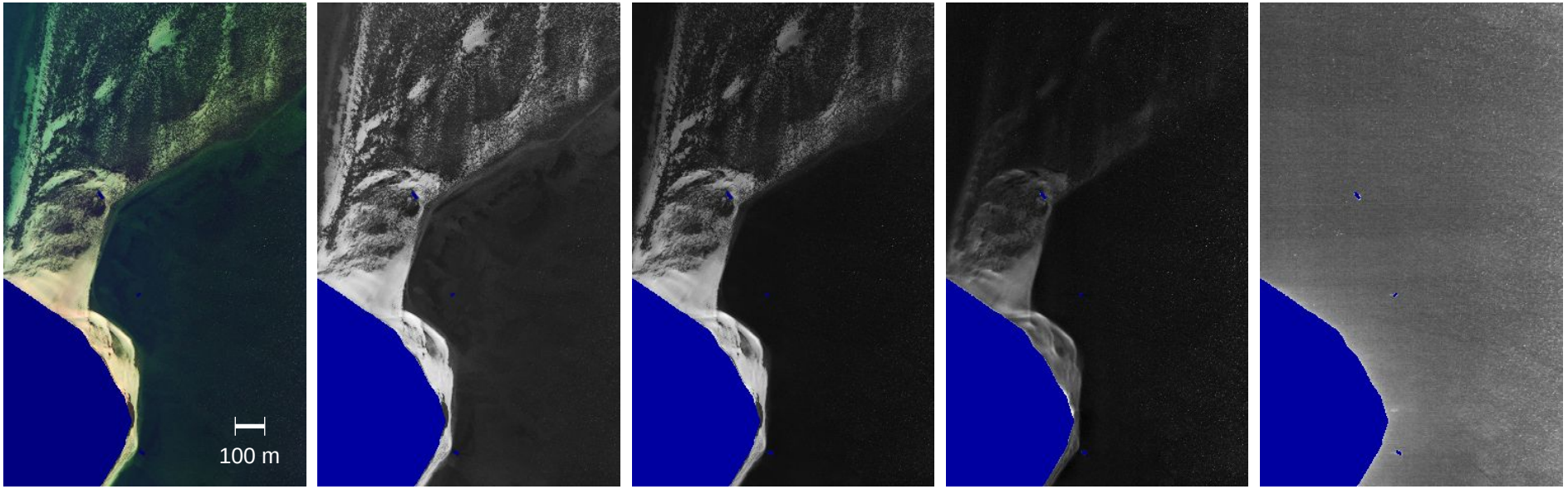
Principles of bathymetry from space

Peter Gege
DLR, Earth Observation Center, Remote Sensing Technology Institute, Oberpfaffenhofen, 82234 Wessling, Germany

SDB Day „Satellite Derived Bathymetry. Technology and User Forum“
Herrsching, Germany, 6-7 June 2018.

Measurement principle

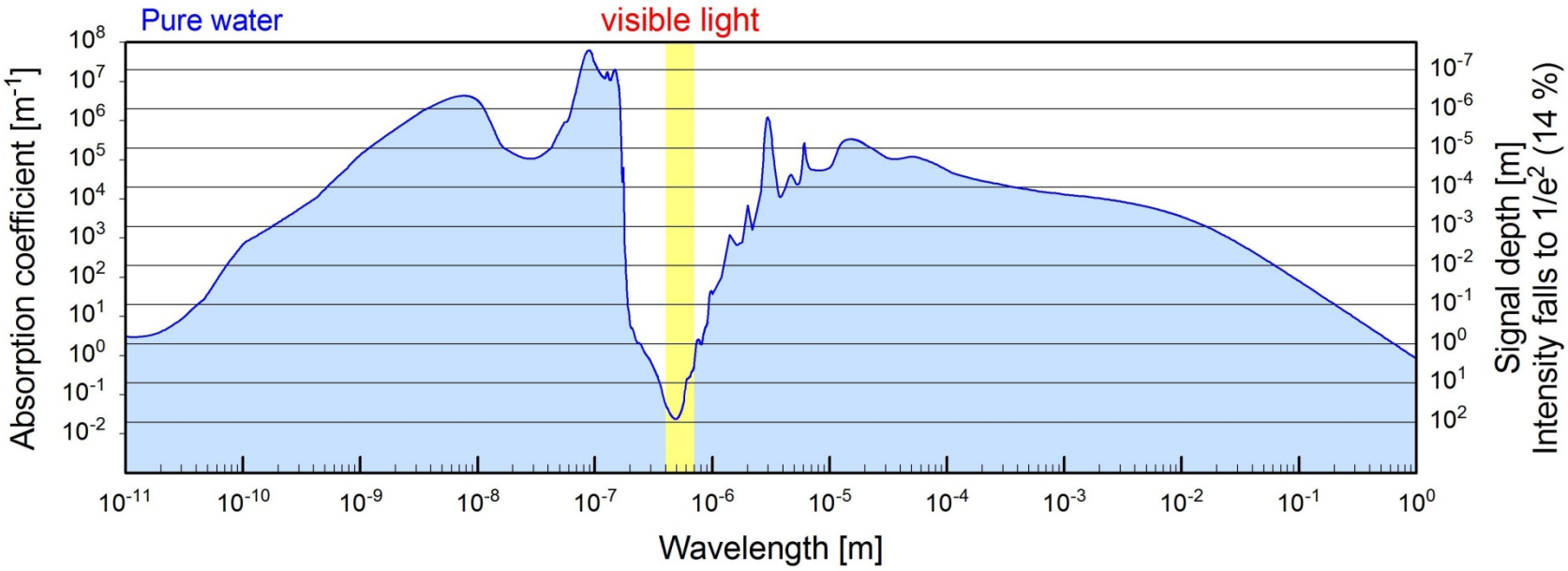
Airborne image from the Baltic Sea acquired with hyperspectral sensor HySpex VNIR-1600



Pseudo true color 440, 550, 650 nm | **550 nm** | **650 nm** | **720 nm** | **1320 nm**

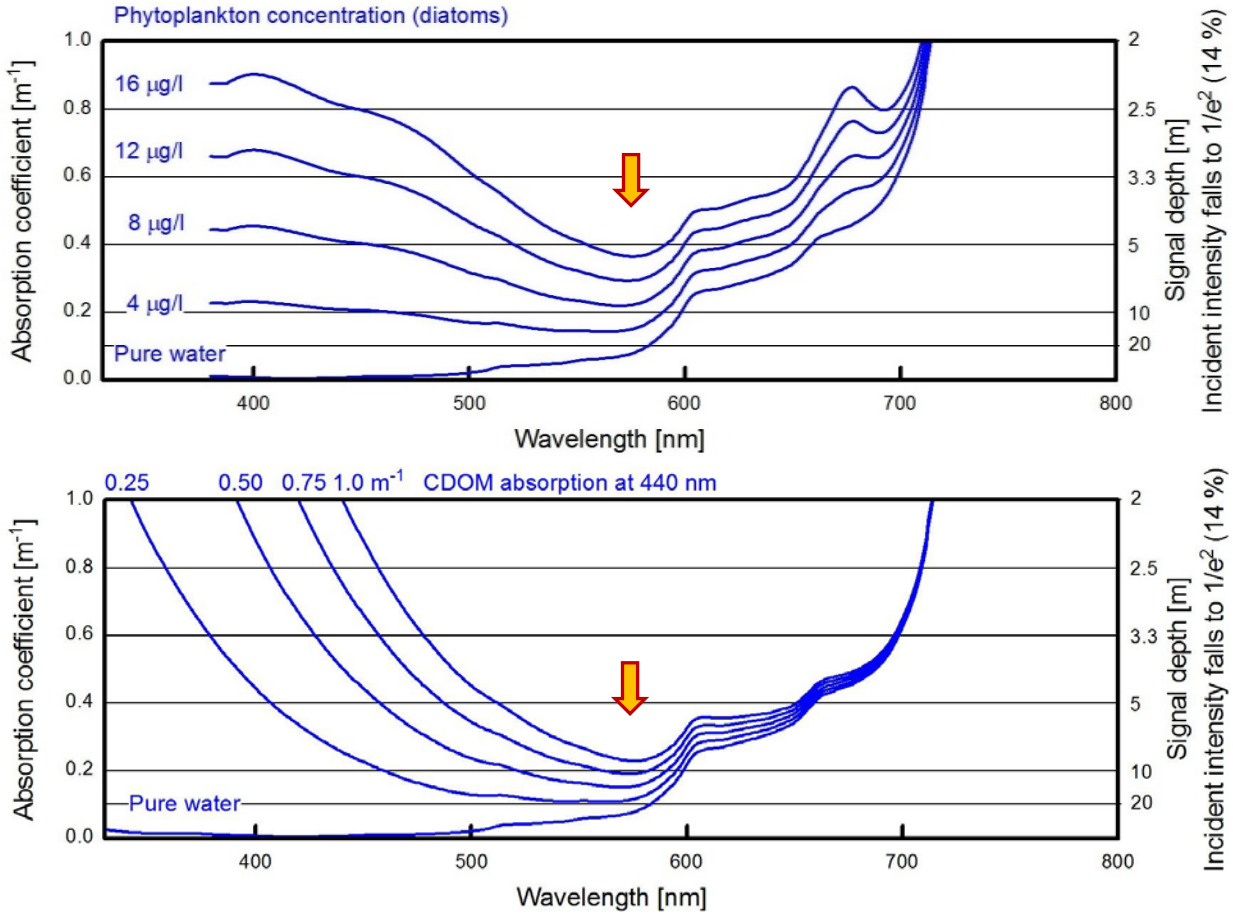
Penetration depth of electromagnetic radiation into water is wavelength dependent

Measurement principle



- **Visible light** penetrates the upper water layer (order of 10-100 m) and may carry information about the sea floor (in shallow waters)
- **The other wavelengths** can be used to derive information about the surface (skin temperature, waves) and the reflected light (useful for atmospheric and sun glint correction)

Impact of water constituents on signal depth



Penetration depth largest in the green (~550 - 580 nm)

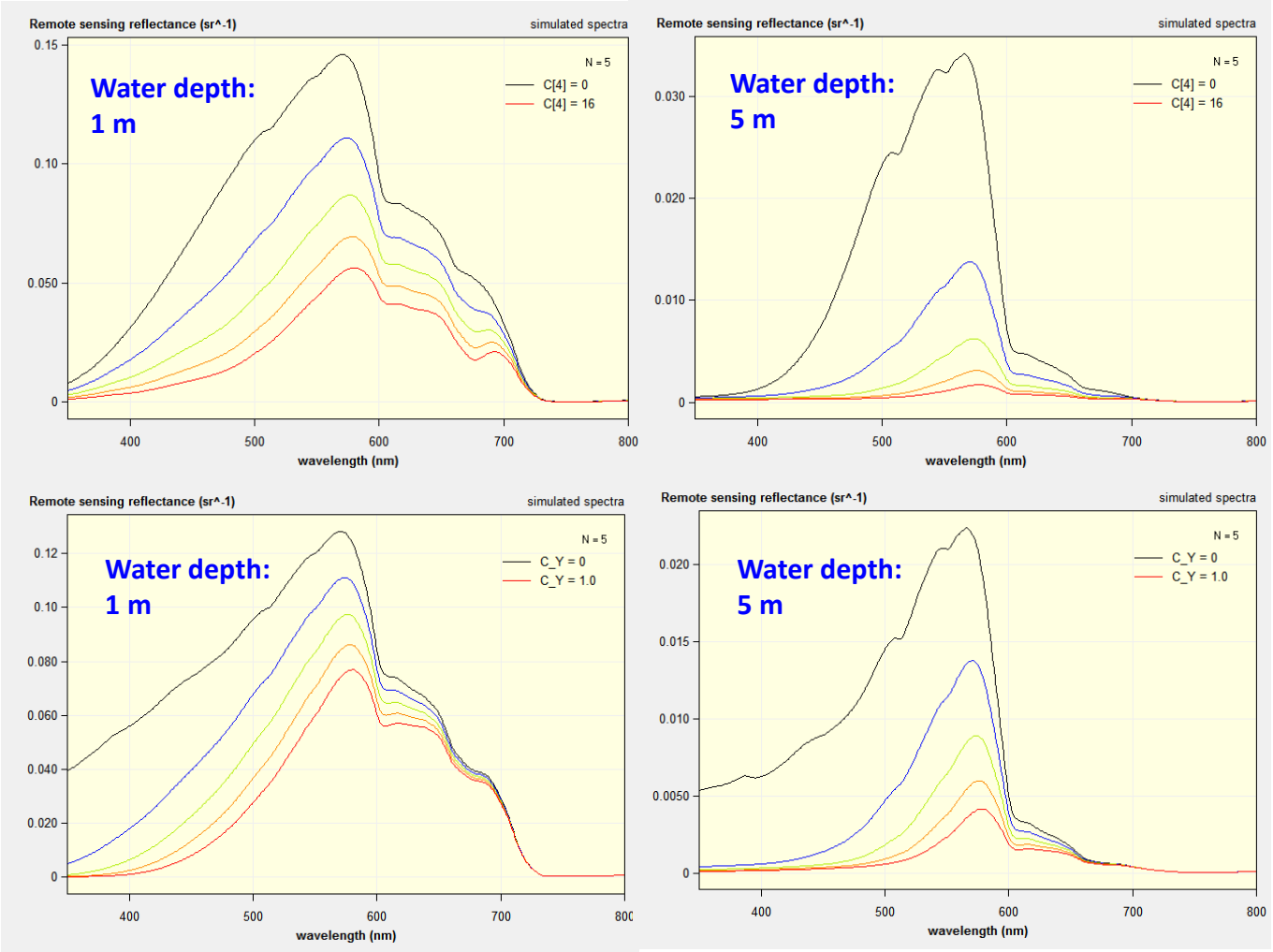
These and all further simulations were made with the software WASI http://www.ioccg.org/data/software.html

- Water constituents reduce the penetration depth of light in water
- The effect is wavelength dependent

Impact of water constituents on reflectance spectrum

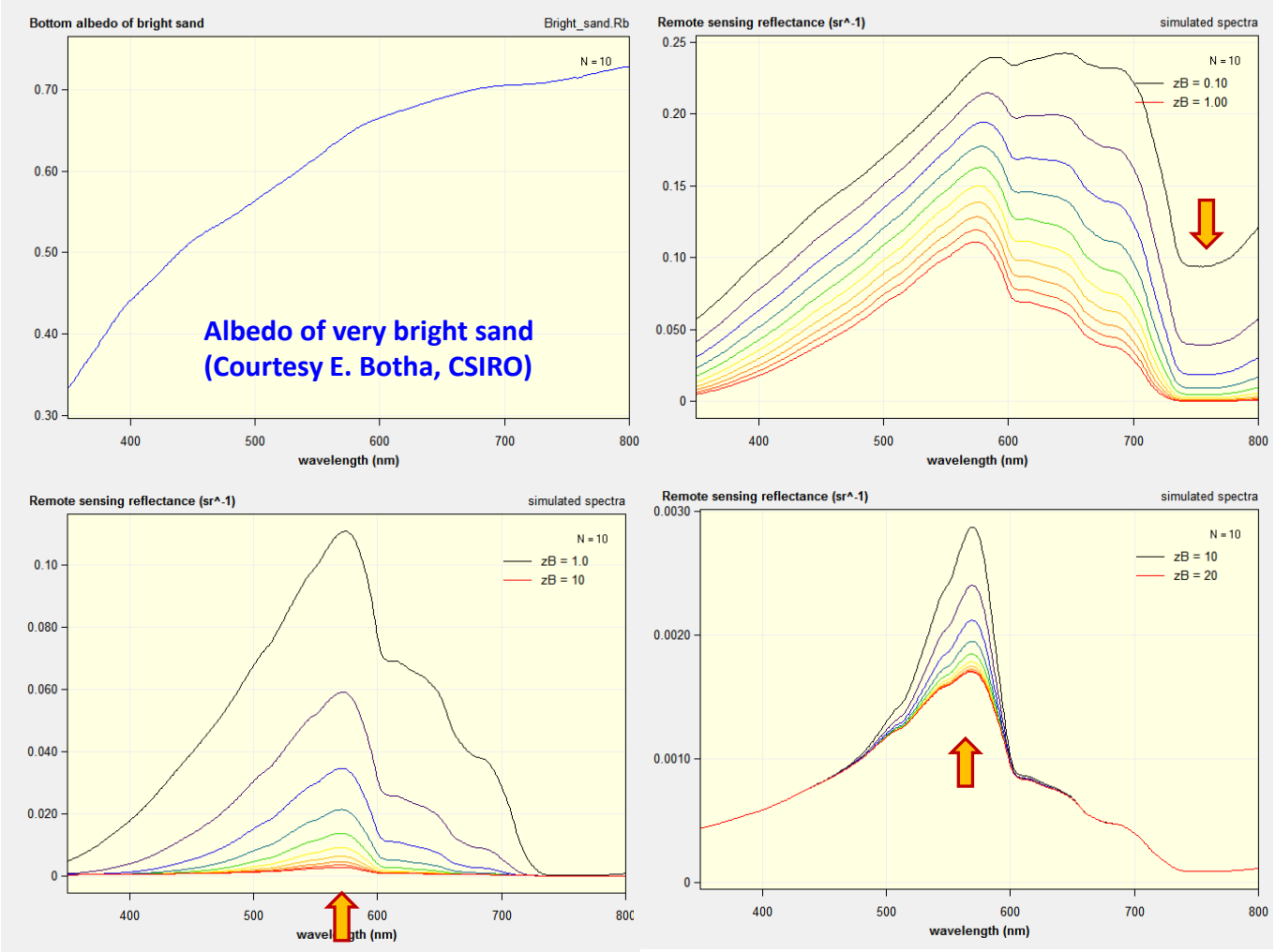
Phytoplankton:
0 – 4 – 8 – 12 16 µg/l
CDOM: 0.25 m-1
TSM: 0.75 mg/l
Bright sand

CDOM:
0 – 0.25 – 0.50 – 0.75 – 1.0 m^{-1}
Phyt.: 4 µg/l
TSM: 0.75 mg/l
Bright sand



- Water constituents have strong impact on reflectance spectra
- Highest reflectance in the green (~550 – 580 nm) *for chosen conditions*

Bathymetry for bright sand



Water depth: 0.1 - 1 m
black to red steps of 0.1 m

Even near Infrared useful

Water depth: 1 - 10 m
black to red steps of 1 m

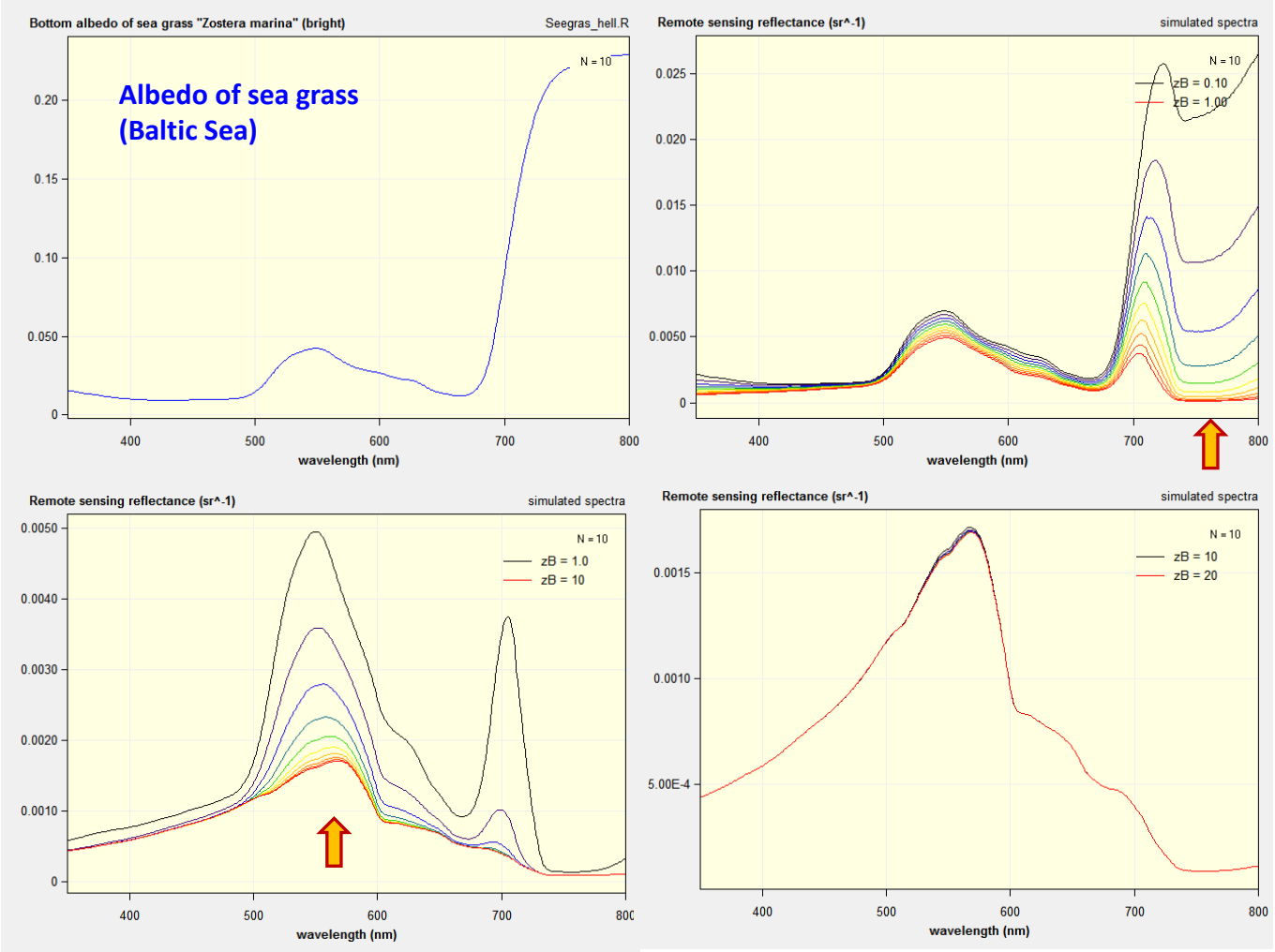
Highest sensitivity in the green (~580 nm)

Water depth: 10 - 20 m
black to red steps of 1 m

Bright sand has a detection limit of ~15 m for chosen conditions

➢ The useable and best-suited wavelength range depends on water depth

Bathymetry for sea grass



Water depth: 0.1 - 1 m
black to red steps of 0.1 m

Highest sensitivity in the NIR (~700-800 nm)

Water depth: 1 - 10 m
black to red steps of 1 m

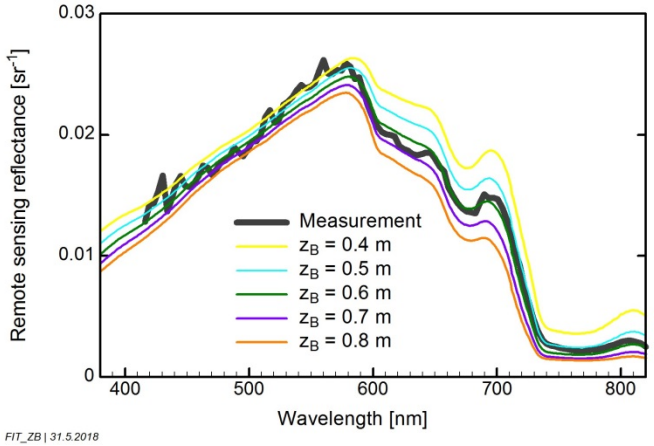
Highest sensitivity in the green (~550-580 nm)

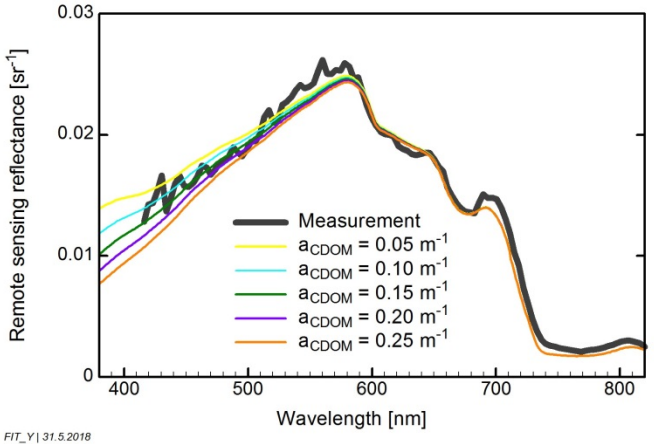
Water depth: 10 - 20 m
black to red steps of 1 m

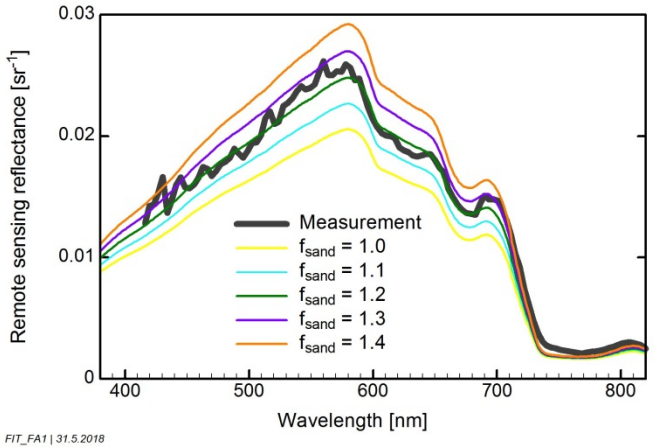
Sea grass has a detection limit of ~7 m for chosen conditions

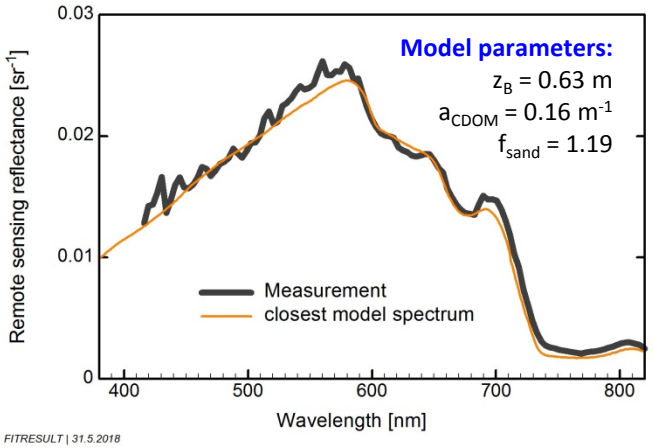
➢ The detection limit depends on the bottom type (brightness)

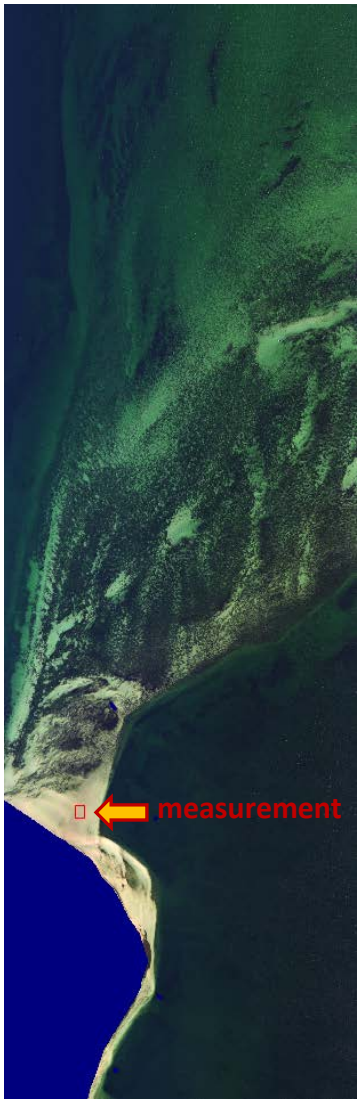
Data analysis principle



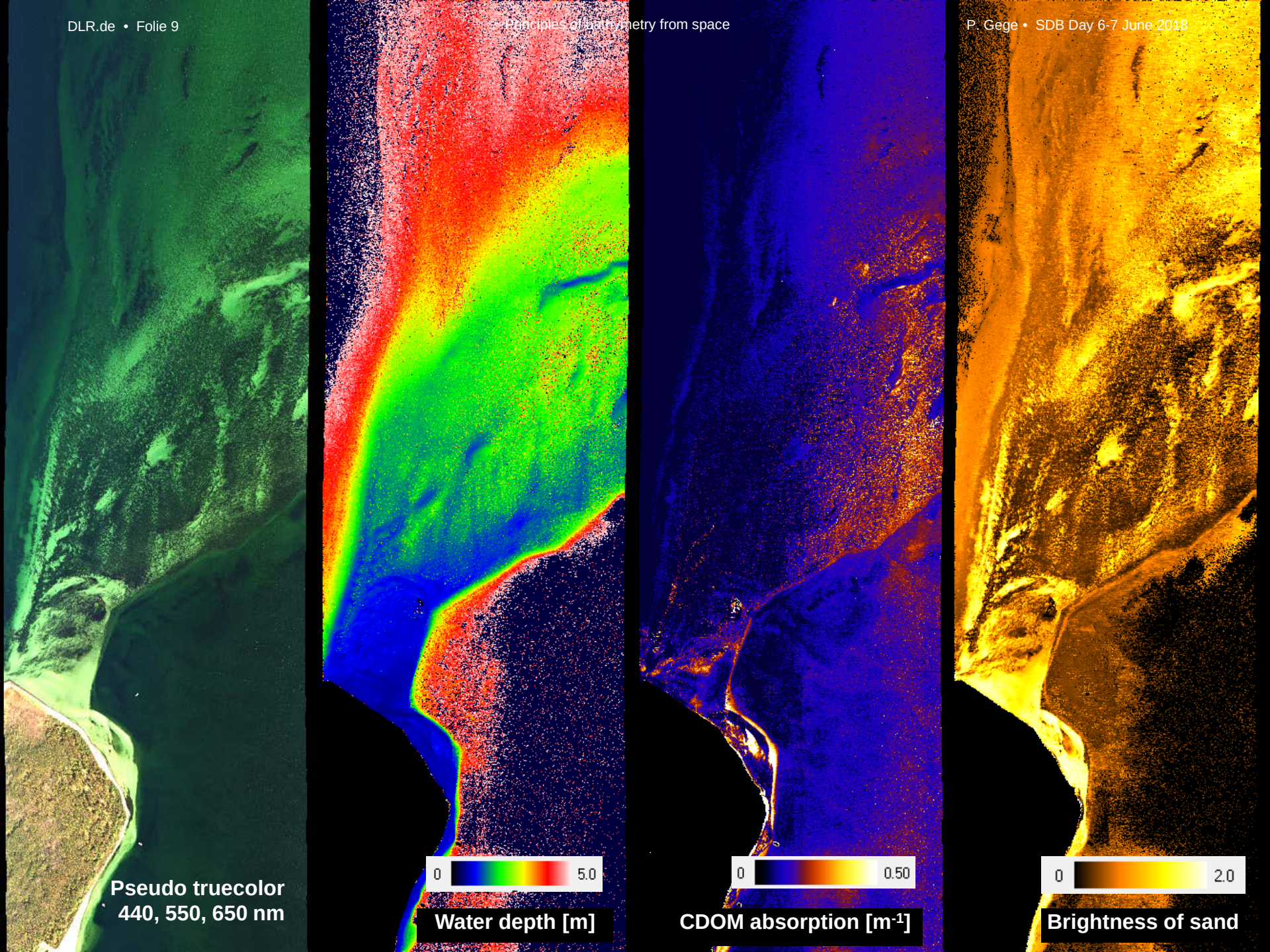








- Different combinations of model parameters lead to different model curves
- The parameters of the best matching curve are the results of data analysis


Pseudo truecolor
440, 550, 650 nm
0
5.0
Water depth [m]
0
0.50
CDOM absorption [m-1]
0
2.0
Brightness of sand

References

Shallow water model

- Albert, A., Mobley, C. D., 2003. An analytical model for subsurface irradiance and remote sensing reflectance in deep and shallow case-2 waters. Opt. Express 11, 2873-2890.

Software WASI for simulation and inverse modeling

- Download: http://www.ioccg.org/data/software.html
- Gege, P., 2004. The water colour simulator WASI: An integrating software tool for analysis and simulation of optical in-situ spectra. Comput. Geosci. 30, 523-532.
- Gege, P., 2014. WASI-2D: A software tool for regionally optimized analysis of imaging spectrometer data from deep and shallow waters. Comput. Geosci. 62, 208-215.

Summary

Bathymetry from space

- **Sensors:** passive multispectral instruments
- **Detection principle**: penetration of light into water depends on wavelength
- **Data analysis principle:** parameters of a physical model are determined by matching measured and modelled reflectance spectrum
- **Data analysis methods:** Look-up tables, Neural networks, inverse modelling...
- **Environmental challenges:** Atmosphere, reflections at the water surface, many spectrally different components in the water and on ground, optical properties are variable
- **Sensor challenges:** number of bands, center wavelengths, noise, calibration