COASTCOLOUR

Possibilities and Limitations of regional processing

Roland Doerffer

HZG

3rd Coastcolour User Consultation Meeting

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What are the issues?

- Coastal waters have a variety of constituents with different optical properties
- These properties may vary with time / season
- Exceptional events may occur such as phytoplankton blooms of species with different optical properties
- Sea bottom might have an effect, depending on the concentrations of water constituents
- Floating material
- Presently it is not possible to meet this variety with one bio-optical model / algorithm

Overview

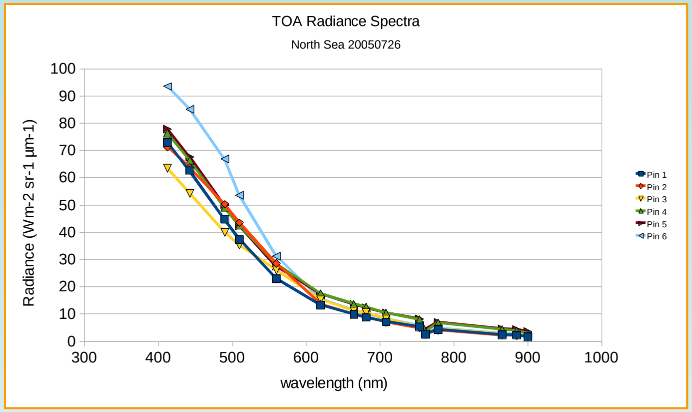
- Challenge of coastel colour research
- Limitations by atmospheric correction
- Limitations by in water algorithms
- Regional processing
- How to detect und push the limits
- Recommendations for next steps

Sources of uncertainties

- Errors in atmospheric correction -> water reflectances
- Link between AC correction and in water retrieval
  - Water reflectance in AC must meet actual (regional) properties
- Bio-optical model of algorithm does not agree with the actual properties
  - e.g. type of mineralic SPM, phytoplankton bloom, red tide
- Masking effect of dominant component (e.g high SPM, low chlorophyll)
- Saturation effect of spectral bands
- Different signal depths for multiband algorithm
- Variability in conversion IOP -> concentration

- Errors and uncertainties of in situ data used as reference
- Match up problems (scale, size of area, time, vertical distribution)

What determines the radiance spectrum at TOA



air molecules

different aerosols

thin clouds

contrails

Sky reflectance

Sun glint

foam

floating material

Suspended particles

dissolved organic matter

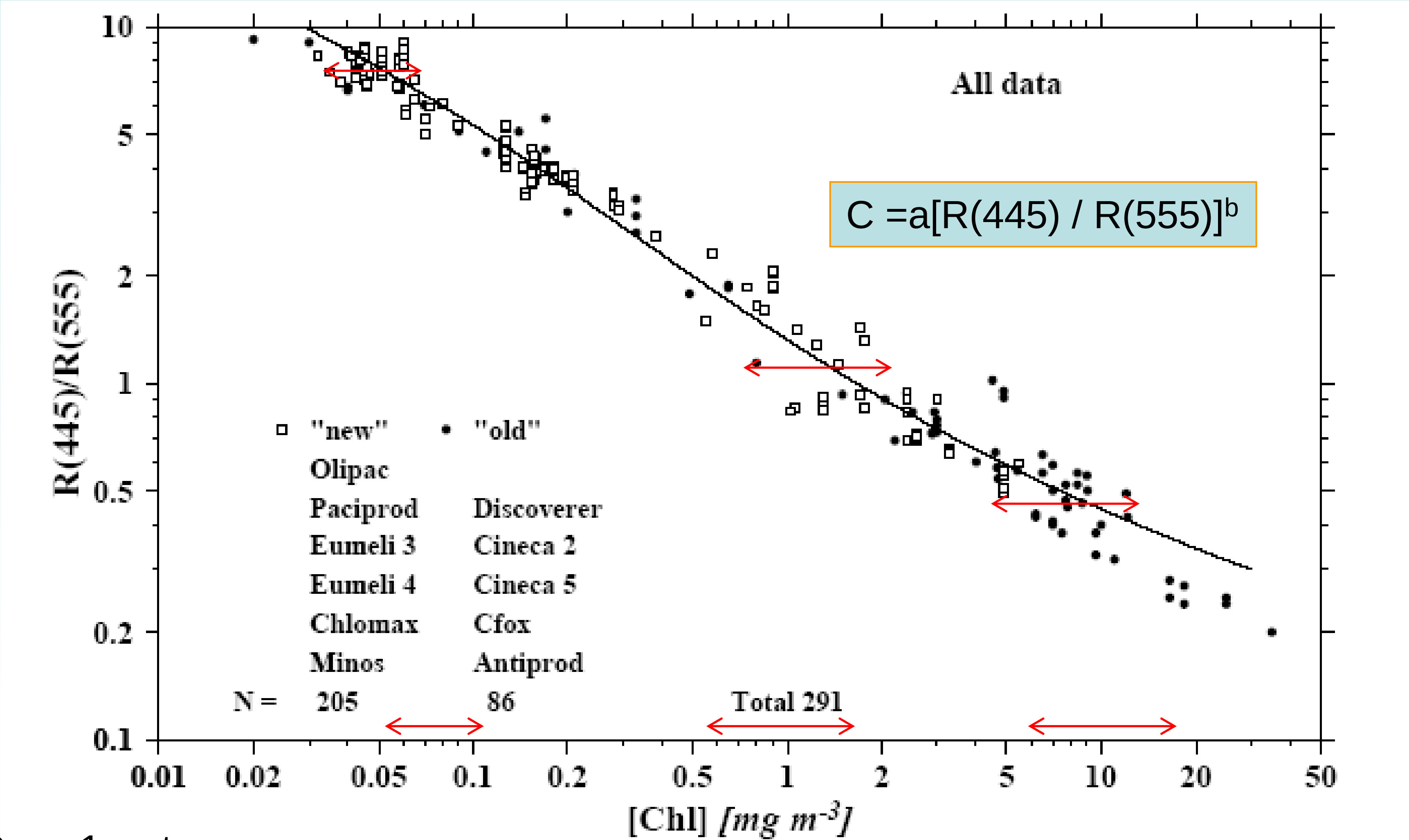
Vertical distribution

chlorophyll

Bottom reflection

different phytoplankton species

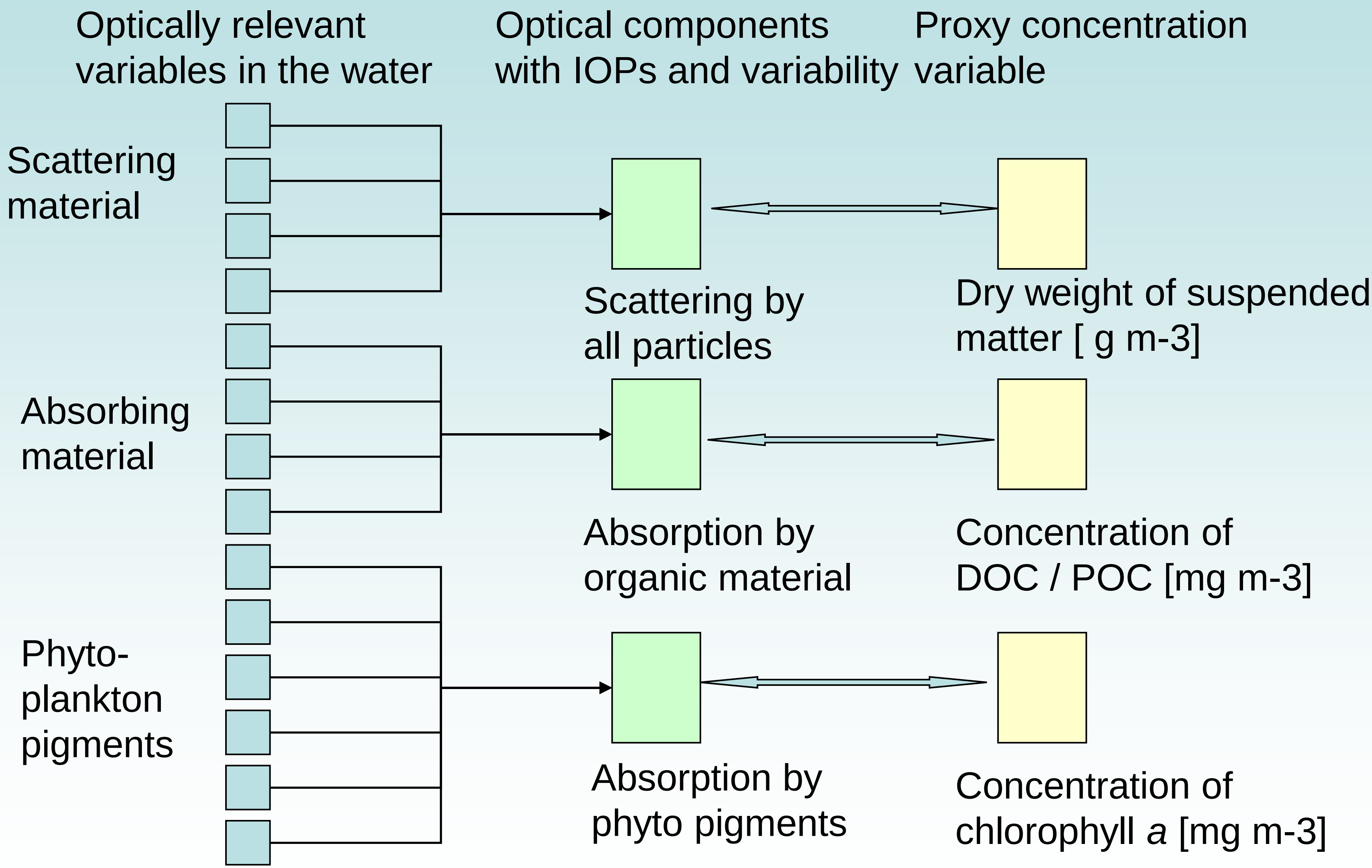
Case 1 water algorithm based on reflectance ratio model R445 / R555



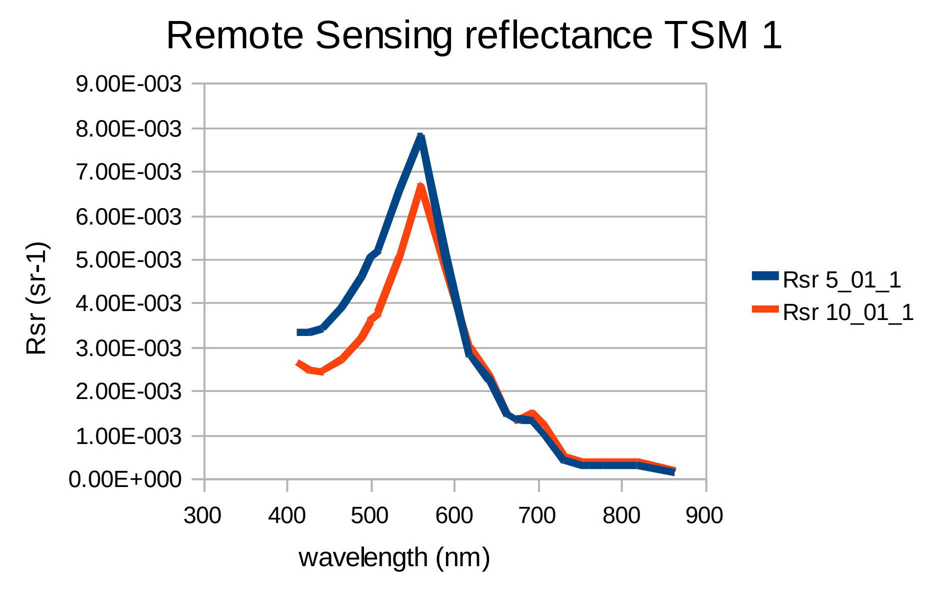
Case 1 water:

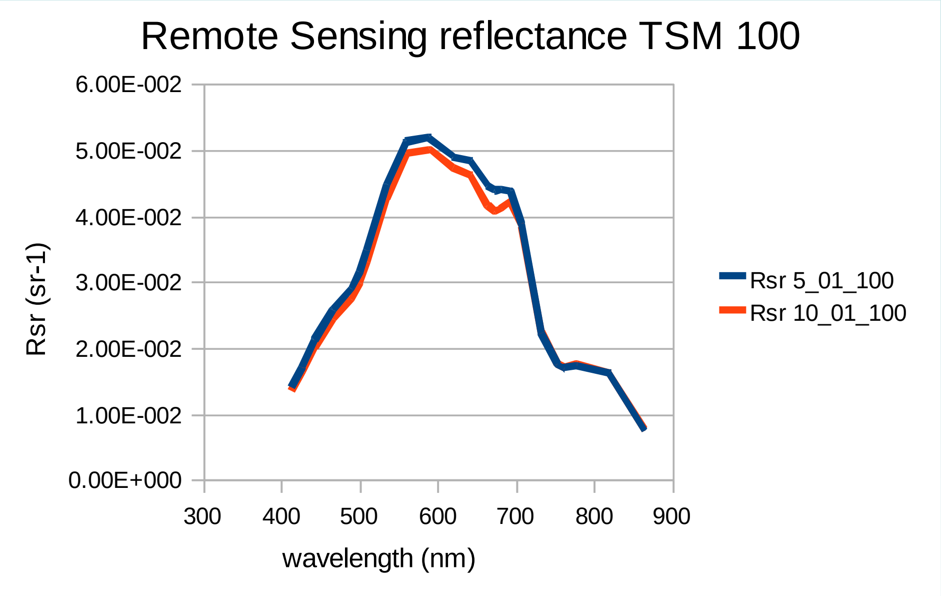
Morel / Antoine MERIS Case 1 water ATBD

Uncertainties due to the bio-optical model



Sensitivity at different concentration ranges and spectral bands



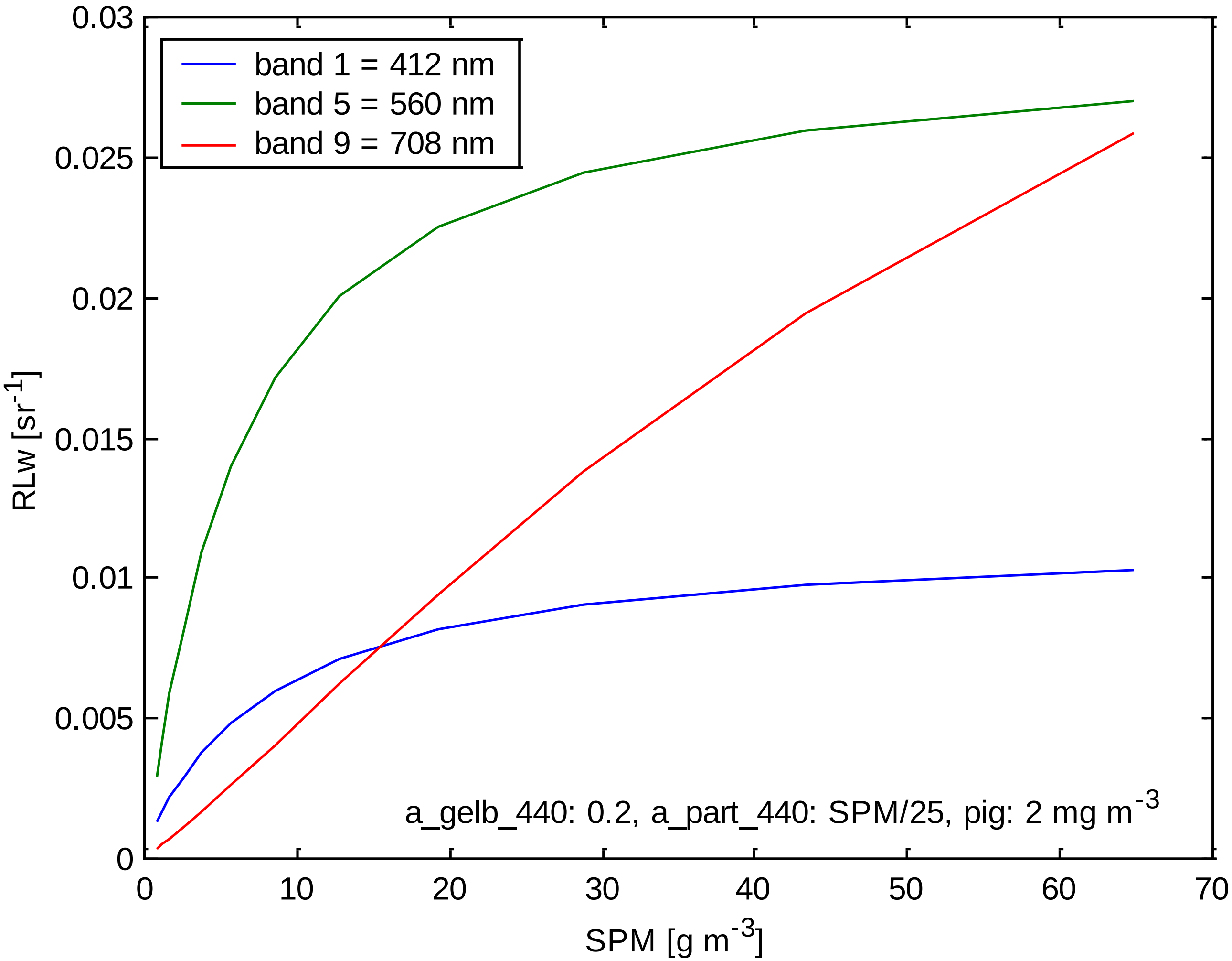


Chl. 5/10 mg m-3
TSM 1 g m-3
aYS(443) 0.1 m-1

Chl. 5/10 mg m-3
TSM 100 g m-3
aYS(443) 0.1 m-1

Sensitivity at different concentration ranges and spectral bands

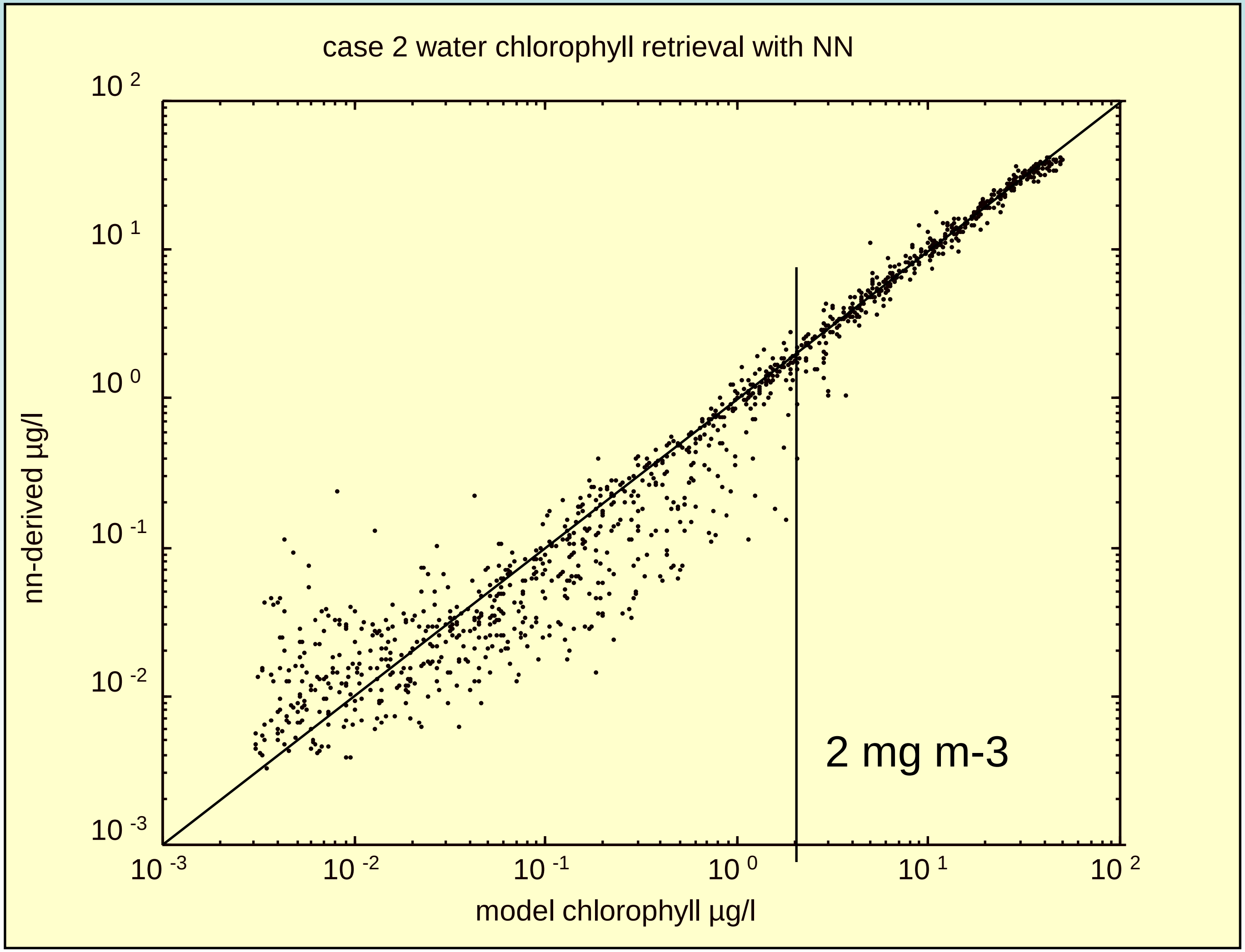
RLw for MERIS bands 1 (412 nm), 6 (560 nm), 10 (708 nm)



Sensitivity of the reflectance at a spectral band depends on the concentration

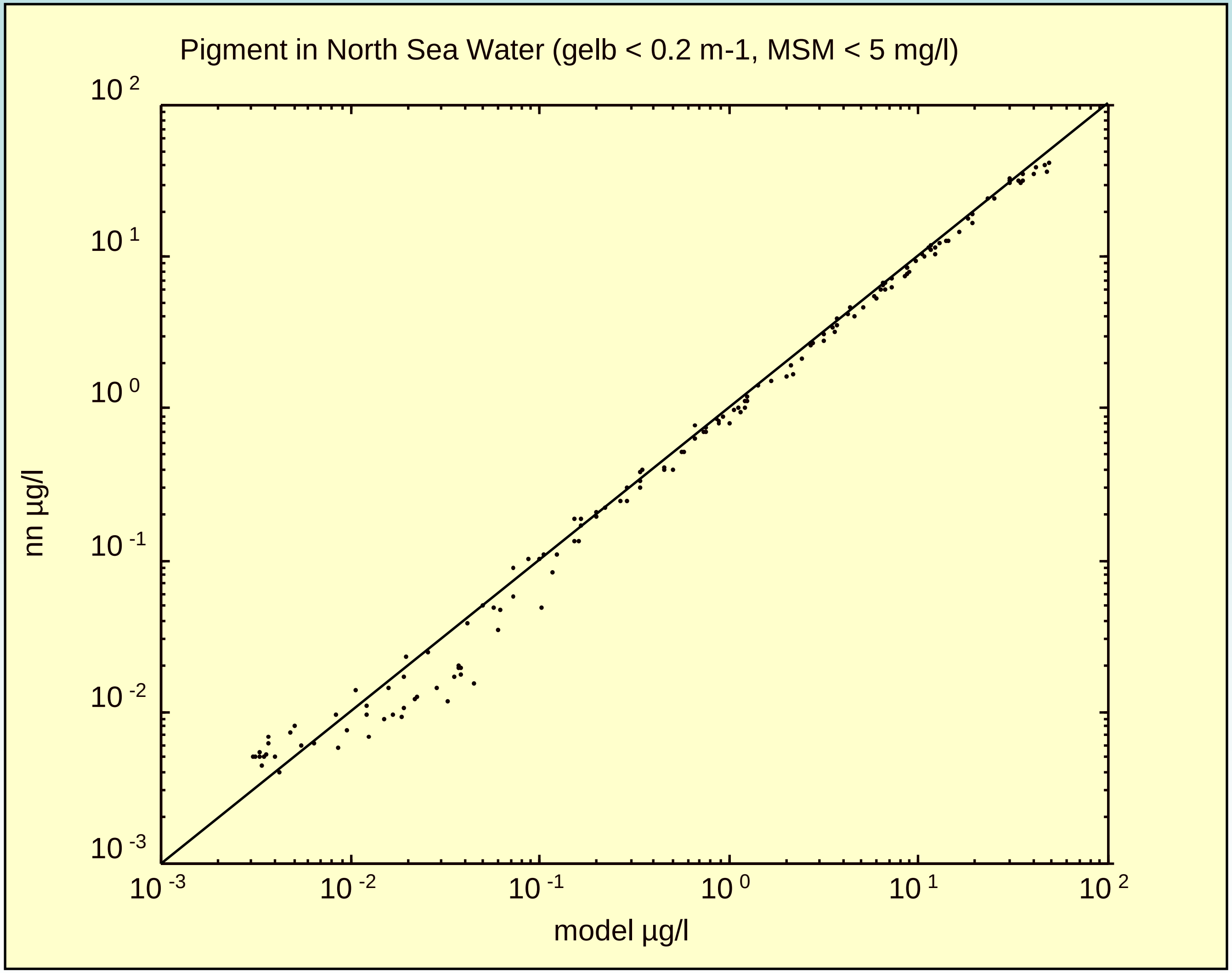
To cover a large concentration range many bands from the blue to NIR range are necessary

Uncertainties due to ambiguities for different concentration mixtures



All cases of turbid water

Ambiguities 2



Typical North Sea coastal water: ay_443: < 0.2 m-1, TSM < 5 mg /l

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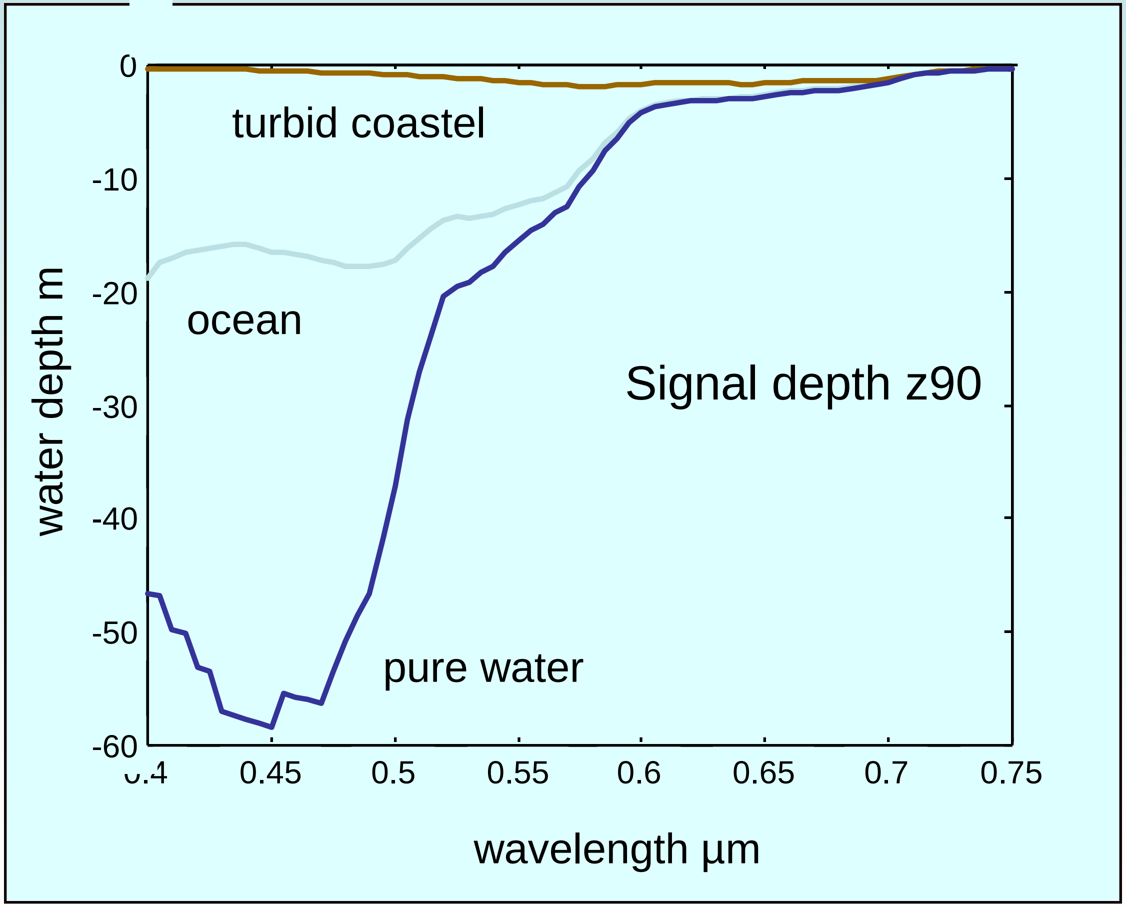
Signal depth at different spectral bands

Multiband algorithms: the information for each band may come from a different water layer



$z_{90} = 1/k$

coastal:
TSM=5 mg/l
Chlor.=5µg/l
Gelb=a_{380}=1m^{-1}

open ocean:
Chlor.=1µg/l

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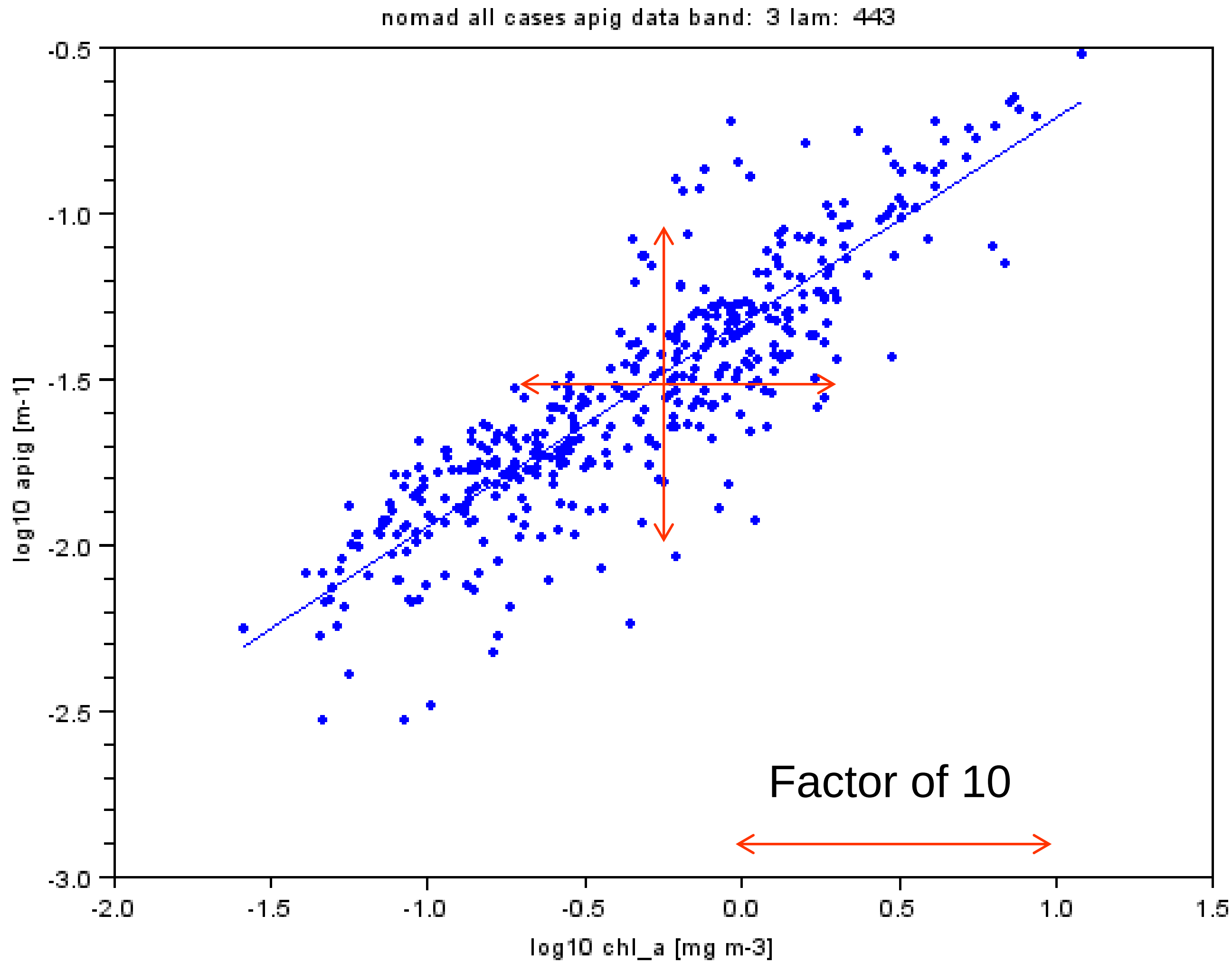
Bio-optical model: relationship between a_pig and chl_a



443 nm, log10 scale, NOMAD data

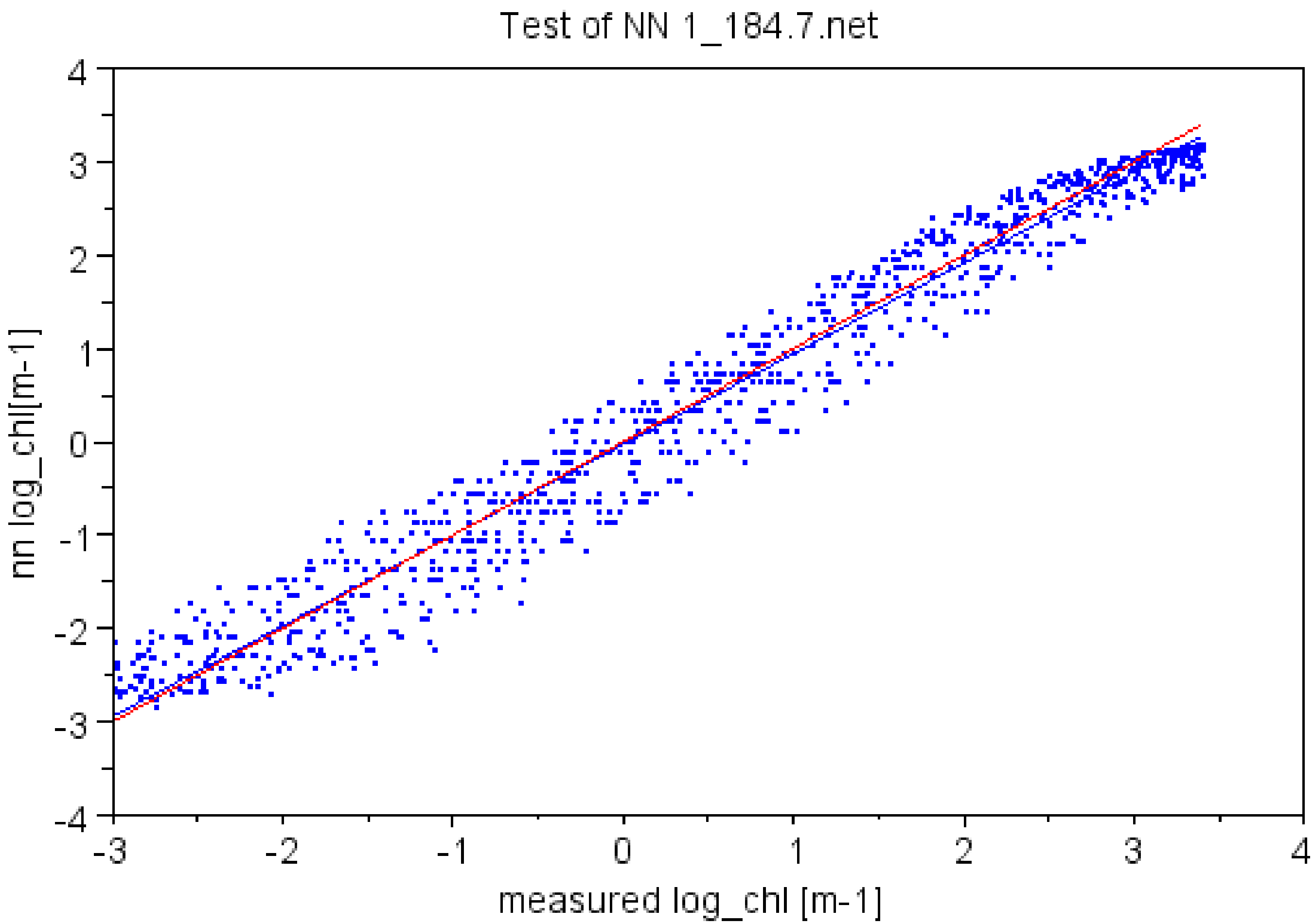
Regional processing

- Specific properties of a region concerning coastal water RS?
  - Nutrient level which might cause high phytoplankton biomass and discolouration (red tides, phaeocystis blooms)
  - water properties such as stratification, salinity, convergence zones, partly together with nutrients, which might cause blooms, e.g. cyanobacteria in the Baltic Sea, Coccolithophiorides
- Shallow water: bottom reflection
- Shallow water and estuaries: high suspended matter concentrations
  - Red clay, yellow clay
- High concentrations of organic matter input
  - High yellow substance in Baltic Sea
  - Extreme high yellow substance in Arctic coastal water, e.g. Laptev Sea
- If these conditions are known, algorithms can be adapted to:
  - Dominant components
  - Concentration ranges
  - Uncertainties for subdominant components can be estimated

Alternative NNs

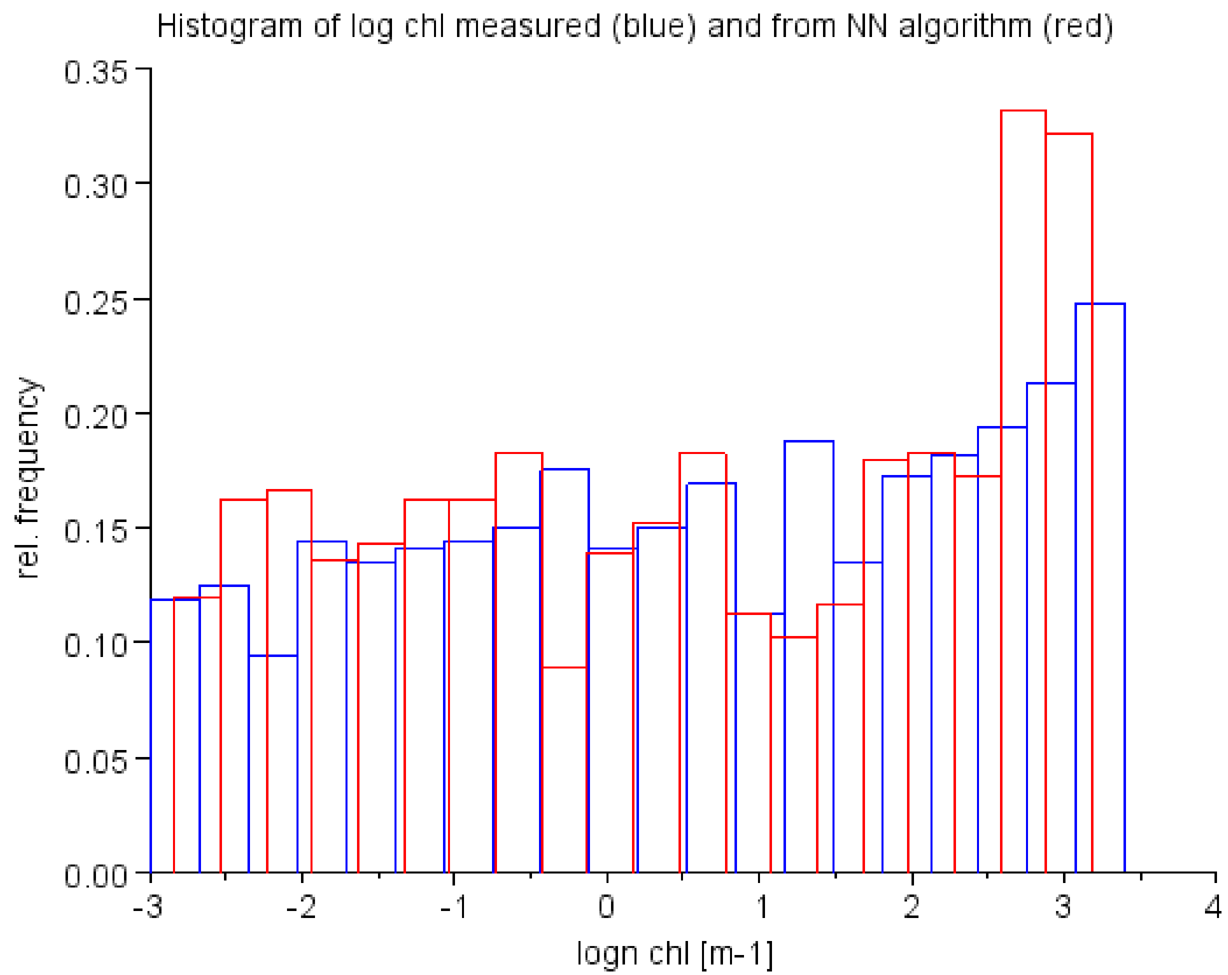
- Bio-optical model based on optical components -> atmospheric correction
- Atmospheric part of AC based on AERONET data model (R. Santer), adapted to coastal aerosol climatology
- Training based directly on field data
- Inverse NN with only 1 output parameter
- Inverse NN with only 1 output parameter and adapted input band sets
- Forward NN used as forward model within an optimization loop

Direct NN, Test of training results: chlorophyll, NOMAD

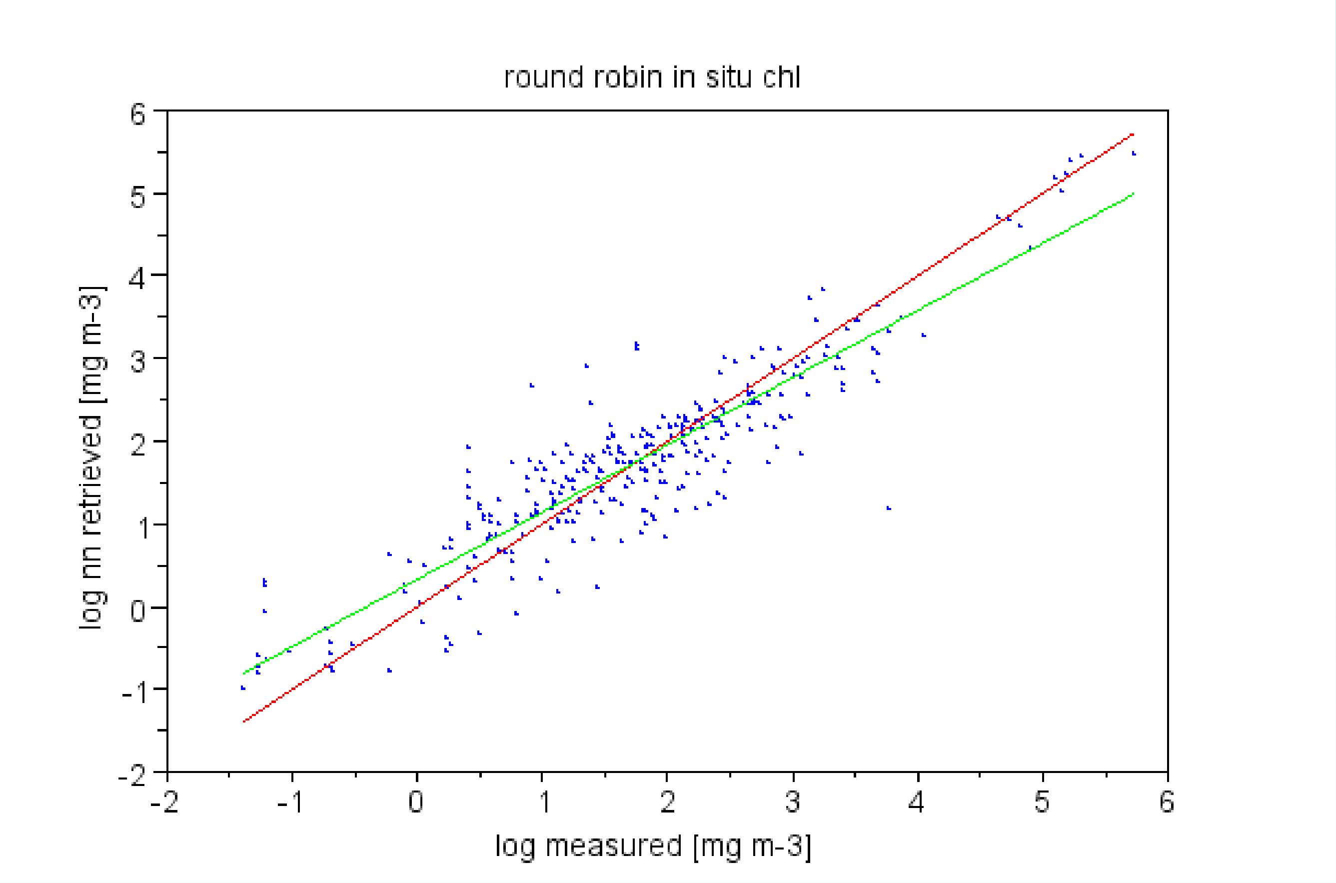


Chlorophyll, logn scale

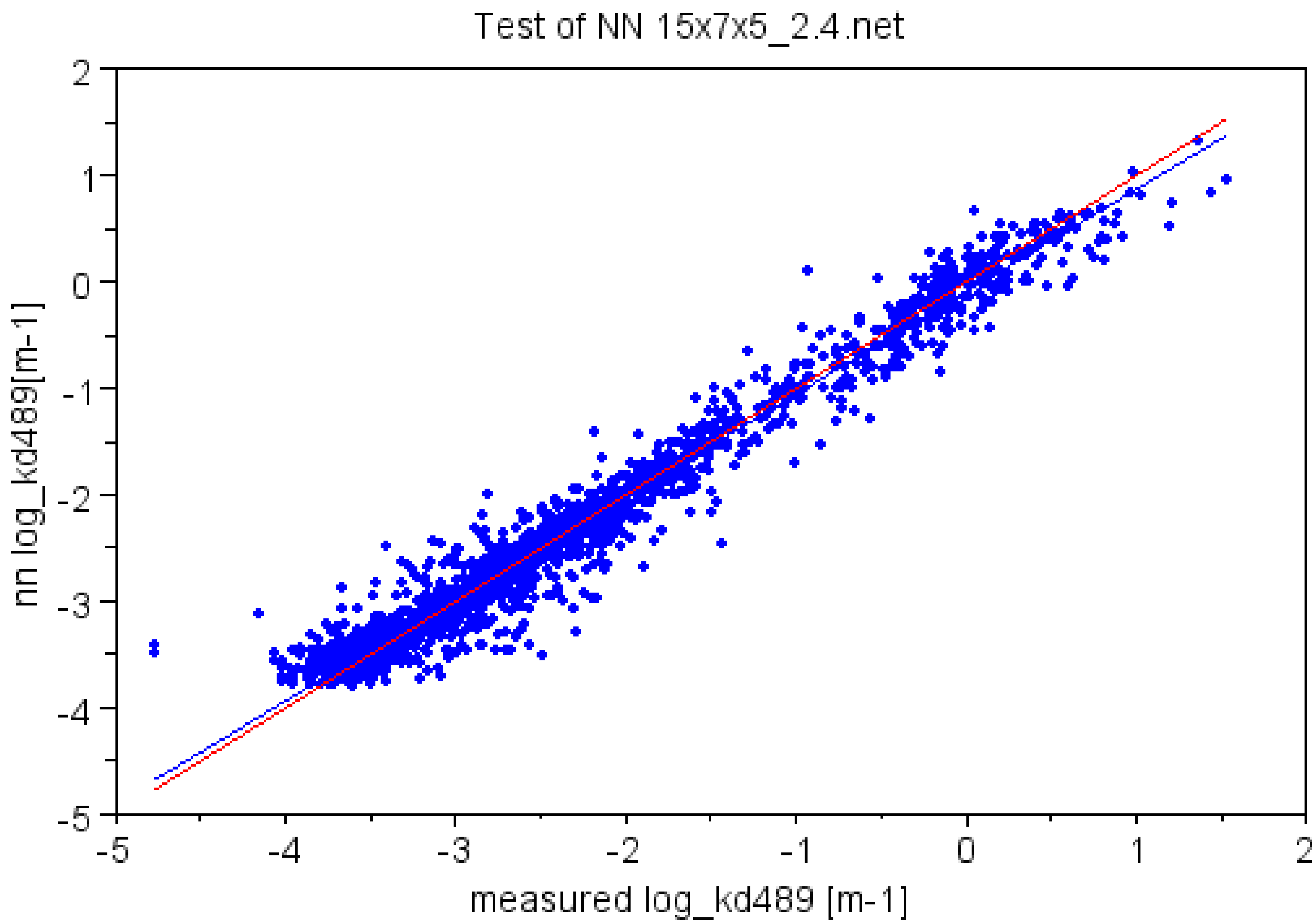
Reproduction of frequency distribution



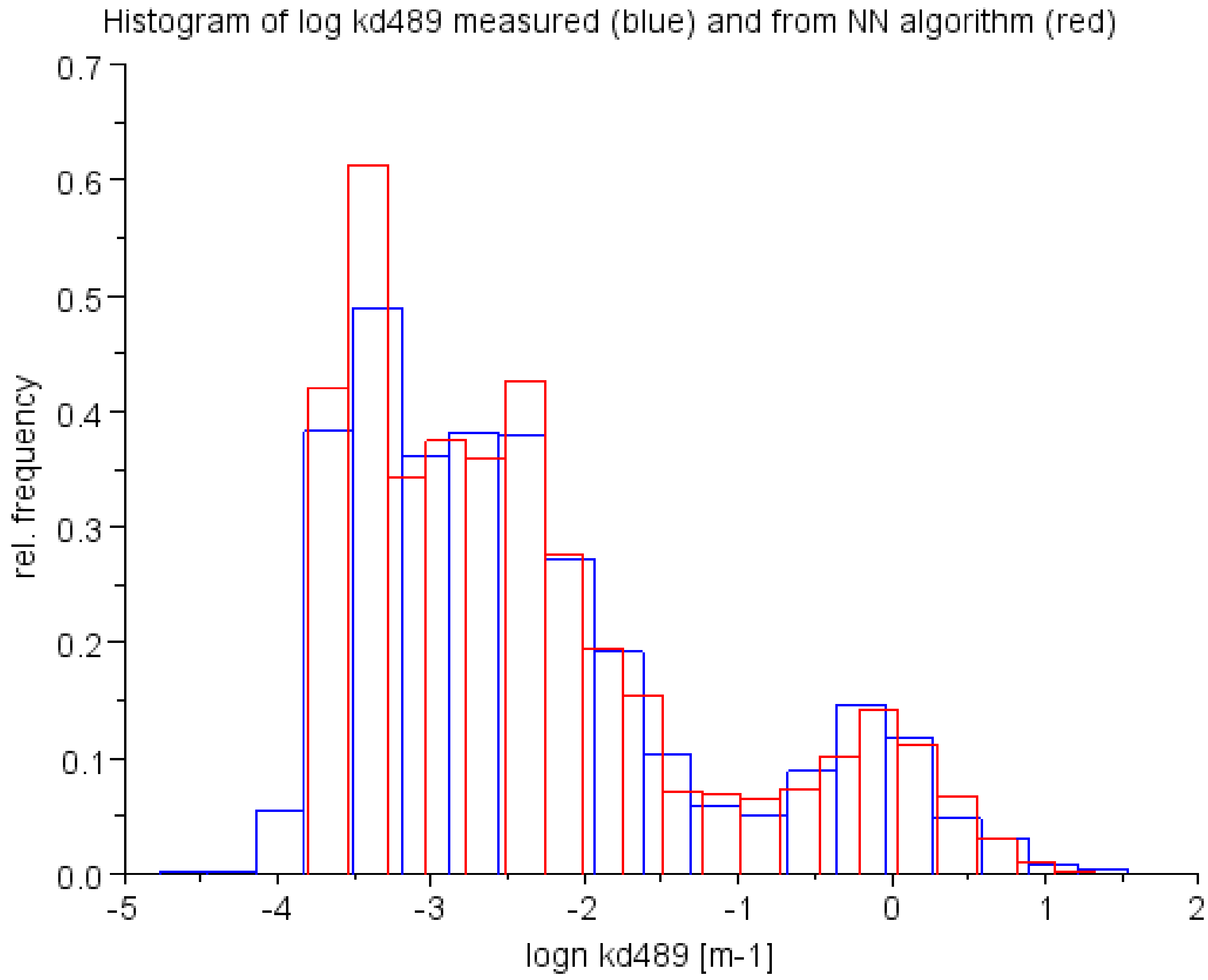
Direct training, round robin in situ data set



NN for kd489


Test of NN 15x7x5_2.4.net
2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
nn log_kd489[m-1]
measured log_kd489 [m-1]

Histogram kd489 measured and NN derived

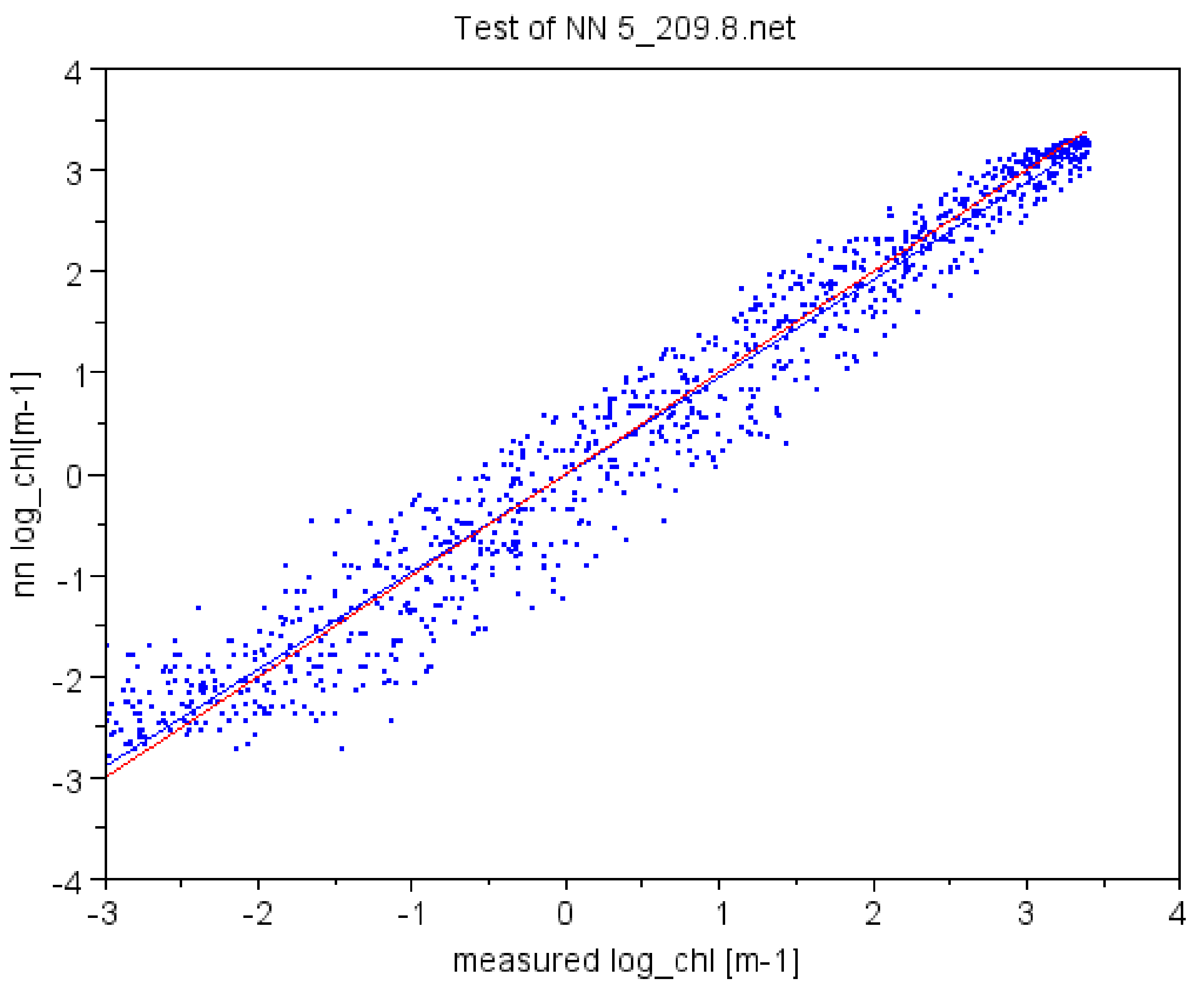


NIR NN algorithm

- Uses bands 560, 620, 665, 708 nm
- Normalized to band 560, i.e. 3 inputs to NN

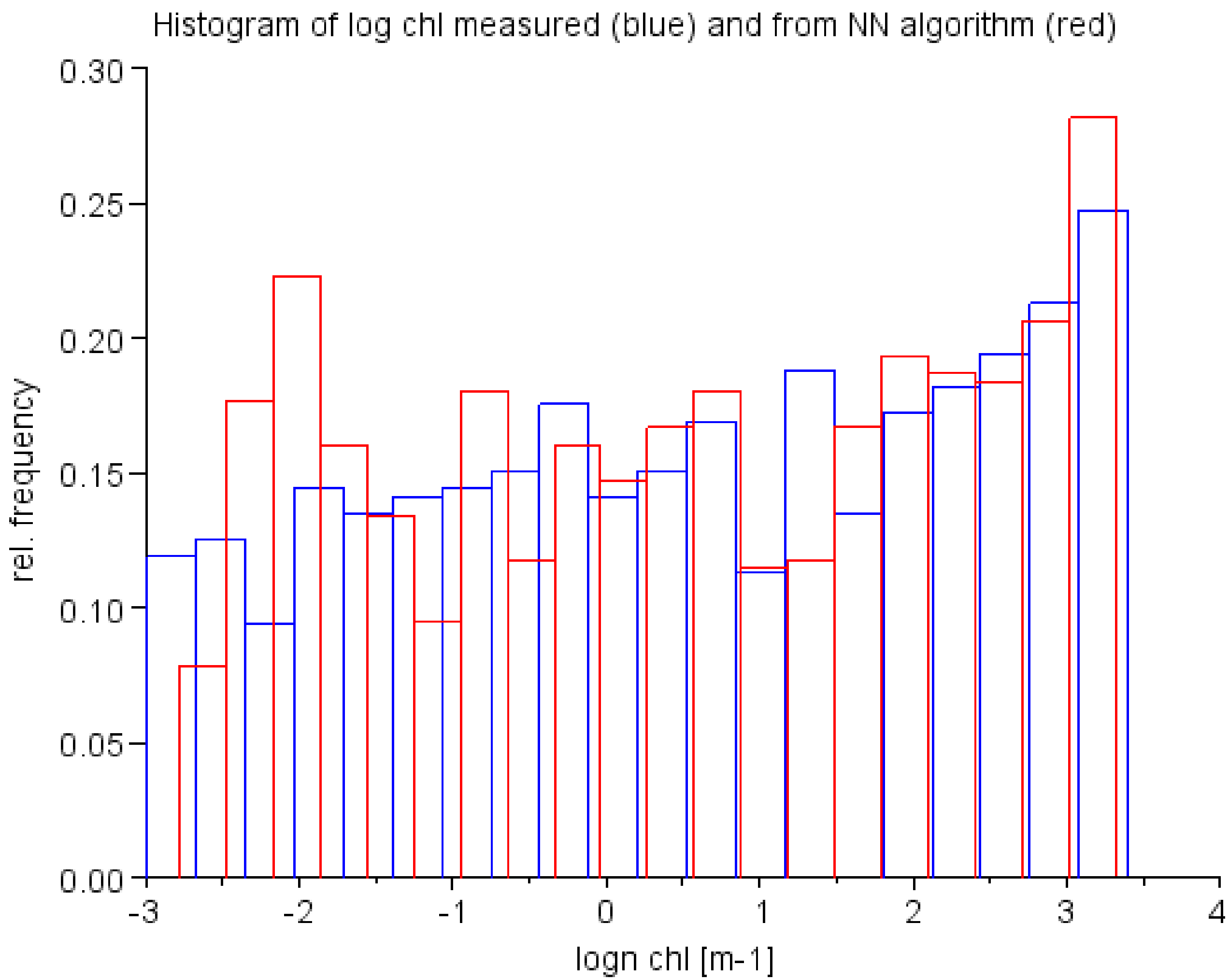
- Advantage:
  - Shallow water application
  - Better separation from yellow substance
  - Works also at very high chl. concentrations
- Disadvantage
  - Less sensitive at low chl. Concentrations (<0.1 mg m-3)

Test of training results NIR bands: chlorophyll



Chlorophyll, logn scale

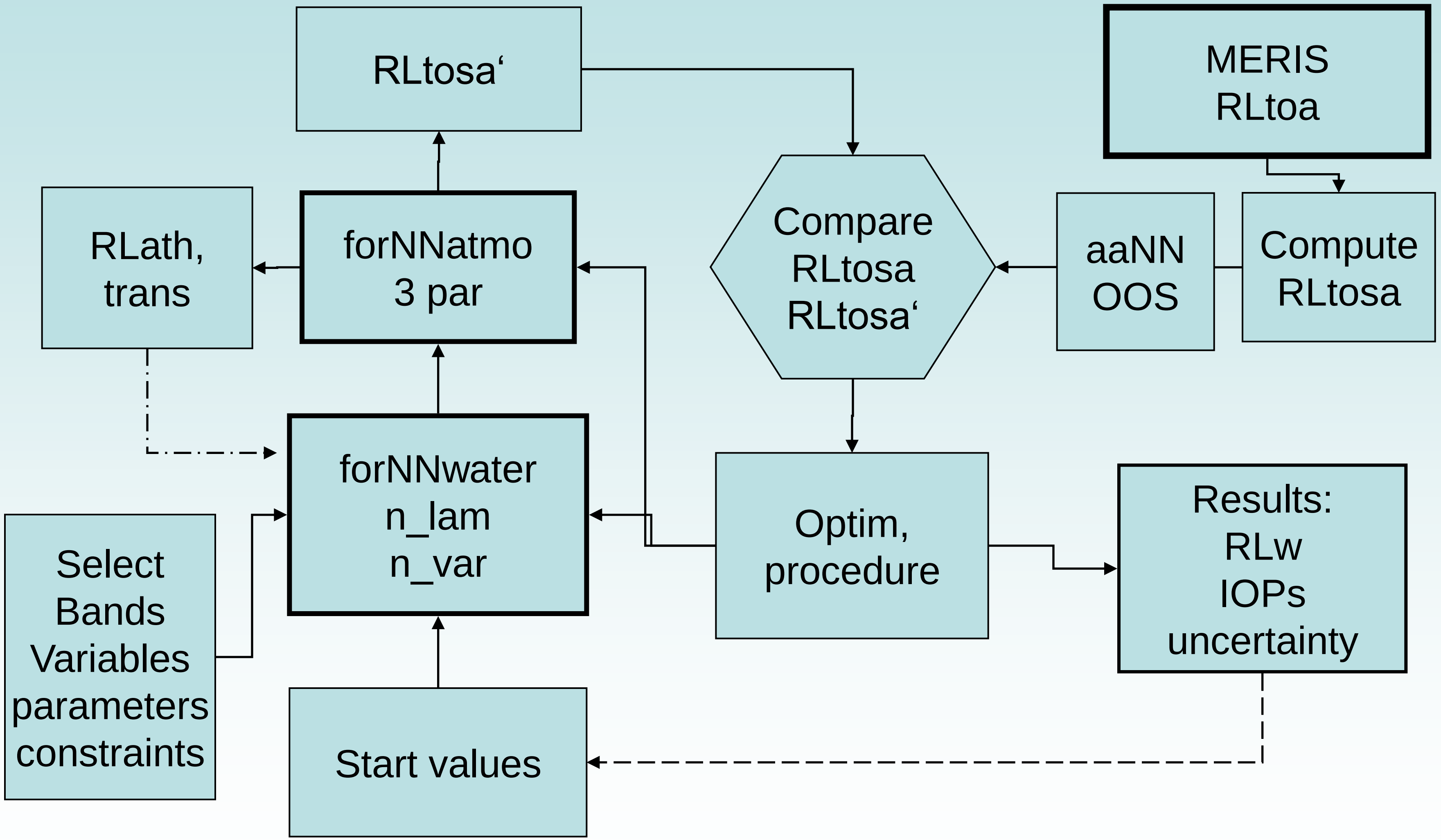
Reproduction of frequency distribution



Further development of AC and water Algorithms

- Present version uses inverse NNs for atmosphere and water
  - Bounded to fixed set of spectral bands
  - Fixed set of retrieval variables with fixed ranges
  - Fast but limited flexibility
- Alternative approach
  - Uses only forward NNs and autoNNs
  - Combined with constrained optimisation procedure (LM)
  - Separate atmosphere and water forwardNN
  - Flexible use of spectral bands for AC and water
  - Flexible use of variables to be retrieved
  - One set of forward NN for different applications
  - Computes uncertainty matrix for all variables
  - Variables and spectral bands can be controlled by switches and boundaries of constraining mechanism
  - Slower due to iterations in optimization loop, but forwardNN faster
- Tests
  - First tests with MERMAID and NOMAD positive

Scheme for forwardNN based procedure



How to compute uncertainties

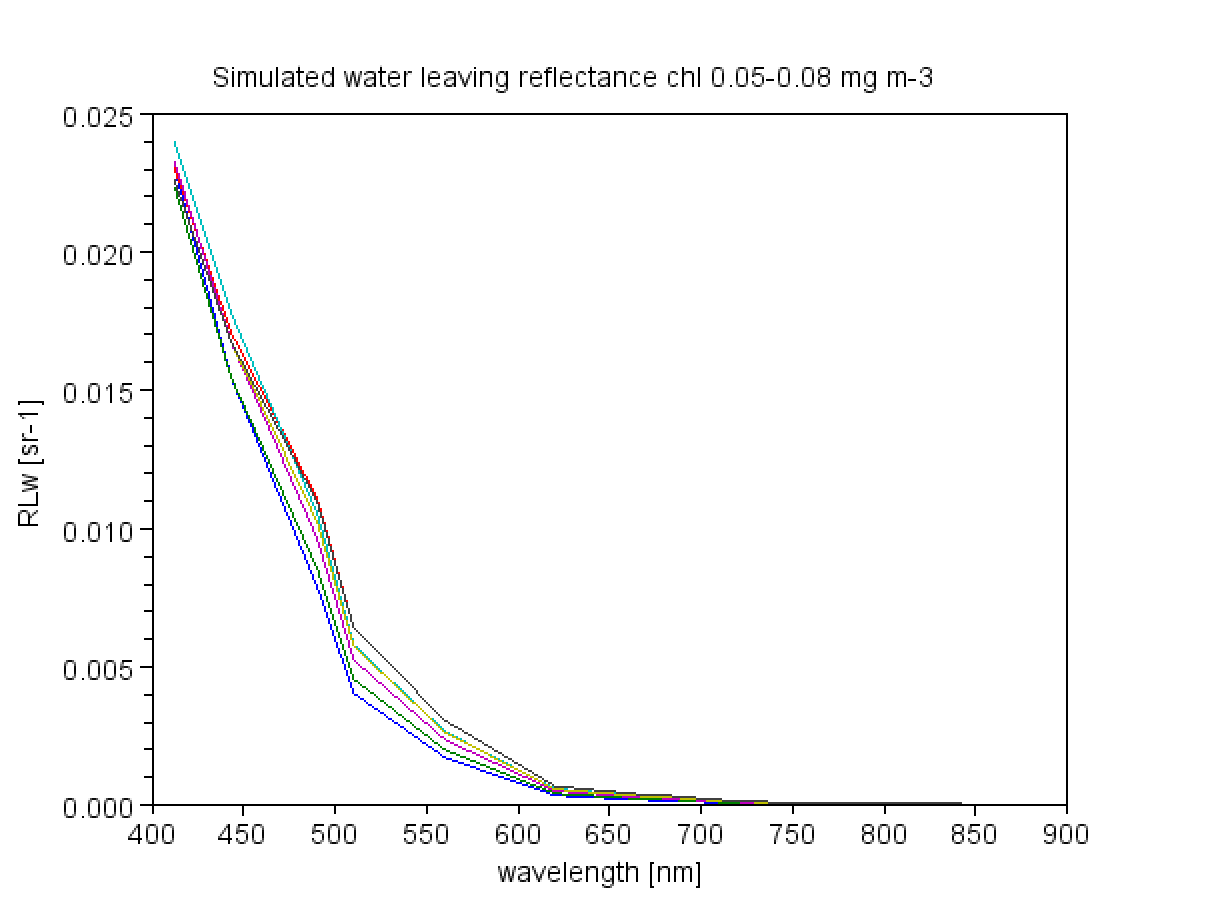
- Uncertainties are defined relative to in situ observations, which have their own uncertainties, which should also be determined

- In OC-CCI 4 methods are discussed:
  - For each optical water class and each concentration level determine uncertainty from comparison with in situ and set up a look-up tables
    - include this in fuzzy logic classification
  - Determine uncertainty range from sensitivity analysis using the model of the algoirthm
  - Determine uncertainty range using the forward model in the optimization loop based on Hessean matrix
  - Use an assemble approach (multiple, different algorithms), different sensors

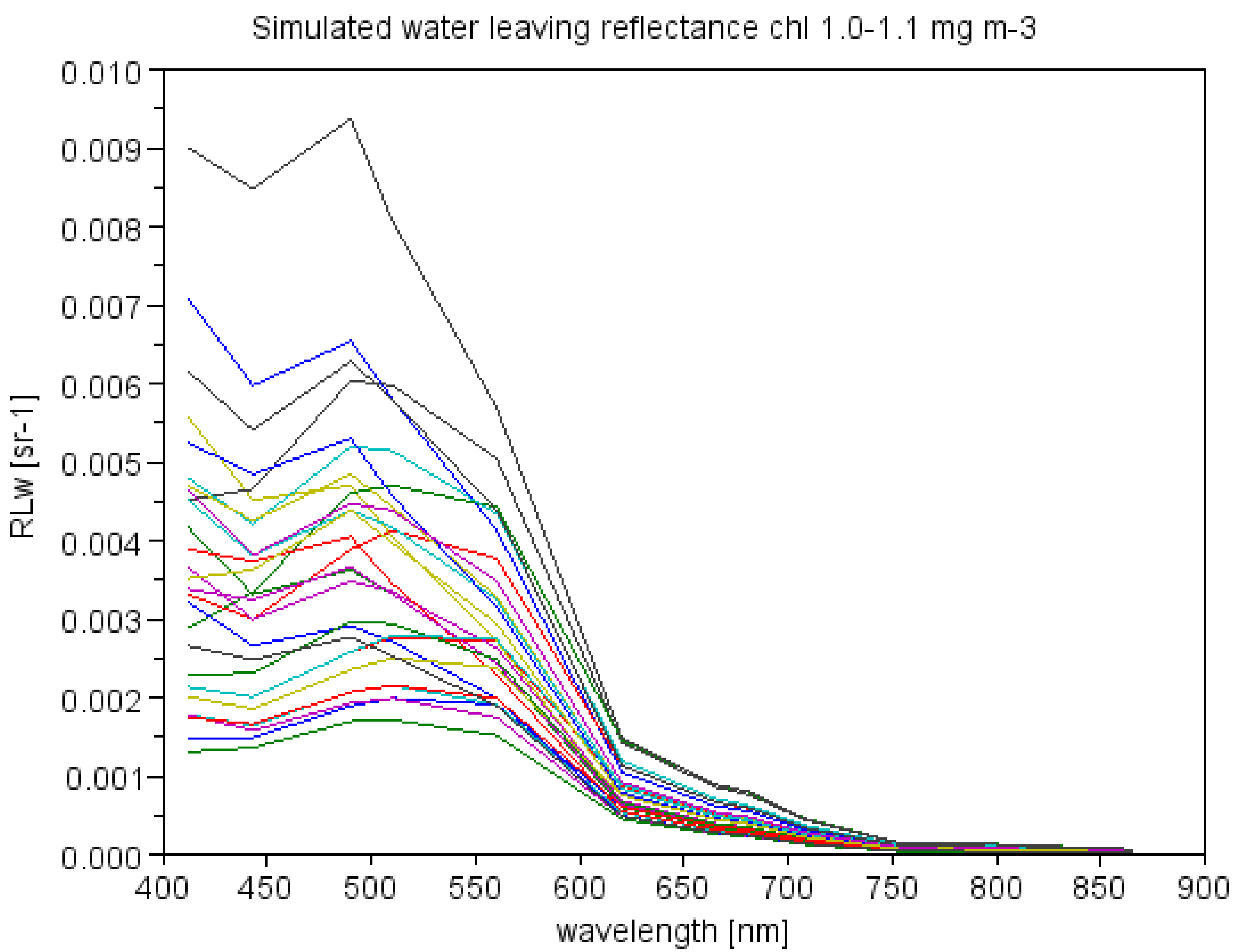
Recommendations

- Classification by
  - TSM level
  - Type of mineralic SPM (red clay, yellow clay)
  - Typical chlorophyll range
  - Water depth
  - Salinity and temperature
- Link these properties to spectral reflection properties
- Use fuzzy logic to get smooth transitions between water classes
- Adapt algorithm (AC and in water) to each class
- Use a library of test cases / diagnostic sites to test the algorithms and their improvements

Oligotrfophic Case 1

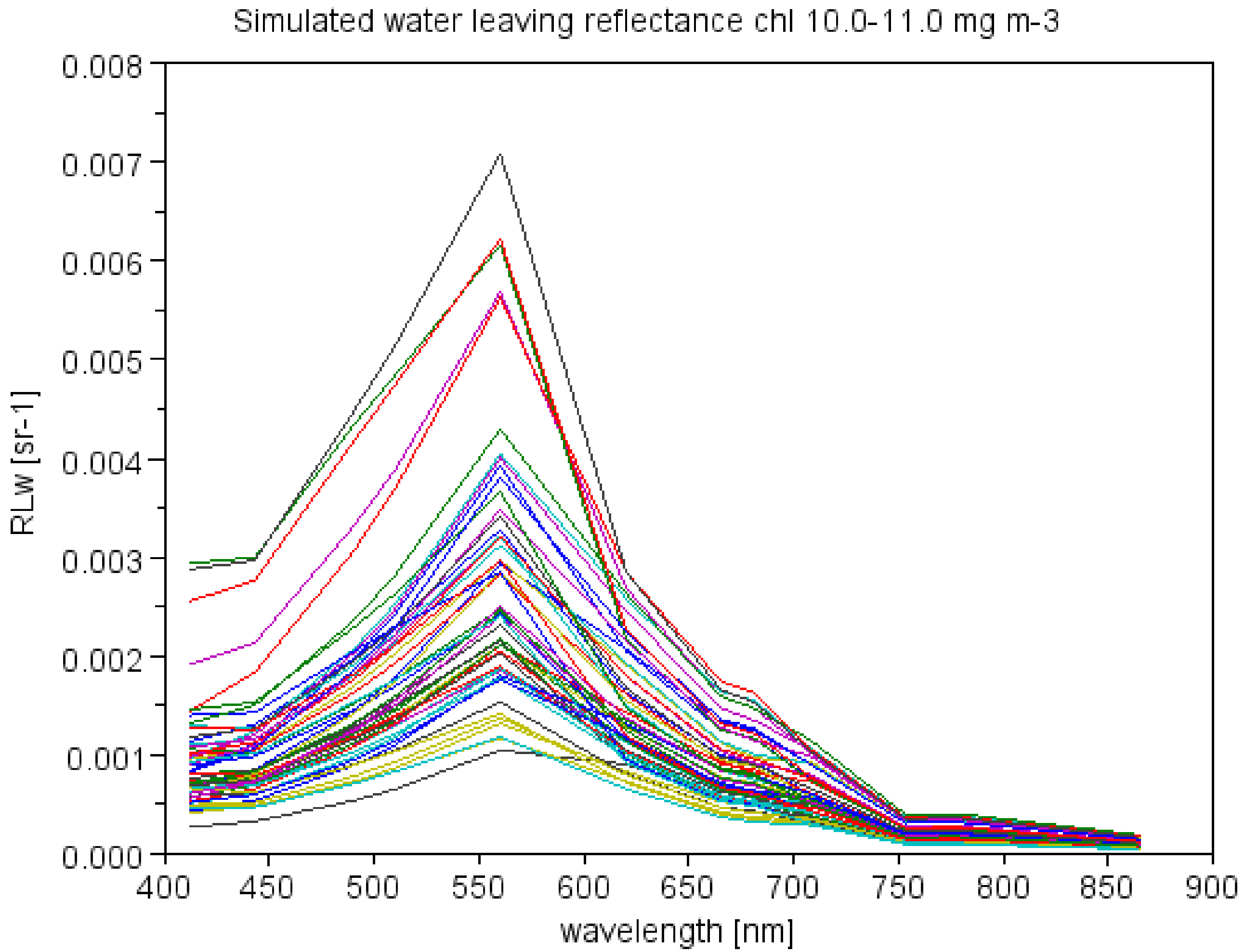


RLw from simulated data set



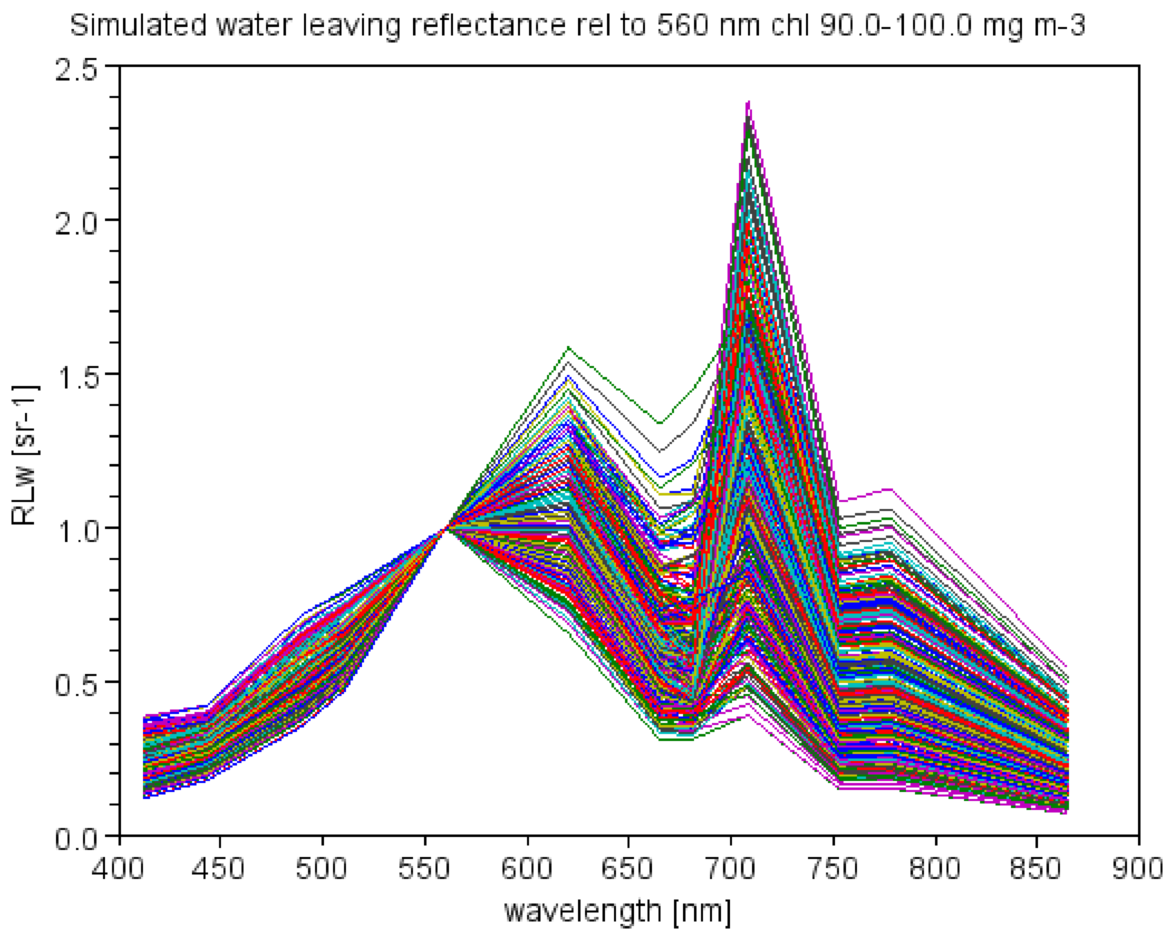
Chl_f 1.0 – 1.1 mg m-3

RLw from simulated data set



Chl_f 10.0 – 11.0 mg m-3

RLw rel to 560 nm from simulated data set



Chl_f 90.0 – 100.0 mg m-3, log scale

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Next steps

- Atmospheric correction with Aeronet climatology (tested)
- Atmospheric correction with water component model (data set prepared and forward NN trained)
- Training of NNs based on measured reflectances, for sites with sufficient data
- Test forward model NN for different sites
- Extend forward model with different types of mineralic SPM
- Revise NOMAD NNs
- Improve test procedures and organisation of test data sets

Questions, remarks ?

Strategy for Water Algorithms Development

- Neural Network
  - Training with measured reflectances, if sufficiently available
  - Training with simulated reflectances, base on bio-optical model
- Generic NN based on NOMAD data set -> bio-optical model
- Regional NN
  - Based on generic, but constrained using regional concentration / IOP ranges
  - NN generation using measured reflectances
  - NN based on regional bio-optical model
- Floating cyanobacteria (Baltic Sea)
  - Linear spectral unmixing -> coverage index

Present Status of water algorithm

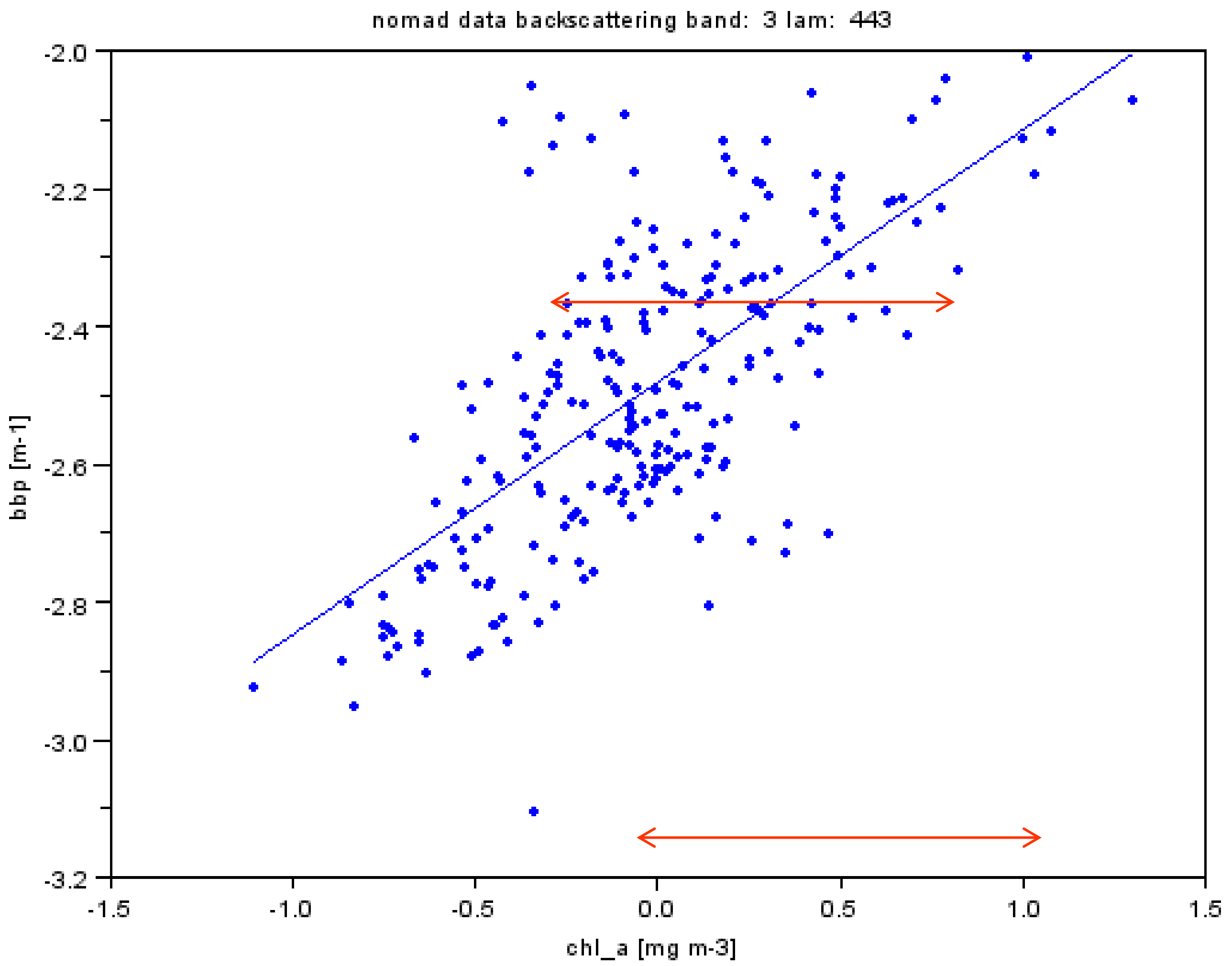
Available

- Generic NNs generated based on NOMAD data set
  - NN with measured data (incl. T and S)
  - NN based on bio-optical model for different wavelength sets,
  - Reflectances and normalized reflectances (ratios)
  - Normalisation NN
  - Standard Products:
    - IOPs: a_pig, a_g, a_d, bbp
    - AOPs: kd490, kd_min, z90_490, z90_max
    - FNU Formazin Nepholometric Units
    - FLH Fluorescence line height
    - MCI   Maximum chlorophyll index

TODO

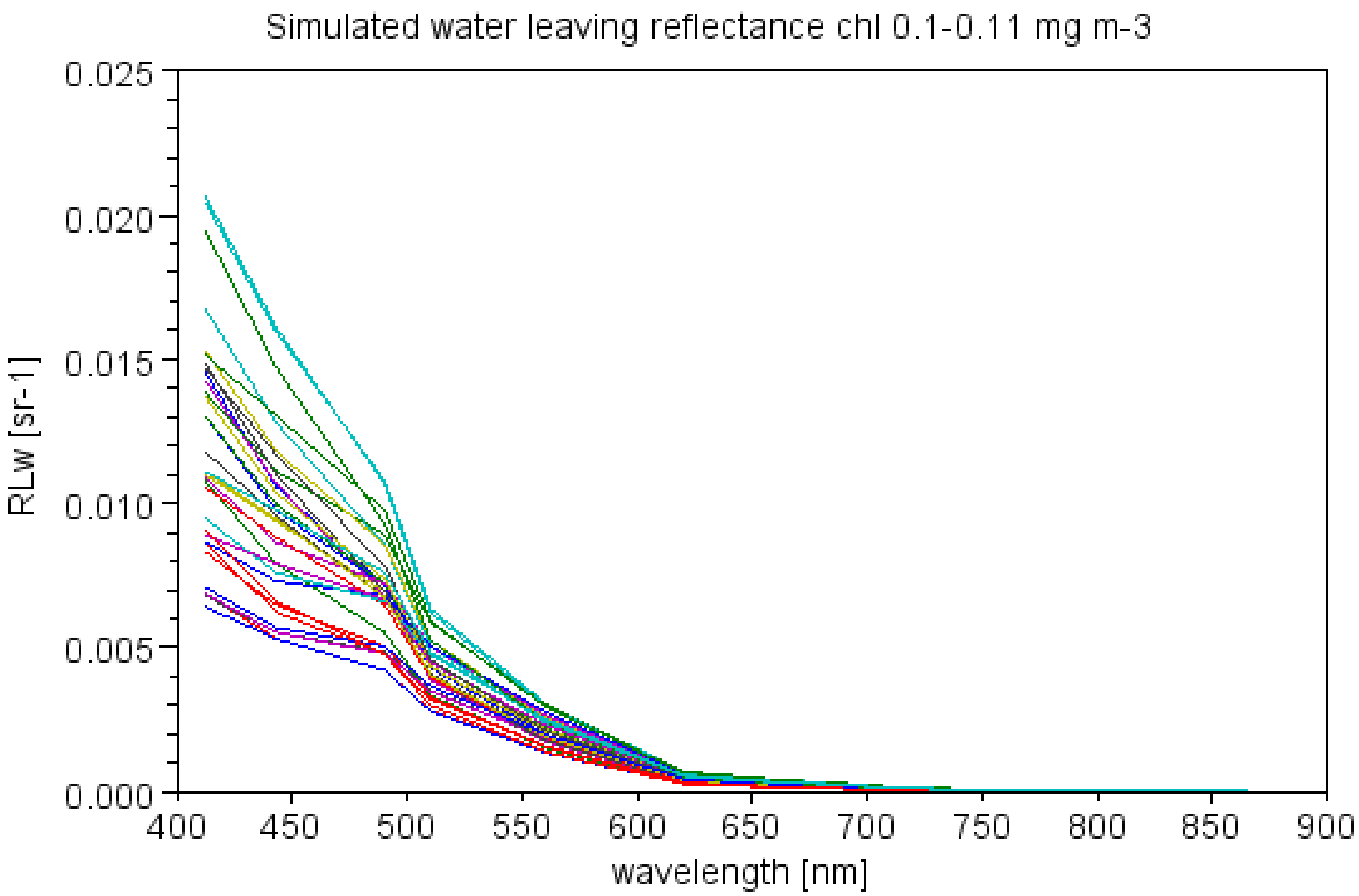
- Products: z_eu, z_sd

Relationship chl_f and backscattering coefficient



443 nm, 249 samples, log10 scale

RLw from simulated data set



Chl_f 0.1 – 0.11 mg m-3

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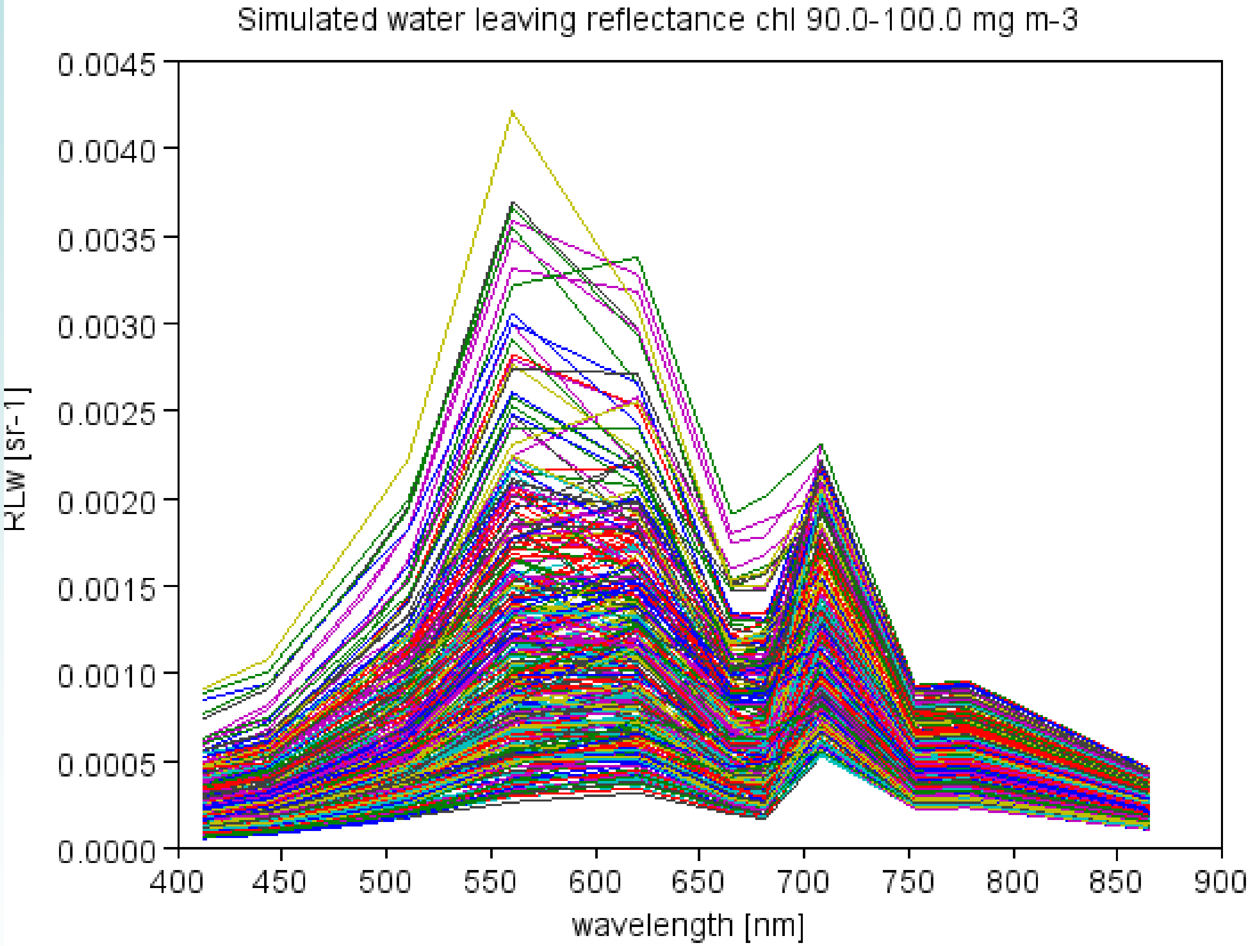
RLw from simulated data set



Chl_f 90.0 – 100.0 mg m-3

CC UCM 3, Lisboa, October 19-20, 2011