International Ocean Colour Science Meeting 2017

Advancing Global Ocean Colour Observations

Breakout Workshop #4

Remote Sensing of Inland and Coastal Waters: Current Status, Challenges, Research Priorities, and End-User Engagement

PLENARY REPORT

Co-Chairs:

Wes Moses, Carsten Brockmann, Andrew Tyler, Quinten Vanhellemont, Nima Pahlevan, Steve Greb, and Paul DiGiacomo

Remote Sensing of Inland and Coastal Waters

Atmospheric Correction

- Current Capabilities and Challenges – Nima Pahlevan

Bio-Optical Modeling

- Do We Need Optical Water Types? – Tim Moore
- Algorithm Selection for Lakes – Vagelis Spyrakos

Sensor Characteristics

- What Do We Need for Inland and Coastal Waters? – Wes Moses

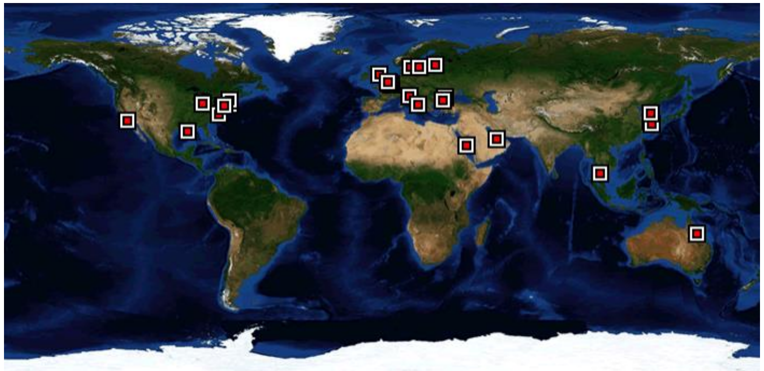
End- User Engagement

- Copernicus Inland Water Service – Carsten Brockmann
- GEO AquaWatch – Steve Greb

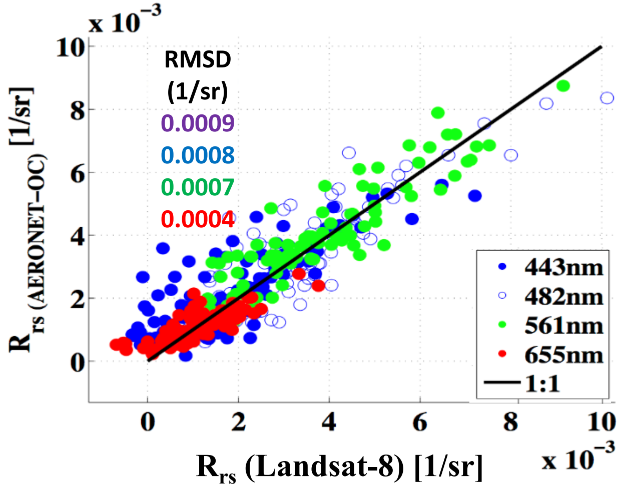
Atmospheric Correction – Capabilities & Challenges

Nima Pahlevan

Validations using AERONET-OC data: necessary but NOT sufficient

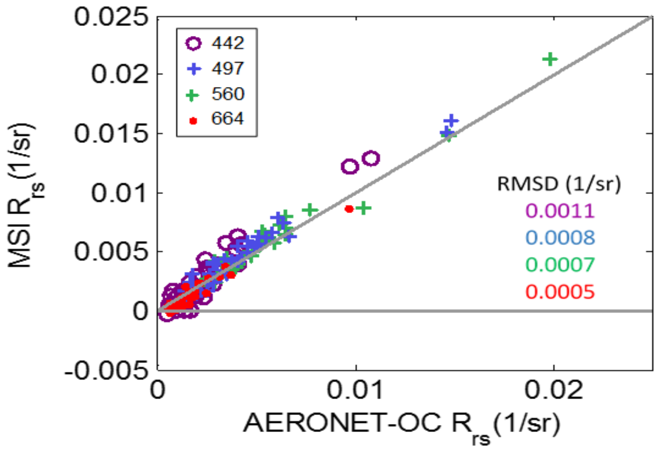


Landsat-8 (OLI)



(Pahlevan et al., 2017)

Sentinel-2A (MSI)



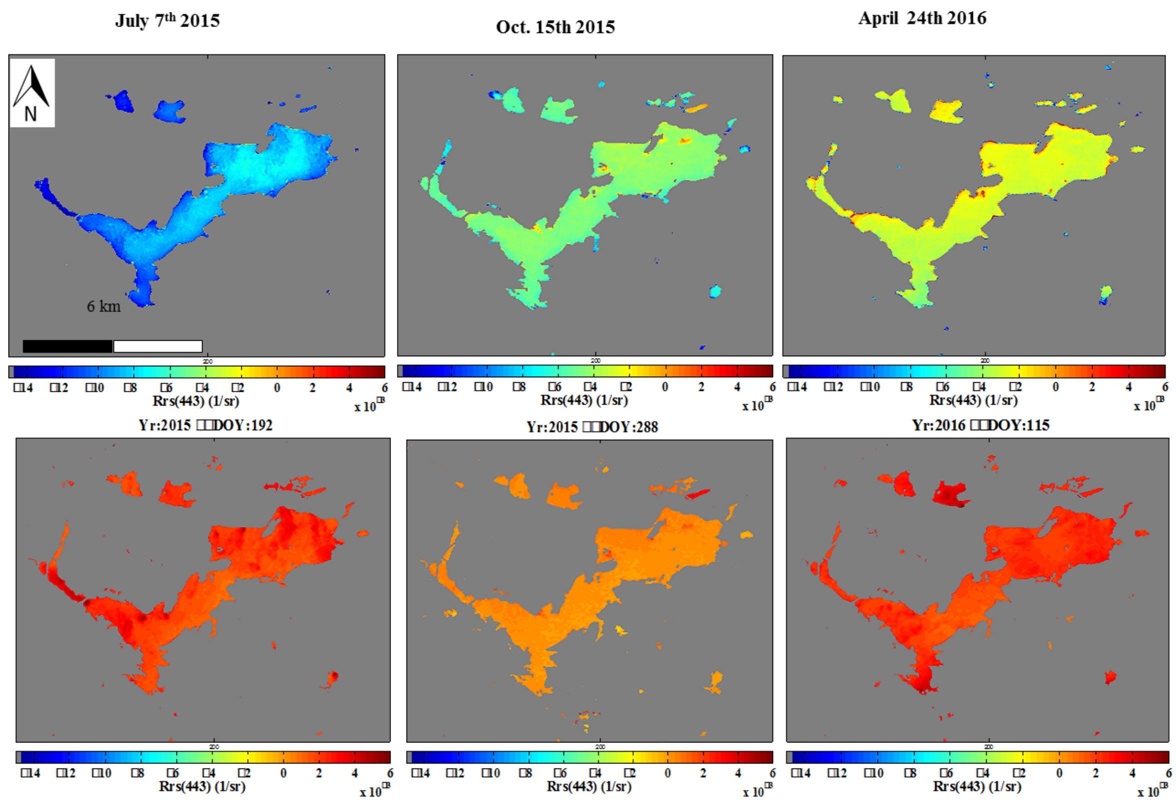
(Pahlevan et al., *submitted*)

Atmospheric Correction – Capabilities & Challenges

Nima Pahlevan

Issues with Aerosol Removal - Representativeness

Landsat-8 derived **R_{rs}(443)** over **Wachusett Reservoir** in Massachusetts



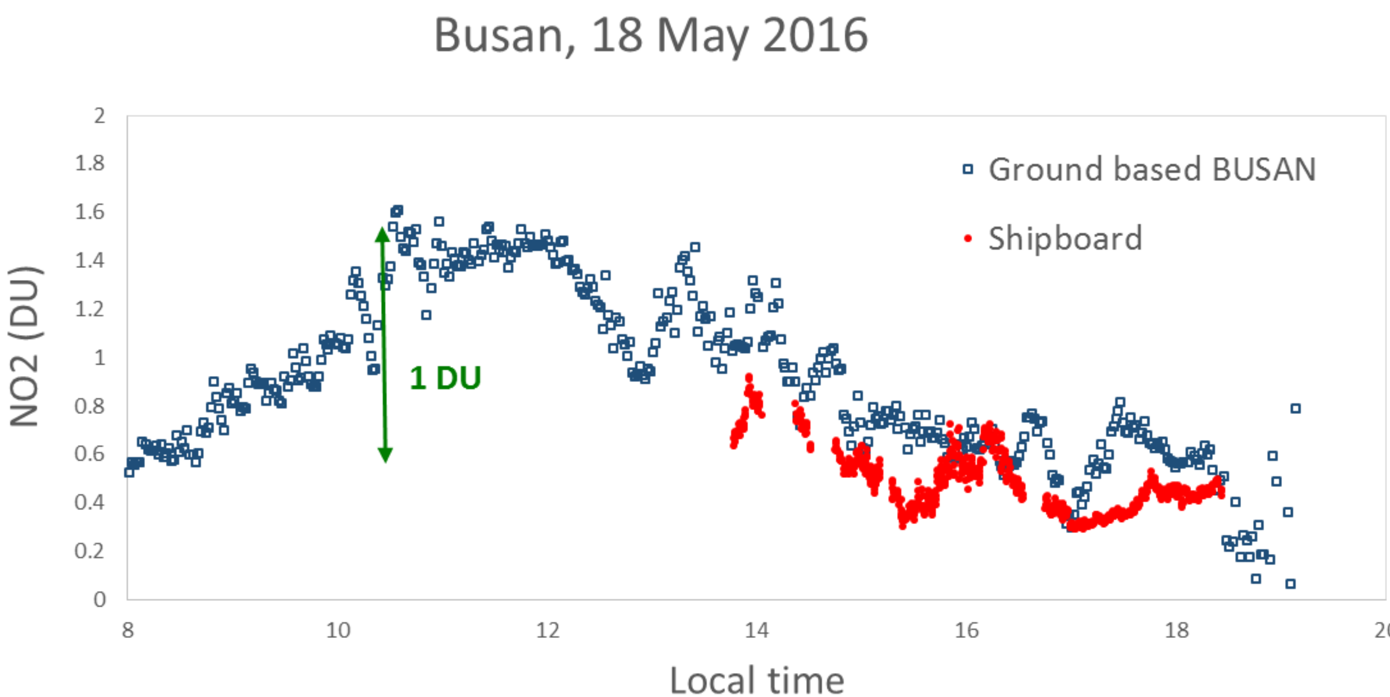
Automated removal of aerosols using existing aerosol LUTs

Manual removal of aerosols using observed AOT spectra

Atmospheric Correction – Capabilities & Challenges

Nima Pahlevan

Issues with Trace Gas Removal - Representativeness



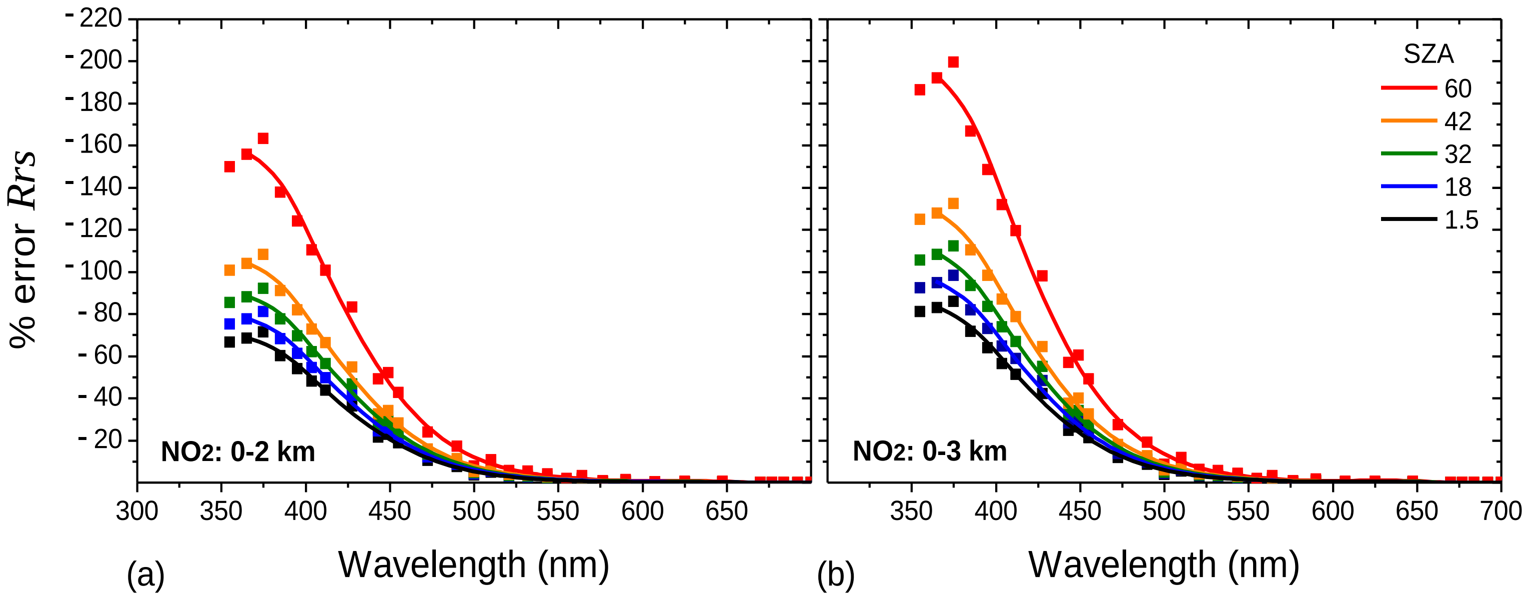
Credit: Maria Tzortziou (KORUS –OC field campaign)

Atmospheric Correction – Capabilities & Challenges

Nima Pahlevan

Issues with Trace Gas Removal - Representativeness

1 DU error results in large errors in Rrs in the UV and blue



(Tzortiou et al., 2017)

Atmospheric Correction – Capabilities & Challenges

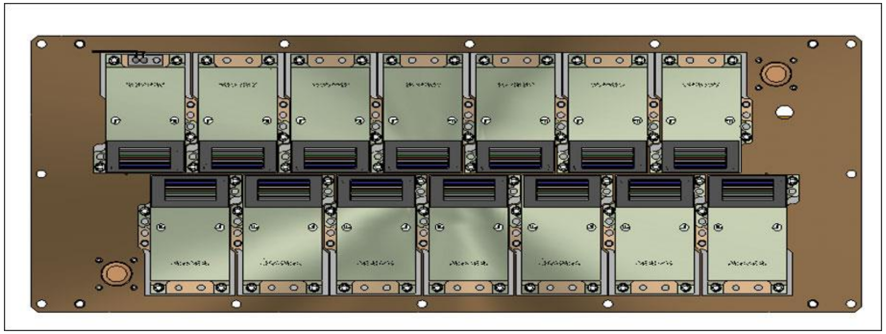
Nima Pahlevan

Adjacency Effects

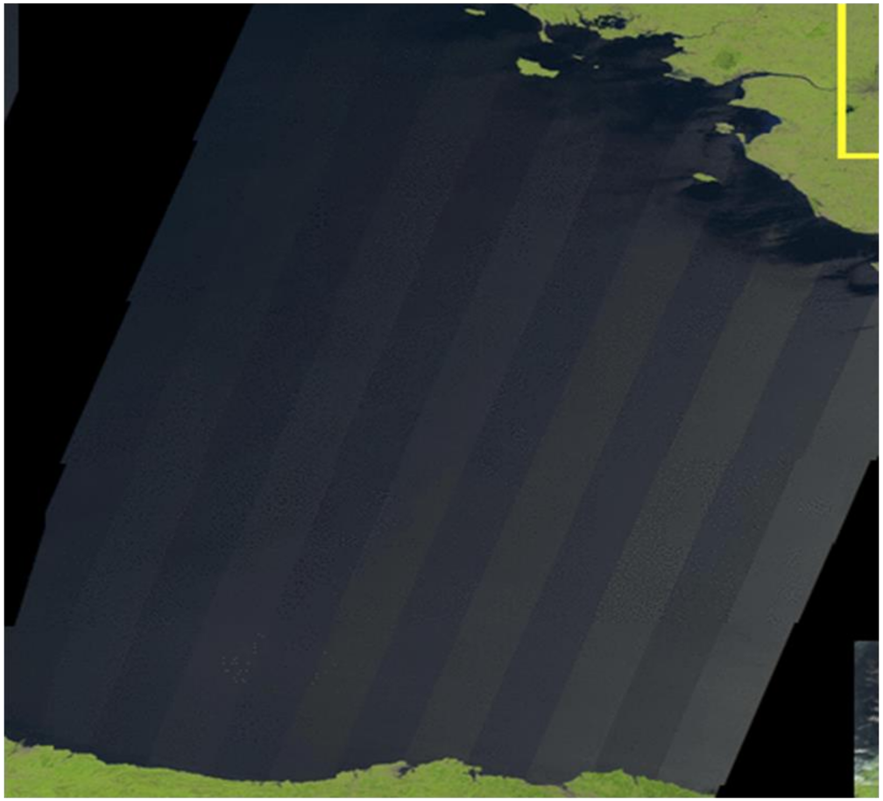
Atmospheric Correction – Capabilities & Challenges

Nima Pahlevan

Sun Glint



Sentinel-2A



Q1. Atmospheric Correction – Discussion

Q1A. How can we improve validation of aerosol retrievals in inland/coastal waters?

- Set up AERONET/AERONET-OC-like stations (some sites may not meet the criteria)
- Encourage researchers to collect aerosol optical thickness using sun photometers and share data (after quality control) on databases such as SeaBASS

Q1. Atmospheric Correction – Discussion

Q1B. How do we deal with complex atmospheres?

- Interact with more and learn from the land community

Q1. Atmospheric Correction – Discussion

Q1C. What is the best approach to correct for adjacency effects?

- Use spectral information
- Might be challenging in near-shore shallow-water regions

Q1. Atmospheric Correction – Discussion

Q1D. How do we mitigate sun glint effects?

- Explore shifting satellite orbital paths for the northern hemisphere
- Explore taking advantage of sun glint signal

Bio-Optical Modeling – Optical Water Types

Tim Moore

Complex optics with large range in conditions create challenges to remote sensing applications for inland lakes.

Bio-Optical Modeling – Optical Water Types

Tim Moore

Cyanobacteria colony surface formation – July 23, 2016 (Part 1)

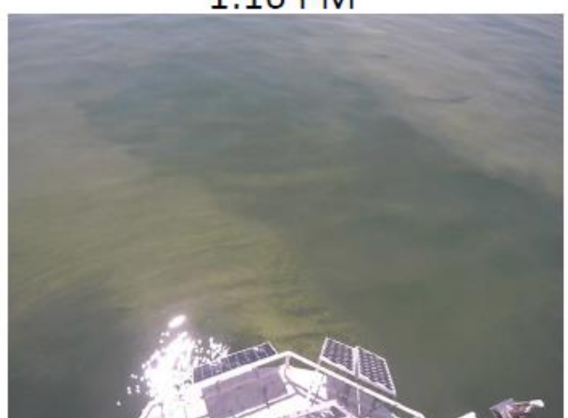
9:16 AM

10:16 AM

11:16 AM

12:16 PM

1:16 PM



2:16 PM

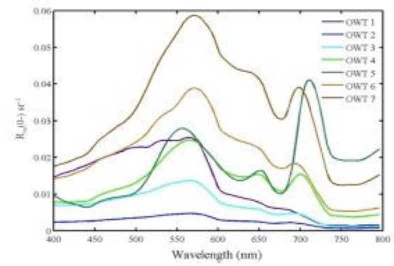
Bio-Optical Modeling – Optical Water Types

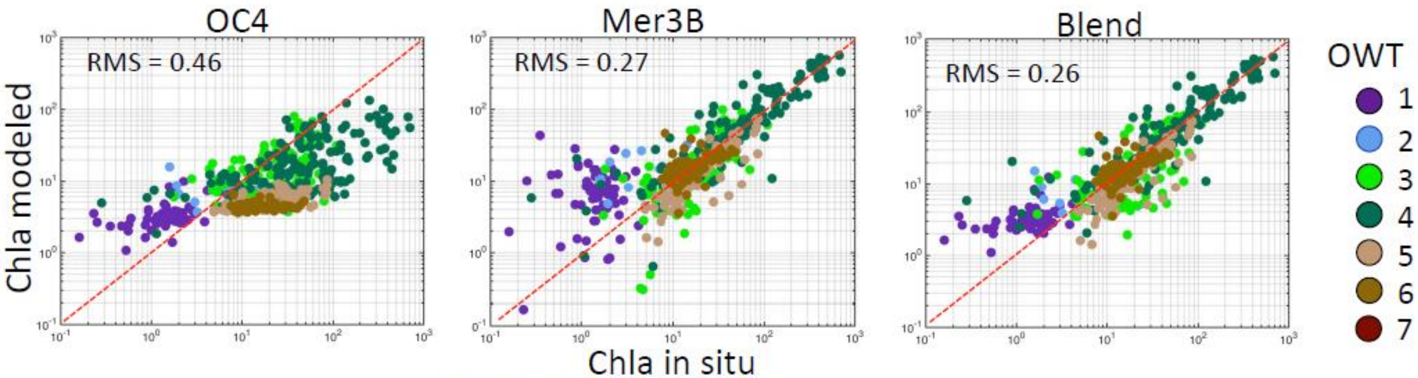
Tim Moore

Algorithm Blending

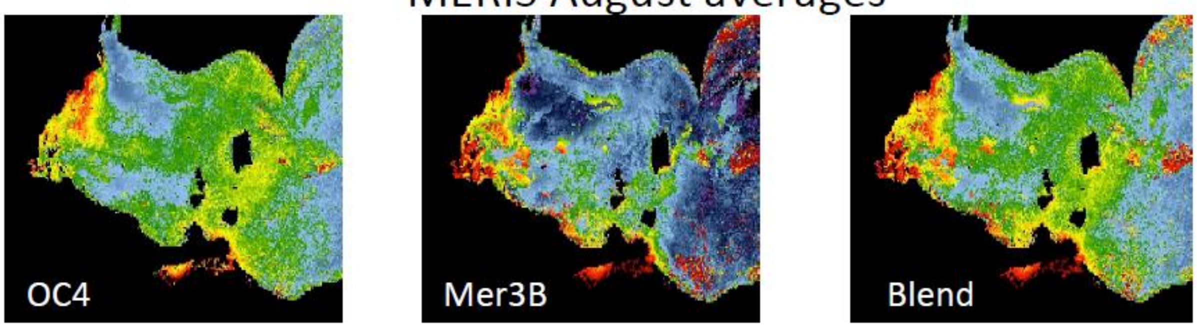
- 7 optical water types used to classify RS imagery
- Water type represents an optical state
- Allows for tuning specific models/ parameters to optical conditions

(Moore et al 2014, RSE)





MERIS August averages

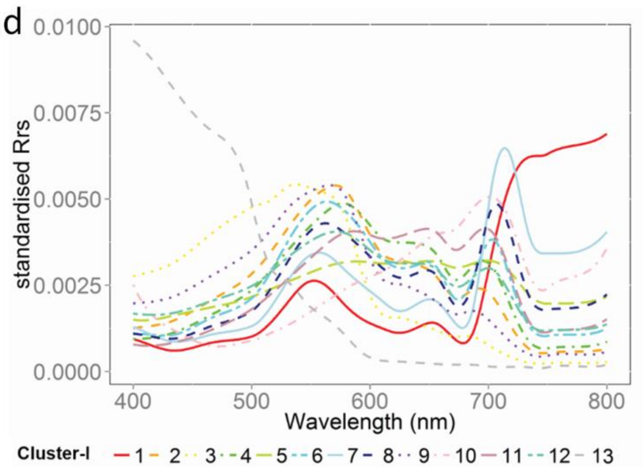


Bio-Optical Modeling – Algorithm Selection

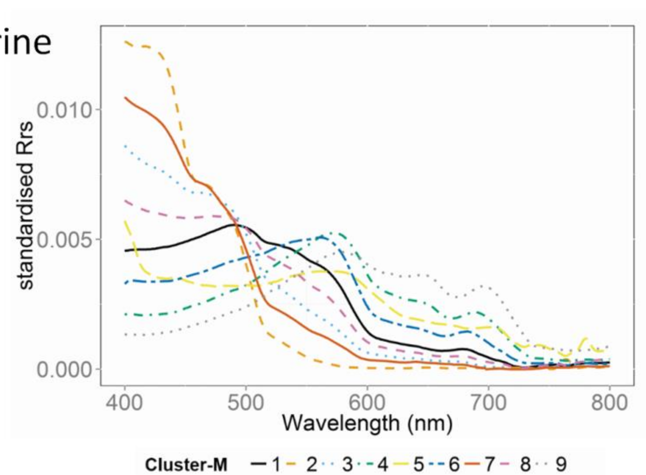
Vagelis Spyrakos

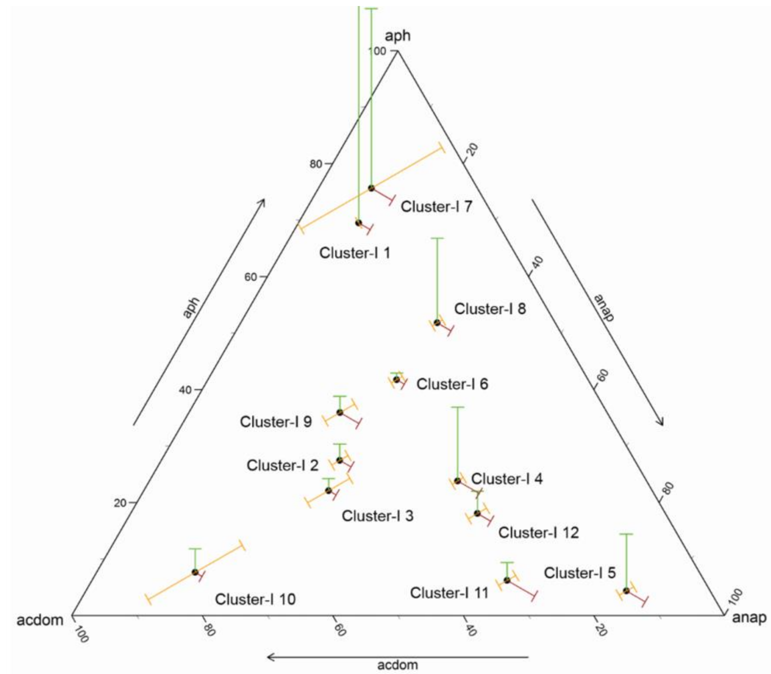
Optical Water Type Classification through Clustering

Inland



Marine



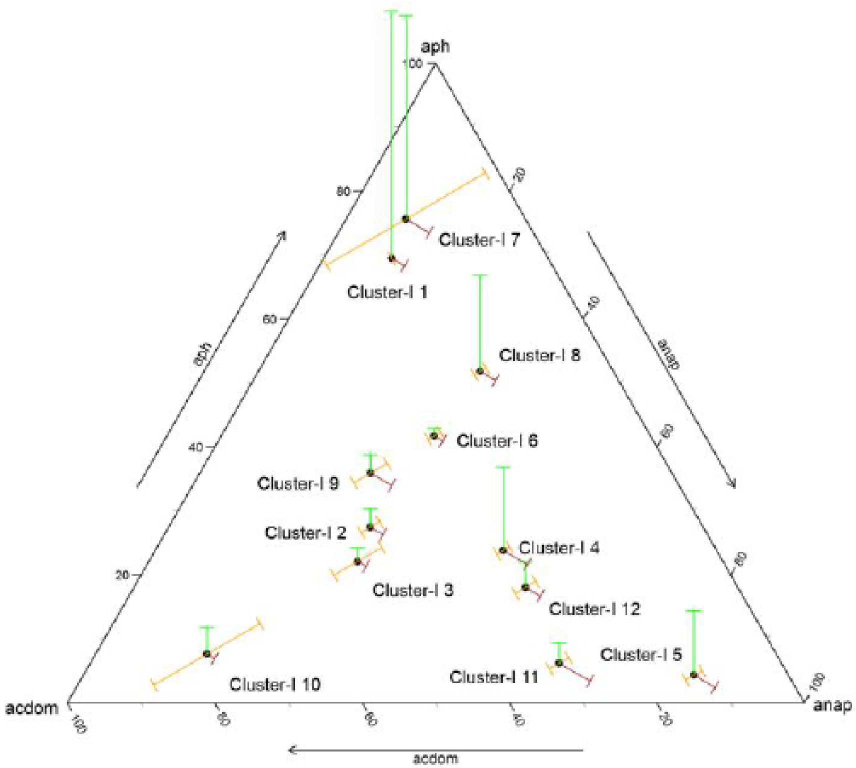


E. Spyrakos et al.: Optical types of natural waters. Submitted to Limnology and Oceanography.

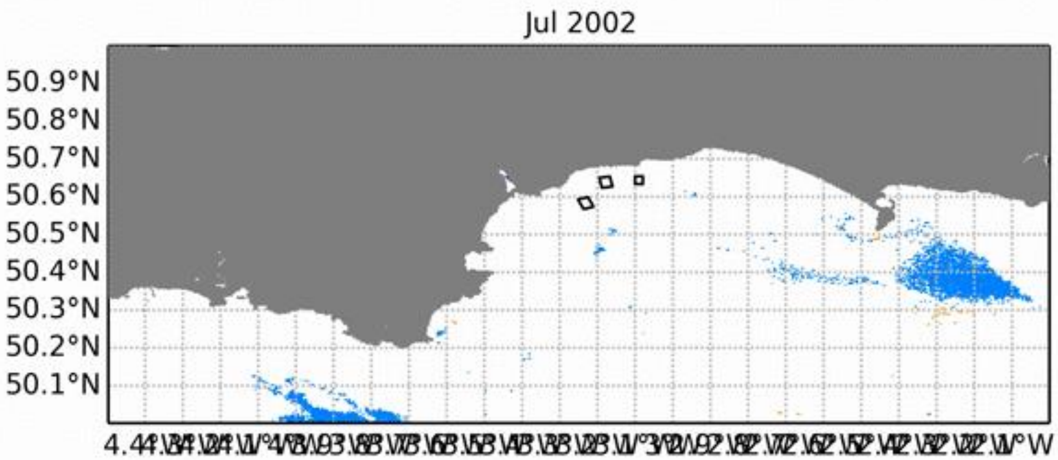
Bio-Optical Modeling – Algorithm Selection

Vagelis Spyrakos

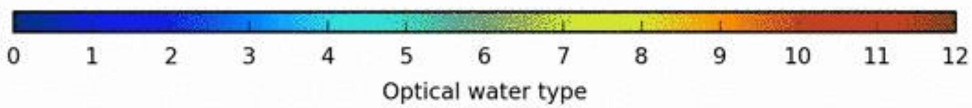
Optical Water Type Classification through Clustering

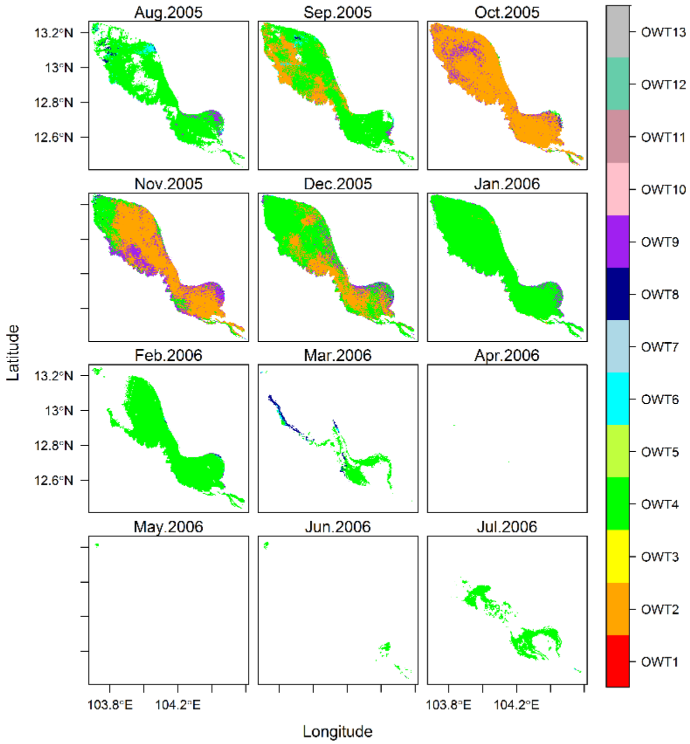


OWT	Dominant characteristics
OWT1	Hyper-eutrophic waters with cyanobacteria scum and vegetation-like reflectance
OWT2	Common case waters with diverse reflectance shape and marginal dominance of pigments and CDOM over inorganic suspended particles
OWT3	Clear waters
OWT4	Turbid waters with high organic content
OWT5	Sediment-laden waters
OWT6	Balanced effects of optically active constituents at shorter wavelength
OWT7	Highly productive waters with reflectance peak with elevated reflectance at red/near-infrared spectral region
OWT8	Productive waters with reflectance peak close to 700 nm
OWT9	Optically neighbouring to OWT2 waters but with higher reflectance at shorter wavelengths
OWT10	CDOM-rich waters
OWT11	High in CDOM waters with cyanobacteria presence and high absorption efficiency by NAP
OWT12	Turbid, moderately productive waters with cyanobacteria presence
OWT13	Very clear blue waters

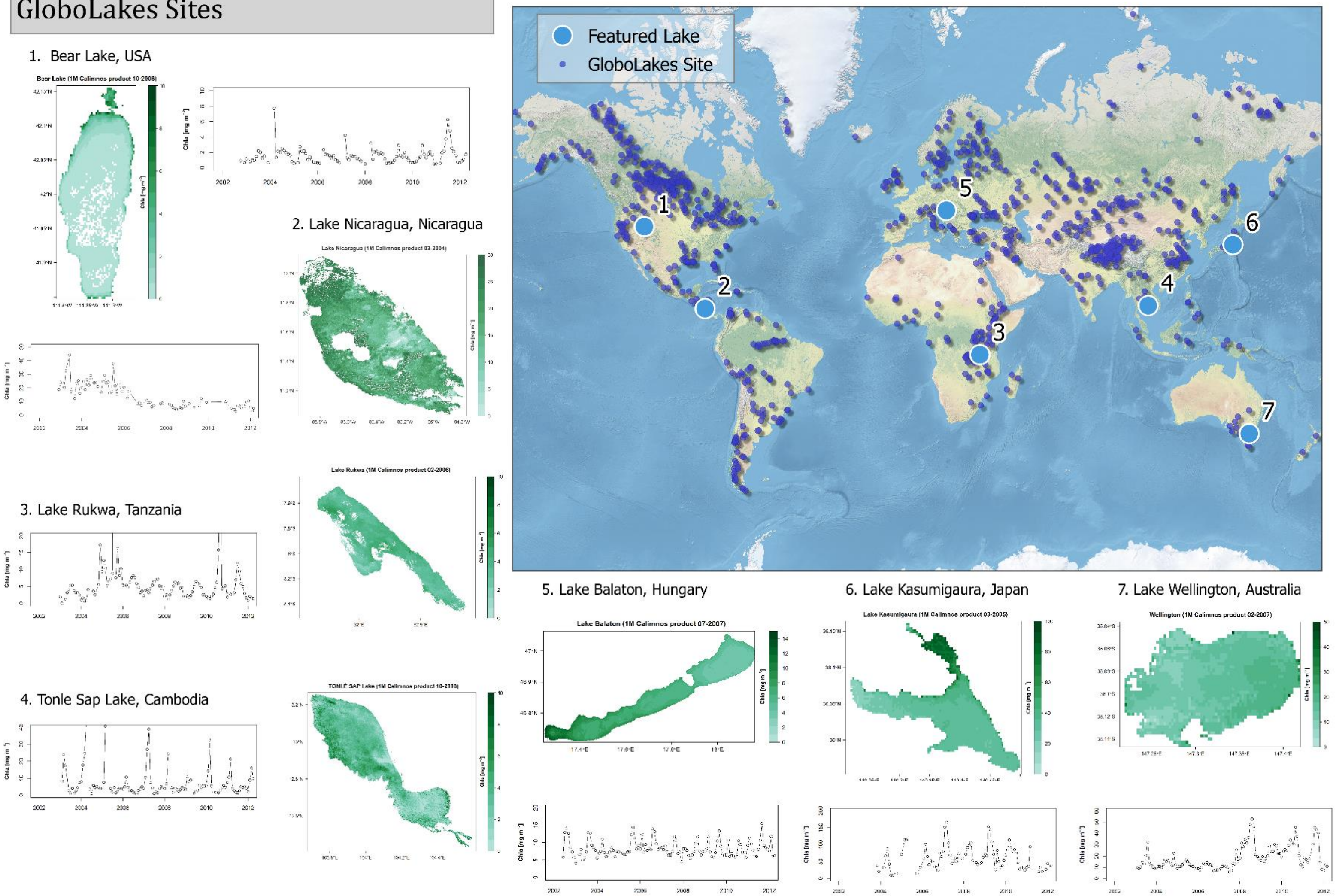


Credits to: Plymouth Marine Laboratory and H2020-TAPAS project





GloboLakes Sites



“1000+1” Lakes

Q2. Bio-Optical Modeling – Discussion

Q2A-D. What is the best approach for applying algorithms to coastal/inland waters?

- Globally developed, locally applied algorithms
- Need for more *in situ* data for evaluating global vs. local relationships
- Standardized data-collection procedures needed, but they are difficult to adopt
- Need for sIOP measurements

Q2. Bio-Optical Modeling – Discussion

Q2E. What are the most critical products sought for water quality monitoring?

- Chl-*a* concentration, by a long shot

Sensor Characteristics

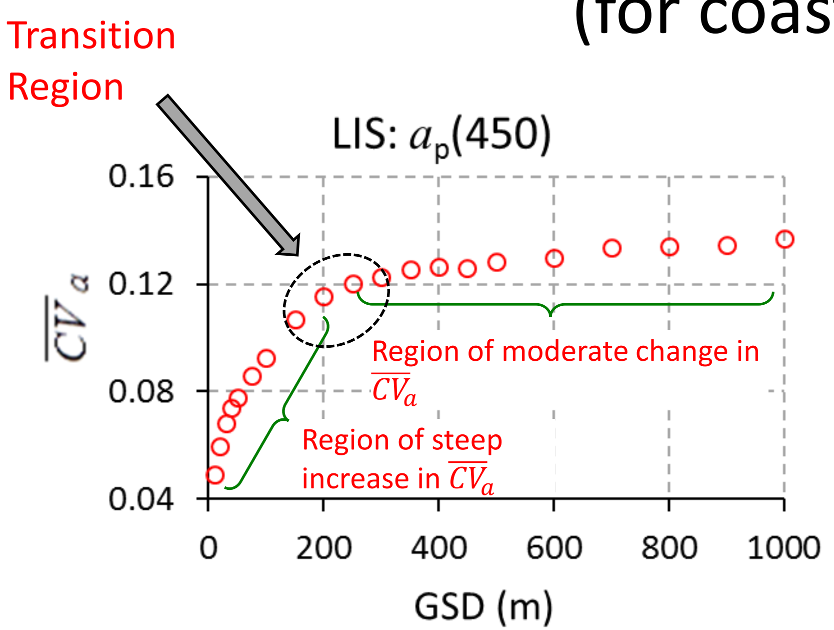
Wes Moses

- Spatial Resolution
- Spectral Resolution
- Signal-to-Noise Ratio
- Temporal Resolution

Sensor Characteristics – Spatial Resolution

Wes Moses

(for coastal waters)



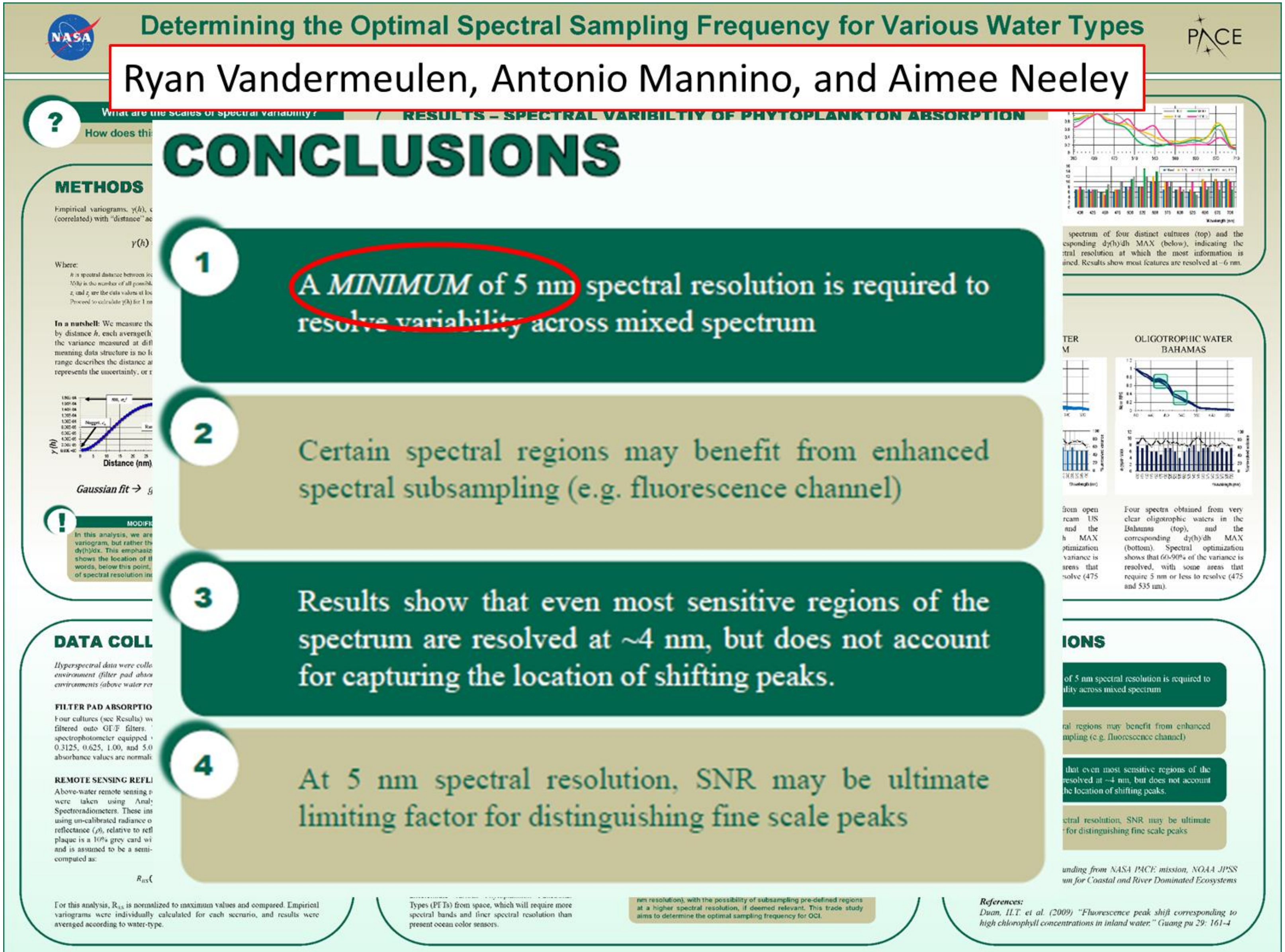
Does not imply that 200 m is sufficient; it simply means that beyond 200 m there is a significant loss in the ability to capture spatial variability

- Bases on analysis of sub-pixel variability, a resolution **no coarser than 200 m** needed to resolve bio-optical features in coastal waters

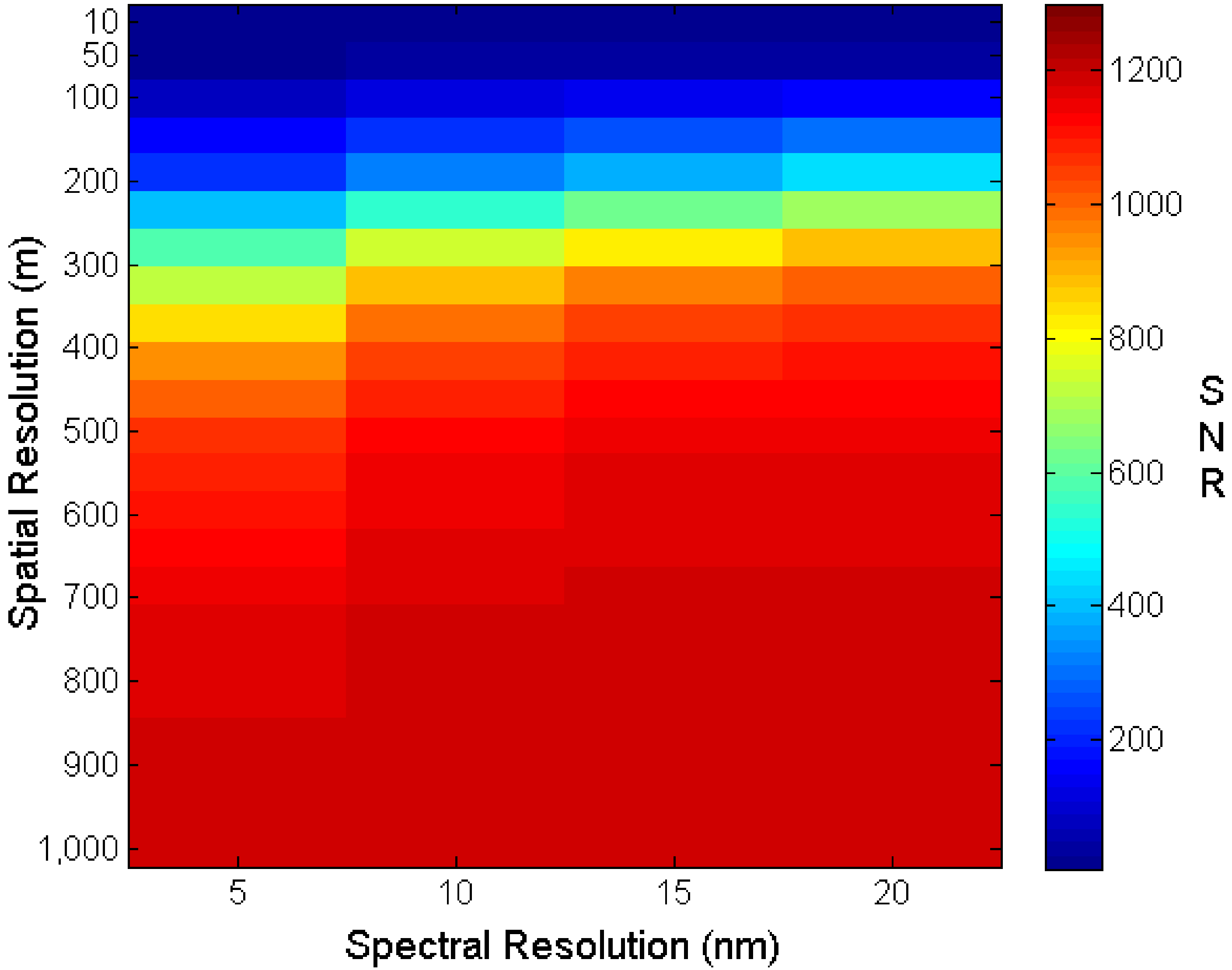
- A finer resolution needed for inland waters

Sensor Characteristics – Spectral Resolution

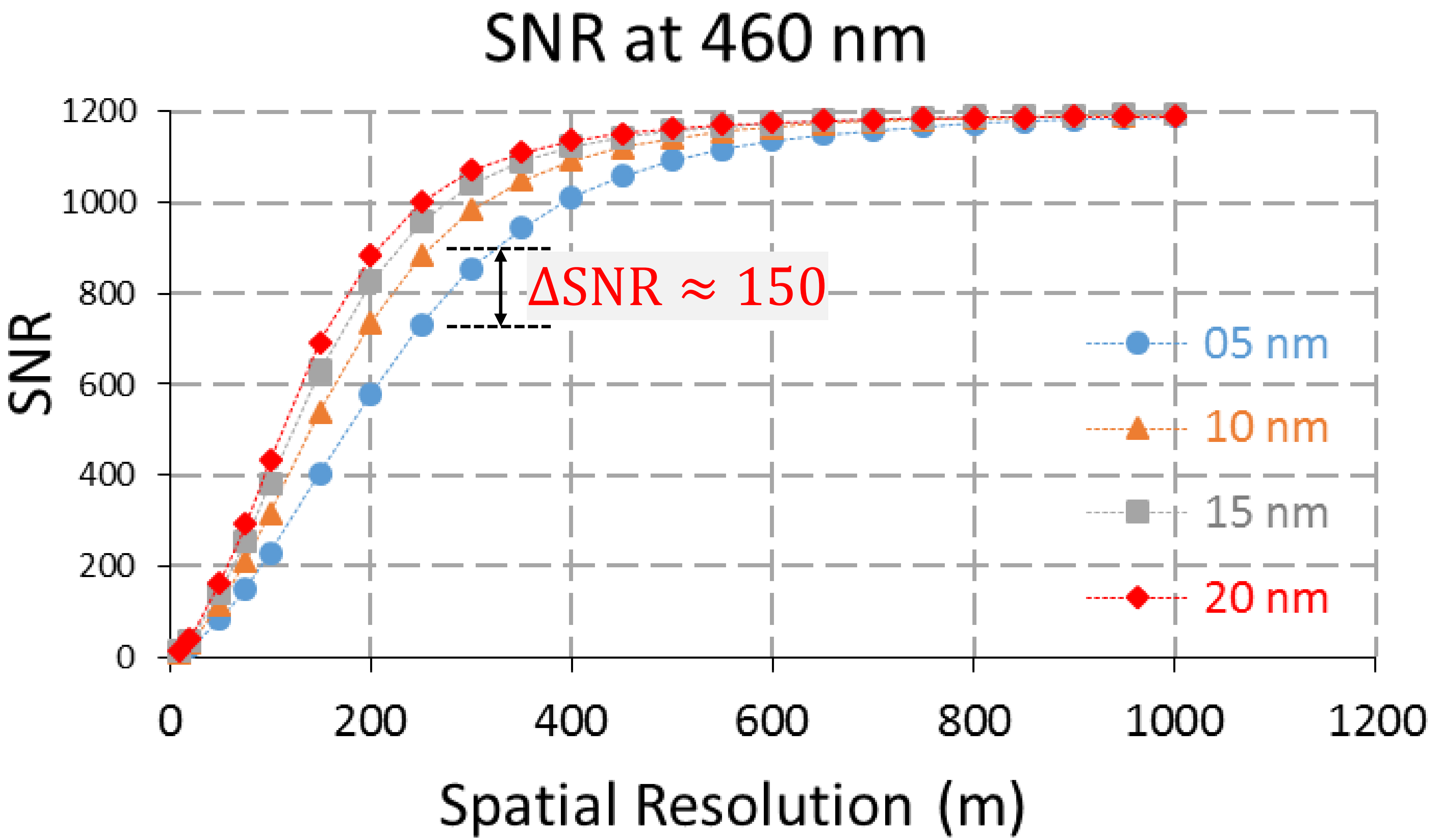
Wes Moses



Trade-off


10
50
100
200
300
400
500
600
700
800
900
1,000
Spatial Resolution (m)
5
10
15
20
Spectral Resolution (nm)
1200
1000
800
600
400
200
SNR

Trade-off



SNR at 460 nm
SNR
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
Spatial Resolution (m)
ΔSNR ≈ 150
05 nm
10 nm
15 nm
20 nm

What does $\Delta \mathbf{SNR} \approx \mathbf{150}$ mean for retrievals?

A single case study

- Add noise to Rrs spectrum at SNR = 700 and 850
- Estimate chl-*a* for both cases and compare to the estimate from noiseless Rrs spectrum to determine the uncertainty due to noise, U_{SNR}
- Effects of SNR on atmospheric correction not considered here
- $U_{SNR=700}$ = 0.17 ± 4.5%
- $U_{SNR=850}$ = 0.15 ± 3.7%

Q3. Sensor Characteristics – Discussion

Q3A. What are the desired sensor characteristics?

- Depends on the water body and the application
- Spatial resolution may be more important than the others
- Need to quantitatively evaluate the impact of various spatial resolutions on retrievals

Q3. Sensor Characteristics – Discussion

Q3B. What is the best approach for designing an inland/coastal water mission?

- Multiple sensors with different characteristics used in a complementary manner; blend data to generate products that may not be produced from just one sensor
- CubeSats are interesting, but questions on radiometric fidelity remain
- Include UV/SWIR bands

Q3. Sensor Characteristics – Discussion

Q3C,D. Should future sensor design be influenced by data product continuity/consistency considerations?

- Spectrally convolve hyperspectral data to create multispectral legacy data products
- Need to identify core spectral bands critical for inland/coastal waters
- Numerical modeling for data continuity (to fill missing data and simulate data for future missions)

Q3. Sensor Characteristics – Discussion

Q3E. What are the agency responsibilities for ensuring product consistency?

- Develop guidelines for quality assurance of products
- Promote consistency in sensor calibration across multiple missions (e.g., lunar calibration)

End-User Engagement – Copernicus

Carsten Brockmann

Copernicus Global Land Service

Monitoring the vegetation, the water cycle and the energy budget at global scale

Bio-geophysical products

- status and evolution of land surface
- at global scale
- at mid and low spatial resolution.
- delivery "in a timely manner"
- complemented by the constitution of long term time series

http://land.copernicus.eu/global/

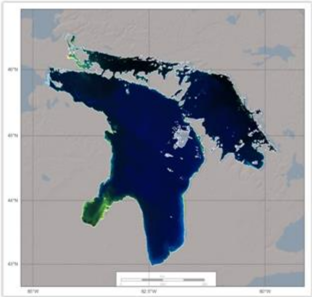
End-User Engagement – Copernicus

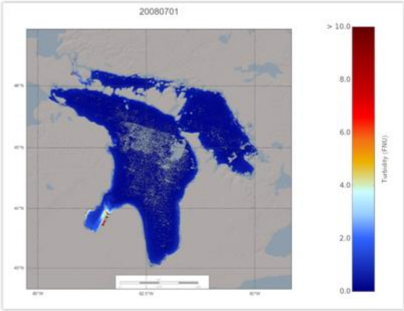
Carsten Brockmann

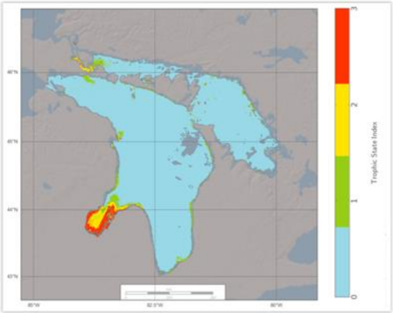
Lake Water Products

- Software readiness
- Metadata
- User Doc.
- Uncertainty Charact.
- Public Access Feedback
- Usage

- Parameters:
  - Lake Surface Temperature (LSWT)
  - Lake Surface Reflectances (LSR)
  - Turbidity (TUR)
  - Trophic State Index (TSI)
- Inputs:
  - MERIS (REPROCESSING 300m, 1km)
  - OLCI (NRT 300m, 1km)
  - S-2 MSI (100m)
- Outputs:
  - 10days averages, best pixel

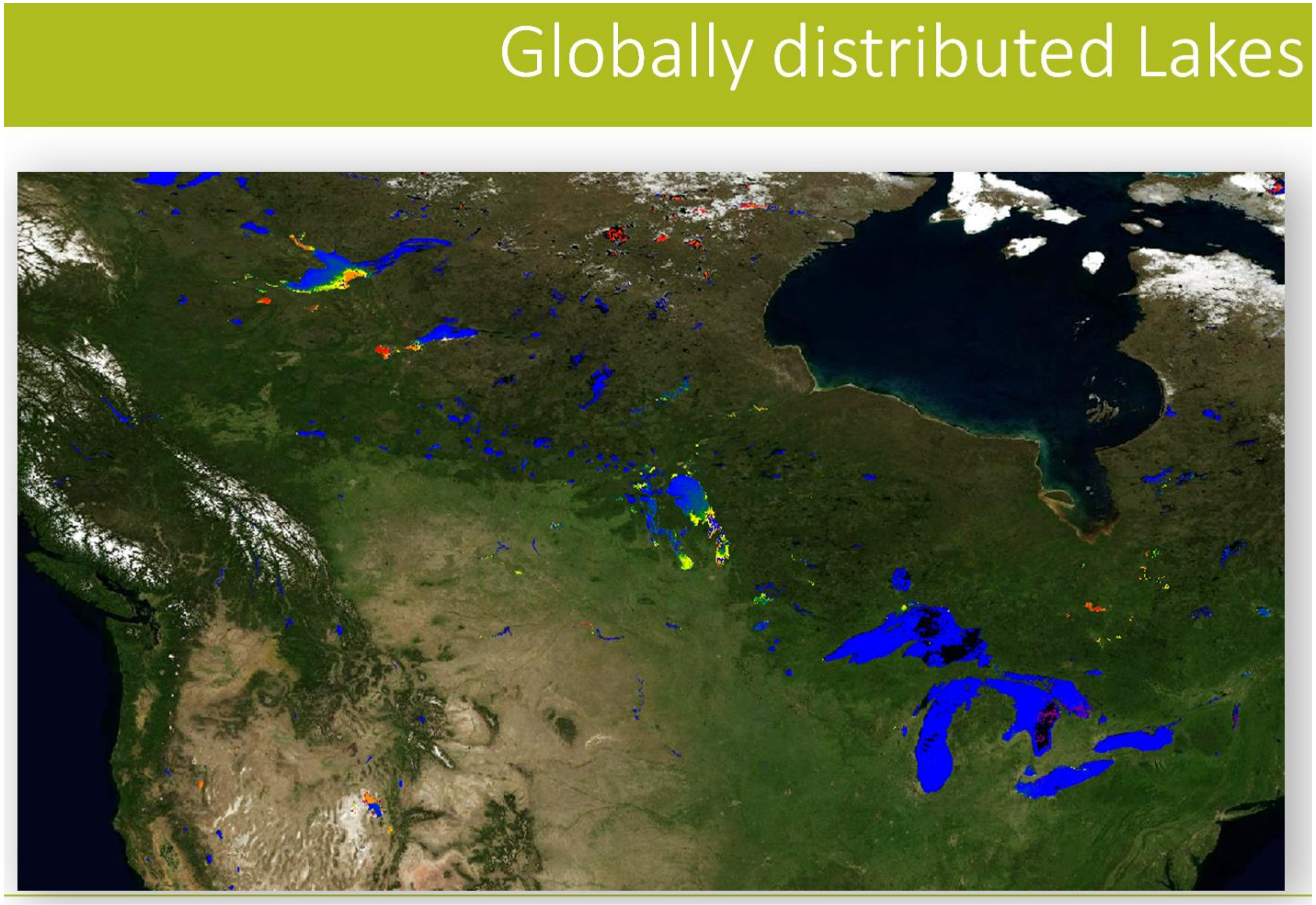






End-User Engagement – Copernicus

Carsten Brockmann



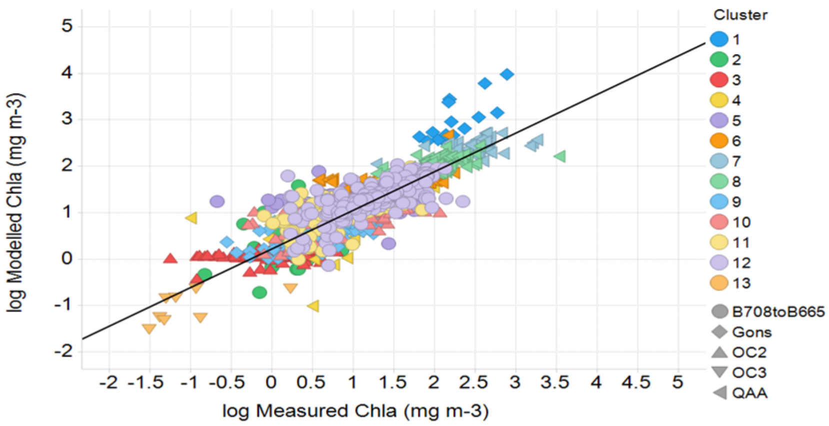
End-User Engagement – Copernicus

Carsten Brockmann

Validation

- Software readiness
- Metadata
- User Doc.
- **Uncertainty Charact.**
- Public Access Feedback
- Usage

- Visual inspection
  - Plausibility of spatial patterns → mapping
  - Plausibility of temporal patterns → time series
  - Identification of Artefacts → mapping
  - Assessment of values in known lakes
- Comparison with in situ data
  - In situ data sources LIMNADES
  - US data bases for lake assessment (EPA)
  - National lake monitoring programs



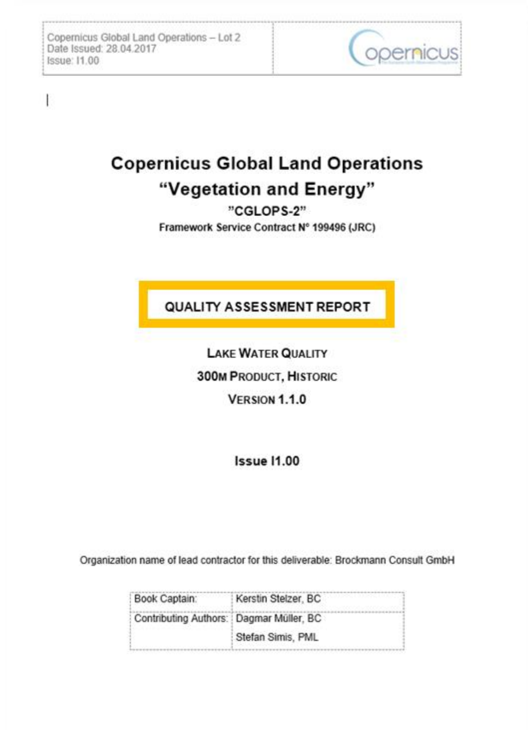
In situ data: LIMNADES, Globolakes

End-User Engagement – Copernicus

Carsten Brockmann

Documents

- Software readiness
- Metadata
- User Doc.
- Uncertainty Charact.
- Public Access Feedback
- Usage


Copernicus Global Land Operations – Lot 2
Date Issued: 28.04.2017
Issue: I1.00

Copernicus Global Land Operations
"Vegetation and Energy"
"CGLOPS-2"
Framework Service Contract N° 199496 (JRC)

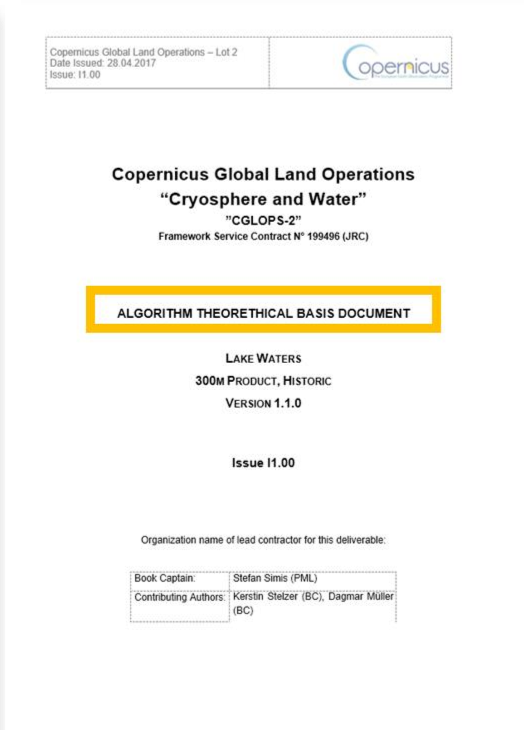
QUALITY ASSESSMENT REPORT

Lake Water Quality
300m Product, Historic
Version 1.1.0

Issue I1.00

Organization name of lead contractor for this deliverable: Brockmann Consult GmbH

Book Captain:	Kerstin Stelzer, BC
Contributing Authors:	Dagmar Müller, BC Stefan Simis, PML


Copernicus Global Land Operations – Lot 2
Date Issued: 28.04.2017
Issue: I1.00

Copernicus Global Land Operations
"Cryosphere and Water"
"CGLOPS-2"
Framework Service Contract N° 199496 (JRC)

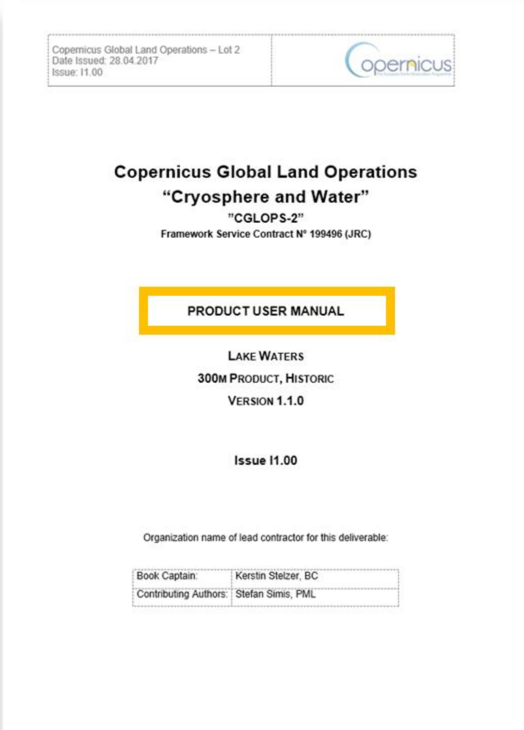
ALGORITHM THEORETHICAL BASIS DOCUMENT

Lake Waters
300m Product, Historic
Version 1.1.0

Issue I1.00

Organization name of lead contractor for this deliverable:

Book Captain:	Stefan Simis (PML)
Contributing Authors:	Kerstin Stelzer (BC), Dagmar Müller (BC)


Copernicus Global Land Operations – Lot 2
Date Issued: 28.04.2017
Issue: I1.00

Copernicus Global Land Operations
"Cryosphere and Water"
"CGLOPS-2"
Framework Service Contract N° 199496 (JRC)

PRODUCT USER MANUAL

Lake Waters
300m Product, Historic
Version 1.1.0

Issue I1.00

Organization name of lead contractor for this deliverable:

Book Captain:	Kerstin Stelzer, BC
Contributing Authors:	Stefan Simis, PML

End-User Engagement – GEO AquaWatch

Steve Greb

GEO AquaWatch

The AquaWatch Mission:

To improve water quality in coastal and inland waters through more effective monitoring, management and decision making.

The AquaWatch Goal:

To develop and build the global capacity and utility of Earth Observation-derived water quality data, products and information to support water resources management and decision making.

GROUP ON EARTH OBSERVATIONS

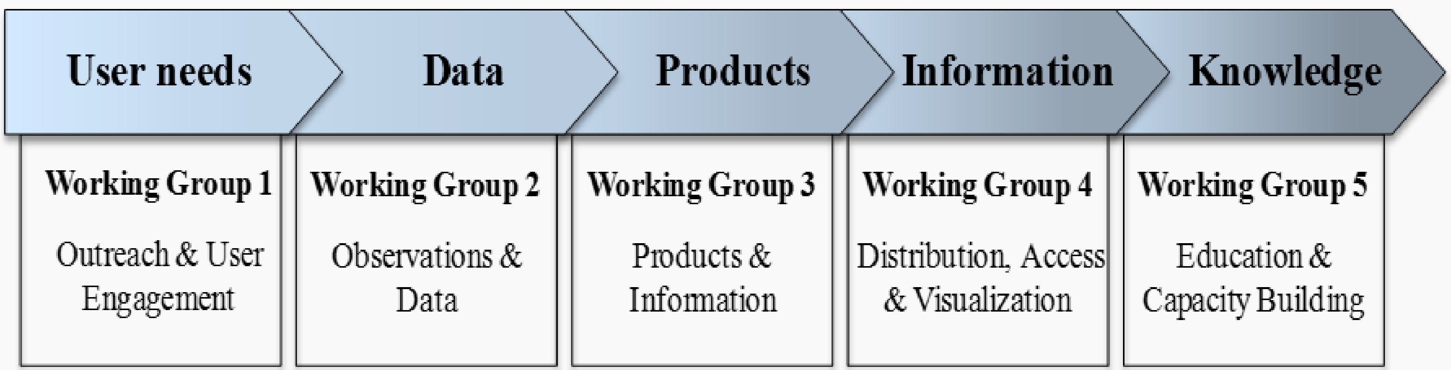
AquaWatch
The GEO Water Quality Community of Practice

End-User Engagement – GEO AquaWatch

Steve Greb

GEO AquaWatch

AquaWatch has formed and populated five working groups. These groups, which correspond to the five objectives, carry out the needed tasks (work packages) to complete the AquaWatch mission.



GROUP ON EARTH OBSERVATIONS

AquaWatch
The GEO Water Quality Community of Practice

Q4. End-User Engagement – Discussion

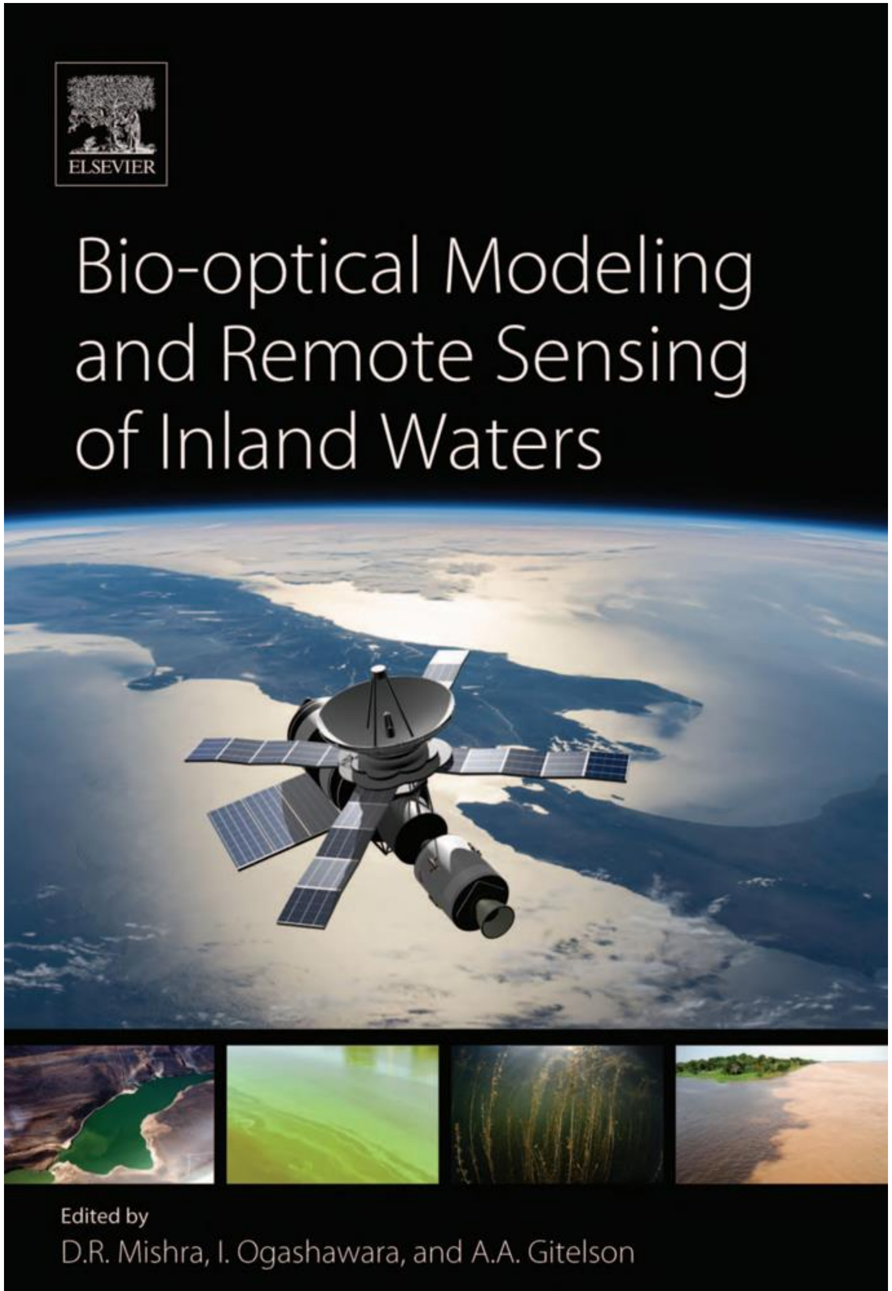
Q4A-E. What are the gaps in existing technology and the measures needed to improve uptake of remote sensing products by end-users?

- Developing/under-developed countries have a greater need
- Capability exists to generate products for these regions, but validation is a challenge
- Citizen science measures for generating *in situ* data for product validation (examples of success in Brazil and Peru)

Acknowledgement

Note-Takers

- Henry Houskeeper
- Andrea Hilborn
- Brice Grunert
- Christiana Ade
- Jeremy kravitz



Chapter 1: Remote Sensing of Inland Waters: Background and Current State-of-the-Art
Igor Ogashawara, Deepak R. Mishra and Anatoly A. Gitelson
Chapter 2: Radiative Transfer Theory for Inland Waters
Peter Gege
Chapter 3: Atmospheric Correction for Inland Waters
Wesley J. Moses, Sindy Sterckx, Marcos Montes, Liesbeth De Keukelaere and Els Knaeps
Chapter 4: Bio-Optical Modeling of Colored Dissolved Organic Matter
Tiit Kutser, Sampsa Koponen, Kari Y. Kallio, Tonio Fincke, and Birgot Paavel
Chapter 5: Bio-Optical Modeling of Total Suspended Solids
Claudia Giardino, Mariano Bresciani, Federica Braga, Ilaria Cazzaniga, Liesbeth De Keukelaere, Els Knaeps and Vittorio E. Brando
Chapter 6: Bio-Optical Modeling of Phytoplankton Chlorophyll-a
Mark William Matthews
Chapter 7: Bio-Optical Modeling of Sun-Induced Chlorophyll-a Fluorescence in Inland and Coastal Waters
Alexander Gilerson and Yannick Huot
Chapter 8: Bio-Optical Modeling of Phycocyanin
Linhai Li and Kaishan Song
Chapter 9: Bio-Optical Modeling and Remote Sensing of Aquatic Macrophytes
Tim J. Malthus

remote sensing

IMPACT FACTOR 3.036

Special Issue

Remote Sensing of Water Quality

Manuscript Submission: Now – 31 Dec 2017

Manuscripts will be reviewed and published soon after they are submitted (i.e., manuscripts may be published before 31 Dec 2017)