IDENTIFYING AND HANDLING OF ERRORS CAUSED BY SPECTRAL AMBIGUITIES OVER WATER

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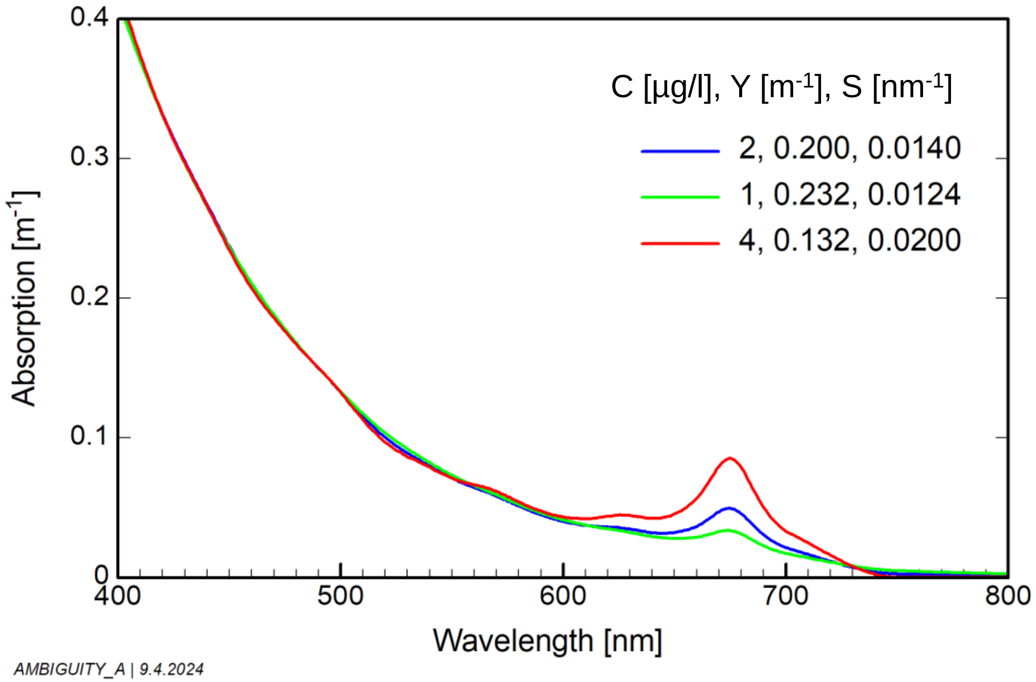
Outline

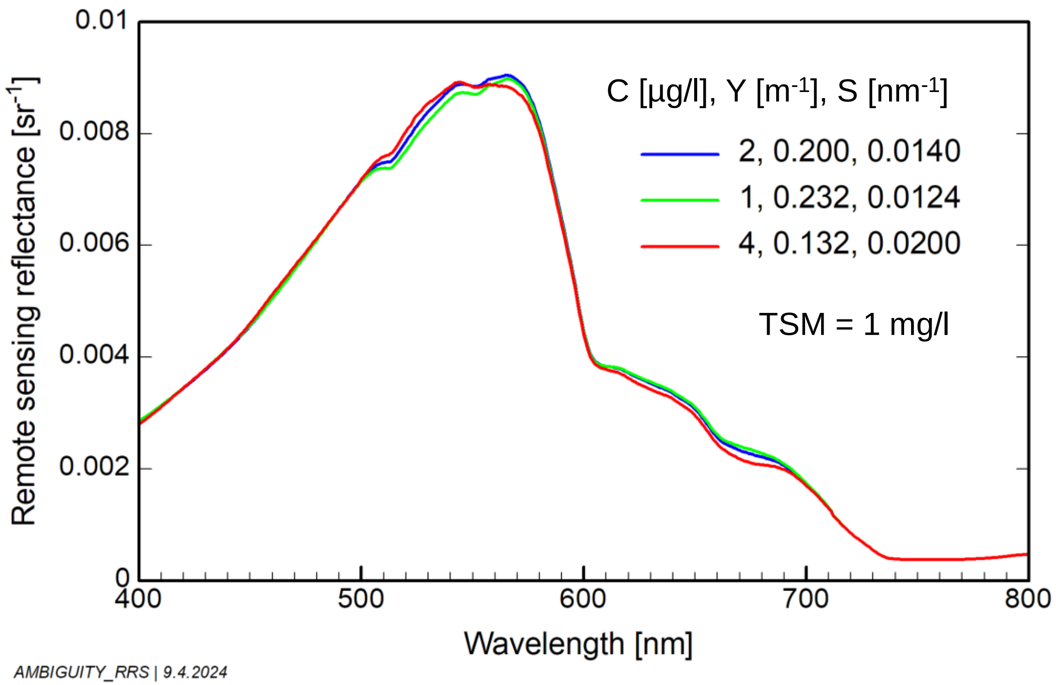
- Challenge: Spectral ambiguities over water
- Identification of spectral ambiguities in an image
- Handling of ambiguity problems
- Example from Lake Constance using DESIS image
- Conclusions

Challenge: Spectral ambiguities

Different combinations of environmental parameters lead to similar spectra



Simulated absorption spectra for different combinations of chlorophyll-a concentration (C), CDOM absorption at 440 nm (Y) and spectral slope of CDOM absorption (S)



Simulated reflectance spectra for the cases shown left

P. Gege, A. Albert (2006): A tool for inverse modeling of spectral measurements in deep and shallow waters. https://doi.org/10.1007/1-4020-3968-9_4

Challenge: Spectral ambiguities

Information content depends on measurement noise and number and position of bands

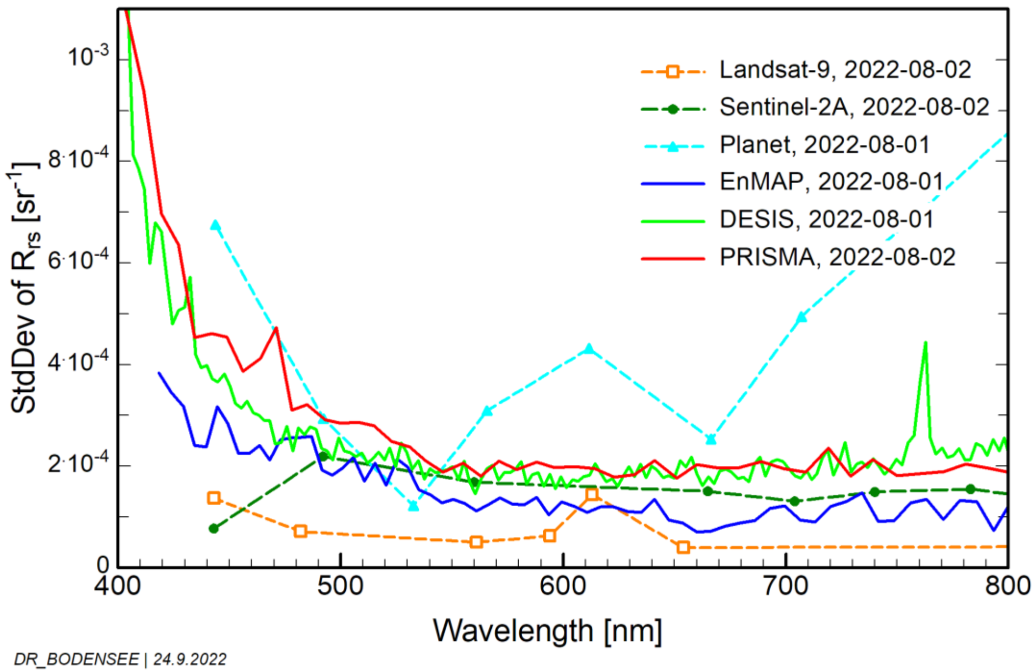
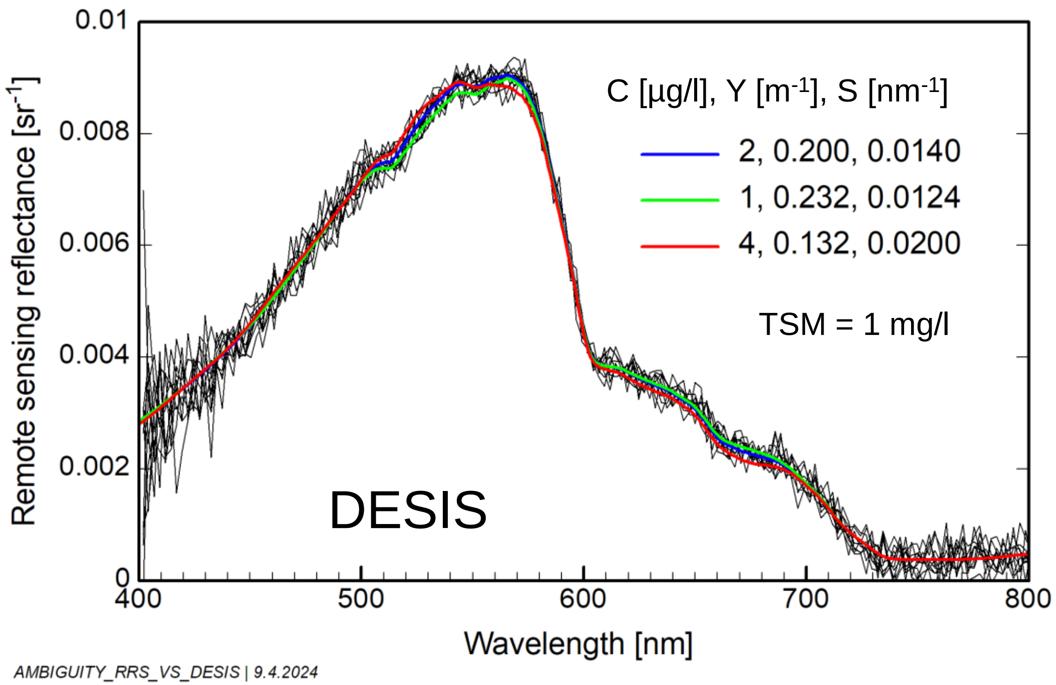


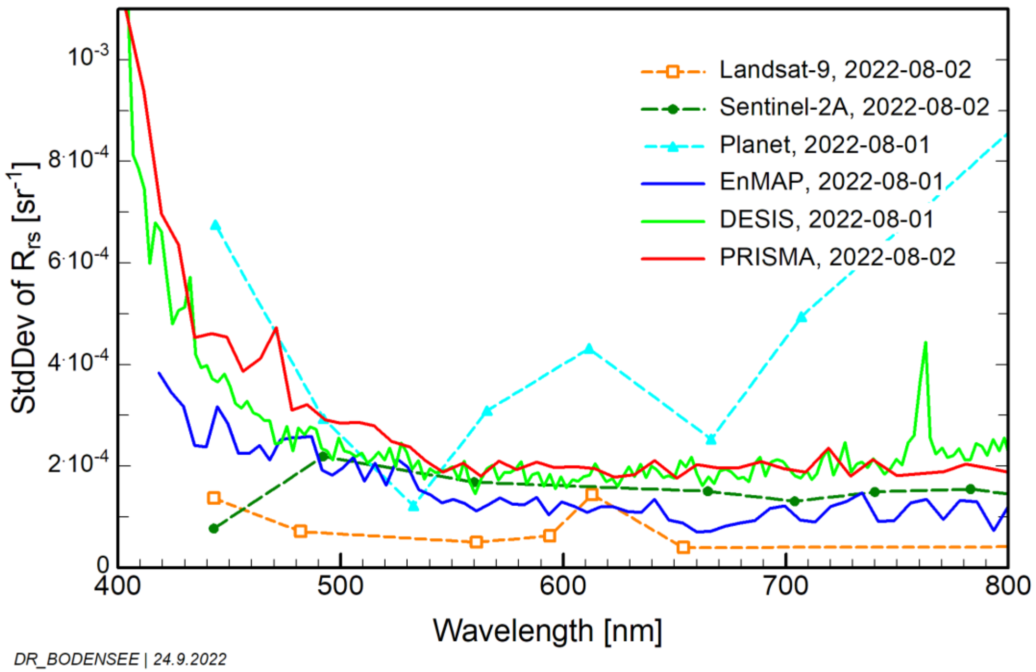
Image noise of different sensors derived from a homogeneous area in Lake Constance with concentrations comparable to the simulated ones



Simulated DESIS spectra without noise (red, green, blue) and with noise from Lake Constance image (10x black)

Challenge: Spectral ambiguities

Information content depends on measurement noise and number and position of bands



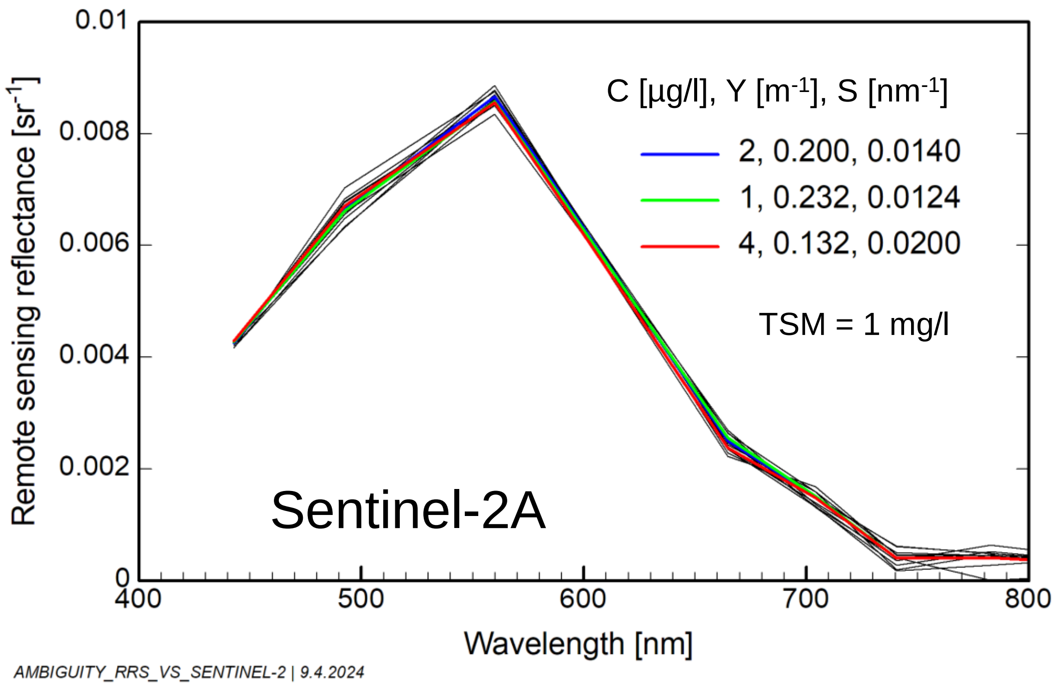


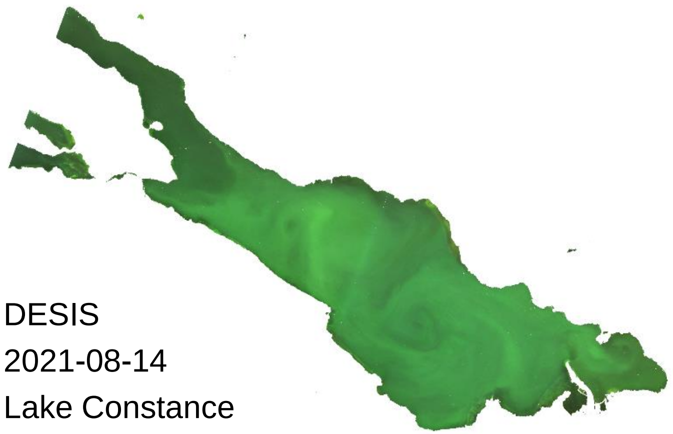
Image noise of different sensors derived from a homogeneous area in Lake Constance with concentrations comparable to the simulated ones

Simulated Sentinel-2A spectra without noise (red, green, blue) and with noise from Lake Constance image (10x black)

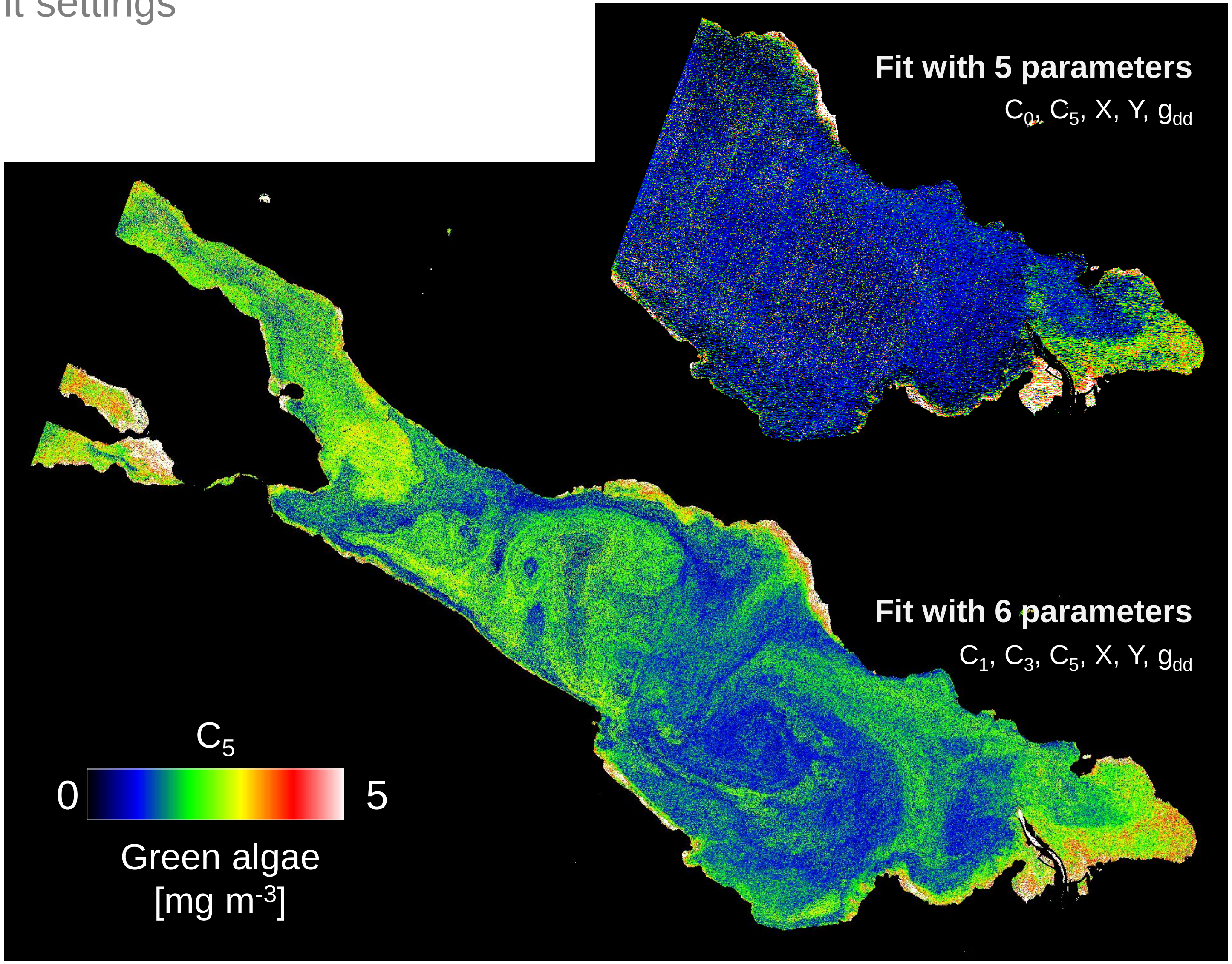
Identification of ambiguity problems in an image

Process image twice with different settings

Changing the fit settings alters the concentration map of green algae drastically: even though the map may appear plausible, it is highly sensitive to the processing details, hence unreliable.



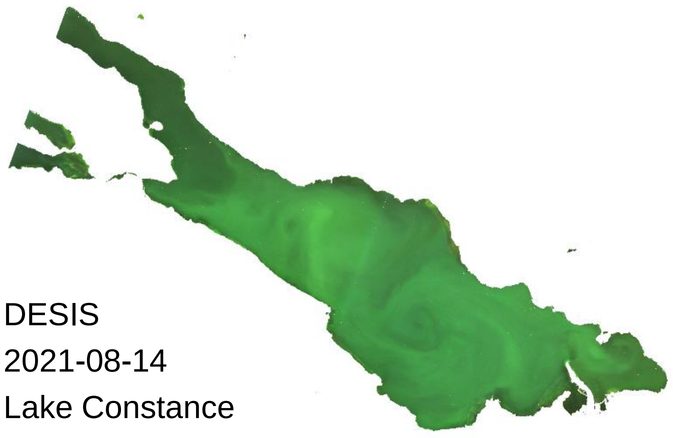
DESIS
2021-08-14
Lake Constance



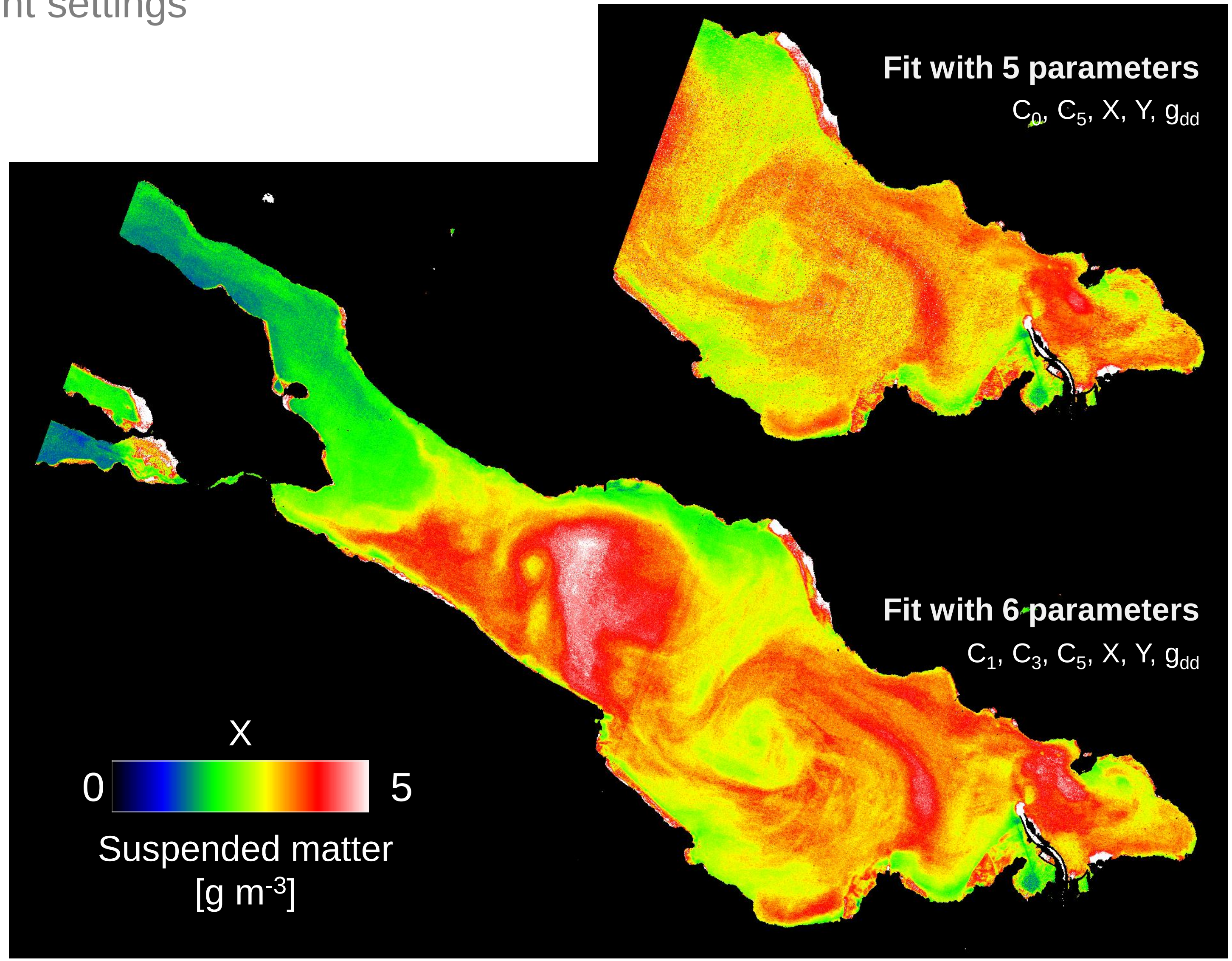
Identification of ambiguity problems in an image

Process image twice with different settings

Changing the fit settings has only a small effect for the concentration map of suspended matter: the map is insensitive to error propagation.



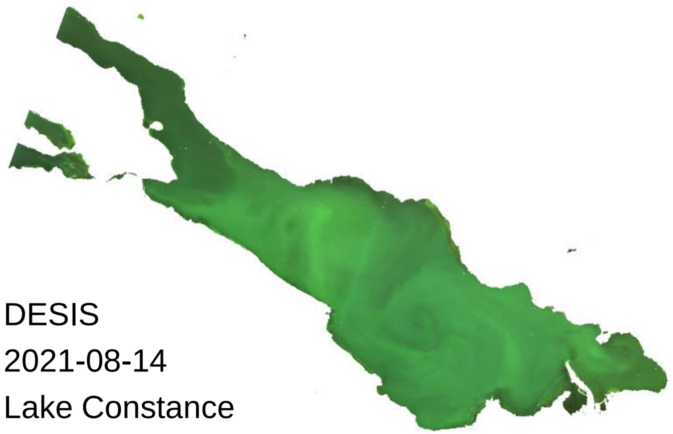
DESIS
2021-08-14
Lake Constance



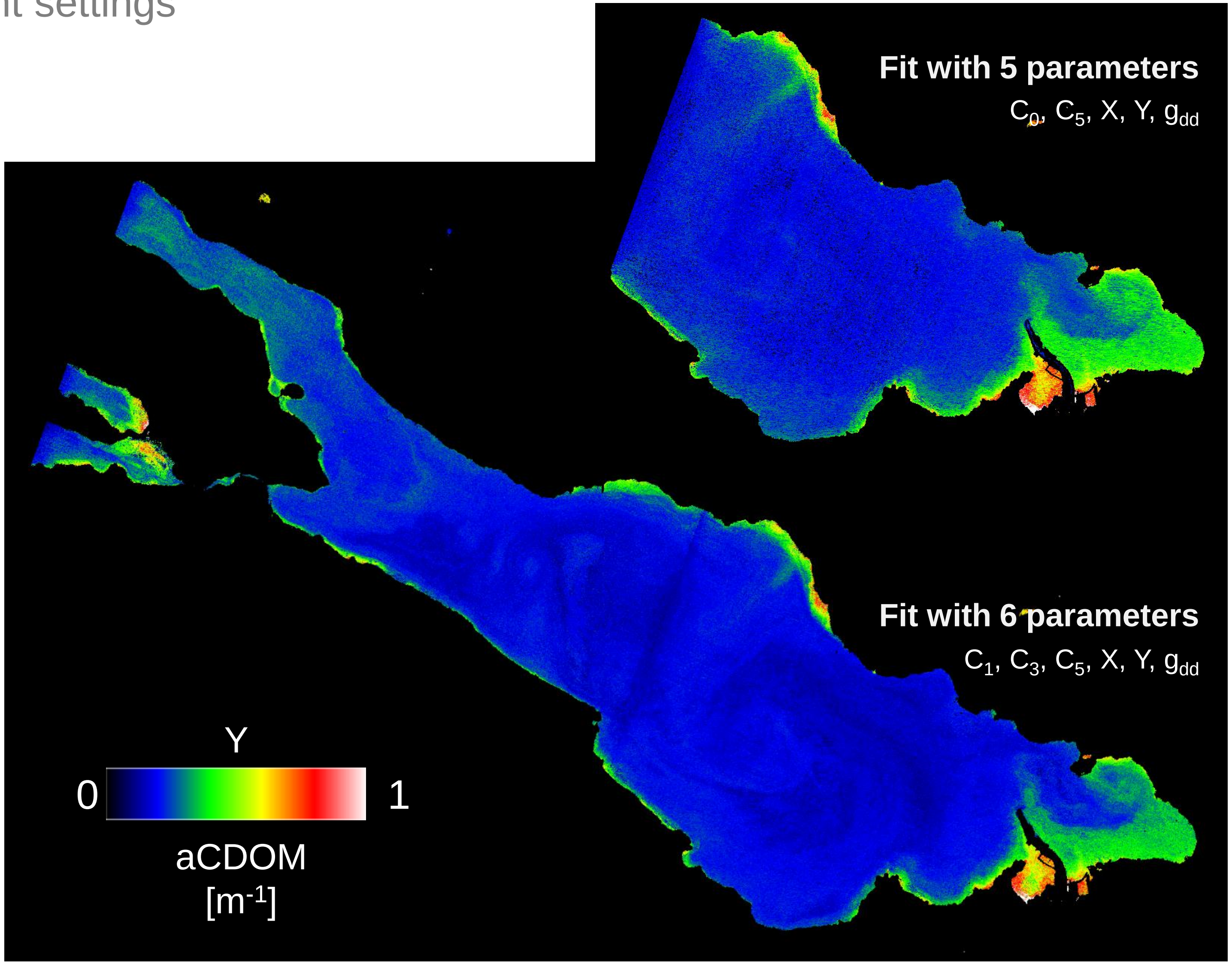
Identification of ambiguity problems in an image

Process image twice with different settings

Changing the fit settings has only a small effect for the map of CDOM absorption: the map is insensitive to error propagation.



DESIS
2021-08-14
Lake Constance



Identification of ambiguity problems in an image

Process image with WASI-AI

- **WASI:** simulation and inverse modelling of spectra from deep and shallow waters

  P. Gege (2004): The water colour simulator WASI: An integrating software tool for analysis and simula-tion of optical in-situ spectra. https://doi.org/10.1016/j.cageo.2004.03.005

- **WASI-2D:** inverse modelling of atmospherically corrected images

  P. Gege (2014): WASI-2D: A software tool for regionally optimized analysis of imaging spectrometer data from deep and shallow waters. http://dx.doi.org/10.1016/j.cageo.2013.07.022.

- **WASI-AI:** apply neural network, trained with random pixels processed with WASI-2D, to images

  M. Niroumand-Jadidi, P. Gege (2024): WASI-AI: Synergistic Integration of AI and Physics for Retrieving Water Quality and Benthic Parameters from Multi- and Hyperspectral Images. *Submitted.*

https://ioccg.org/

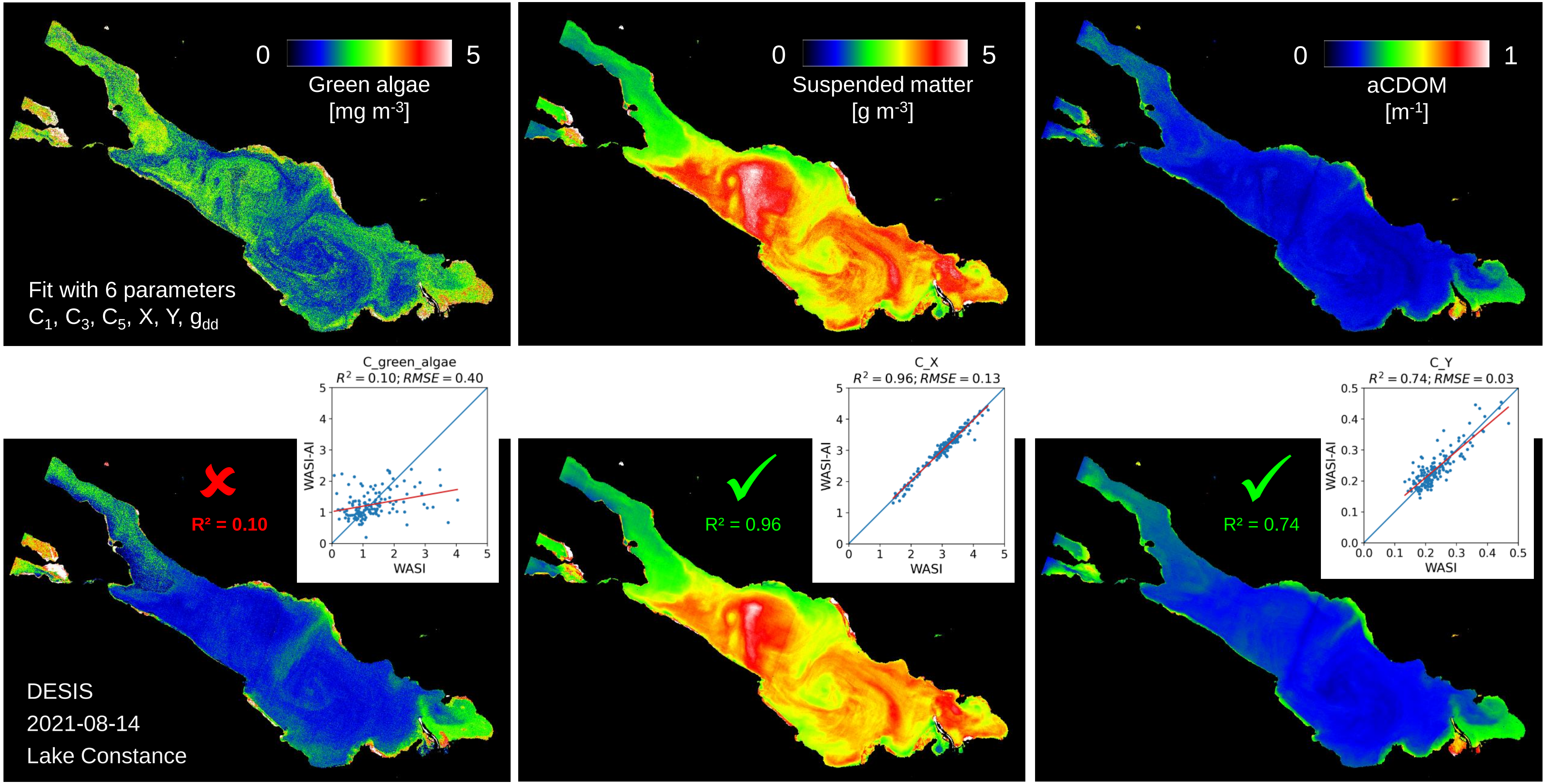
RESOURCES – Software – Software Used to Process Ocean Colour Data – WASI (Water Colour Simulator)

Identification of ambiguity problems in an image

Correlate results obtained with two different methods for random pixels

WASI-2D

WASI-AI



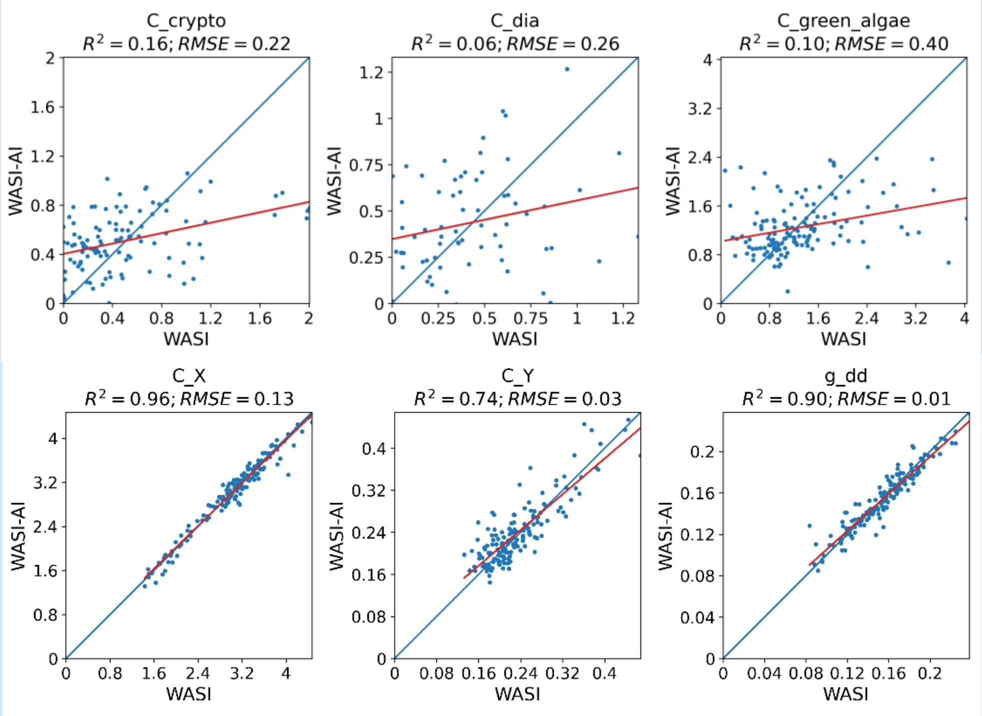
AI_DESIS-HSI-L2A-DT0621427604_MOSAIC-20210814T132751-V0214_6p

Handling of ambiguity problems

Change fit parameters, reduce their number

6 fit parameters

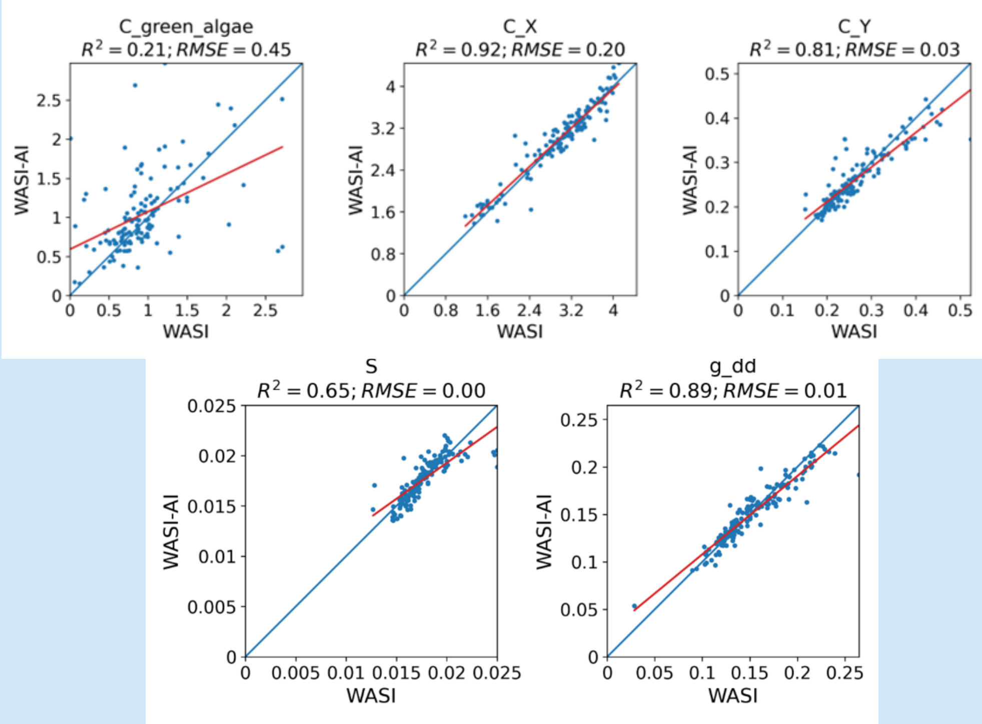
3 of them have a large ambiguity problem



AI_DESIS-HSI-L2A-DT0621427604_MOSAIC-20210814T132751-V0214_6p

5 fit parameters

1 of them has a reduced ambiguity problem



AI_DESIS-HSI-L2A-DT0621427604_MOSAIC-20210814T132751-V0214_5p.gew1

DESIS 2021-08-14 Lake Constance

Handling of ambiguity problems

Methods implemented in WASI-2D

- Change number of fit parameters
- Restrict spectral range of data analysis to useful bands
- Increase weight of bands relevant for parameter of interest
- Utilize site-specific knowledge
  - Replace default inherent optical properties with local measurements
  - Set model constants to local conditions
  - Initialize fit parameters with values typical for the site
  - Restrict range of fit parameters to variability within image
- Include errors from atmospheric correction in model

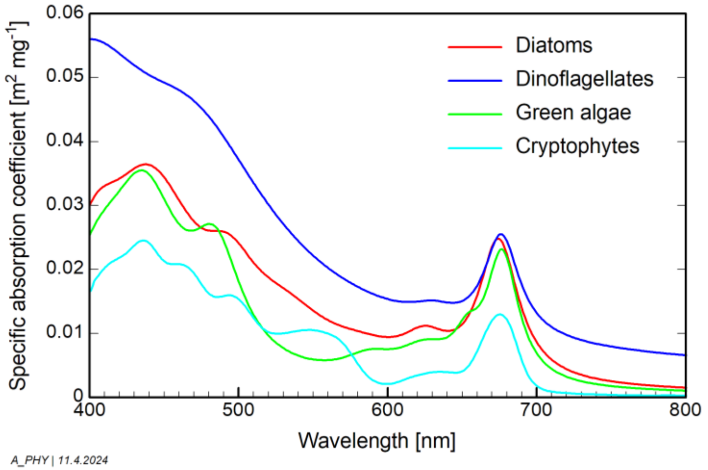
Example

- Goal: distinguish different phytoplankton groups that occur as mixtures at low to moderate concentrations
- DESIS has the highest spectral resolution, therefore DESIS images from Lake Constance as test dataset

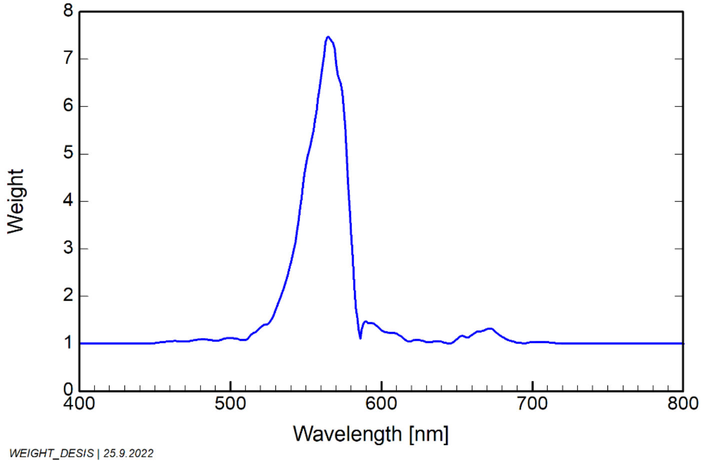
Handling of ambiguity problems

Utilize site-specific knowledge, increase weight of bands relevant for parameter of interest

Regional IOPs of phytoplankton from Lake Constance



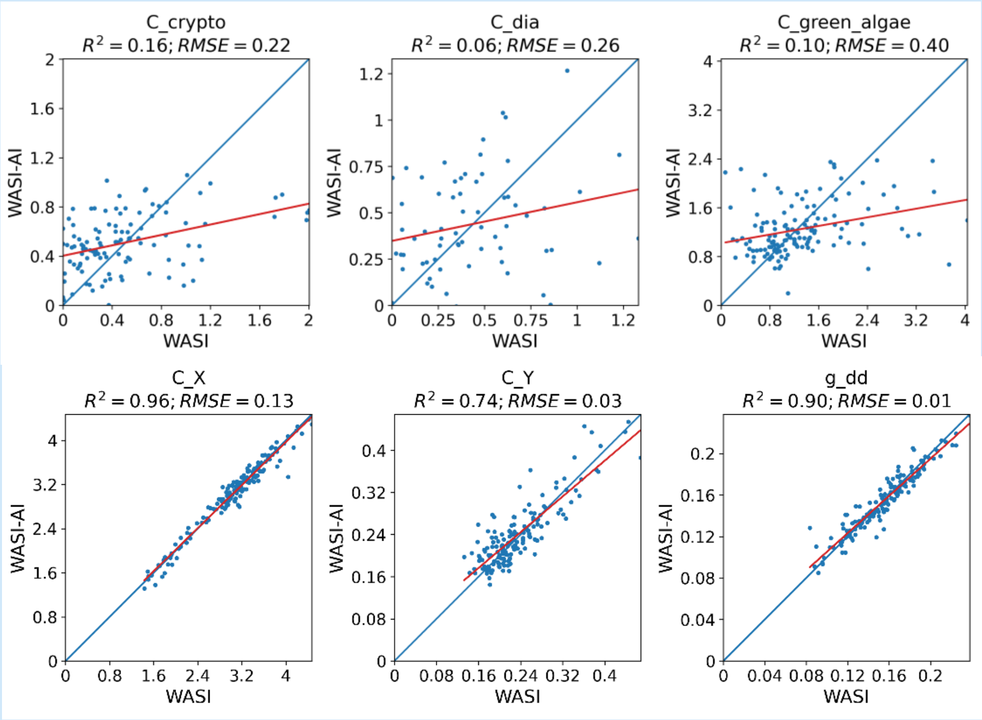
Weight function adapted to SNR of DESIS image from Lake Constance and to task of phytoplankton classification



P. Gege (2023): A spectral weighting function for improving phytoplankton classification. https://doi.org/10.1364/HMISE.2023.HW4C.2

6 fit parameters

3 of them have a large ambiguity problem

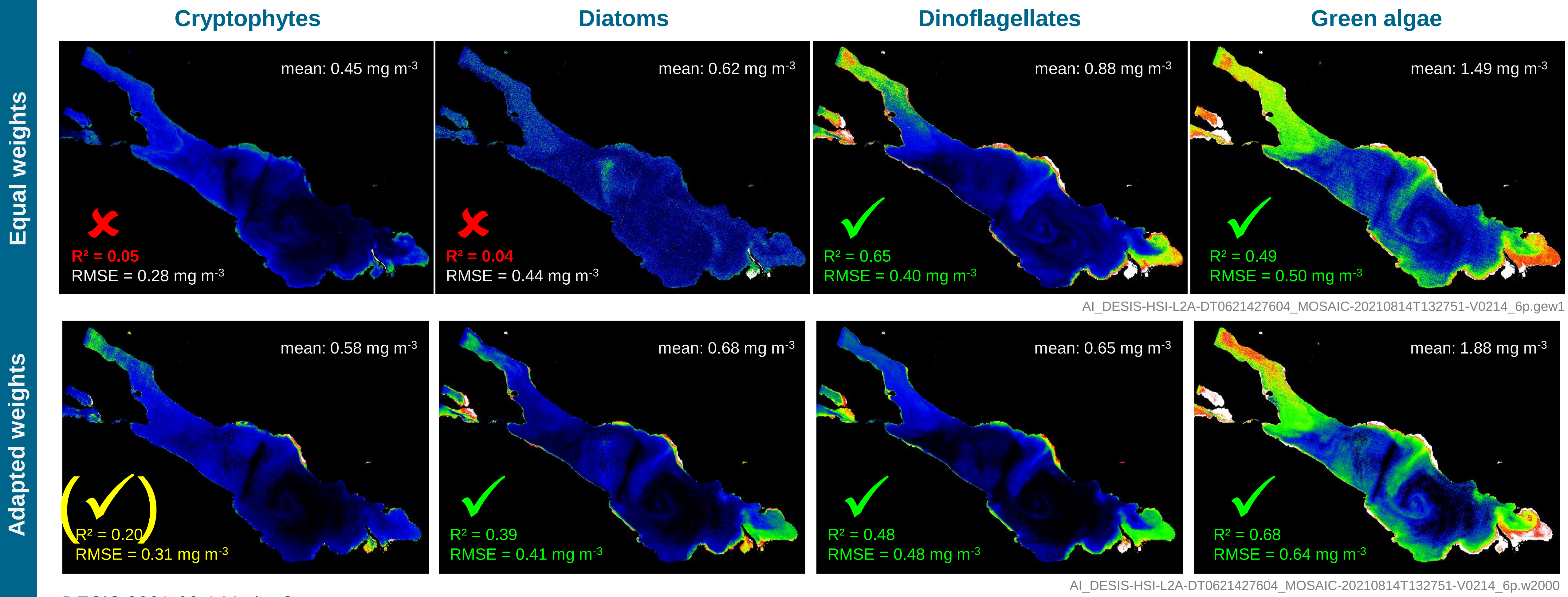


AI_DESIS-HSI-L2A-DT0621427604_MOSAIC-20210814T132751-V0214_6p

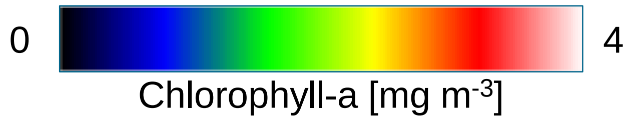
DESIS 2021-08-14 Lake Constance

Results

Quality assessment of phytoplankton classification



DESIS 2021-08-14 Lake Constance



Summary and conclusions

- Spectral ambiguities can make retrieval of some fit parameters challenging/unfeasible
- Ambiguity problems can be identified by repeating the processing with altered model settings or different algorithms
- WASI-2D offers a number of measures to handle ambiguity problems
- WASI-AI allows identifying ambiguity problems using correlation plots comparing AI-based and physics-based inversion results
- WASI-AI quantifies the error introduced by spectral ambiguities

Acknowledgements

- Astrid Bracher and Mariana Soppa (AWI): Measuring absorption of CDOM and cryptophytes of Lake Constance
- Ian Somlai (DLR): Preparing DESIS image, correlation plots and image statistics