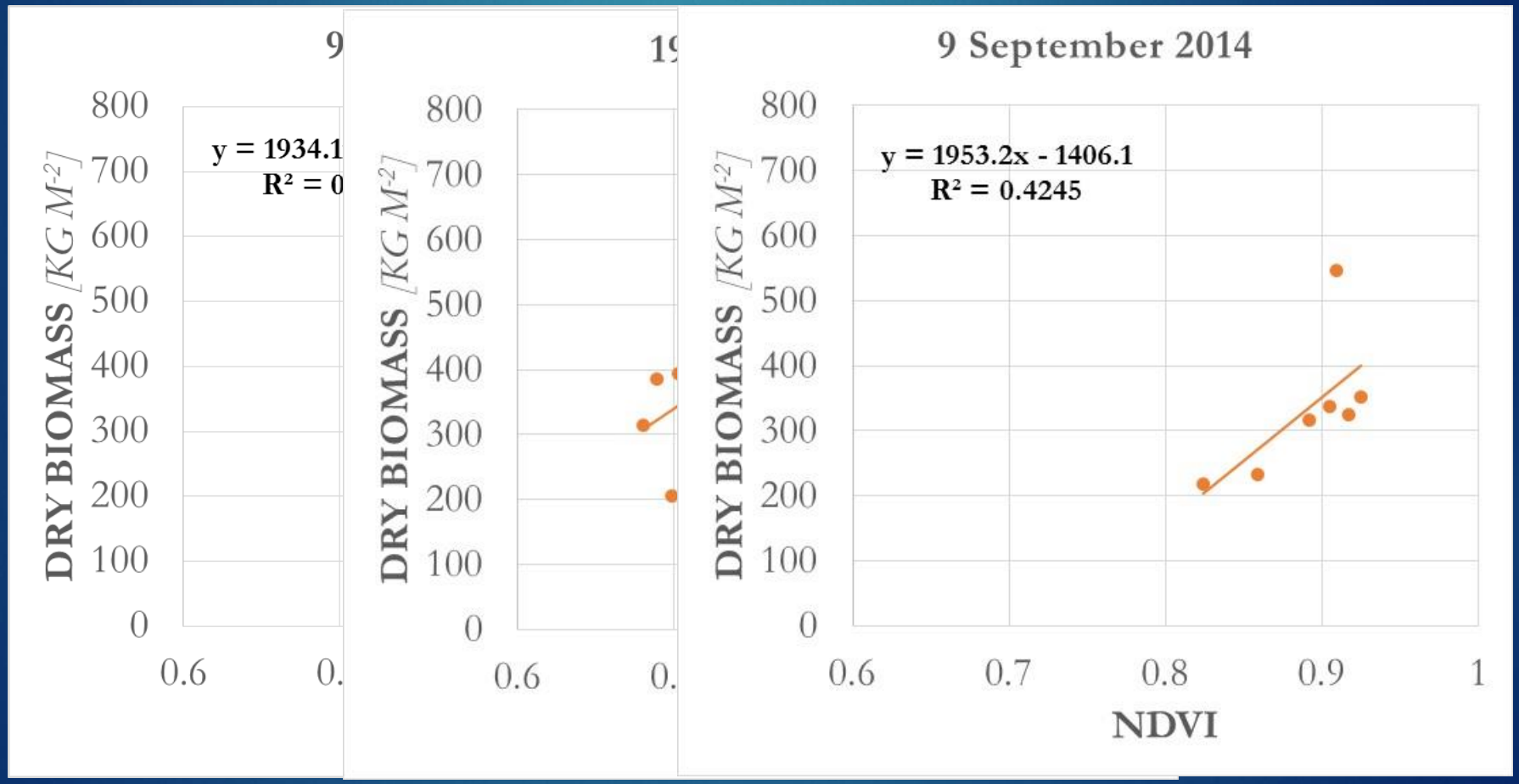
Data processing
Reflectance calculations

- Variable (automatic) exposure time during flights

and when taking image of the Teflon plate → normalizing all exposure times to that of the calibration pictures to get comparable reflectance values for the different images

Results
NDVI

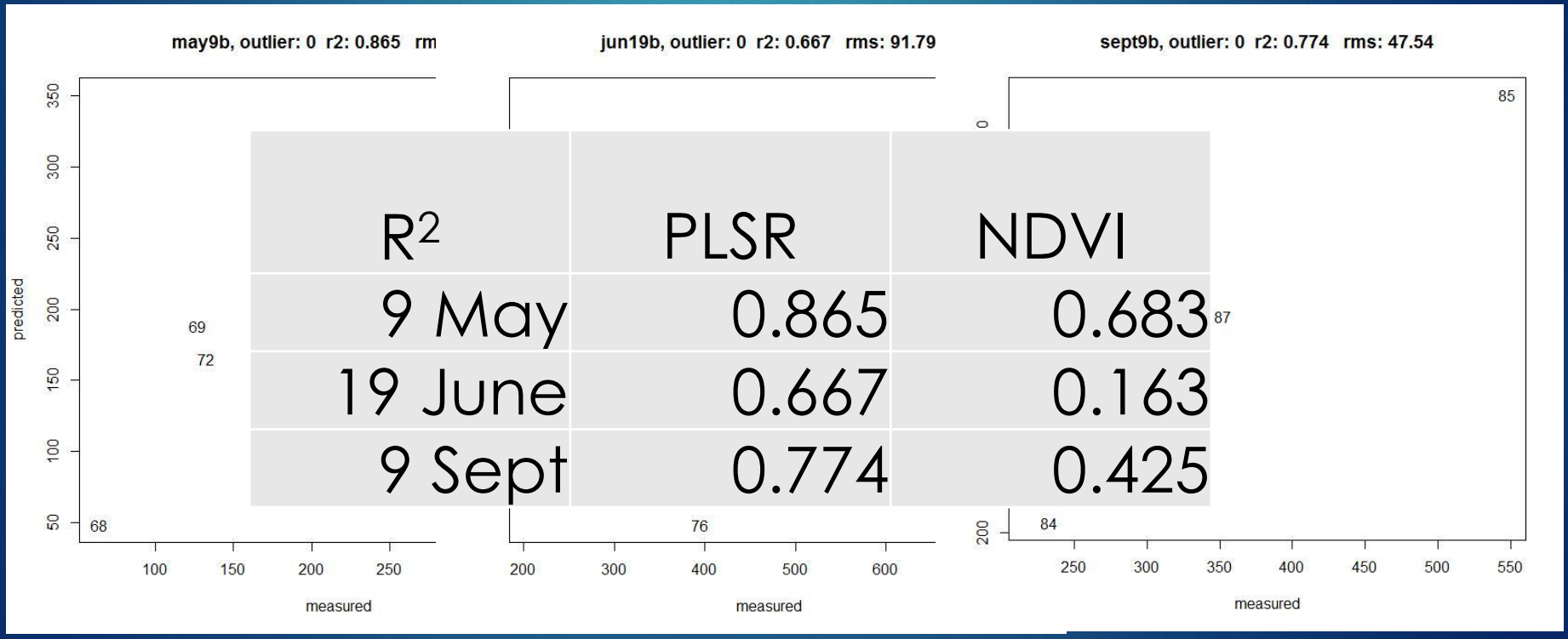
NDVI was calculated from the bands 680 and 800 nm.



Results

Partial least squares regression

- Use of partial least squares regression model (plsr in R) to use the available channels (4 cameras) simultaneously to explain larger part of biomass variance.
  - Input: 4 reflectance values and biomass as dependent variable



R^2	PLSR	NDVI
9 May	0.865	0.683
19 June	0.667	0.163
9 Sept	0.774	0.425

Further possible steps when using PLSR:

- Search for outliers: leaving out one of the seven calibration quadrats (BSQ) leading to the largest increase in PLSR's R2.
- Inclusion of standard deviation (of a ROI around the pixel) in PLSR to increase the number of input variables. (assumption: larger standard deviations may arise from higher variation of biomass within the BSQ and/or shadows due to size differences of plants).
- Test (validation) of the plsr approach: not finished yet, first result are disappointing. Using the "leave one out" method results in large RMSE

Conclusions

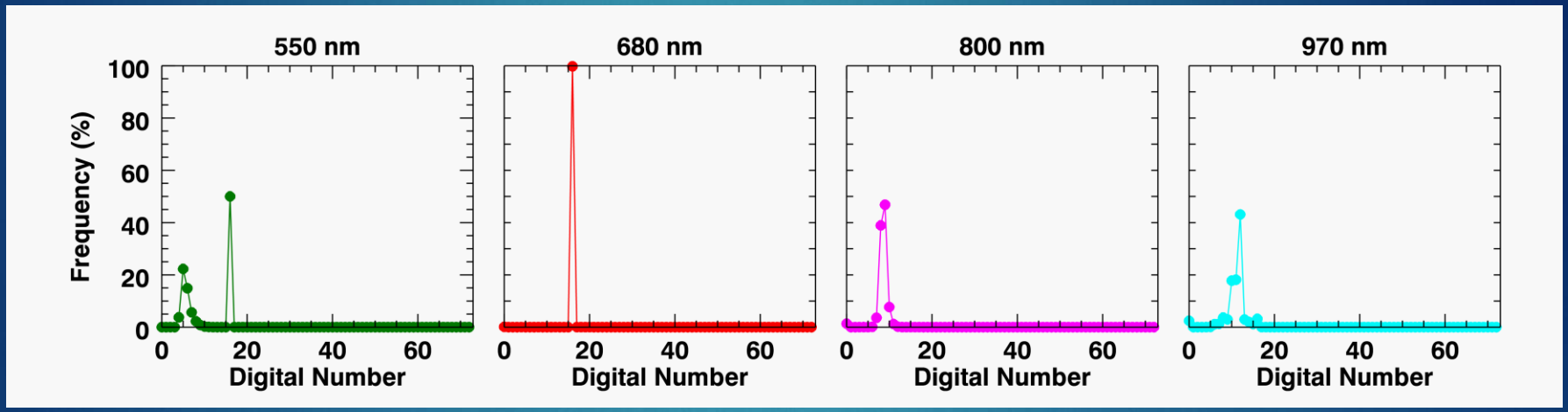
- Flights at wind speeds less than 5 ms^{-1} - requires early flights during the day ←→shadows
- Flights during noon hours ←→ windy and cloudy conditions.
- Auto exposure (master) is needed to avoid over or under exposition of the master.
- Problems with the exposure times (some of the channels may be over or underexposed compared to the master) – adjusting the relative exposure times to avoid over or under exposition AND to increase the dynamic range. This may decrease the weight of the black noise significantly.
- Use of ILS for to get direct reflectance values
- Increasing the number of biomass sampling quadrats (ground control) is not really feasible.
- Use of PLSR: underway, results are generally better than those from simple NDVI indices – validation of regression is the next step.

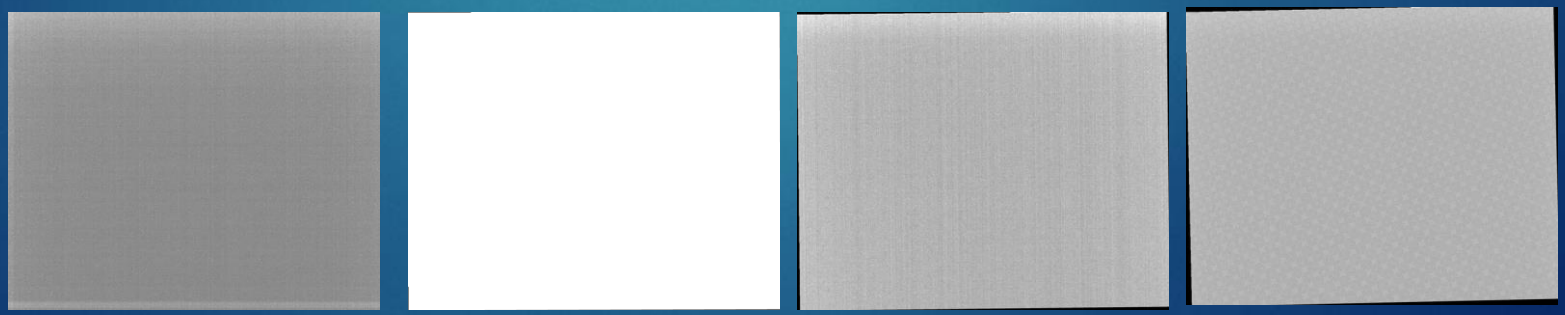
Thank you for your attention!

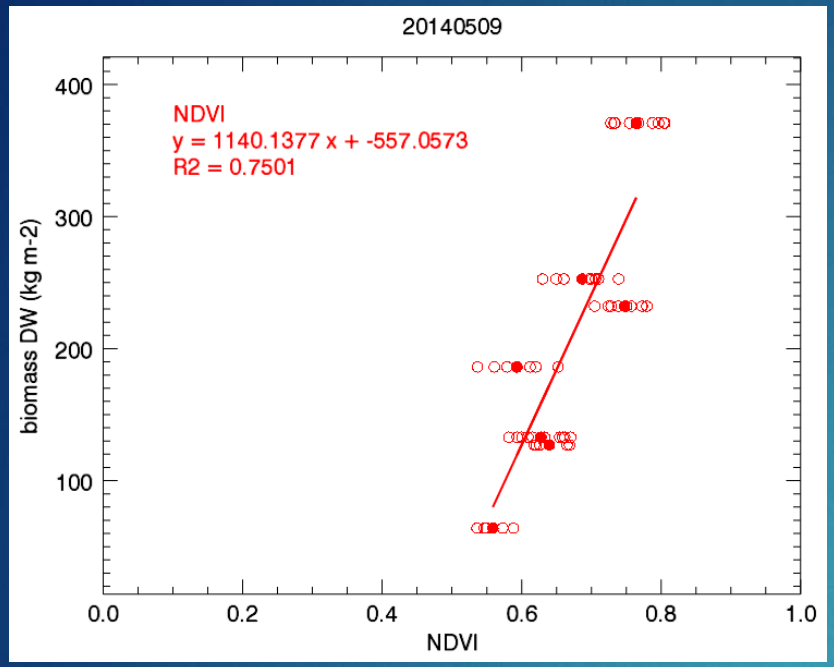
Dark noise filtering

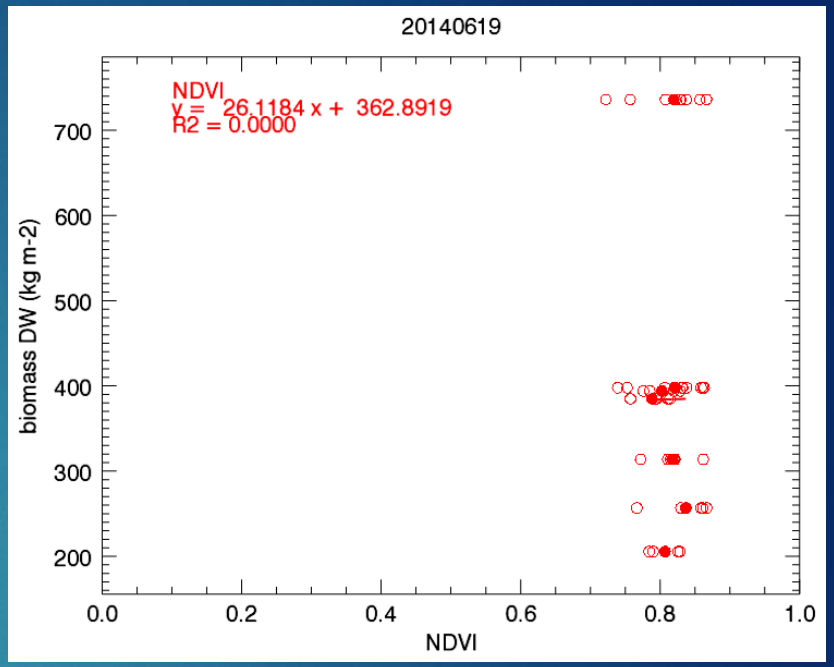
after Kelcey and Lucier, Remote Sens. 2012,4,1462-1493

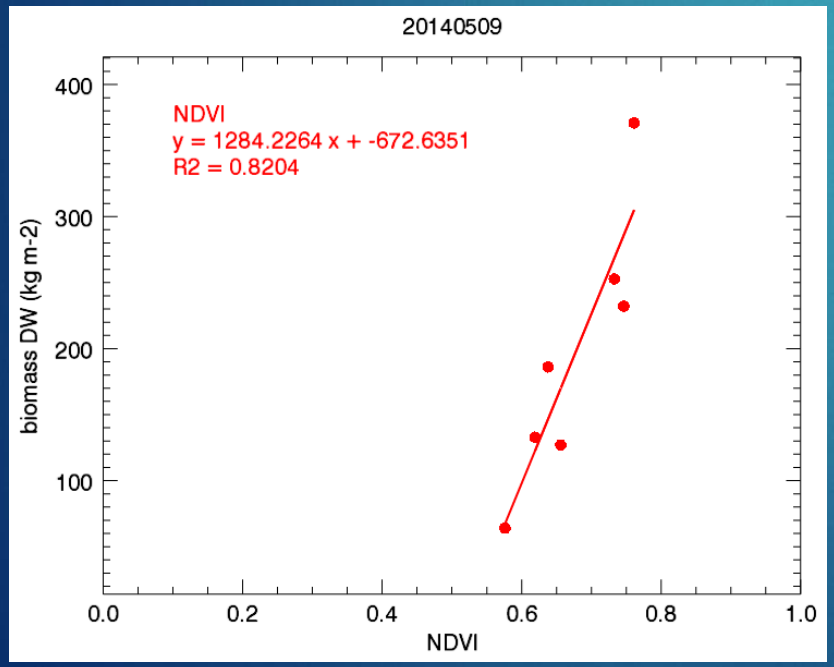
Average of 125 pictures (10bit) taken inside a dark box

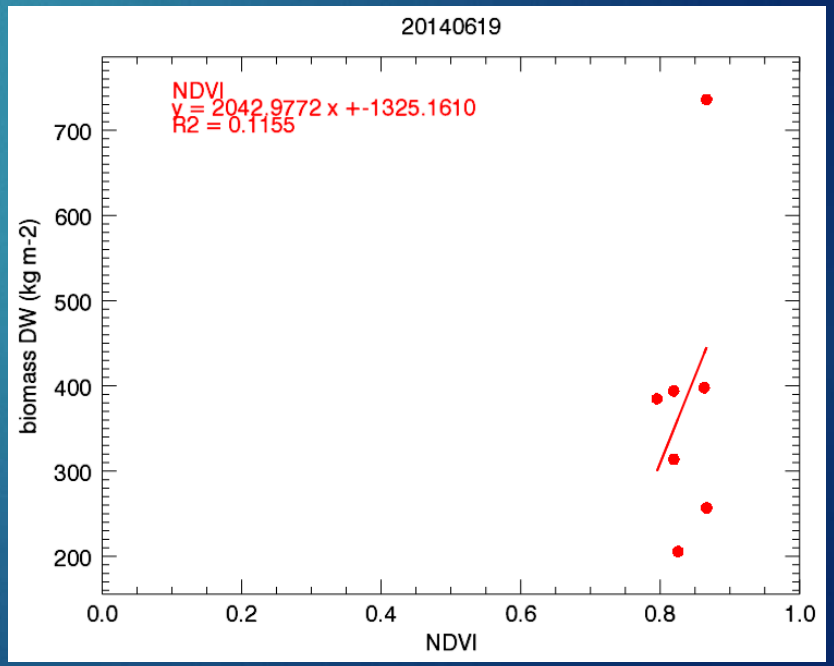





20140509
NDVI
y = 1140.1377 x + -557.0573
R2 = 0.7501
biomass DW (kg m-2)
NDVI
0.0
0.2
0.4
0.6
0.8
1.0
100
200
300
400


20140619
NDVI
y = 26.1184 x + 362.8919
R2 = 0.0000
biomass DW (kg m-2)
NDVI
0.0
0.2
0.4
0.6
0.8
1.0
200
300
400
500
600
700


20140509
NDVI
y = 1284.2264 x + -672.6351
R2 = 0.8204
biomass DW (kg m-2)
NDVI
0.0
0.2
0.4
0.6
0.8
1.0
100
200
300
400


20140619
NDVI
y = 2042.9772 x +-1325.1610
R2 = 0.1155
biomass DW (kg m-2)
NDVI
0.0
0.2
0.4
0.6
0.8
1.0
200
300
400
500
600
700