7th FerryBox Workshop

Flow-through PSICAM – Detecting changes in phytoplankton based on autonomous hyperspectral absorption measurements

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Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Part 1

MOTIVATION, BACKGROUND AND TECHNICAL DEVELOPMENT

Introduction: Motivation

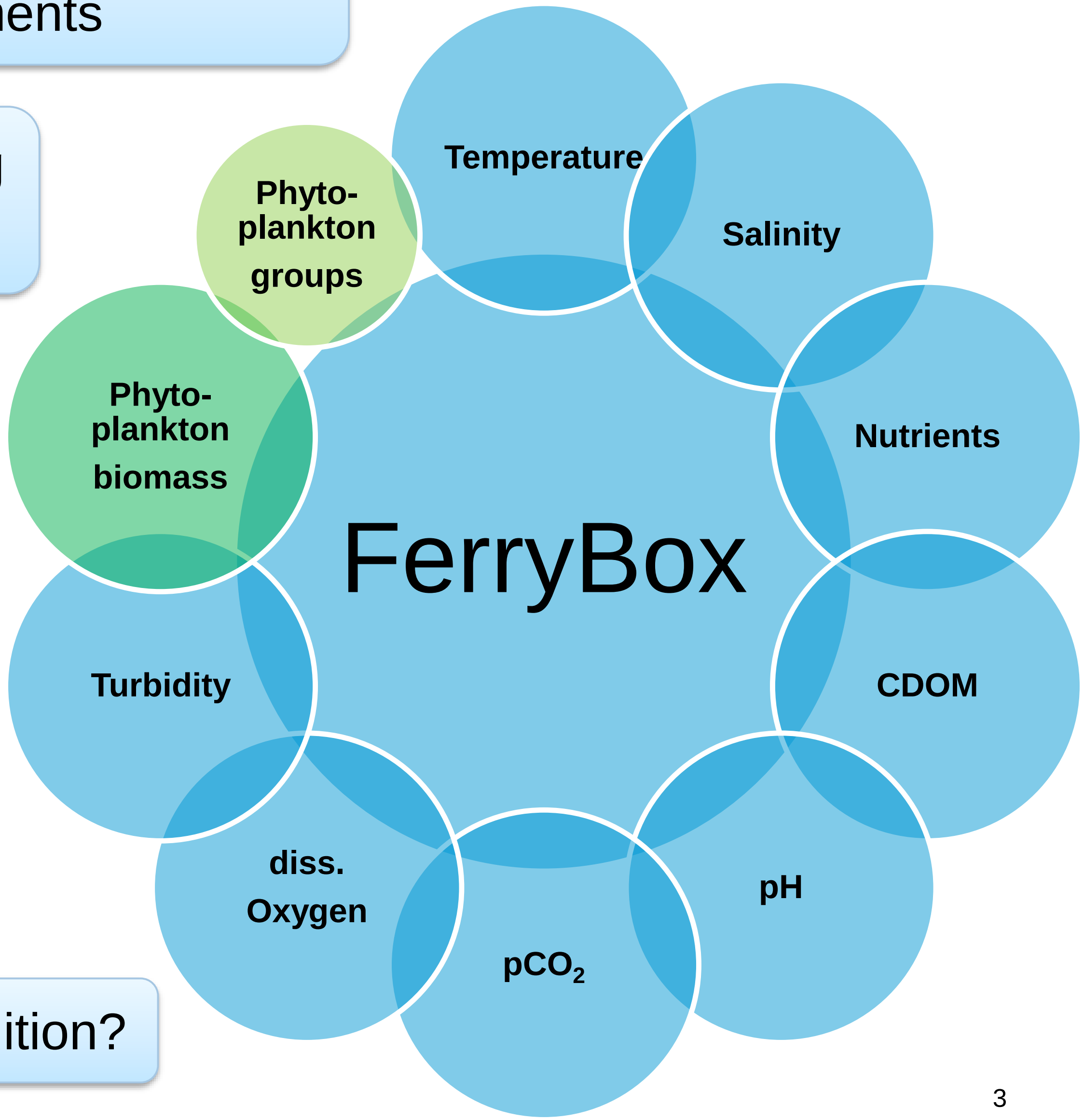
High quality monitoring of the marine environment benefits from autonomous, high frequency measurements

Autonomous devices like FerryBox operating on VOS further reduce monitoring effort

Phytoplankton mostly estimated by fluorescence

- Mostly bulk biomass
- Limited taxonomical information
- Variable due to physiological condition of the cells
- Frequent calibrations necessary

Absorption as a more stable alternative/addition?

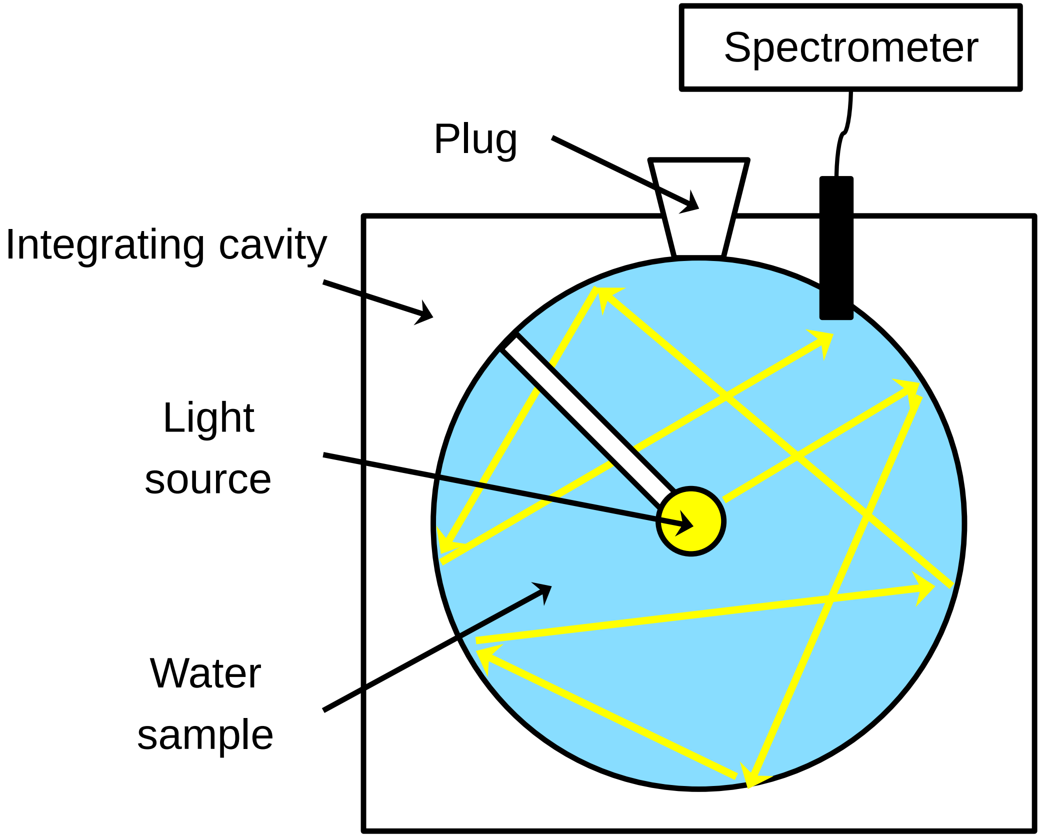


Introduction: The integrating cavity approach

Obstacles in absorption measurements:

- Particles scatter light
  - Additional light loss
  - Correction necessary
- Low amount of absorbing material
  - Concentration necessary
  - Manual handling
  - Long cuvettes

point-**s**ource **i**ntegrating **c**avity **a**bsorption **m**eter (PSICAM)



Aim: Adapting the PSICAM approach for flow-through operation

Current status of development

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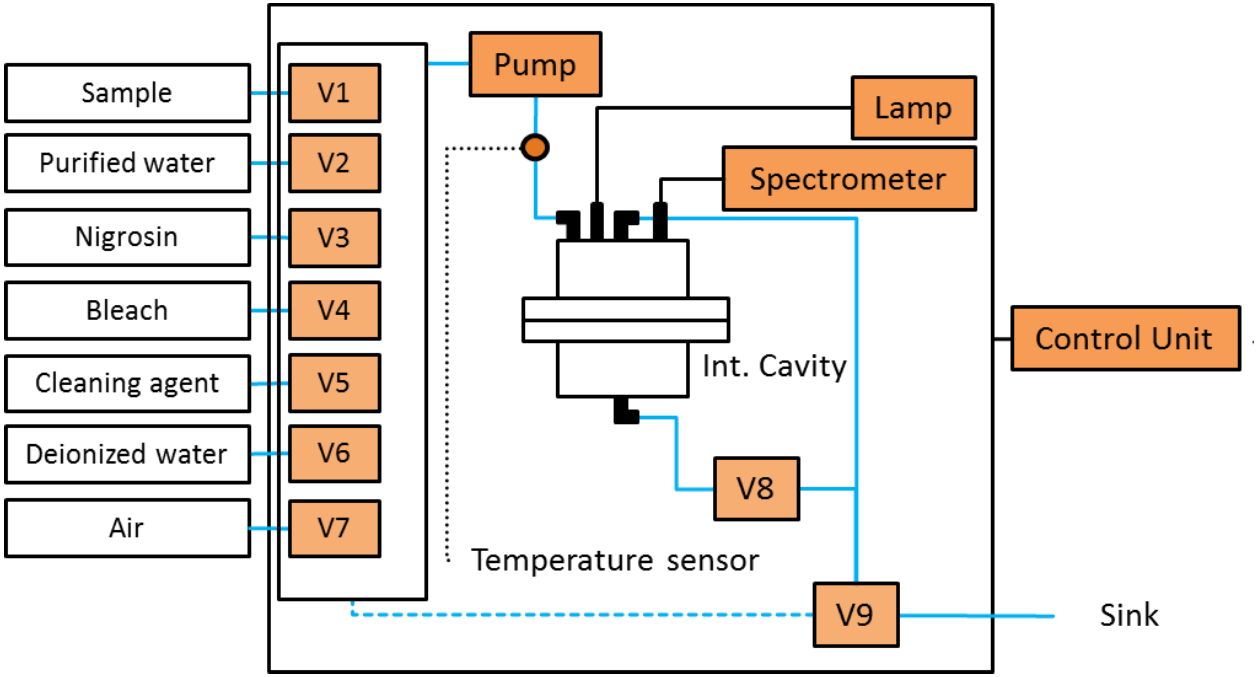
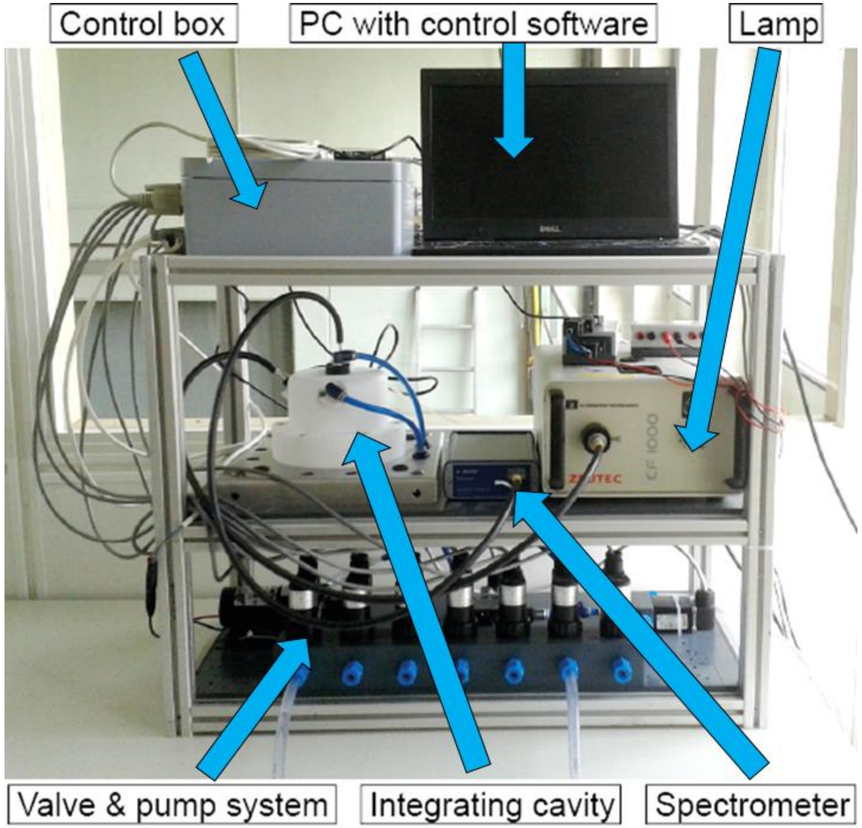
The Hyperspectral Absorption Sensor (HyAbS)





- LabView-based software
- Automated operation
  - By time schedule
  - Only refill of necessary liquids
- Stand-alone or connectable to FerryBox

Absorption spectra

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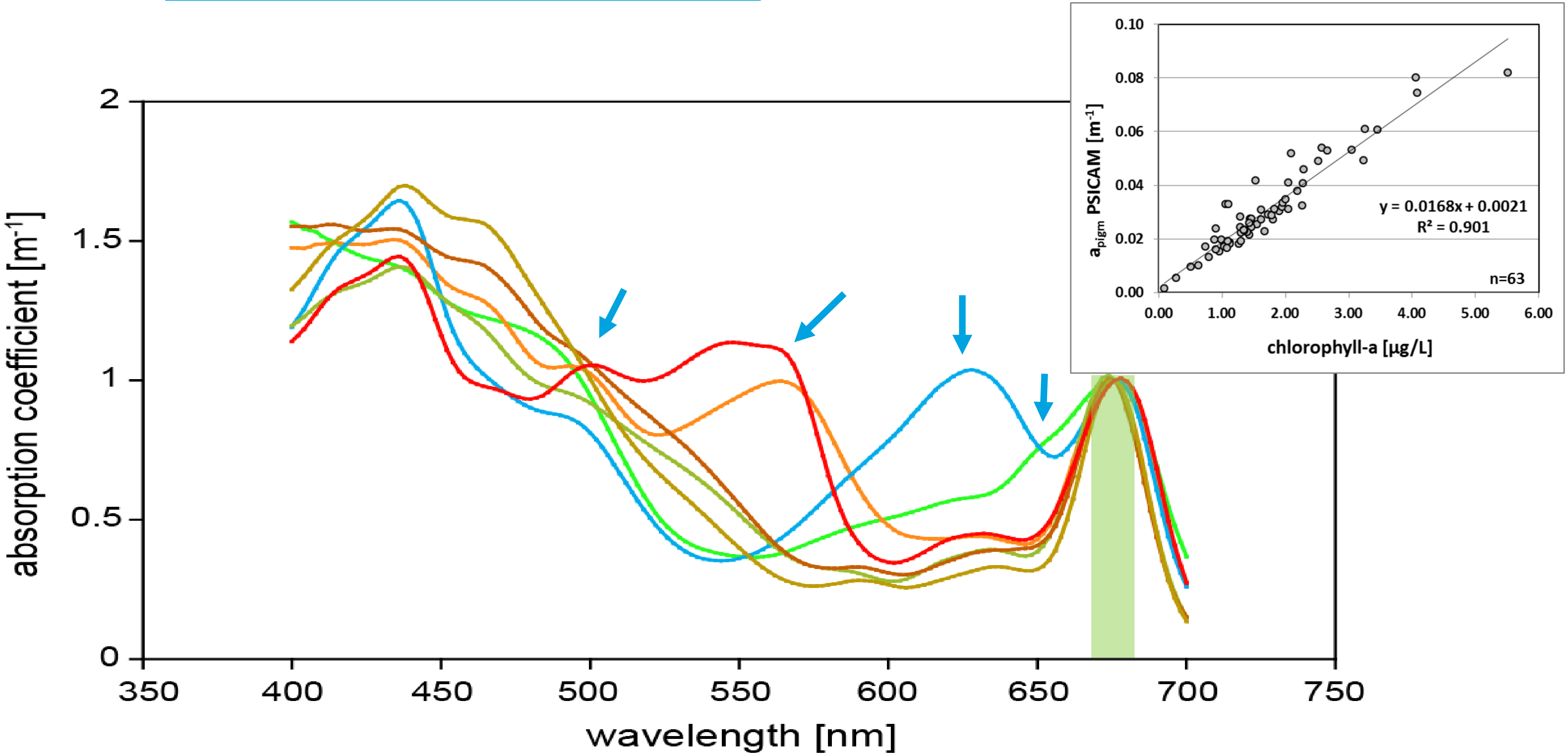

a_{pigm} 676 nm: Indicator of **biomass**

(a_{pigm} 676 nm = a_p 676 nm – a_p 700 nm)

Shape: Influenced by pigments present

Indicator for **composition**

Part 2

APPLICATION AND DATA EVALUATION

Field test in the Norwegian Sea

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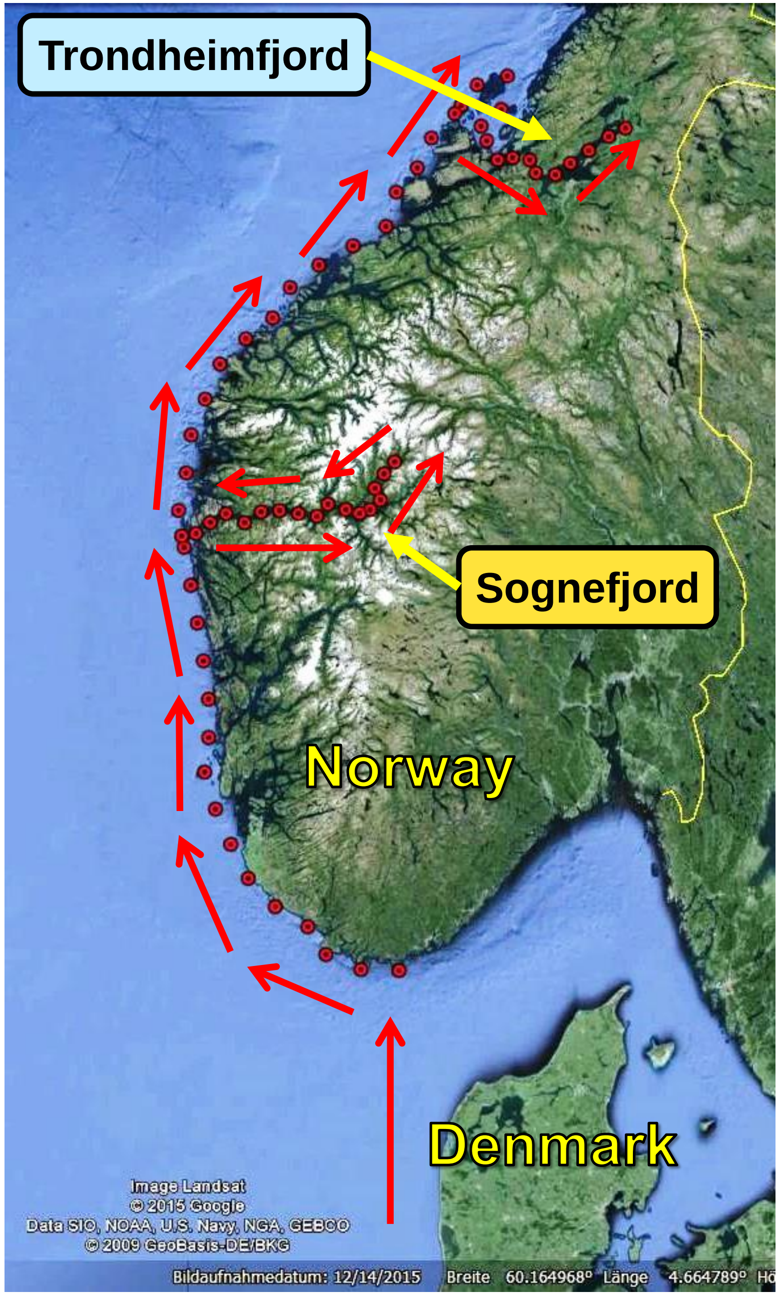
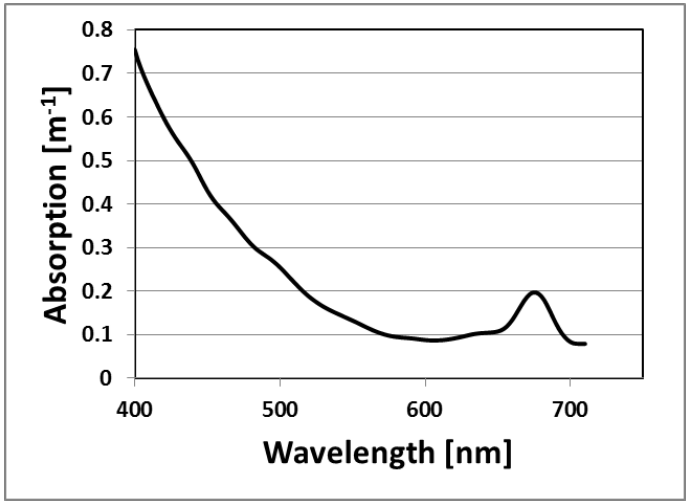
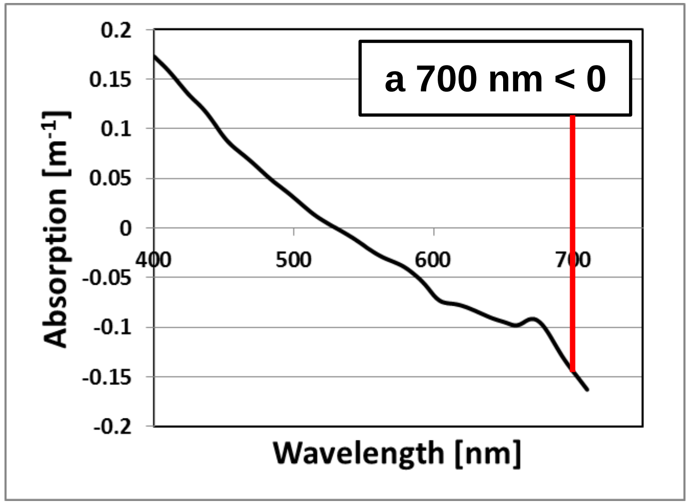
- Different water masses (coast + fjord regions)
- Continuous automated operation over 19 days
- No major technical problems
- One spectrum per minute (approx. 20000)

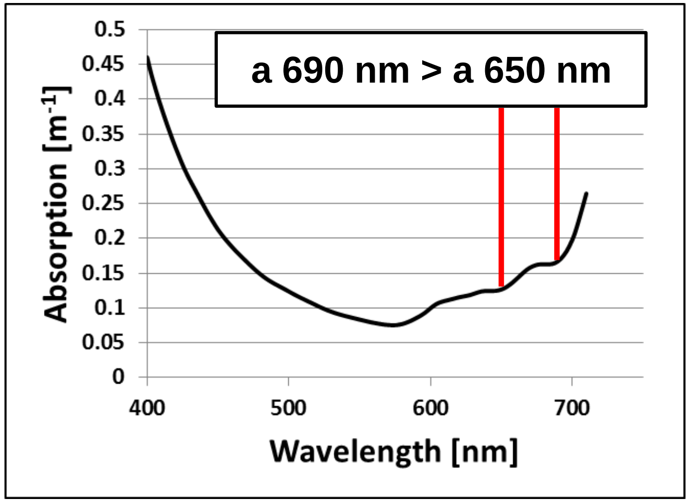
- Control measurements by conventional PSICAM
- Continuous in situ fluorescence measurements



Data examples





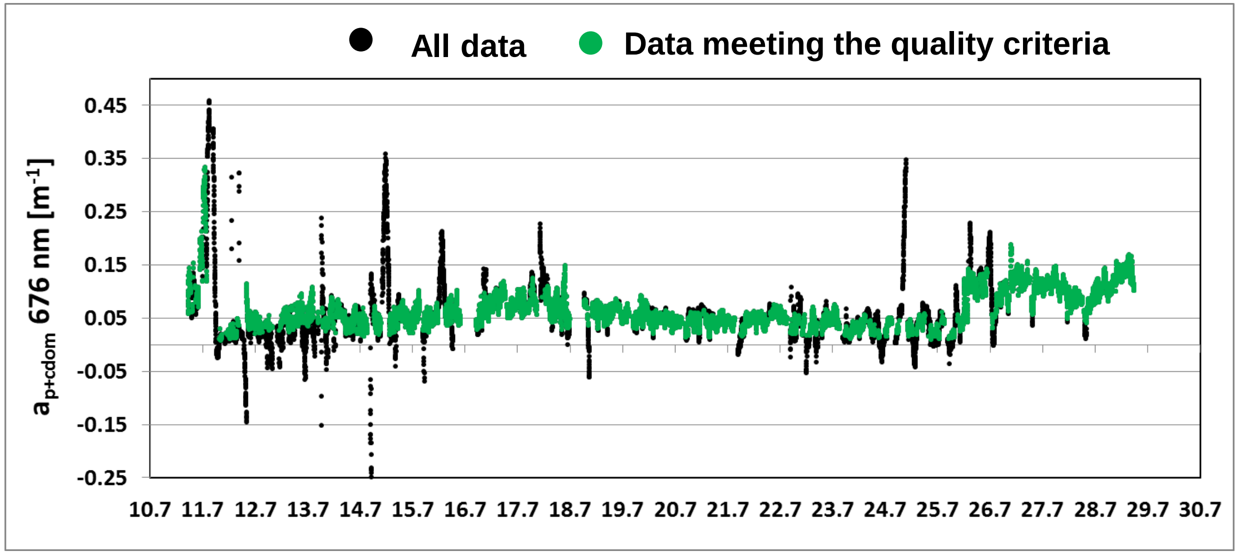


Partially, spectra were distorted

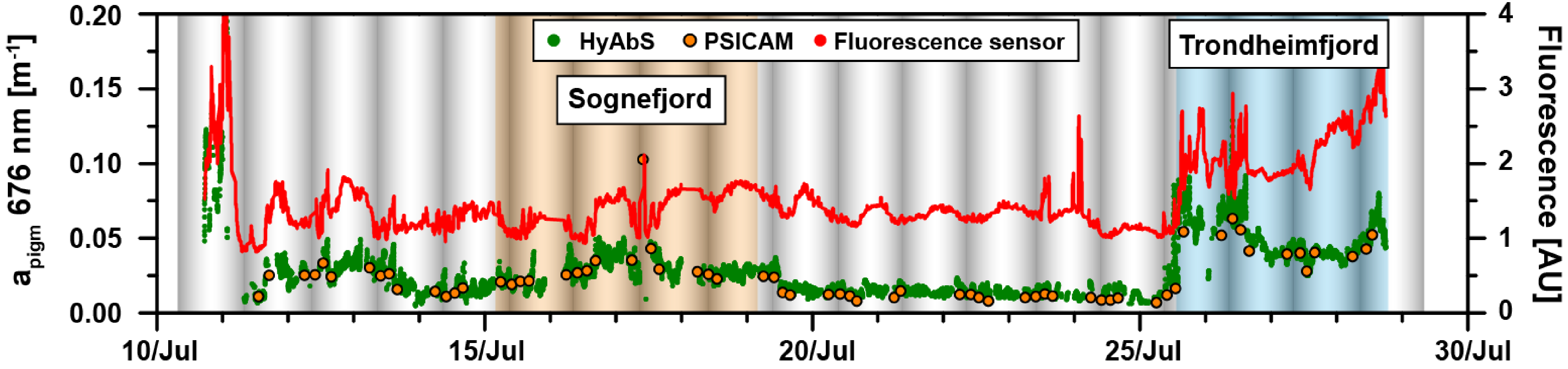
Potential reason: Light measurements biased by air bubbles in the cavity

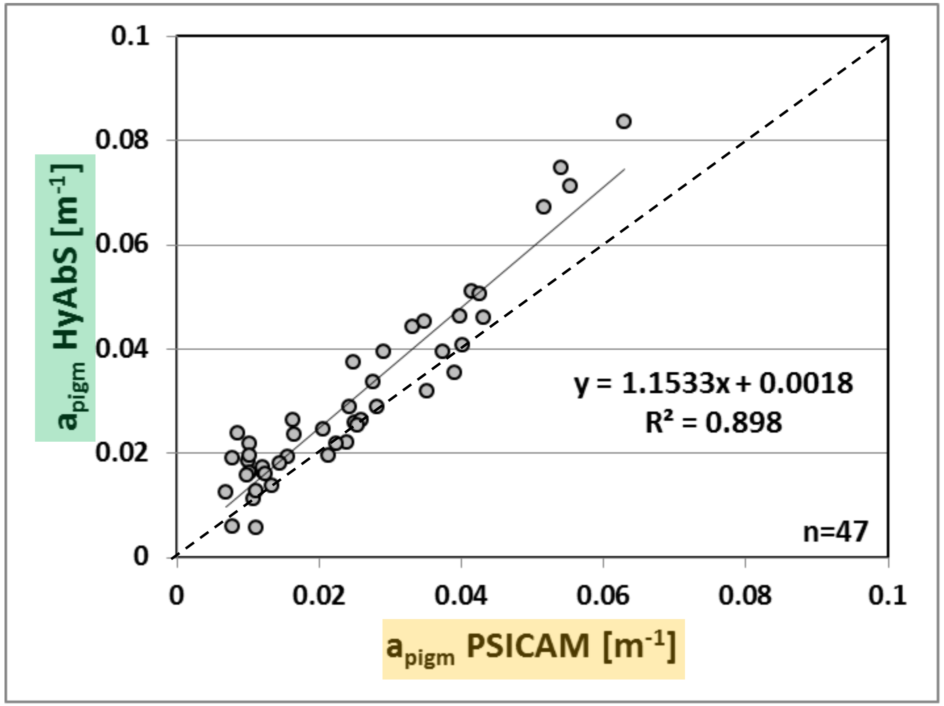
High number of data requires automated quality check

73 % of data are compliant to these criteria



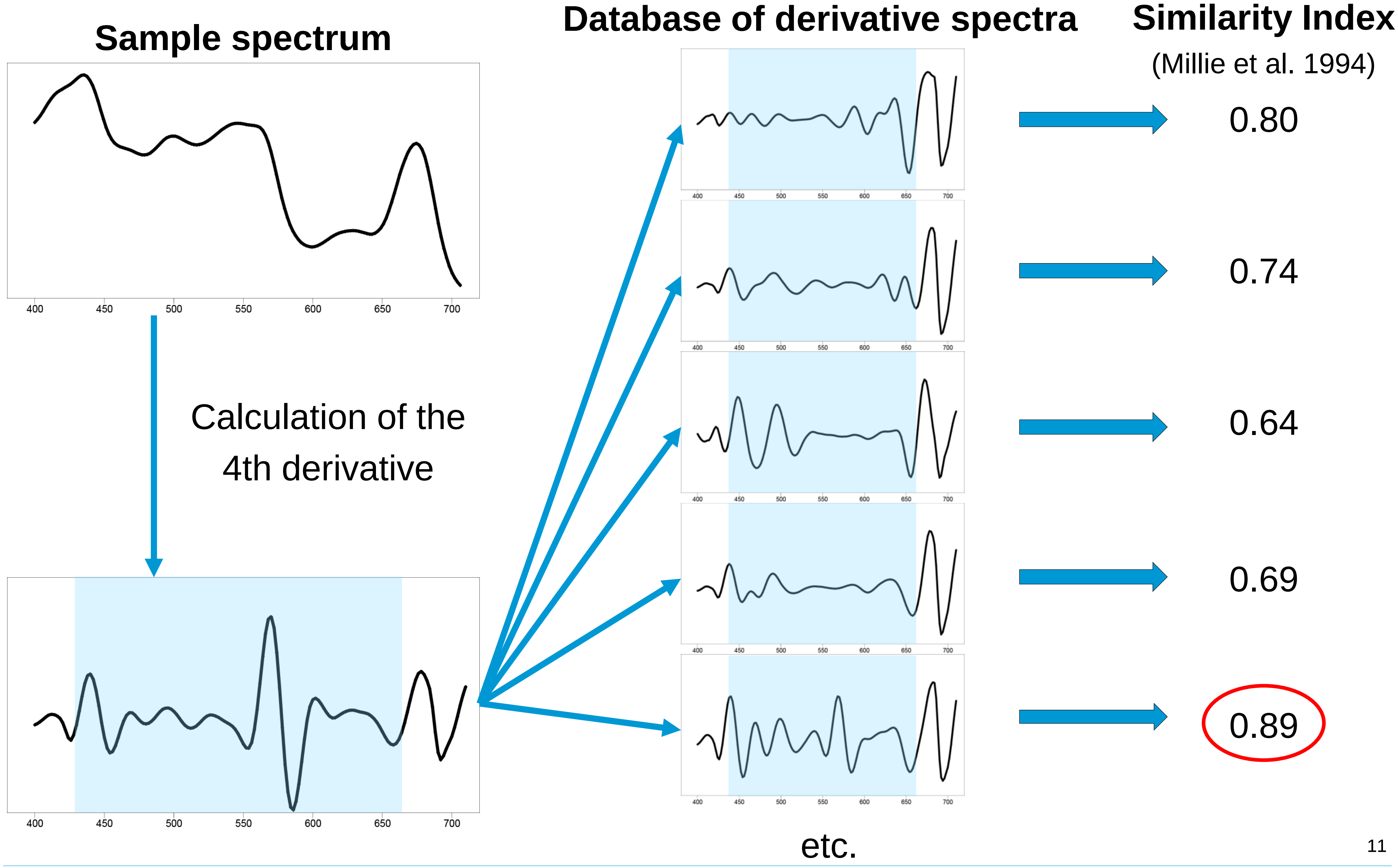
Biomass estimation





- Good accordance between continuous and manually obtained data
- No light induced variations

Group determination: Approach



Group determination: Test with cultures

140 spectra of algal cultures

(85 species, 16 spectral groups)

Mathematical creation of artificial communities

- All possible combinations
- One dominant spectrum, one background spectrum
- Different proportions (90:10, 80:20, 70:30, 60:40, 50:50)

Result:

Reference library of

approx. 80000 mixed spectra

Test sample dataset

Test reference dataset

Evaluation:

Identification of dominant group in samples by comparison with references

Group determination: Results of lab test

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Dominating group (60 %)	Recognized correctly [%]
Diatoms	87
Chlorophyte Type I	95
Chlorophyte Type II	59
Chlorophyte Type III	43
Chrysophyte	91
Cryptophyte Type II	94
Cyanobacteria Type I (bluegreen)	93
Cyanobacteria Type II (brown)	96
Cyanobacteria Type III (Prochlorococcus)	96
Dinophyte	56
Haptophyte	38

- Good identification of
  - Crysophytes
  - Cryptophytes
  - various groups of cyanobacteria
- Chlorophytes were often confused with each other, but not with other groups
- Summarizing chlorophytes in one group?
- Difficult identification of diatoms, dinophytes and haptophytes
- Summarizing in one group?

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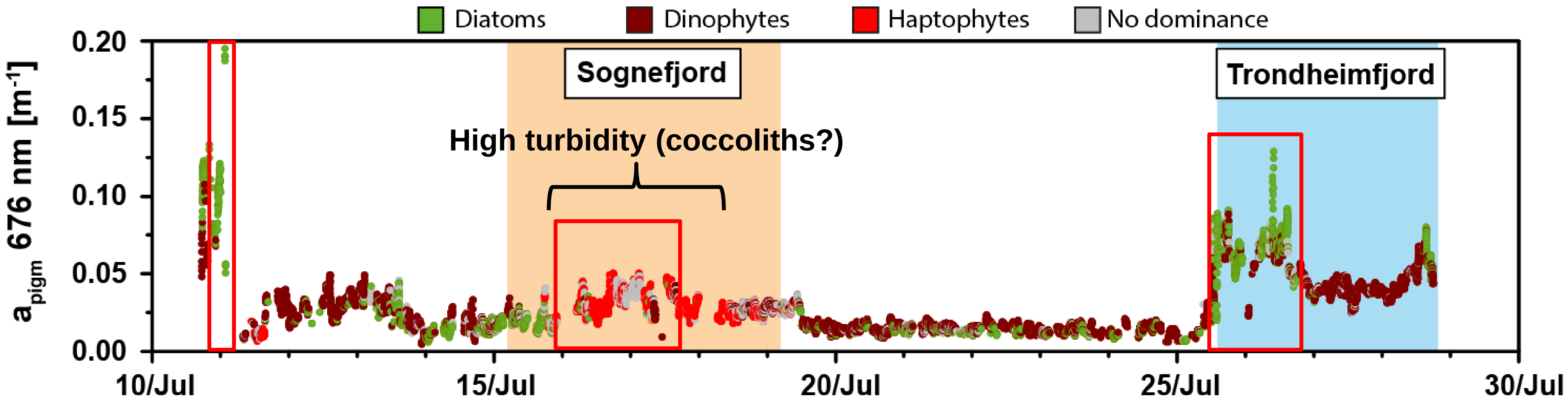
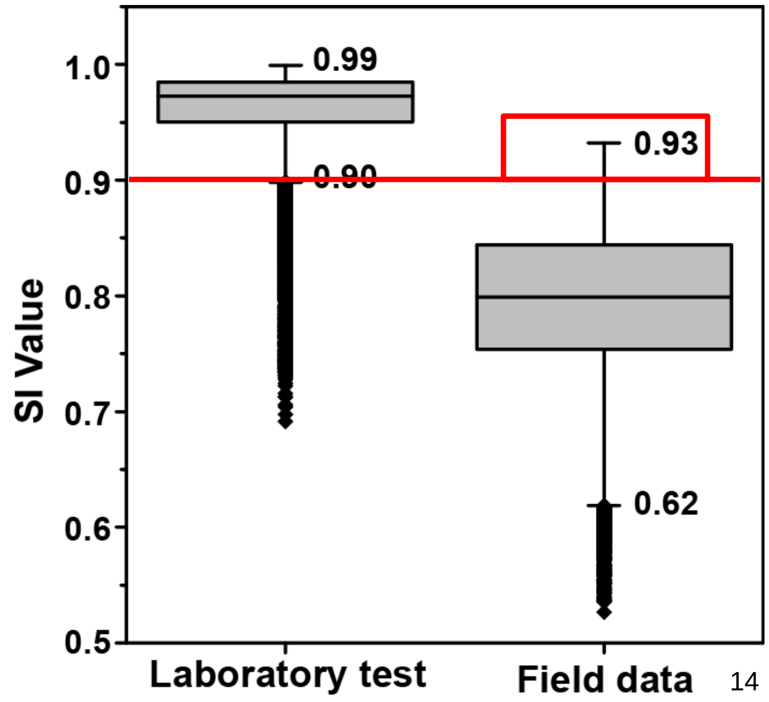
Application to field data



- Only occurrence of „difficult groups“
- **But:** Difference between the two fjords visible
- Results reliable?
- SI field samples < SI culture samples
- Limited number of culture spectra in database
- Light conditions different

➡ Inclusion of field spectra in database required



Conclusions

- Progress regarding continuous automated hyperspectral absorption measurements
- Emphasis has to be put on avoiding air in the system
- Applied criteria for quality check allow a reasonable filtering of the data
- Phytoplankton identification algorithm shows successful detection of groups with distinctive pigments
- Differences between regions also in field data visible
- Further validation of results necessary (microscopy, pigment data)
- Further improvement of identification by supplementing the database with field spectra

Thank you for your attention

Group determination: Test with cultures

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Group dominating the sample	Degree of dominance [%]	Dominant group was recognized as [% of samples]															
		Bacillariophyte	Chlorophyte I	Chlorophyte II	Chlorophyte III	Chrysophyte	Cryptophyte I (Cryptomonas)	Cryptophyte II	Cyanobacteria I (Bluegreen)	Cyanobacteria II (Brown)	Cyanobacteria III (Prochlorococcus)	Cyanobacteria IV (Red)	Cyanobacteria V (Limnothrix)	Dinophyte	Euglenophyte	Haptophyte	Rhodophyte
Bacillariophyte	60	87	6	1	0	1	0	1	2	0	0	0	0	2	0	1	0
	70	91	5	1	0	1	0	0	1	0	0	0	0	1	0	0	0
	80	94	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	90	98	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyte I	60	1	95	1	0	0	0	0	1	0	0	0	0	1	0	0	0
	70	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	80	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	90	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyte II	60	7	24	59	0	1	0	1	3	0	0	0	0	2	0	1	0
	70	5	22	67	0	1	0	1	3	0	0	0	0	0	0	1	0
	80	3	23	70	0	1	0	0	1	0	0	0	0	0	0	0	0
	90	1	22	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyte III	60	10	16	16	43	2	0	2	3	0	0	0	0	4	0	2	0
	70	7	16	18	50	2	0	1	3	0	0	0	0	0	0	1	0
	80	5	13	26	49	1	0	0	3	0	0	0	0	0	0	1	0
	90	2	6	33	57	0	0	0	1	0	0	0	0	0	0	0	0
Chrysophyte	60	1	1	0	0	91	0	0	3	0	0	1	0	1	0	0	0
	70	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
	80	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
	90	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
Cryptophyte II	60	2	1	0	0	0	0	94	1	0	0	1	0	0	0	1	0
	70	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
	80	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Cyanobacteria I (Bluegreen)	60	1	2	0	0	1	0	0	93	1	0	0	0	0	0	1	0
	70	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
	80	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
Cyanobacteria II (Brown)	60	0	2	0	0	0	0	1	0	96	0	1	1	0	0	0	0
	70	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0
	80	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0
Cyanobacteria III (Prochlorococcus)	60	1	0	0	0	0	0	1	1	0	96	1	1	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
	80	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
	90	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
Dinophyte	60	15	16	2	0	2	0	2	4	0	0	0	0	56	0	2	0
	70	11	13	2	0	1	0	1	3	0	0	0	0	66	0	1	0
	80	12	9	1	0	1	0	1	2	0	0	0	0	73	0	2	0
	90	11	2	0	0	1	0	0	1	0	0	0	0	82	0	2	0
Haptophyte	60	21	18	2	0	2	0	2	5	0	0	0	0	10	0	38	0
	70	21	18	1	0	2	0	1	4	0	0	0	0	10	0	43	0
	80	23	15	0	0	2	0	1	3	0	0	0	0	12	0	44	0
	90	29	6	0	0	1	0	0	2	0	0	0	0	16	0	44	0

- Good identification of
  - Crysophytes
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  - various groups of cyanobacteria
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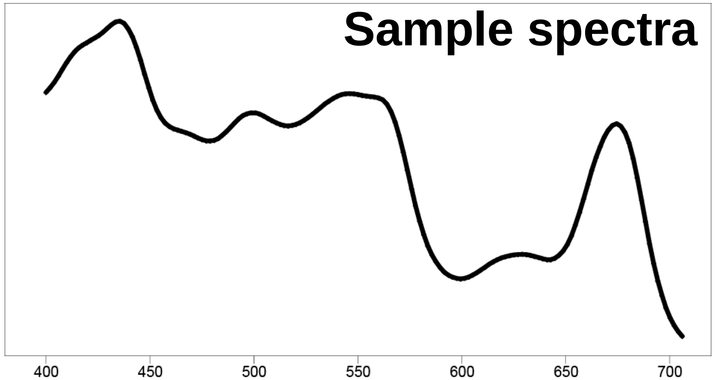
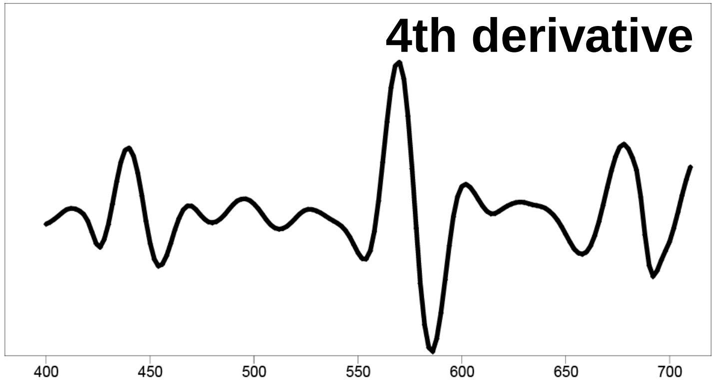
- Summarizing in one group?

Quantifying differences in spectral shape

1.) Enhancement of spectral features





2.) Calculation of similarity

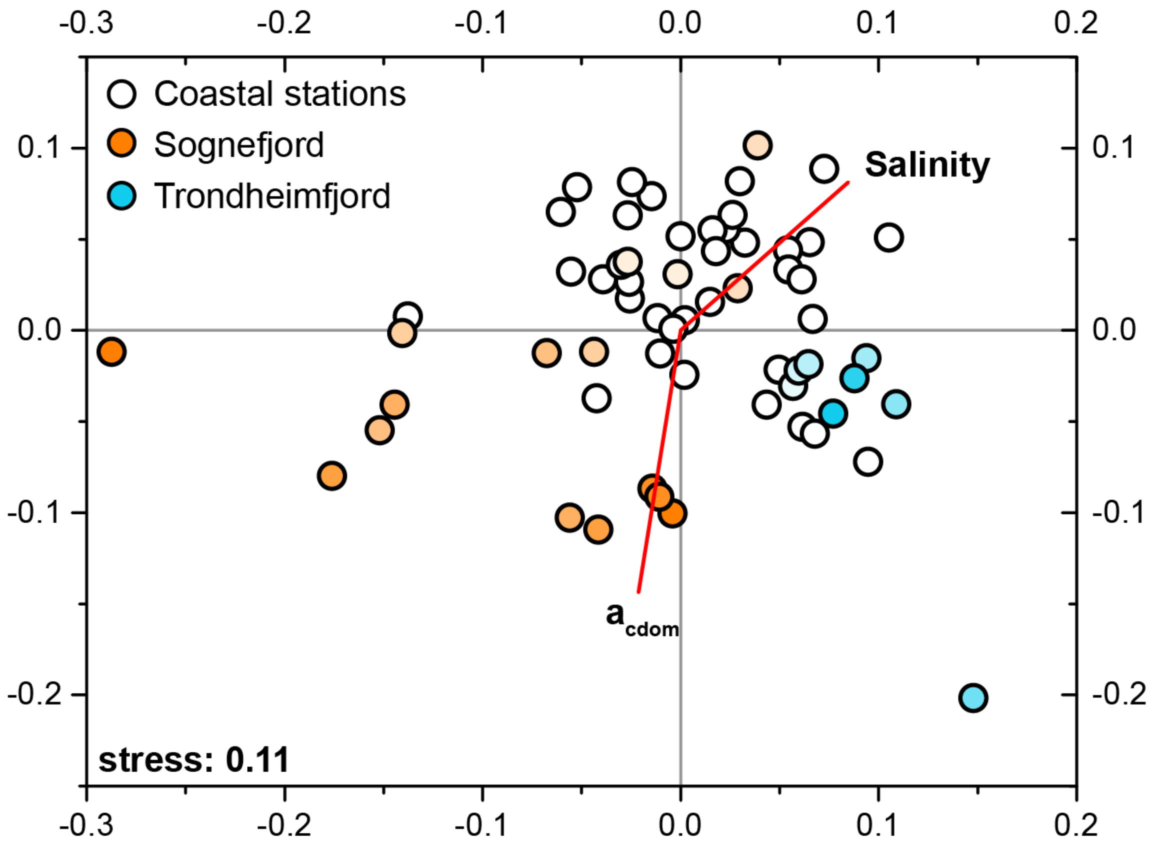
Similarity Index
(Millie et al. 1994)
Range: 0 to 1

Matrix
of Similarity Indices
between samples

3.) Arrangement of stations according to their similarity

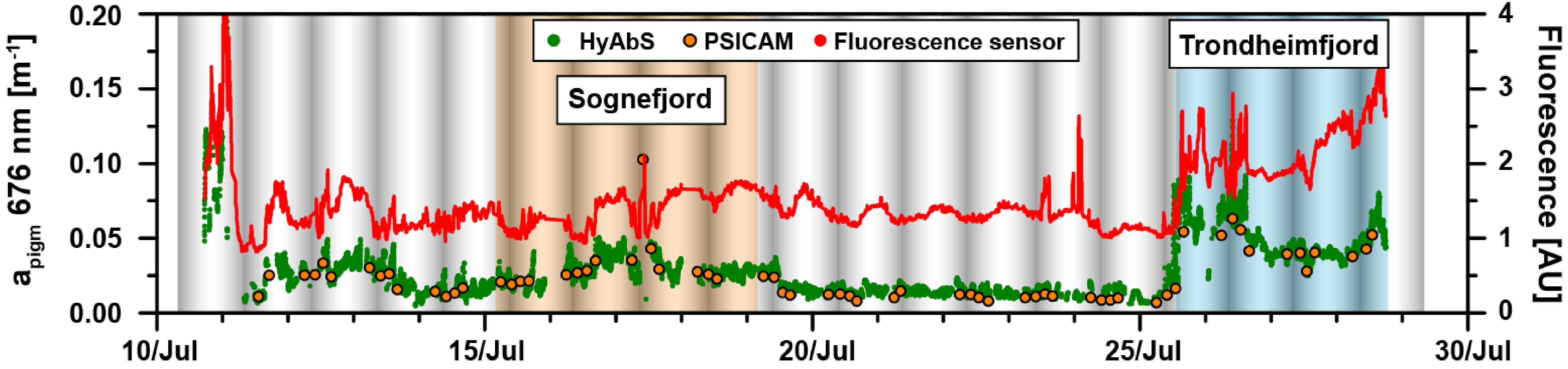
	Sample 1	Sample 2	Sample 3
Sample 1		0.95	0.89
Sample 2	0.95		0.92
Sample 3	0.89	0.92	

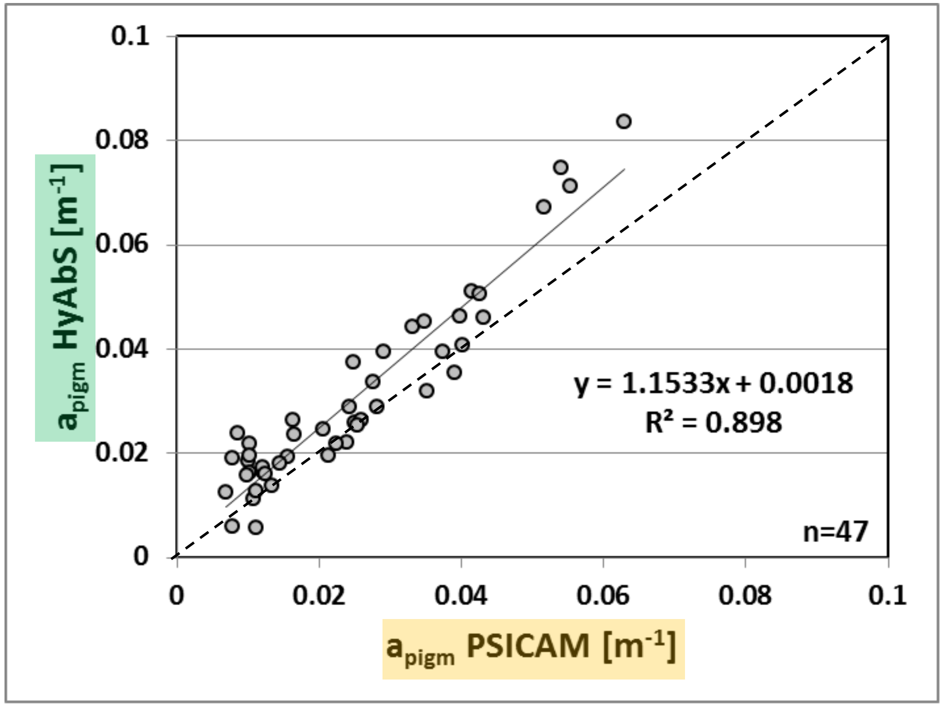
Example for conventional PSICAM data

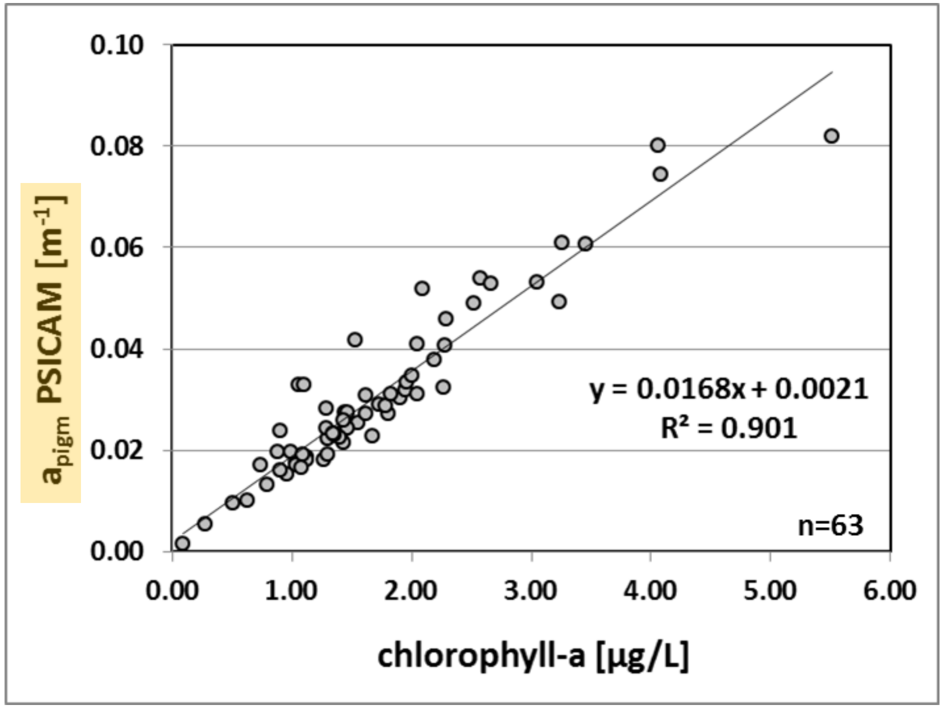


- Regional differences in spectral shape are visible

Biomass estimation







In progress: Solid Standard Calibration

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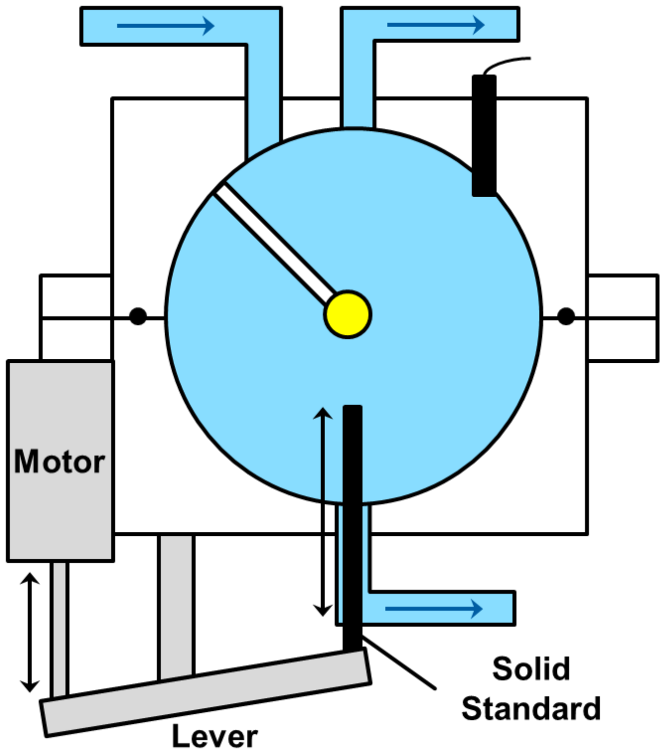
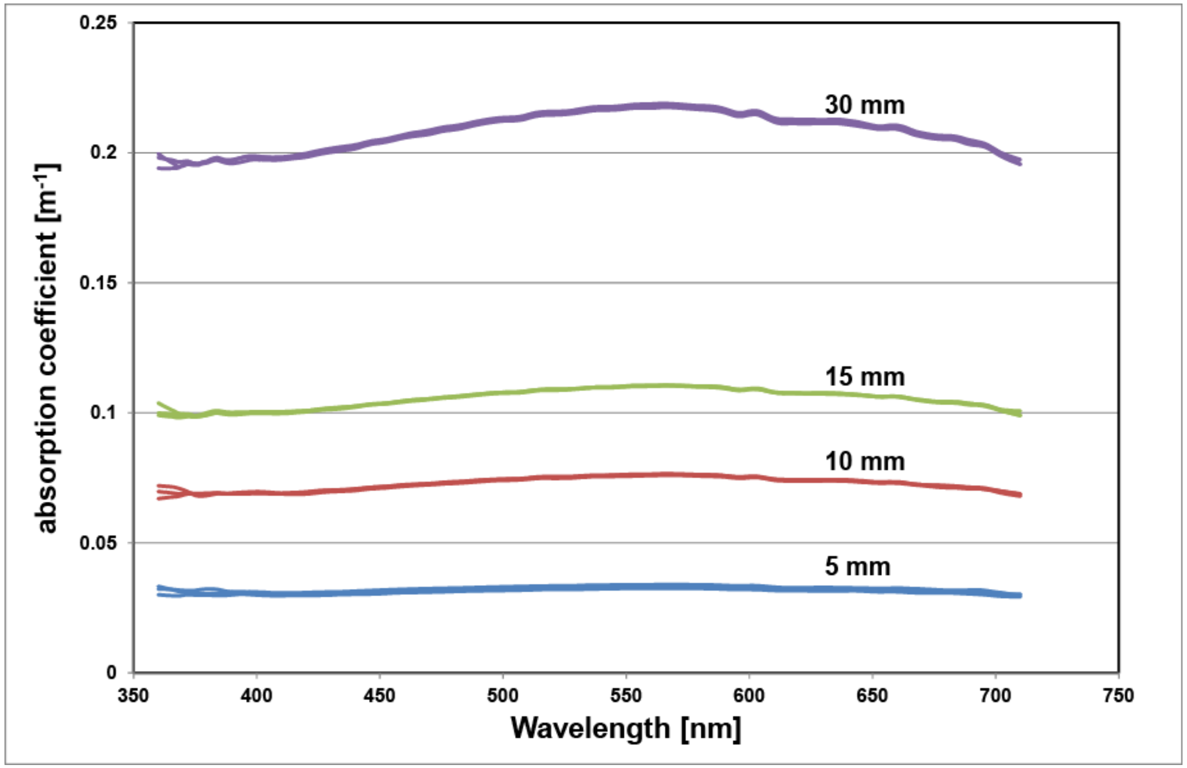
Problem: In integrating cavities, optical path length is a function of cavity-reflectivity

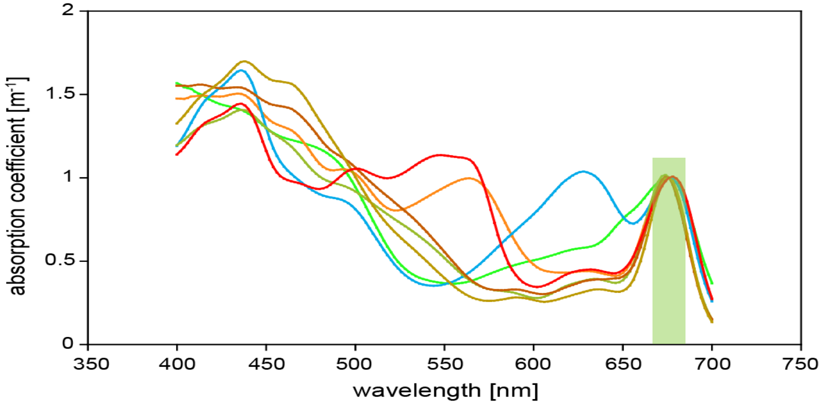
- Reflectivity can be calculated using a dye with known absorption
- Requires cleaning and regular dye supply

Solution: Creating a known absorption for reflectivity calculation using a solid standard





Biomass estimation



a_{pigm} 676 nm is a reasonable proxy for chl-a