Constituent retrieval in lakes and other deep and optically complex waters from satellite imagery

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Based on: Odermatt, D., Gitelson, A., Brando, V. , & Schaepman, M. (2012). Review of constituent retrieval in optically deep and complex waters from satellite imagery. Remote Sensing of Environment, 118/0, 116-126.

Outline

- **Challenge**
  - Where to apply which algorithms
- **Introduction**
  - Optical water classes and recent criticism
- **Methods**
  - Validation studies review approach
- **Results**
  - Quantitative literature analysis
  - Choice of algorithms derived for *diversity 2*
- **Conclusions**

Introduction

Forel-Ule scale (1889)

esa diversity inland waters

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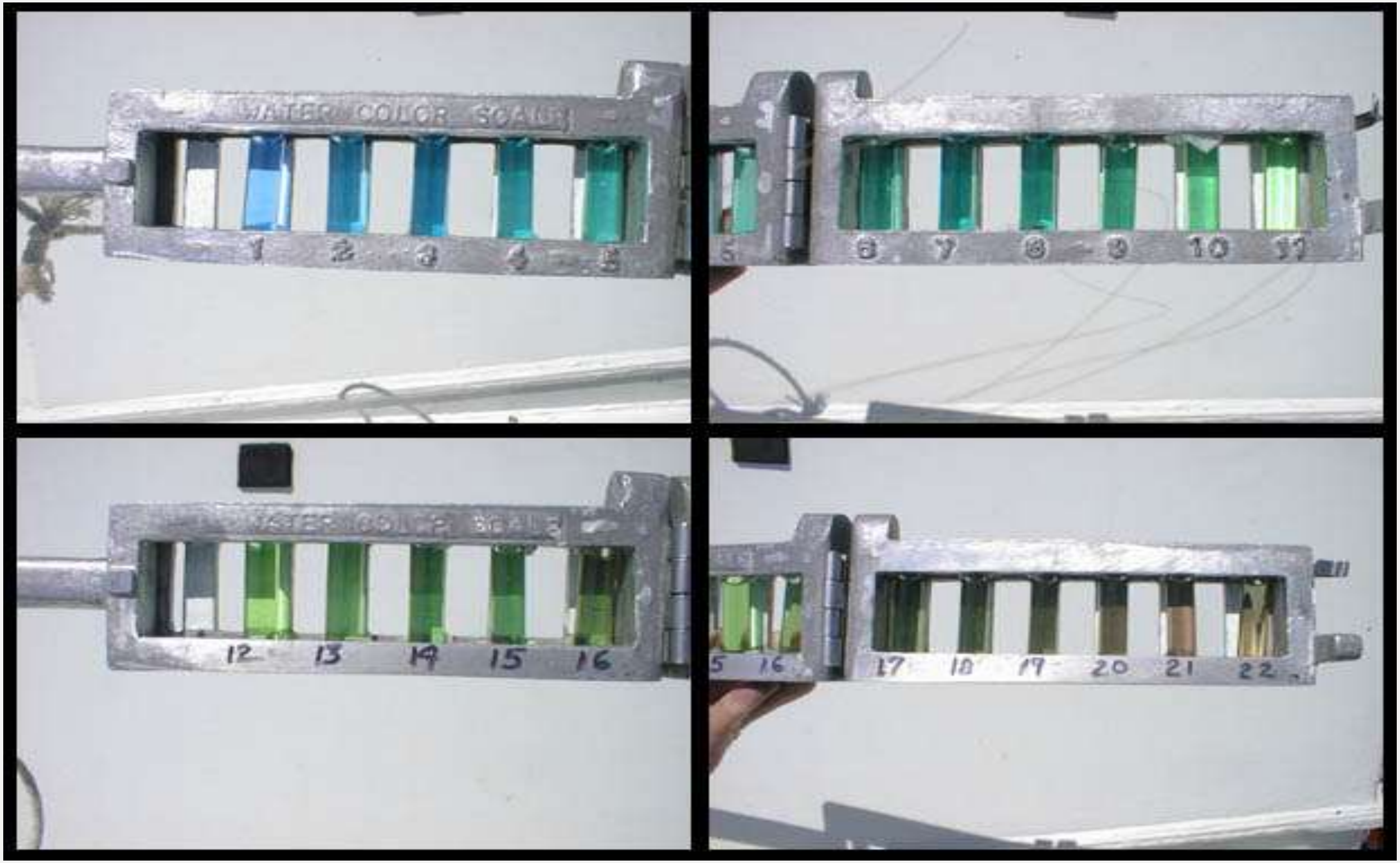

Photos by Janet Vail (Arnone et al., 2004)

Introduction

Jerlov water types

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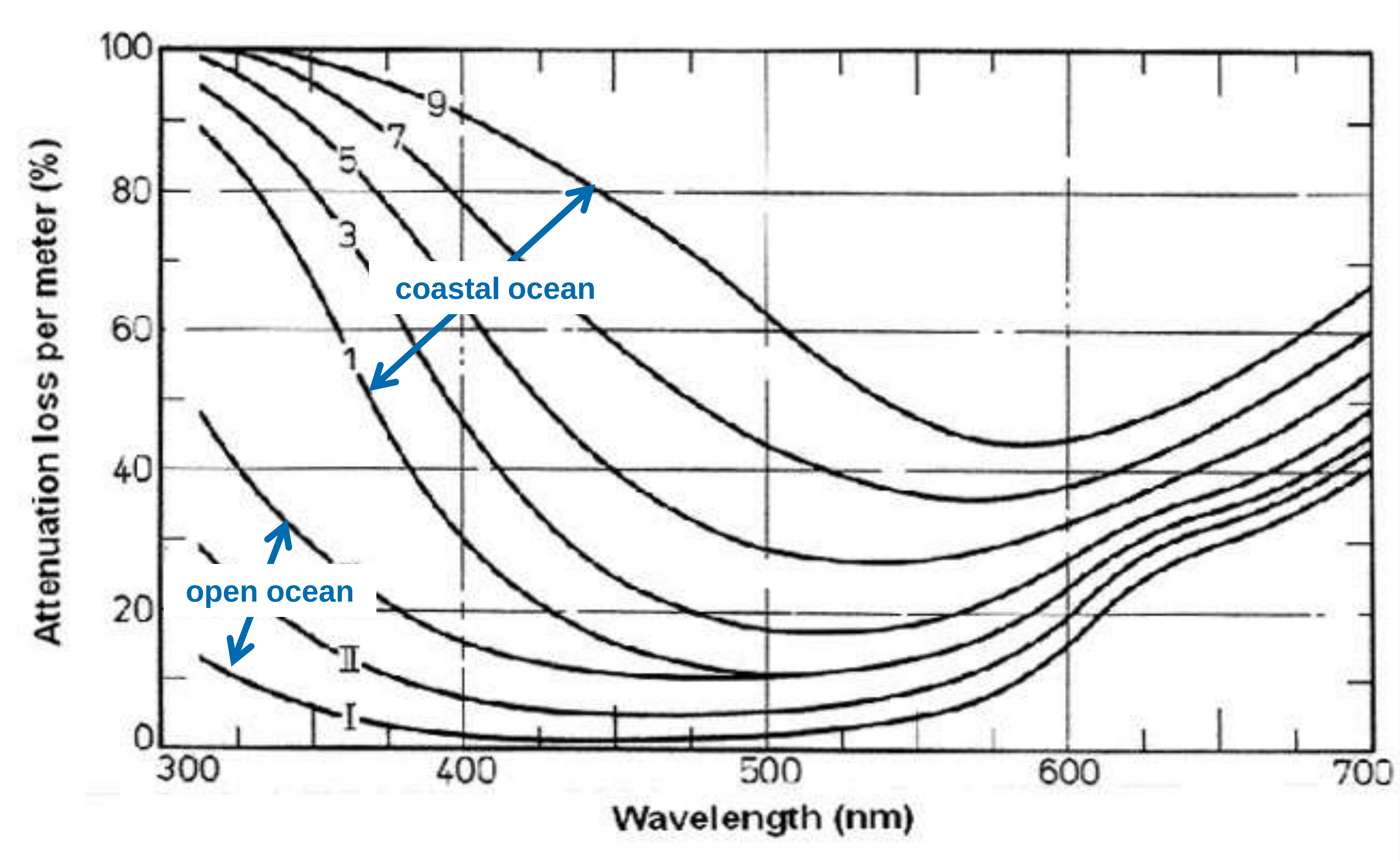

Introduction

triangular scheme

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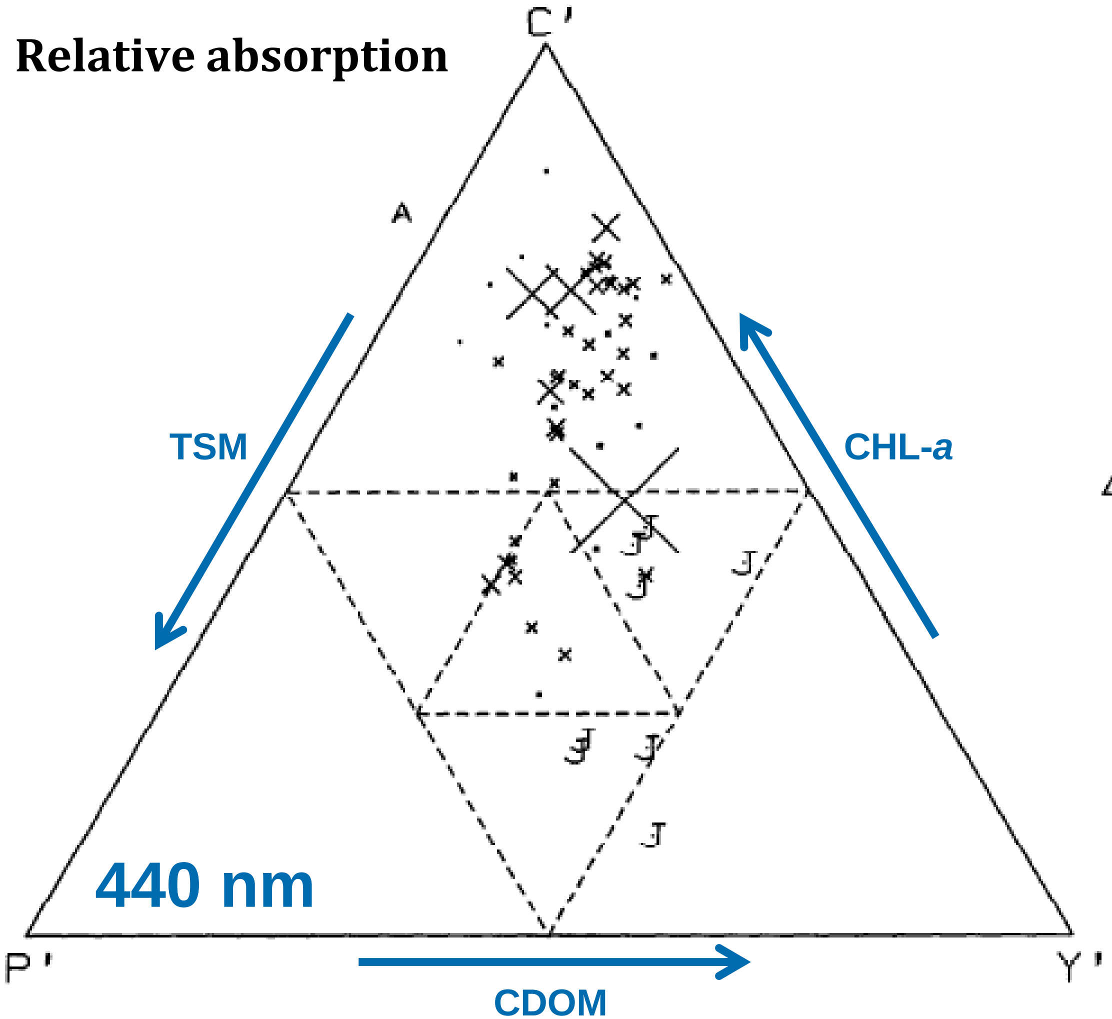
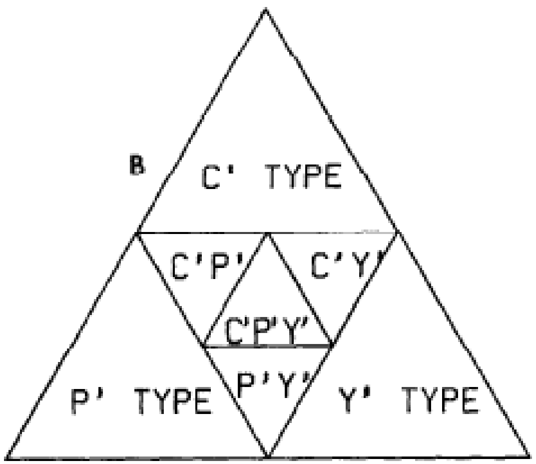




J Jerlov types 1B-9

× ✕ size ≈ bulk absorption

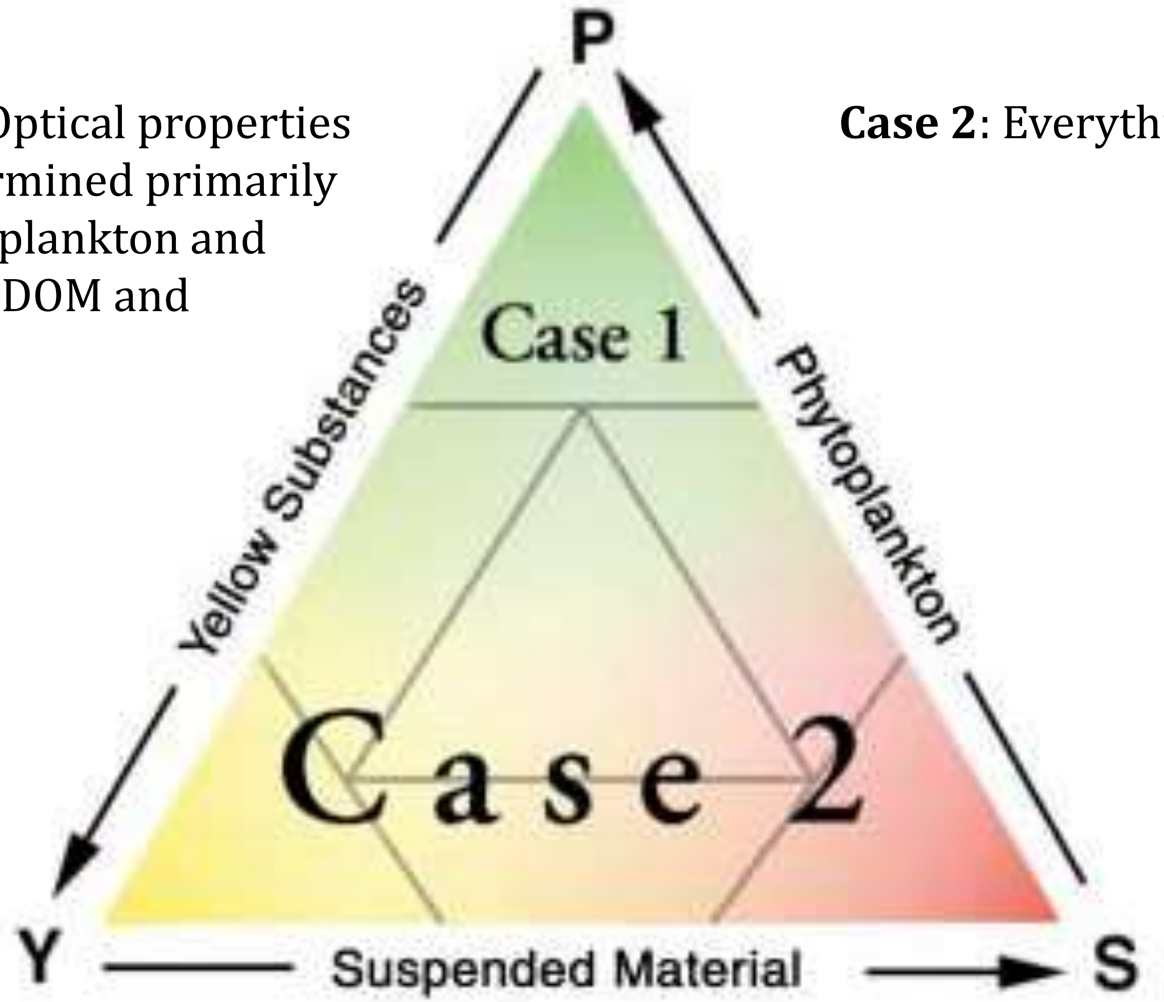
Prieur & Sathyendranath (1981) based on Morel & Prieur (1977)

Introduction

case 1, case2

Case 1: Optical properties are determined primarily by phytoplankton and related CDOM and detritus.

Case 2: Everything else.



Sathyendranath in IOCCG (2000), definitions by Morel (1988)

Introduction

criticism of case 1, case 2

- **Strengths**
  - Guided the development of early bio-optical models
  - Conduced to the success of the first ocean colour sensors
  - Helps to prevent the inappropriate use of algorithms

- **Weaknesses**
  - Is a simplification for a past stage of knowledge
  - “May bring ambiguity, confusion, misuse, or an excuse for poor performance of algorithms”

Mobley et al. (2004)

Methods

retrieval algorithm review

To which optically complex waters do recent "Case 2" algorithms apply?

The literature review includes:

- **Matchup** validation studies
- Constituent retrieval from **satellite** imagery
- Optically **deep and complex** waters
- Explicit **concentration** ranges and $\mathbf{R^2}$
- Published in **ISI listed** journals
- Between Jan **2006** and May **2011**

These criteria apply to a total of 52 papers.

Odermatt et al. (2012)

Methods

retrieval algorithm review

diversity inland waters

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The literature review aims to:

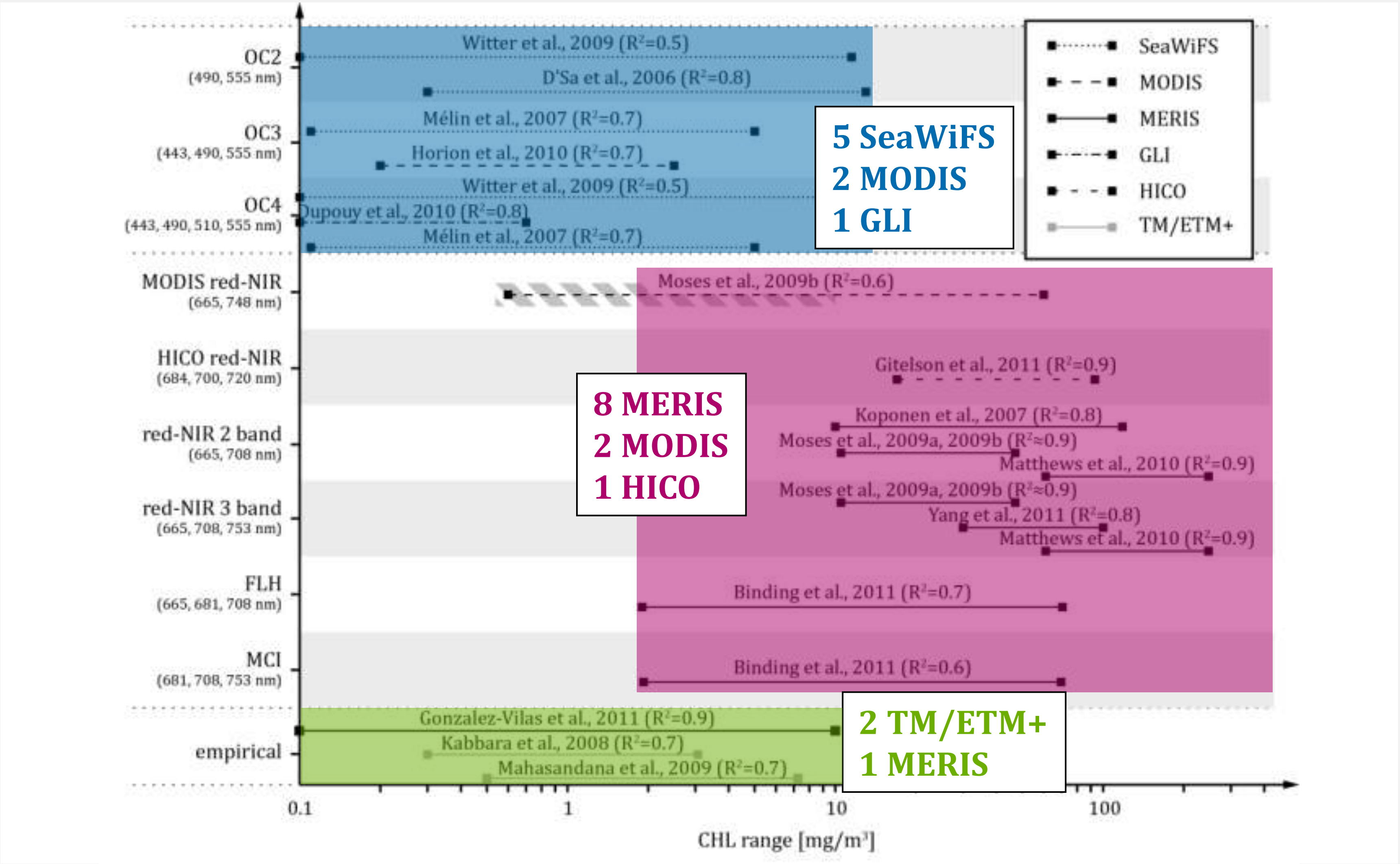
- Quantify the use of recent algorithms and sensors
- Derive algorithm applicability ranges within "case 2"
- Clarify the ambiguous use of attributes like "turbid" and "clear"

Authors	Oligotrophic	Mesotrophic	Eutrophic	Hypereutr.
Chapra & Dobson (1981)	0-2.9	2.9-5.6	>5.6	n.a.
Wetzel (1983)	0.3-4.5	3-11	3-78	n.a.
Bukata et al. (1995)	0.8-2.5	2.5-6	6-18	>18
Carlson & Simpson (1996)	0-2.6	2.6-20	20-56	>56
Nürnberg (1996)	0-3.5	3.5-9	9-25	>25
This study	*0-3*	*3-10*	*>10*	*?*

Odermatt et al. (2012)

Results

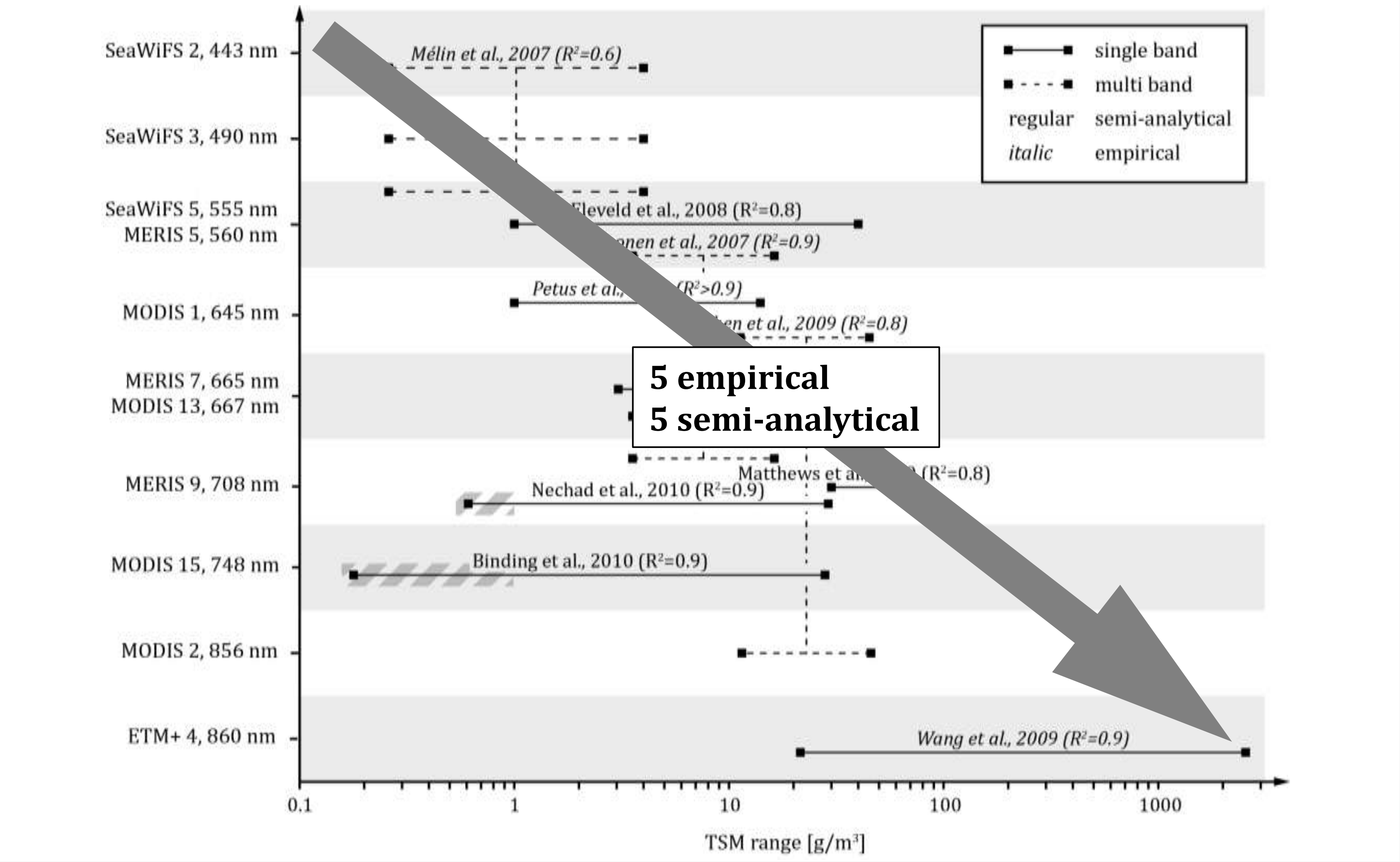
CHL band ratios



Odermatt et al. (2012)

Results

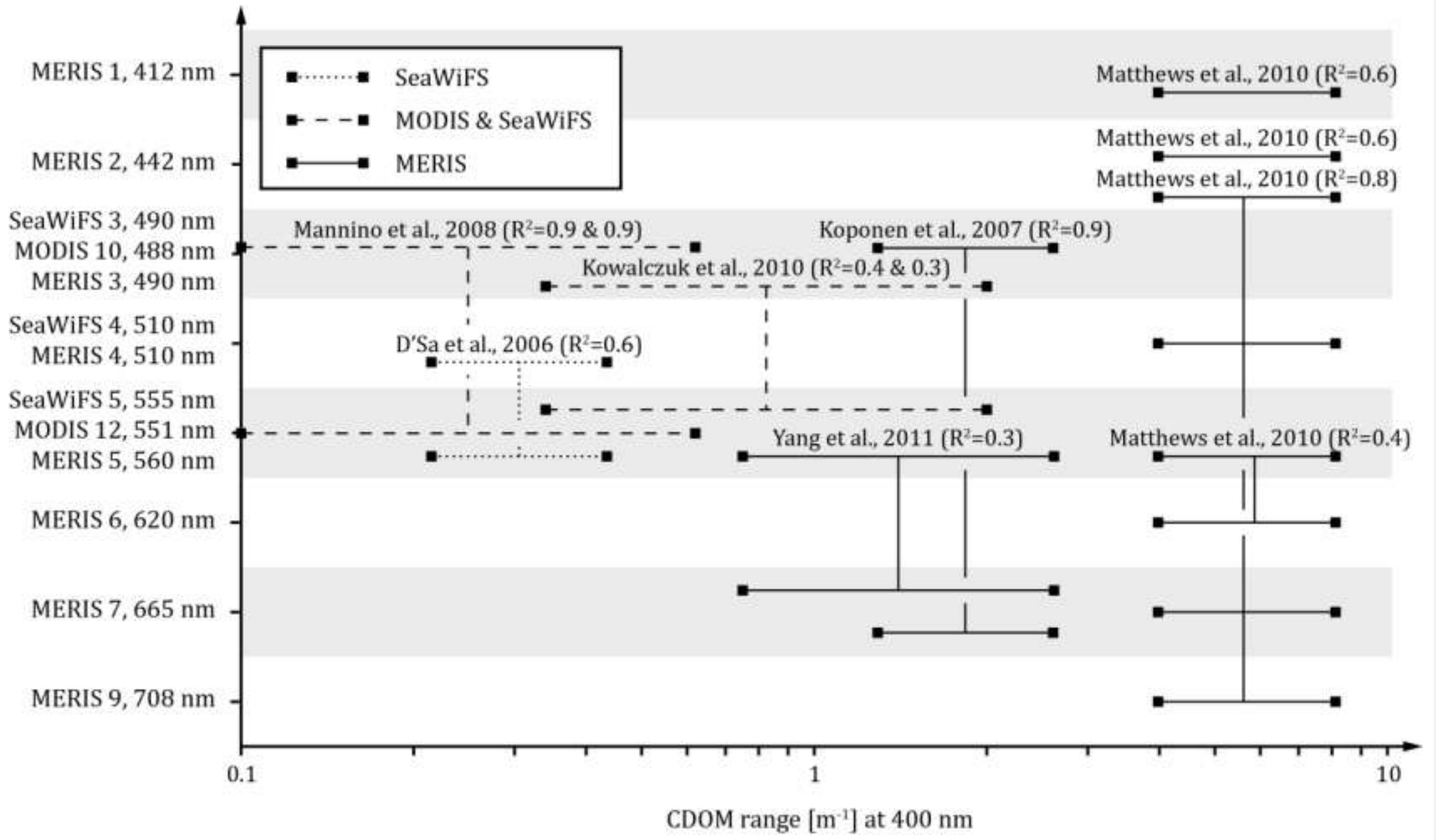
TSM band ratios



Odermatt et al. (2012)

Results

CDOM band ratios



Odermatt et al. (2012)

Results

spectral inversion

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Validation of C2R/algal_2/(FUB):

- Numerous and independent
- Adequate for low to medium concentrations
- Inadequate for high concentrations

Validation of other algorithms:

- Limited in number and independence
- Often restricted to “domestic” use

Authors	Algorithm	CHL [mg/m³]		TSM [g/m³]		CDOM [m⁻¹]	
		max	min	max	min	max	min
		70.5	1.9	19.6	0.8	7.1	0.5
		16.1	0.7	67.8	1.5	2.0	0.7
		9.0	0.0	-	-	-	-
		70.5	1.9	19.6	0.8	7.1	0.5
		74.5	11.7	-	-	4.0	1.3
		247.0	69.2	60.7	30.0	7.1	3.4
		9.0	0.0	-	-	-	-
		12.6	0.1	14.3	2.7	2.0	0.8
		2.5	0.1	2.7	1.3	3.5	0.0
		2.2	1.3	2.1	0.9	-	-
		4.0	0.6	-	-	-	-
		5.0	1.8	13.0	3.0	0.8	0.1
		20.0	0.0	30.0	0.0	1.6	0.0

Odermatt et al. (2012)

validated | falsified | threshold R^2=0.6

Results *variability scheme*

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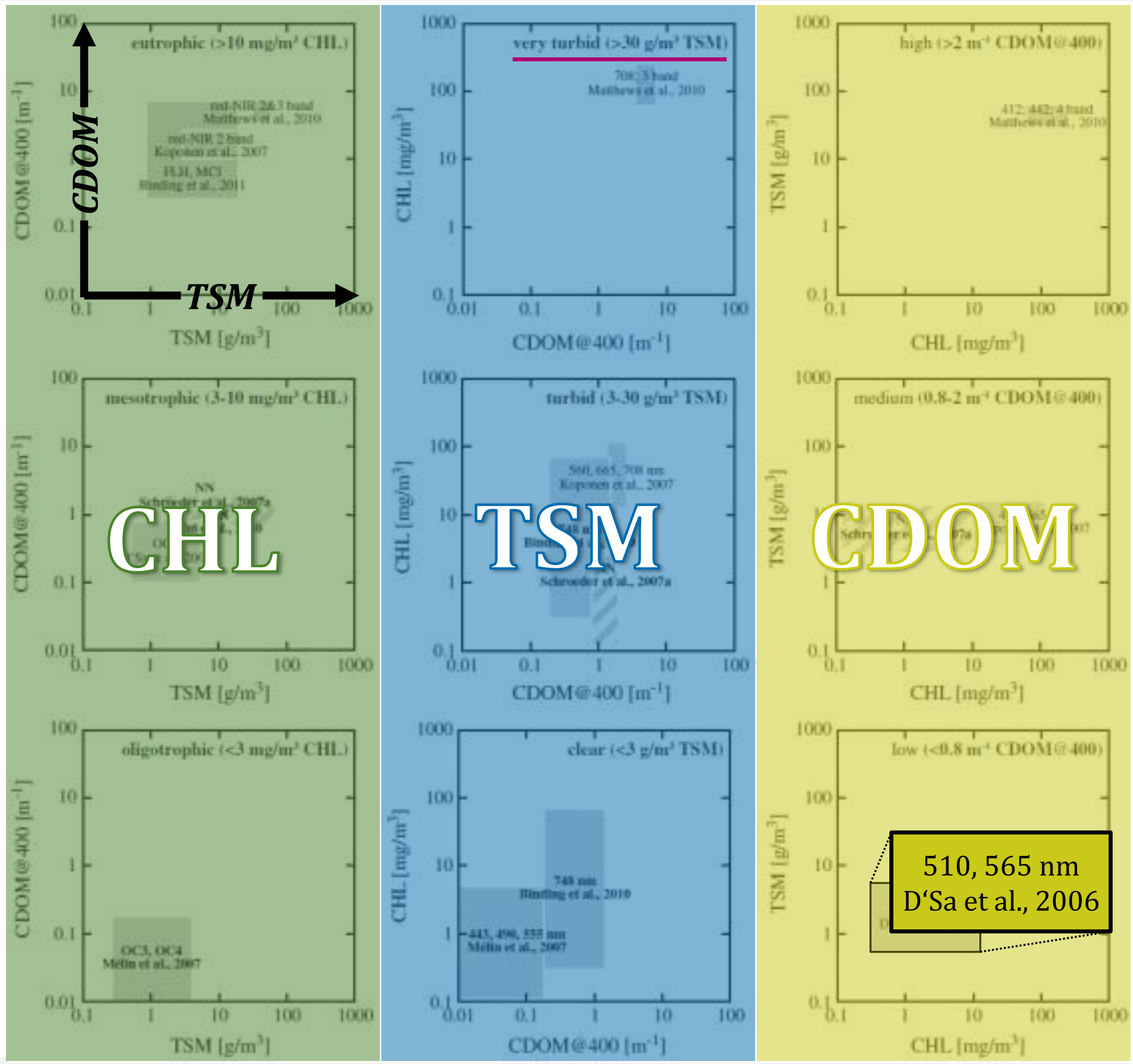
Retrieved constituent

concentration level

type

contravariance



high

medium

low

Reading example:
D'Sa et al. (2006) retrieve low CDOM with 510, 565 nm bands at *0.3-13.0 mg/m³ CHL* and *0.5-5.5 g/m³ TSM*

Odermatt et al. (2012)

Results

validation ranges

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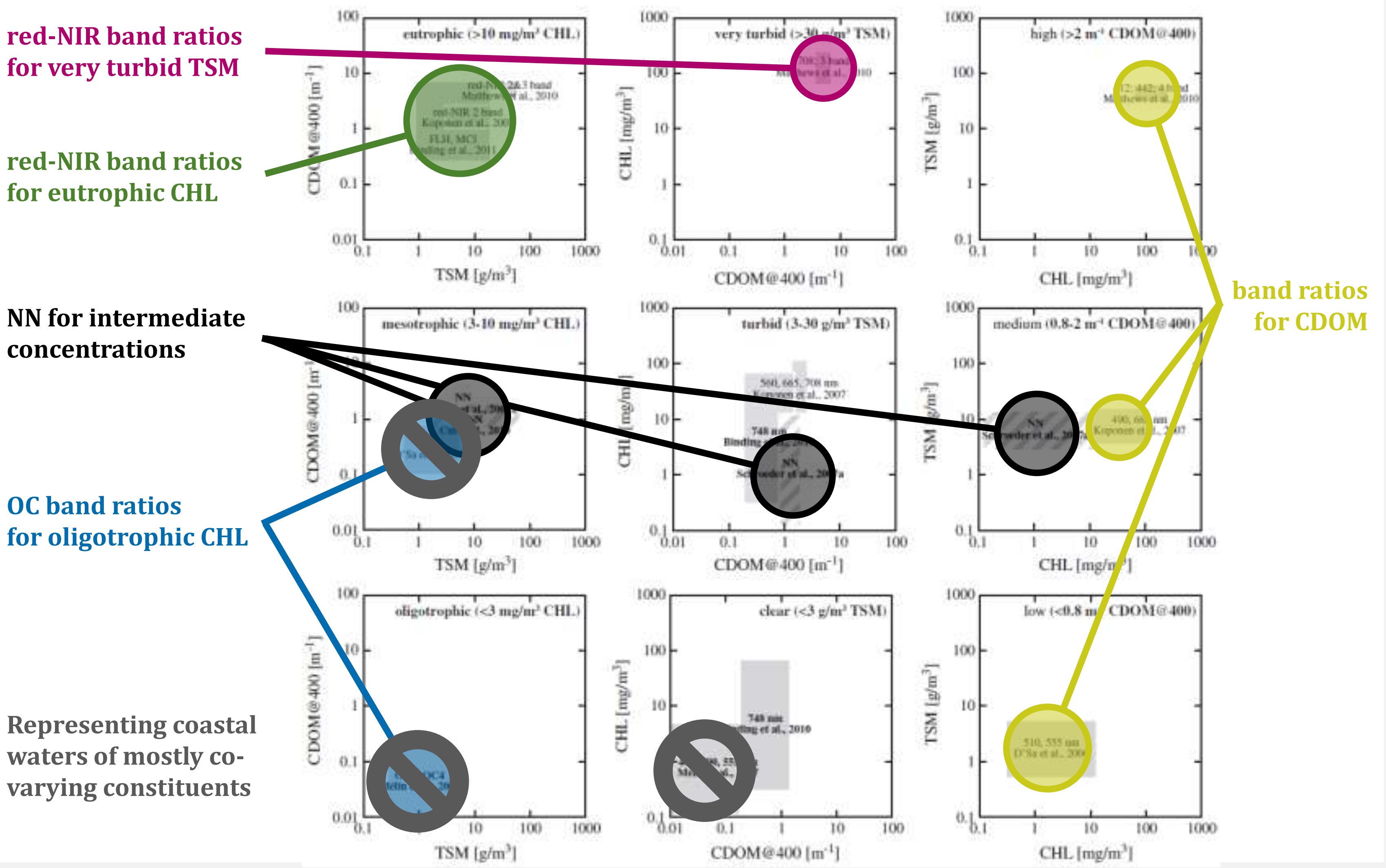


Odermatt et al. (2012)

Results

algorithm-specific classes

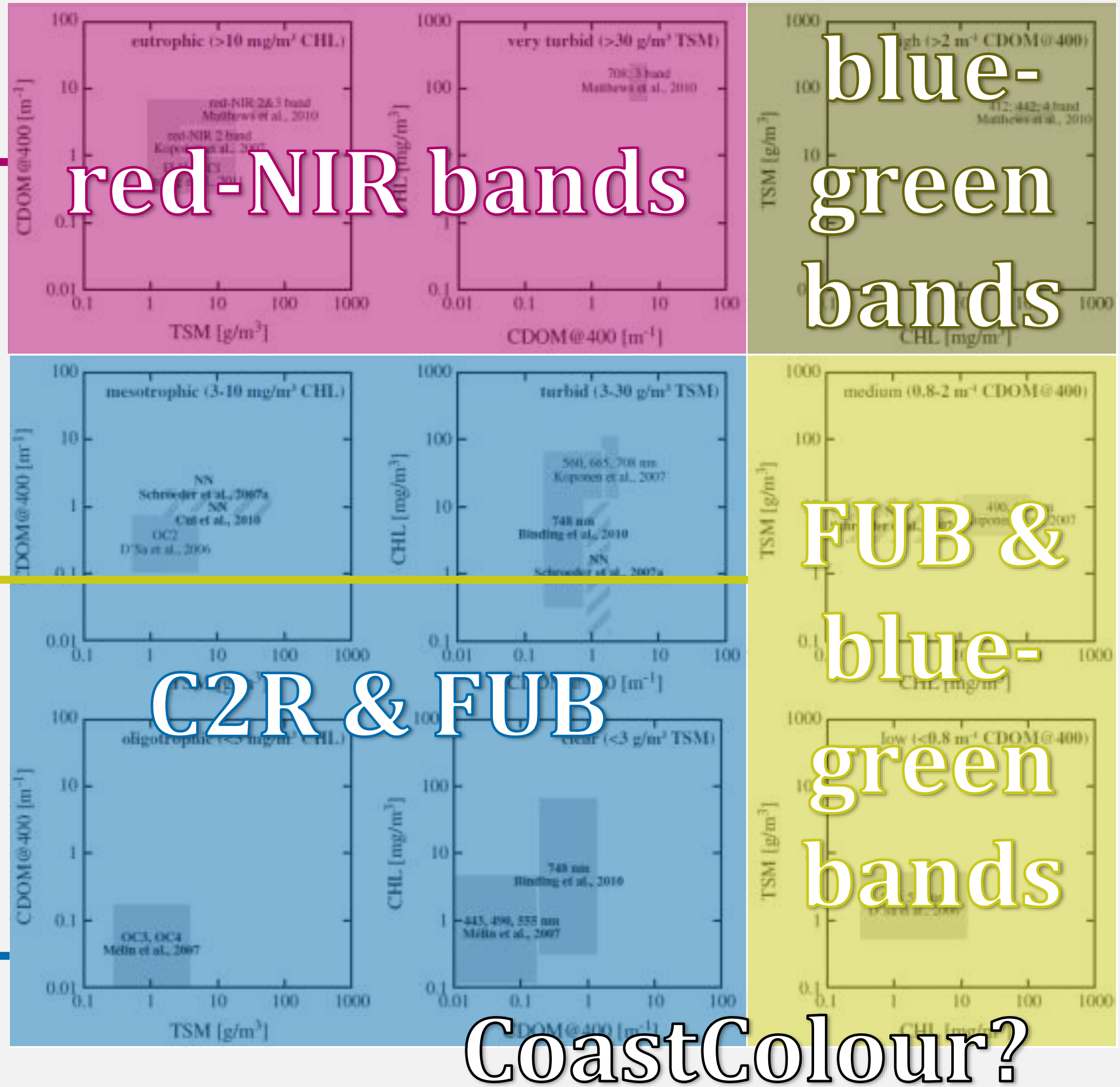
wc retrieval:
- FLH, MCI
- Gitelson 2/3-band

atm. correction:
- none
- SCAPE-M

wc retrieval:
- FUB
- blue-green bands

atm. correction:
- C2R (+ICOL!)
- FUB (+ICOL?)

wc retrieval & atm. correction:
- C2R
- FUB



Summary

Conclusions from the validation review:

- Band ratio validation studies allow a good estimate of validity ranges
- MERIS neural networks are the only spectral inversion algorithms with sufficient validation from several independent studies
- MERIS’ 708 nm band provides unparalleled accuracy for eutrophic waters
- A justified, water-type specific choice of algorithms can be derived

Open issues for use of the findings in *diversity 2*:

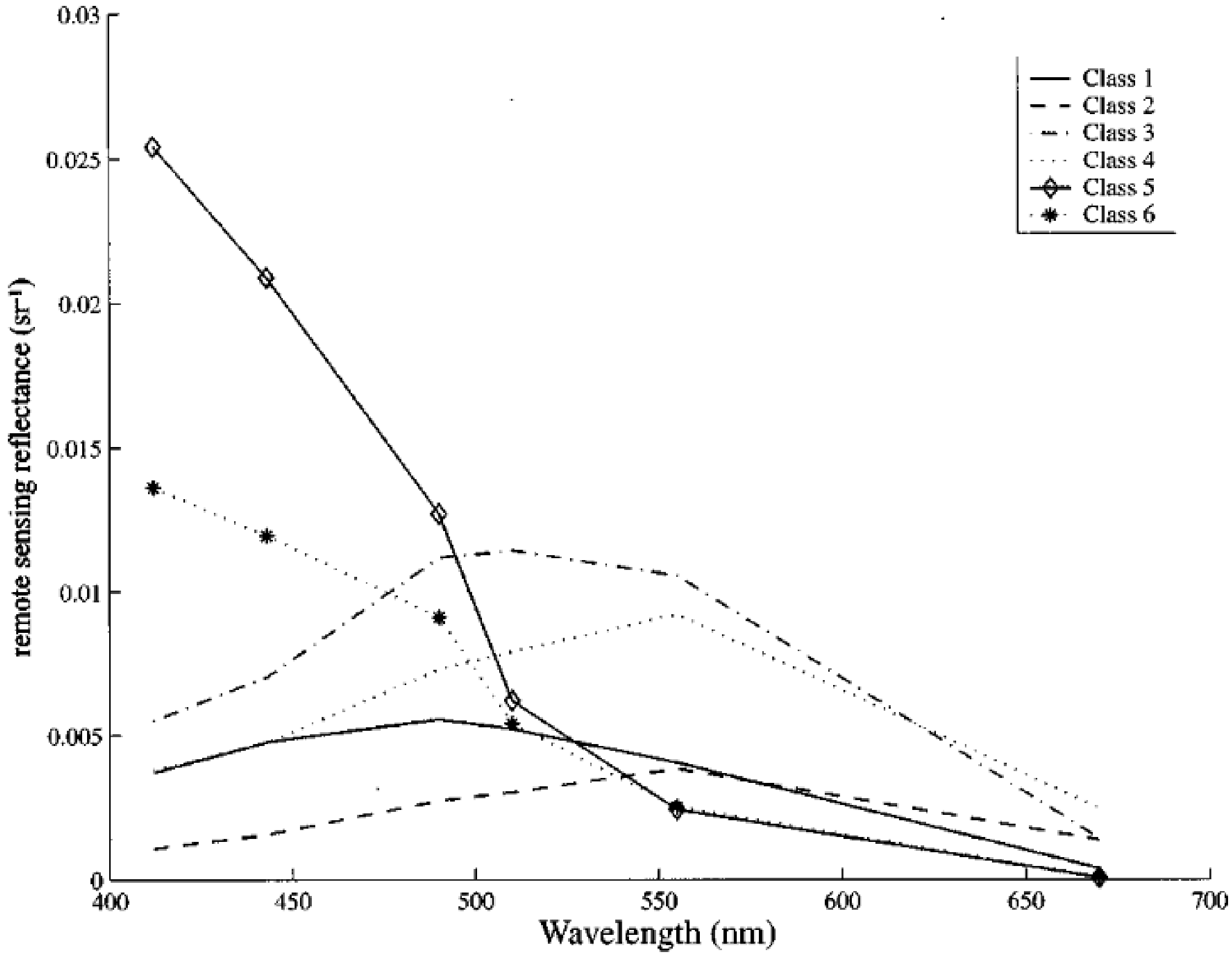
- *How* is the required preclassification applied?
    - Based on previous knowledge or on-the-flight?
    - Spatio-temporally static or dynamic? – based on previous knowledge or iterative processing?
    - Should algorithm blending be applied?

Conclusions

- **Optical lake water preclassification**
  - varies temporally and across classes (fuzziness)
  - may require multiple or blended algorithms

- **Validity range classes**
  - are currently defined by concentrations
  - require extensive *in situ* data
  - or iterations with constituent retrieval
  - or transformation to corresponding reflectance classes

Fuzzy c-means (FCM) clusters for *in situ* reflectance



Moore et al. (2001), Moore et al. (2009)

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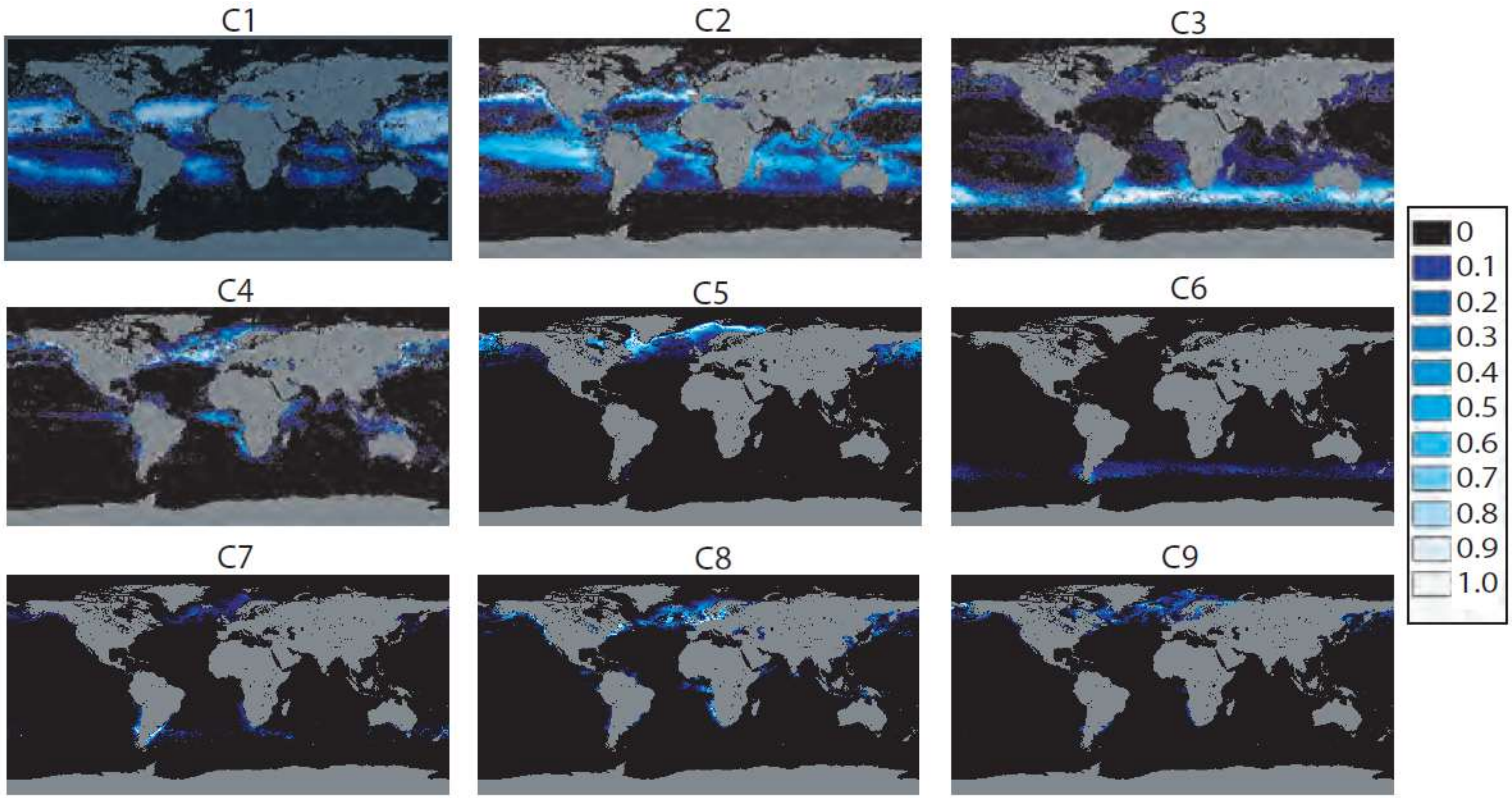
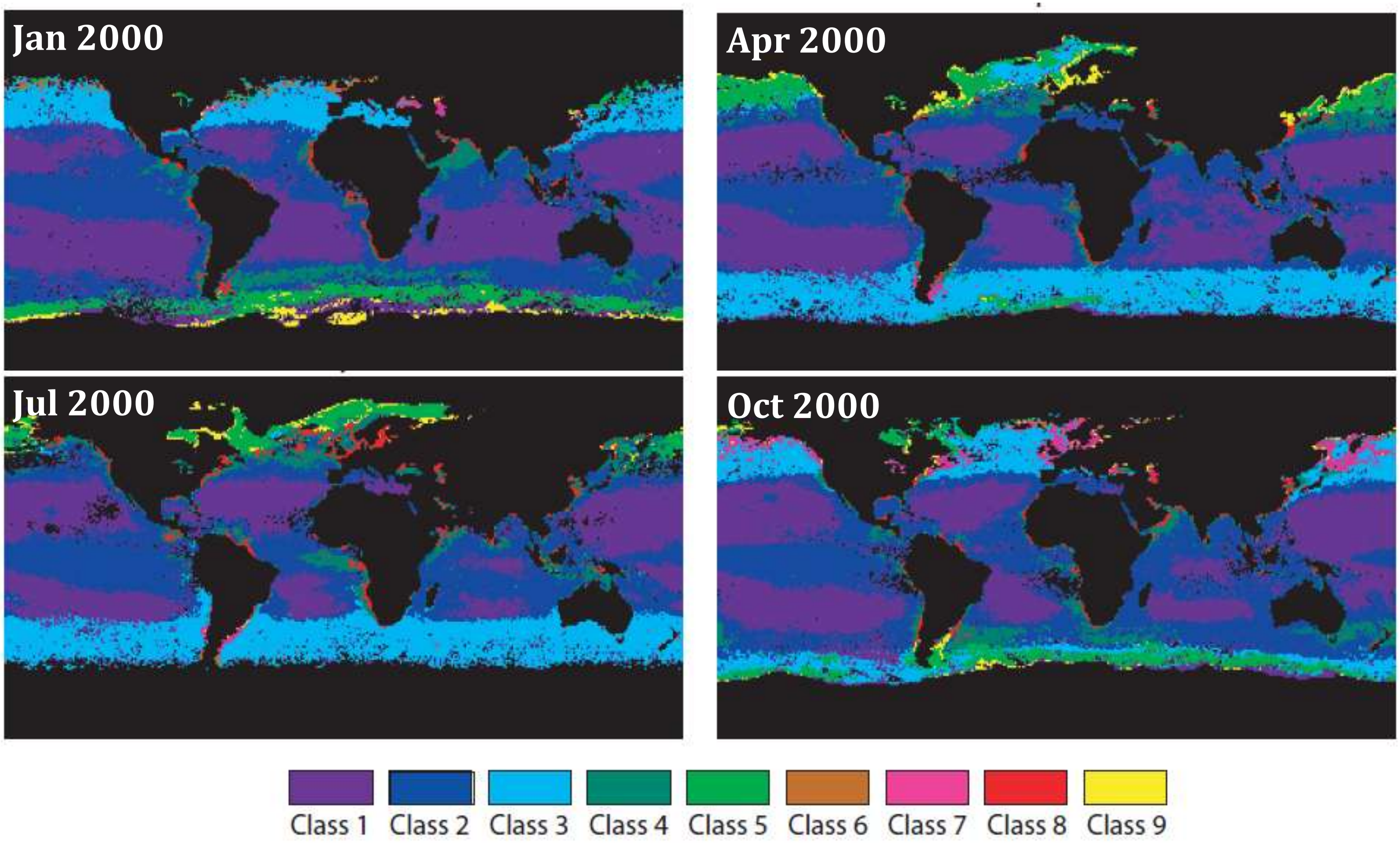
FCM (SST, PAR, CHL derived) ecological provinces in July 2000:



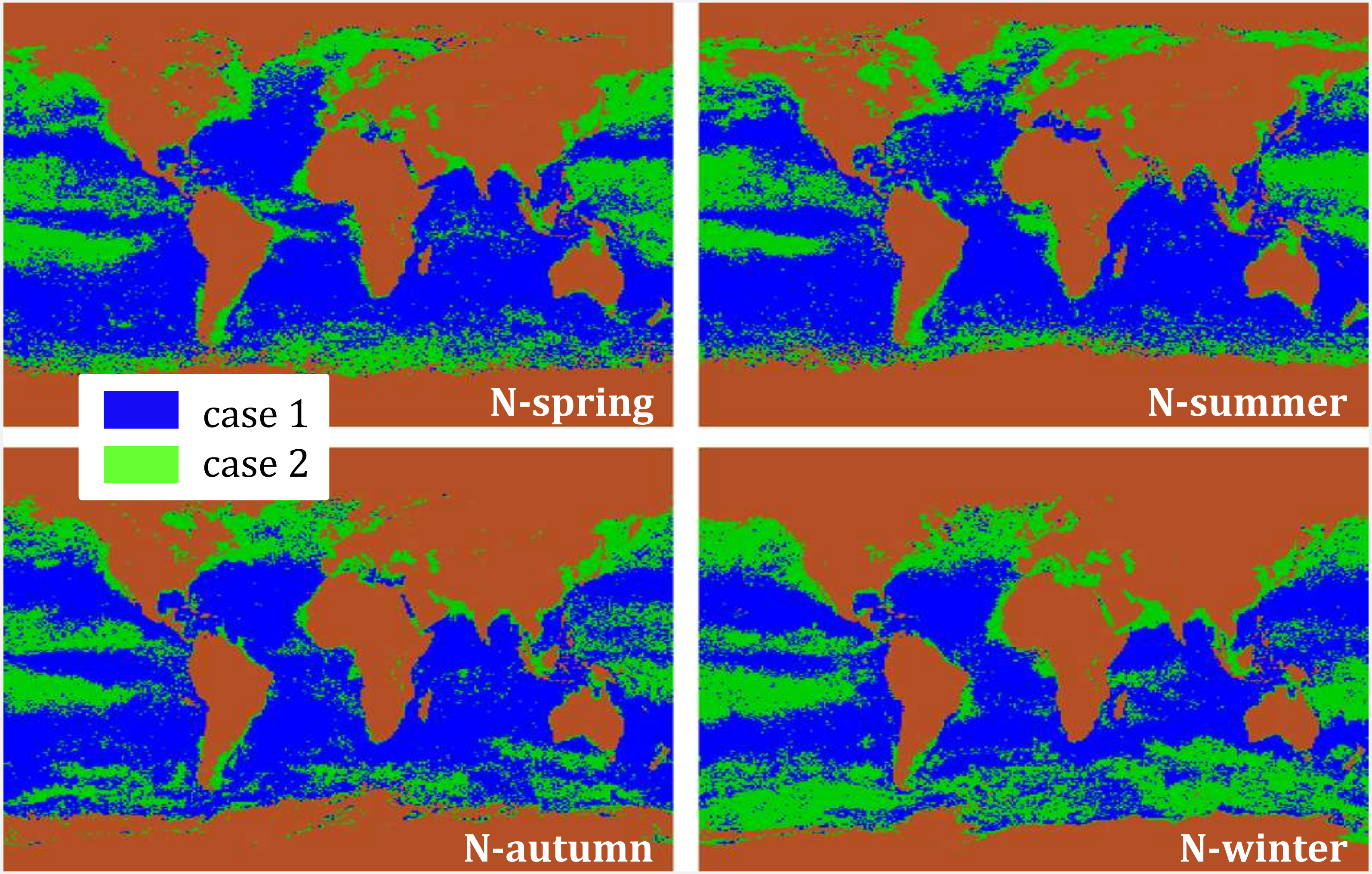
Dowell et al. in IOCCG (2009)

Seasonality of „hardened“ ecological provinces:



Dowell et al. In IOCCG (2009)

Annex *partition by SeaWiFS*



Lee & Hu (2006)

Outroduction

This work:

Odermatt, D., Gitelson, A., Brando, V.E., & Schaepman, M. (2012). Review of constituent retrieval in optically deep and complex waters from satellite imagery. *Remote Sensing of Environment,* 118/0, 116-126

See also:

Matthews, M. W. (2011). A current review of empirical procedures of remote sensing in inland and near-coastal transitional waters. International Journal of Remote Sensing, 32(21), 6855–6899.