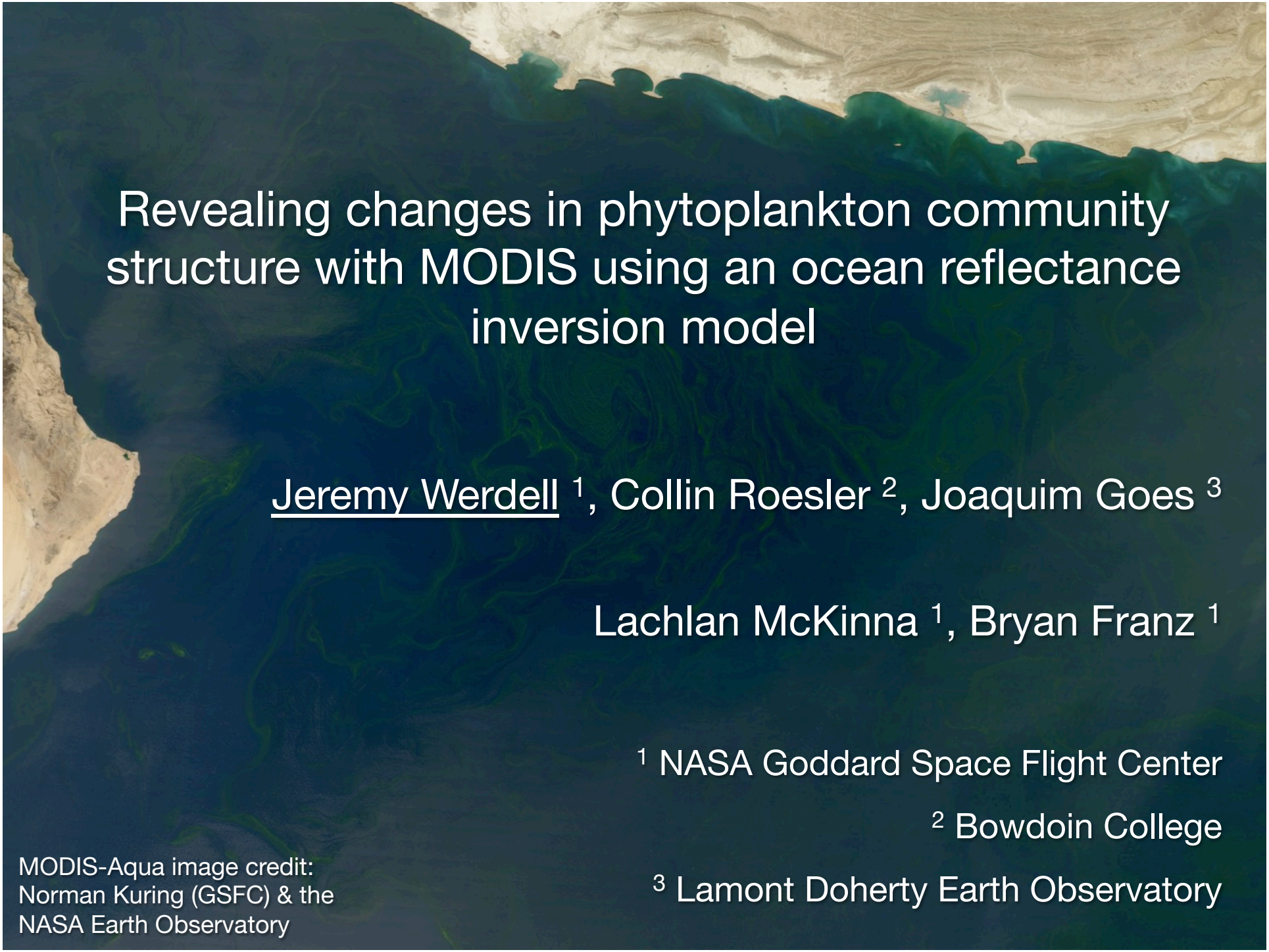


Revealing changes in phytoplankton community structure with MODIS using an ocean reflectance inversion model

Jeremy Werdell [1], Collin Roesler [2], Joaquim Goes [3]

Lachlan McKinna [1], Bryan Franz [1]

[1] NASA Goddard Space Flight Center

[2] Bowdoin College

[3] Lamont Doherty Earth Observatory

MODIS-Aqua image credit:
Norman Kuring (GSFC) & the
NASA Earth Observatory

Remote-sensing of phytoplankton communities: A consumers' market

Reports and Monographs of the International Ocean-Colour Coordinating Group

An Affiliated Program of the Scientific Committee on Oceanic Research (SCOR)
An Associated Member of the (CEOS)

IOCCG Report Number 15, 2014

Phytoplankton Functional Types from Space

Edited by:
Shubha Sathyendranath (Plymouth Marine Laboratory)

Report of an IOCCG working group on Phytoplankton Functional Types, chaired by Shubha Sathyendranath and based on contributions from (in alphabetical order):

Jim Aiken, Séverine Alvain, Ray Barlow, Heather Bouman, Astrid Bracher, Robert J. W. Brewin, Annick Bricaud, Christopher W. Brown, Aurea M. Ciotti, Lesley Clementson, Susanne E. Craig, Emmanuel Devred, Nick Hardman-Mountford, Takafumi Hirata, Chuanmin Hu, Tihomir S. Kostadinov, Samantha Lavender, Hubert Loisel, Tim S. Moore, Jesus Morales, Cyril Moulin, Colleen B. Mouw, Anitha Nair, Dionysios Raitsos, Collin Roesler, Shubha Sathyendranath, Jamie D. Shutler, Heidi M. Sosik, Inia Soto, Venetia Stuart, Ajit Subramaniam and Julia Uitz.

NASA/TM–2015-217528

Report on IOCCG Workshop

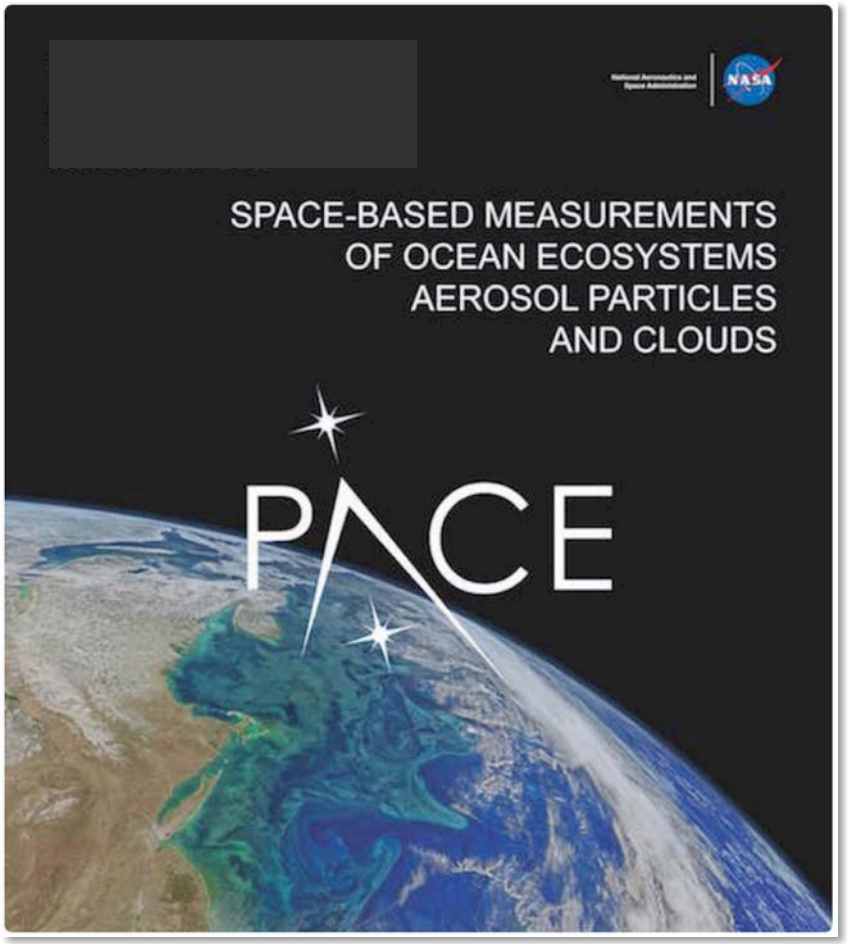
Phytoplankton Composition from Space: Towards a validation strategy for satellite algorithms

Astrid Bracher, Nick Hardman-Mountford, Takafumi Hirata, Stewart Bernard, Emmanuel Boss, Robert Brewin, Annick Bricaud, Vanda Brotas, Alison Chase, Aurea Ciotti, Jong-Kuk Choi, Lesley Clementson, Emmanuel Devred, Paul DiGiacomo, Cécile Dupouy, Toru Hirawake, Wonkook Kim, Tihomir Kostadinov, Ewa Kwiatkowska, Samantha Lavender, Tiffany Moisan, Colleen Mouw, Seunghyun Son, Heidi Sosik, Julia Uitz, Jeremy Werdell, and Guangming Zheng

The International Ocean-Colour Coordinating Group (IOCCG)
25–26 October 2014
Portland, Maine, USA

http://www.ioccg.org/groups/PFT.html
http://ioccg.org/groups/PFT-TM_2015-217528_01-22-15.pdf

New satellite missions sold with a promise of resolving phytoplankton community structure



Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) Mission Science Definition Team Report

The threshold ocean science questions (SQ) addressed by the OCI option are listed below. The SQ are addressed by the ocean science instrument (OCI) and the mission requirements, as specified in Appendices I and II of this summary.

SQ-1: What are the standing stocks, compositions, and productivity of ocean ecosystems? How and why are they changing?

SQ-2: How and why are ocean biogeochemical cycles changing? How do they influence the Earth system?

SQ-3: What are the material exchanges between land and ocean? How do they influence coastal ecosystems and biogeochemistry? How are they changing?

SQ-4: How do aerosols influence ocean ecosystems and biogeochemical cycles? How do ocean biological and photochemical processes affect the atmosphere?

SQ-5: How do physical ocean processes affect ocean ecosystems and biogeochemistry? How do ocean biological processes influence ocean physics?

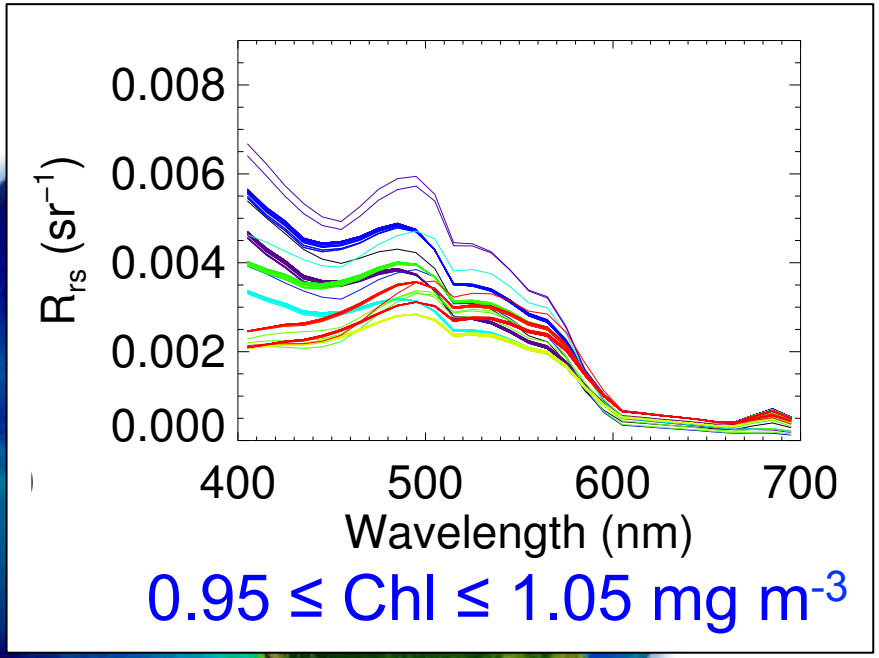
SQ-6: What is the distribution of both harmful and beneficial algal blooms and how is their appearance and demise related to environmental forcings? How are these events changing?

SQ-7: How do changes in critical ocean ecosystem services affect human health and welfare? How do human activities affect ocean ecosystems and the services they provide? What science-based management strategies need to be implemented to sustain our health and well-being?

Two flavors of algorithms exist

abundance methods

assume **a given phytoplankton biomass**, defined by either Chl or absorption – **covaries with the dominance** of or fraction of a particular community



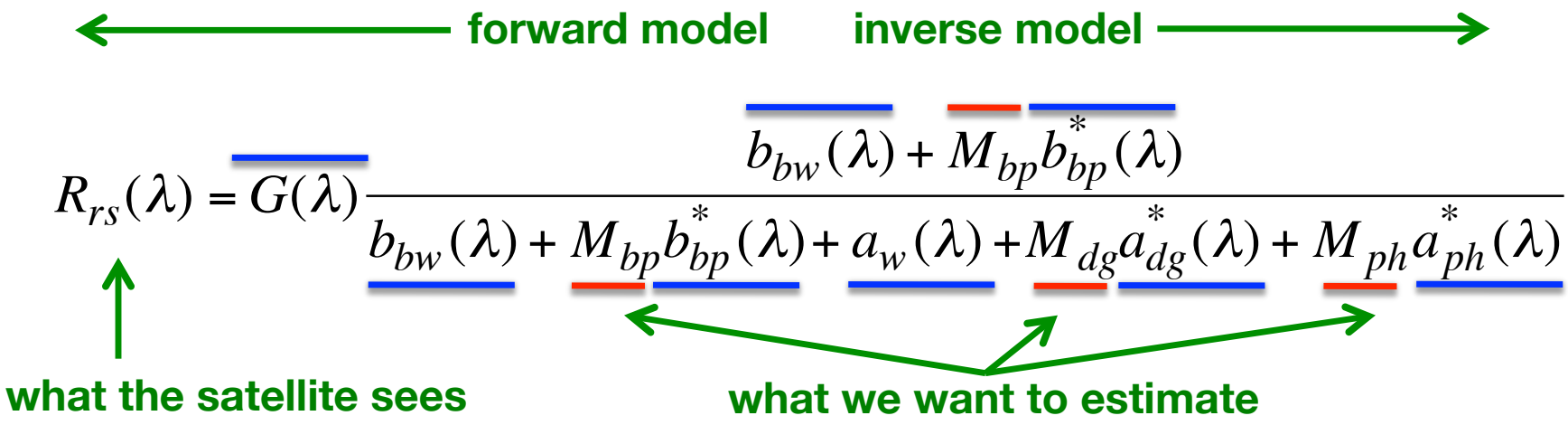
spectral methods

variations realized in the spectral shape of $R_{rs}(\lambda)$ or absorption vary with community structure

unlike abundance approaches, these can **detect different communities with common total biomass,** *provided the groups have contrasting optical signatures*

but, often **confounded by variations of spectral characteristics of the same community** due to growth conditions, nutrient availability, & ambient light regimes

Ocean reflectance inversion algorithms (one spectral method)



terms with **blue bars** have pre-assigned spectral shapes associated with them (known or modeled)

find combination of ***M'***s (**red bars**) such that right hand side best reconstructs left hand side

Quick aside: Our MODIS work

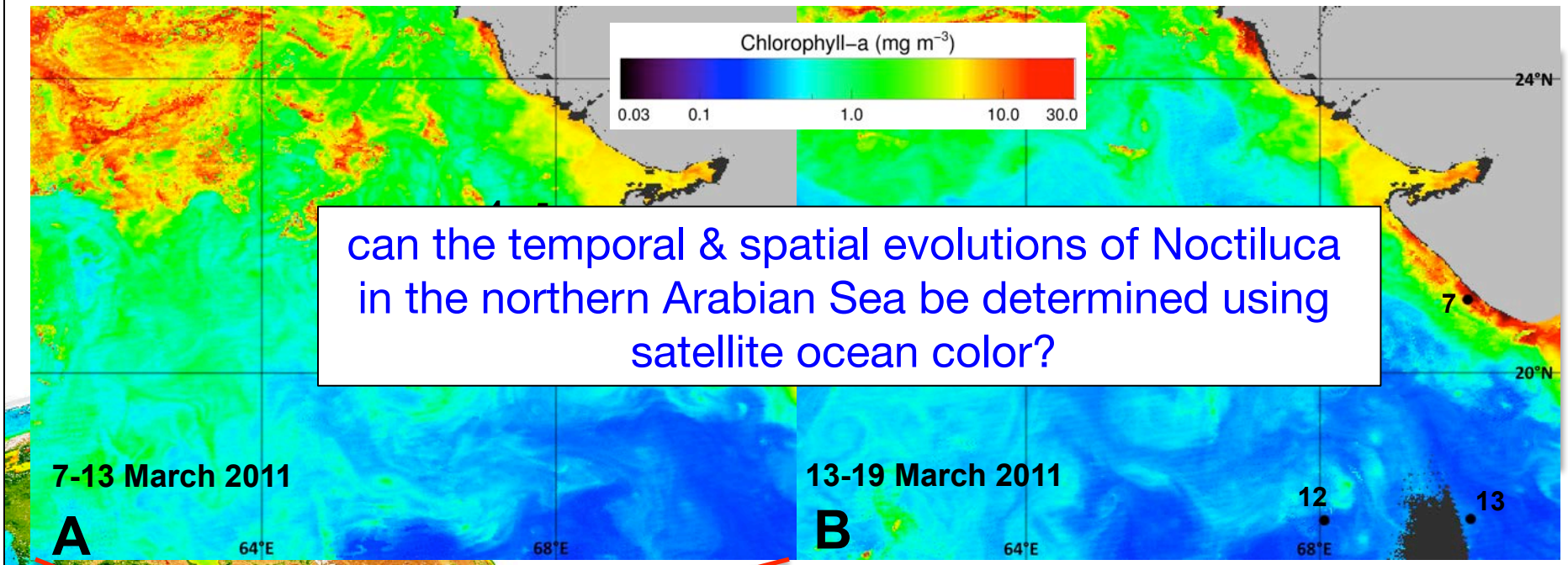
Generalized Inherent Optical Property (GIOP) framework

- Standard OBPG (community supported) software for deriving spectral absorption & scattering coefficients from MODIS, VIIRS, others
- Default parameterization, but **alternate configurations available at runtime**
- Learn more: *Werdell et al. (2013a)*, *Franz and Werdell (2010)*

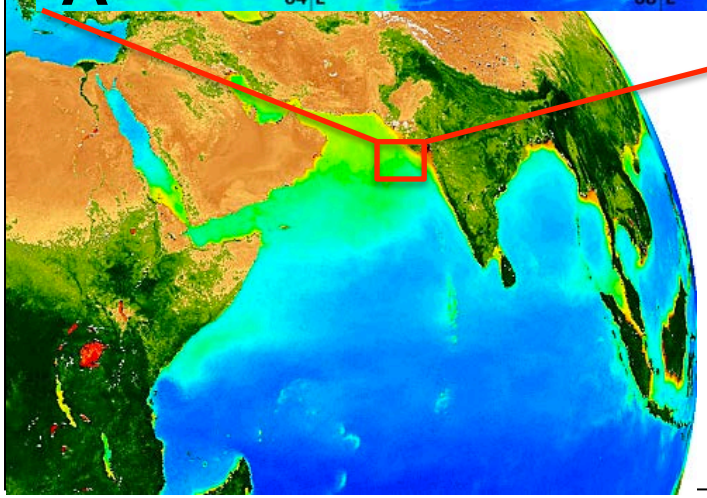
MODIS T&A award to enhance GIOP & develop improved spectral absorption & scattering coefficients

- Seawater backscattering temp & salinity dependencies (*Werdell et al. 2013b*)
- Iterative mode per Wang et al. 2005, Brando et al. 2012 (aLMI)
- Configurable expanded solution space (e.g., M_{ph}^{1} … M_{ph}^{N}) (*Werdell et al. 2014*)
- Configurable BRDF effects
- Raman effects per Westberry et al. 2013, Lee et al. 2013 (*McKinna et al. 2016*)

Resolving community structure using (spectral) inversion algorithms



can the temporal & spatial evolutions of Noctiluca in the northern Arabian Sea be determined using satellite ocean color?

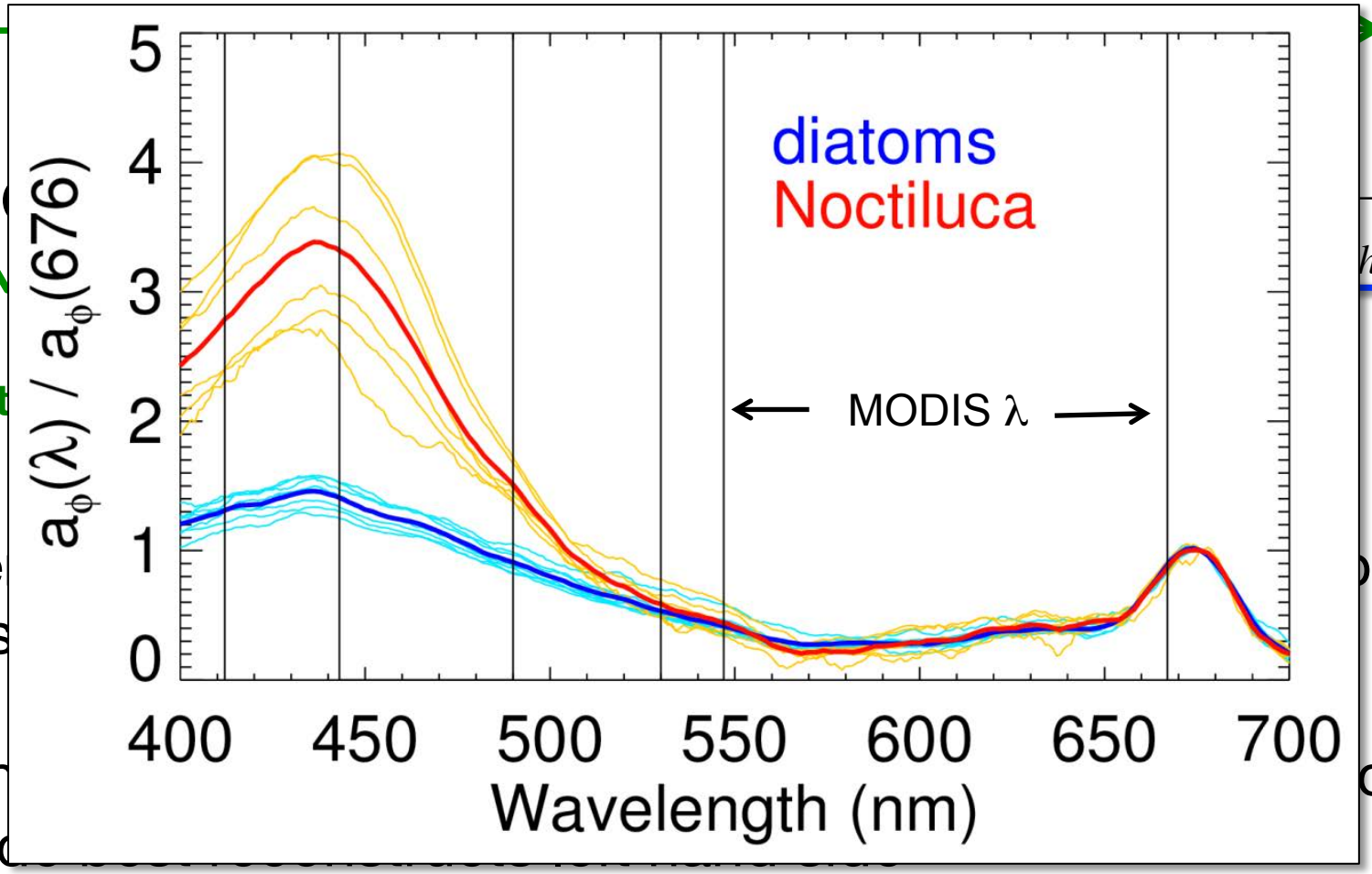


a mixotrophic dinoflagellate
(green version)

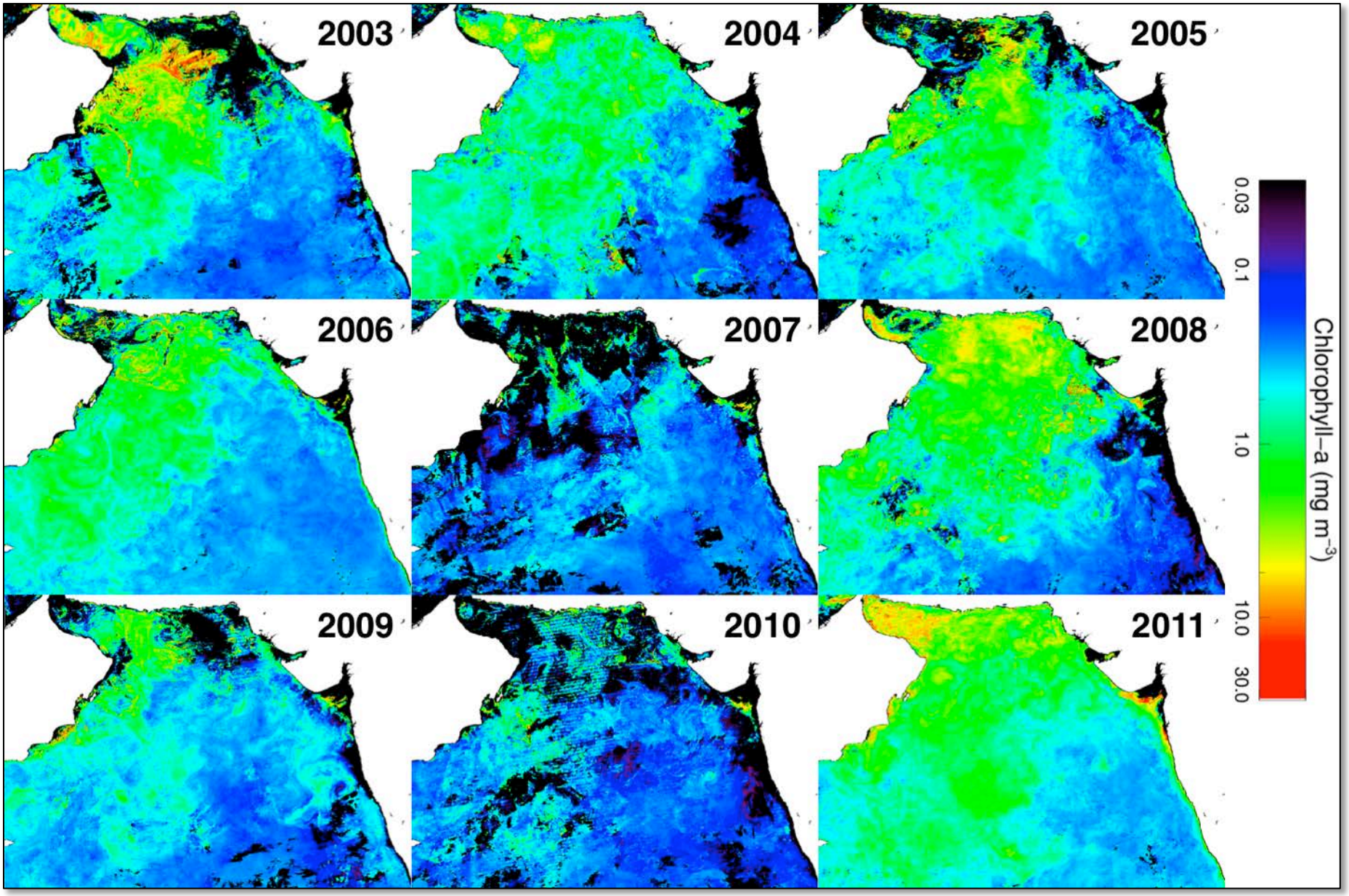
(1) heterotrophy - feeds on bacteria, diatoms, copepod eggs, detritus, *Trichodesmium* (?)

(2) symbiosis – houses the photosynthetic, green flagellate *Pedinomonas noctilucae*

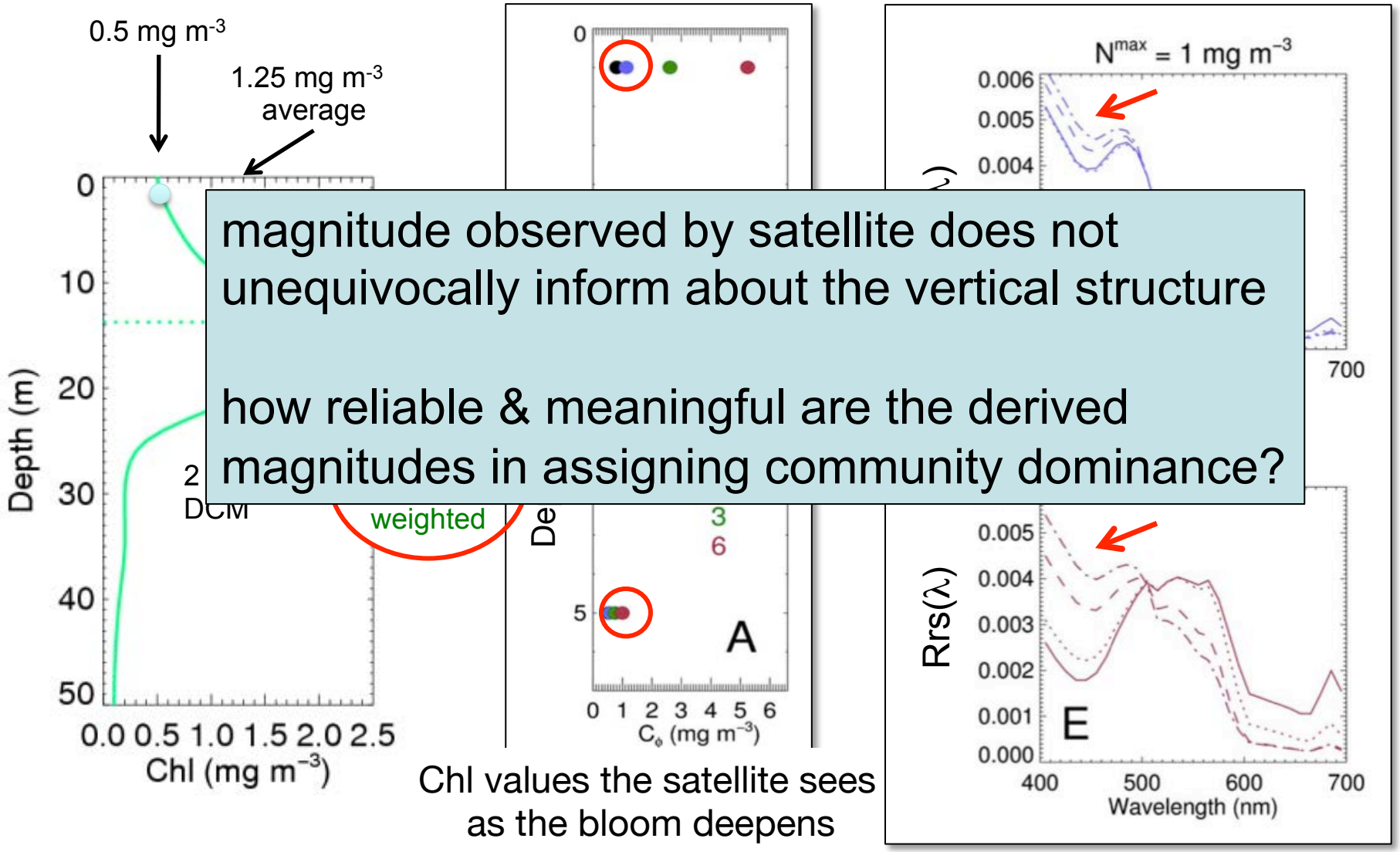
Resolving community structure using (spectral) inversion algorithms



Tools & data sets



Vertical structure & mixed communities are problems

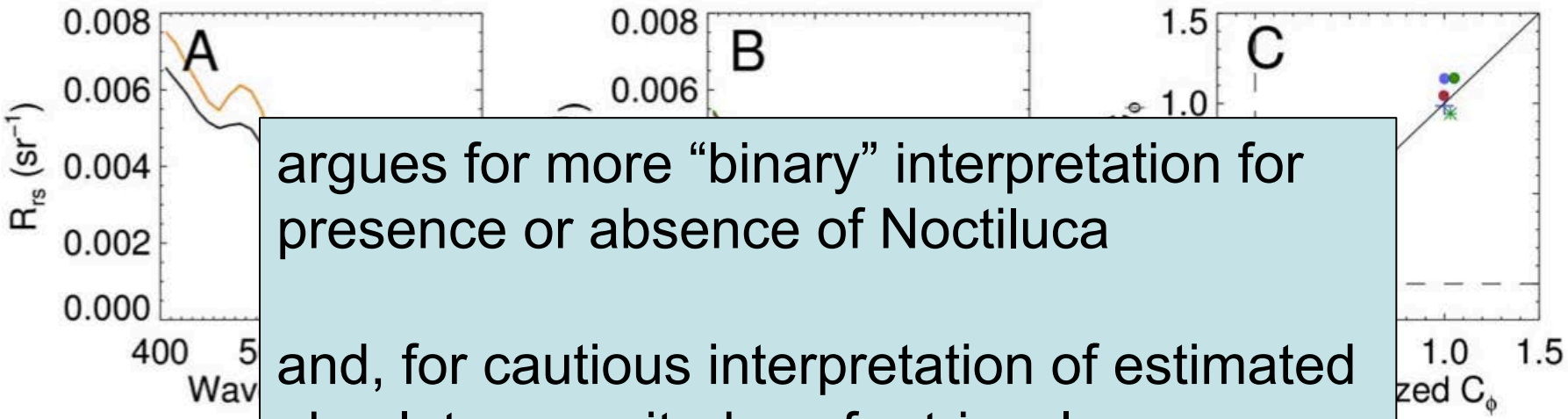


magnitude observed by satellite does not unequivocally inform about the vertical structure

how reliable & meaningful are the derived magnitudes in assigning community dominance?

Chl values the satellite sees as the bloom deepens

Vertical structure & mixed communities are problems



argues for more "binary" interpretation for presence or absence of Noctiluca

and, for cautious interpretation of estimated absolute magnitudes of retrievals

only diatoms ~0.5 mg m^{-3}

only Noctiluca ~0.5 mg m^{-3}

only Noctiluca ~1 mg m^{-3}

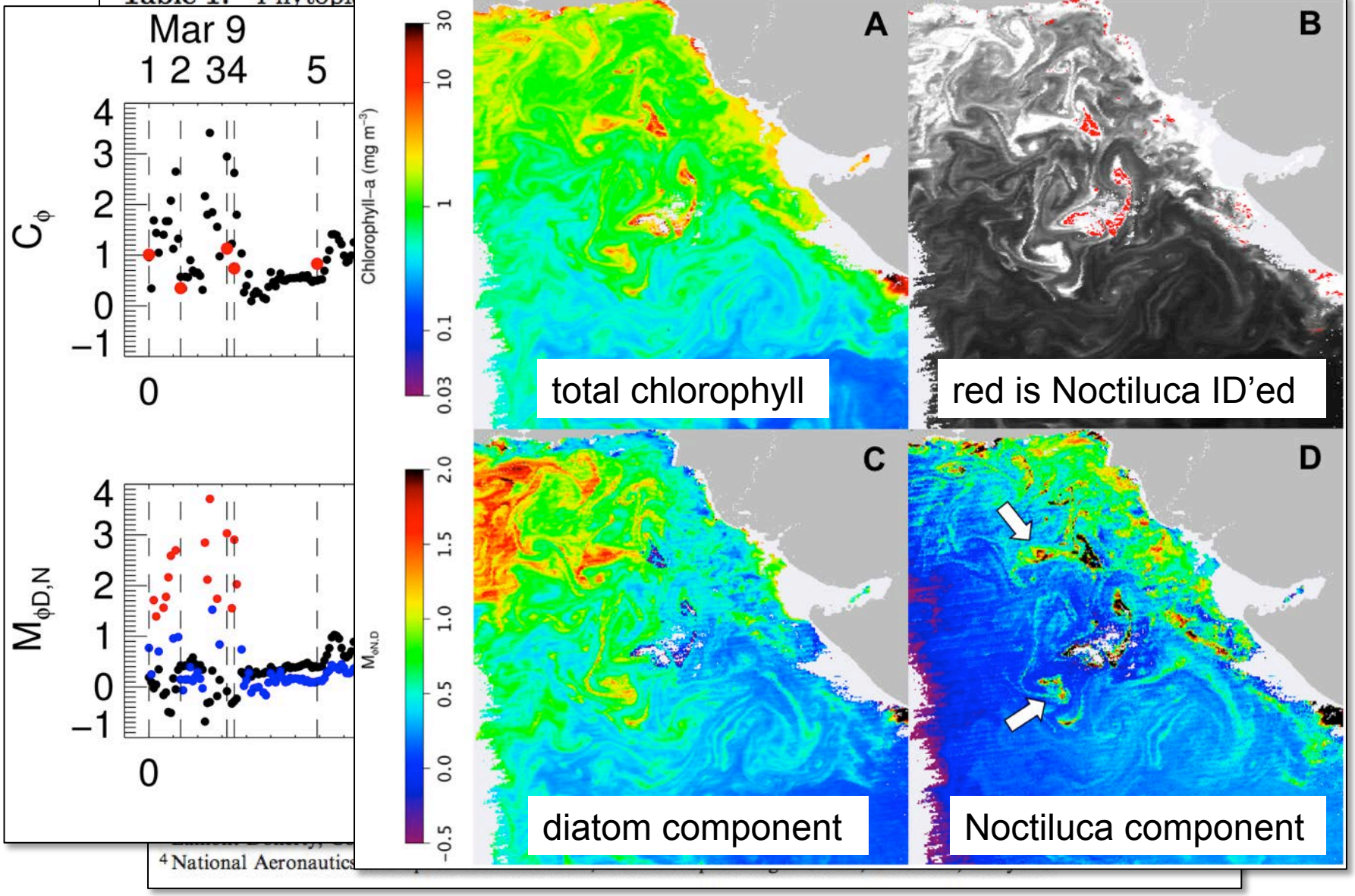
0.5 mg m^{-3} each (= 1 total)

some false positives for diatoms when only Noctiluca present

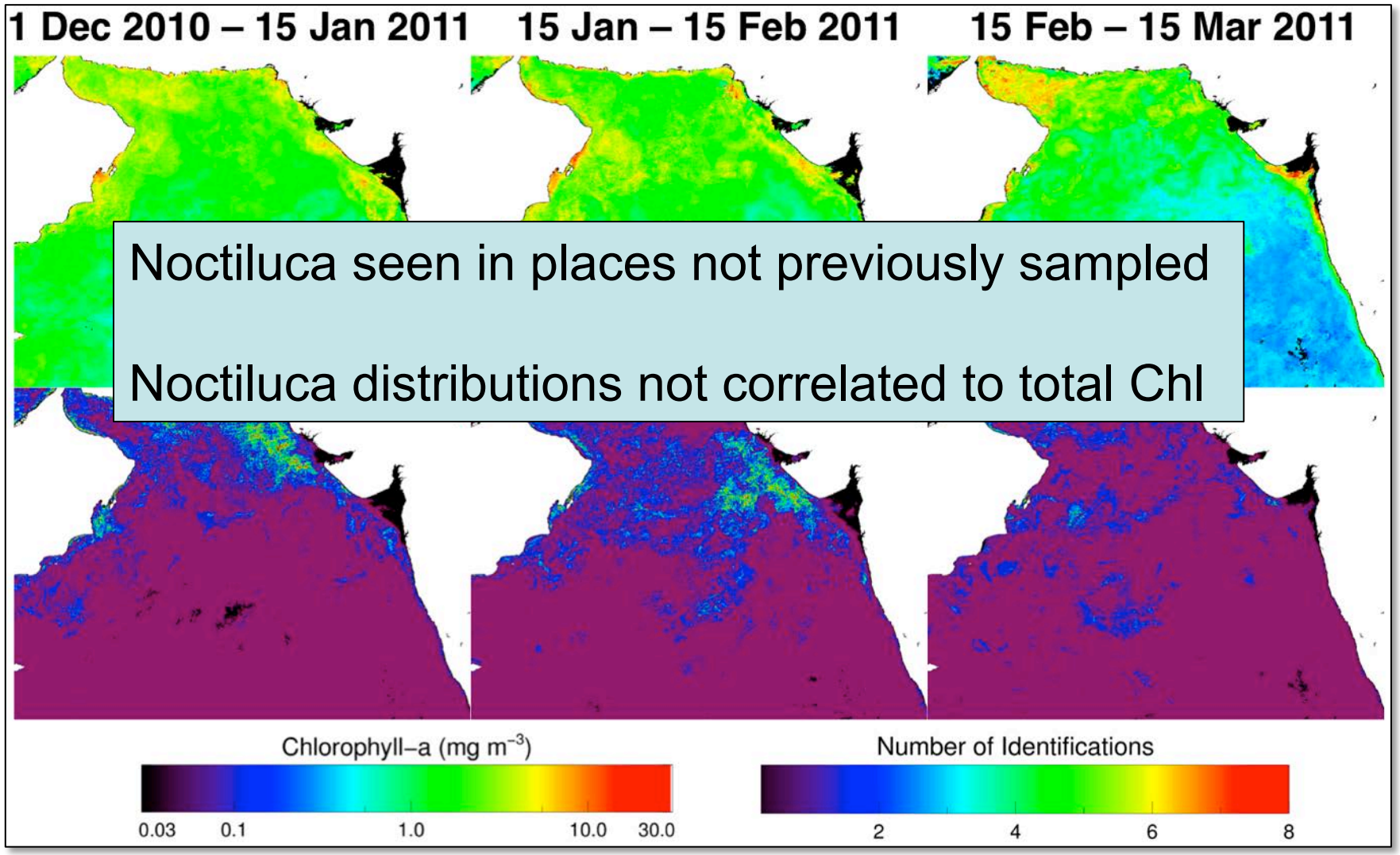
few false positives for Noctiluca when only diatoms present

separation of two in mixed communities less reliable

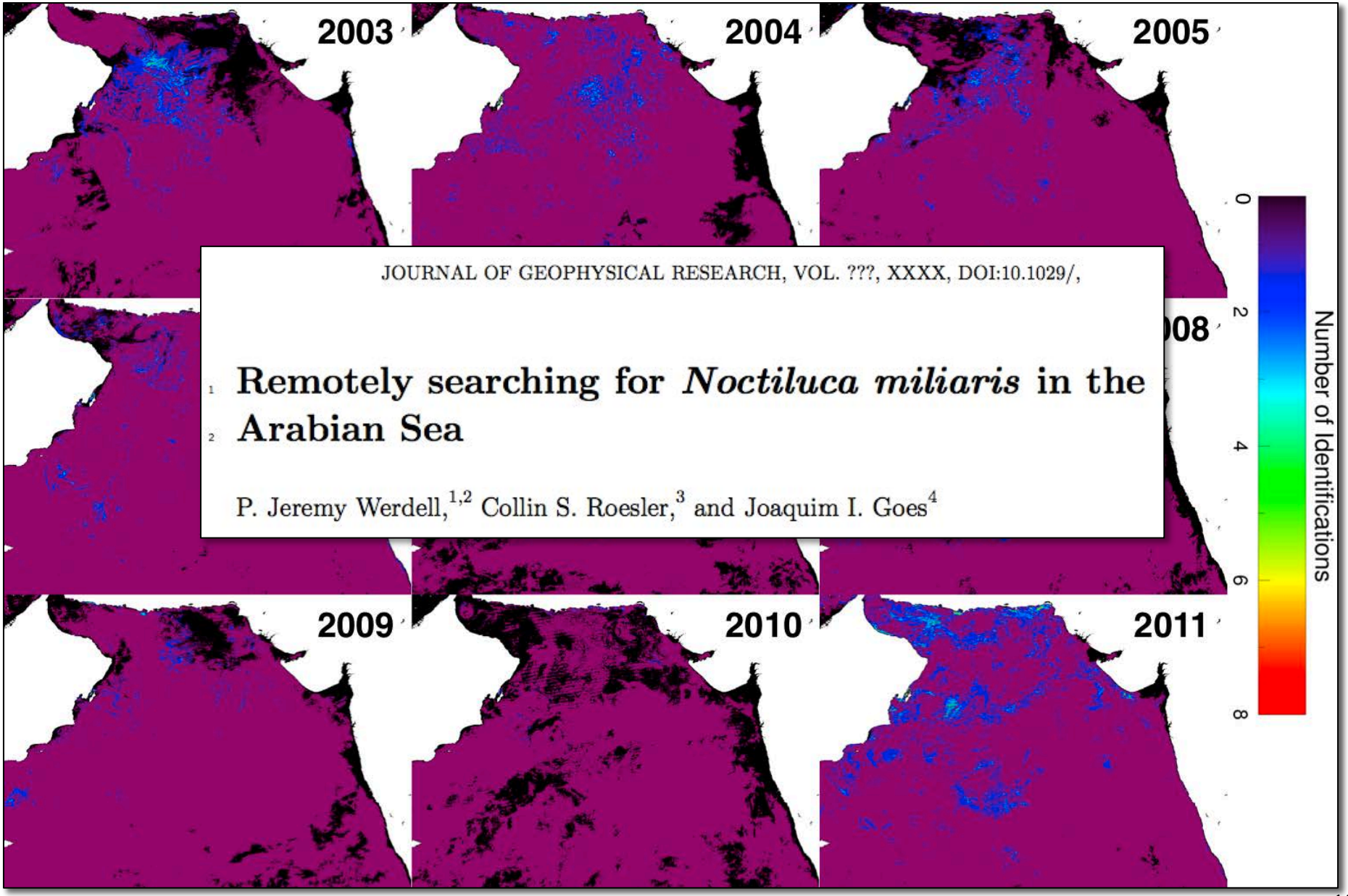
Is it there or is it not?



Application to MODIS-Aqua time-series



Application to MODIS-Aqua time-series



JOURNAL OF GEOPHYSICAL RESEARCH, VOL. ???, XXXX, DOI:10.1029/,

Remotely searching for *Noctiluca miliaris* in the Arabian Sea

P. Jeremy Werdell,[1,2] Collin S. Roesler,[3] and Joaquim I. Goes[4]

Lessons were learned

Ocean color inversion methods address ill-posed problems

- Can successfully identify presence of a dominant species (with TLC*, when assumed spectral shapes match reality*)
- Less successful providing information on vertical structure
- Retrieved magnitudes require careful interpretation

Oc
co

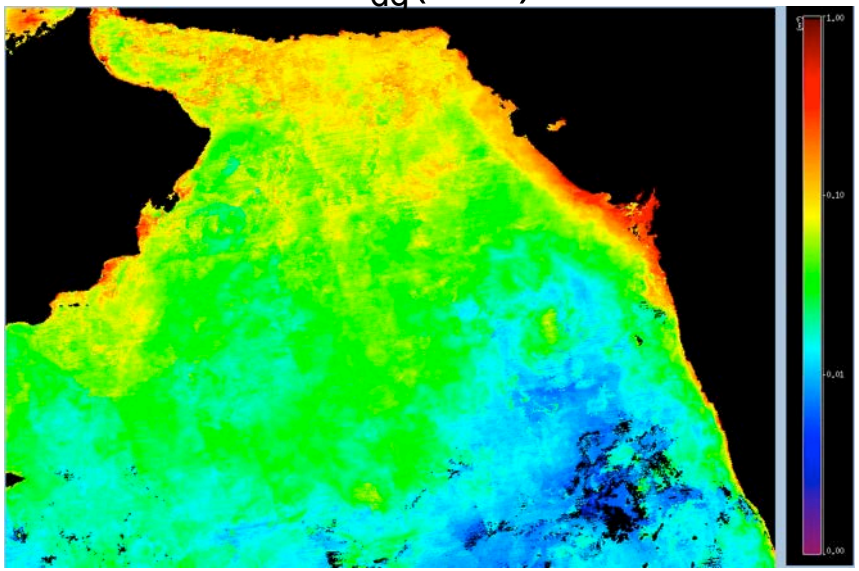
- Do the right *in situ* data sets (and, instruments) exist?
- Can these data sets be post-processed in such a way to reproduce the integrates values seen by the satellite?

(Not shown) **Validation remains challenging** & other ocean color products (backscattering, fluorescence) can be useful

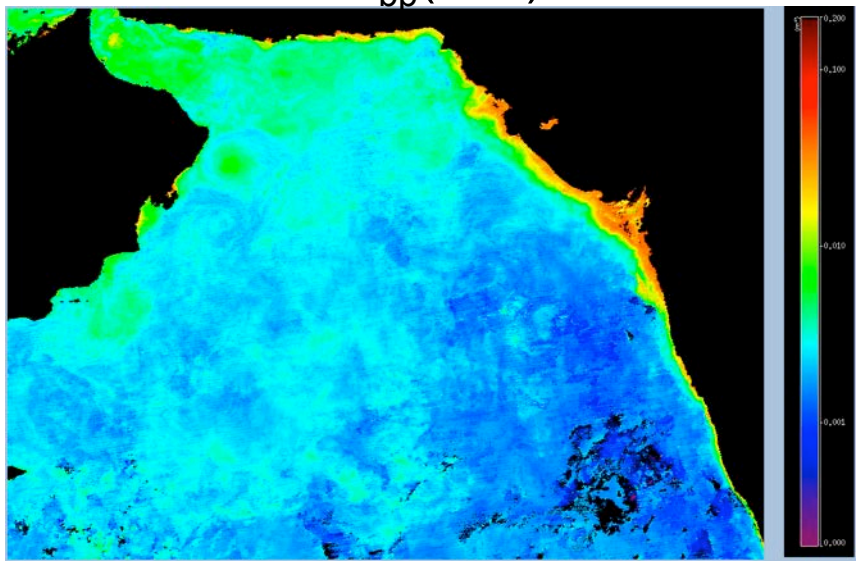

thank you

March 2011 optical properties

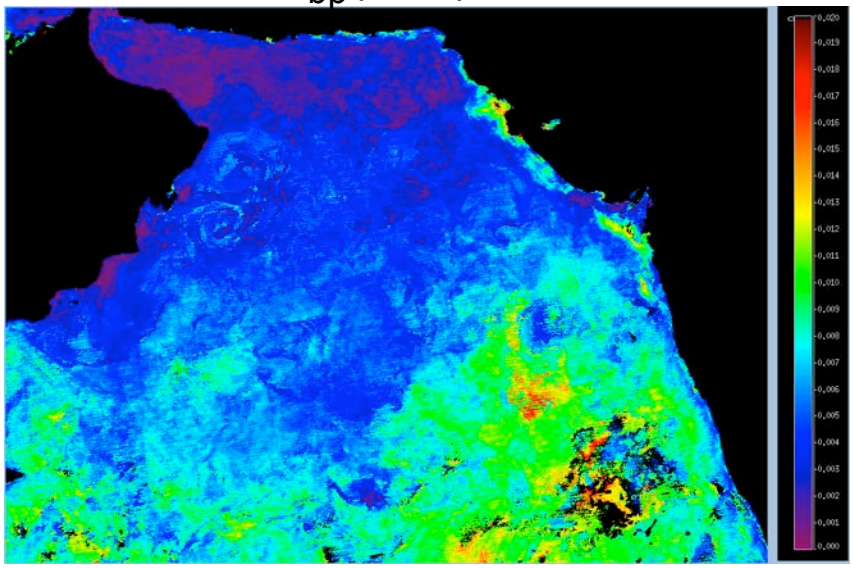
$a_{dg}(443)$



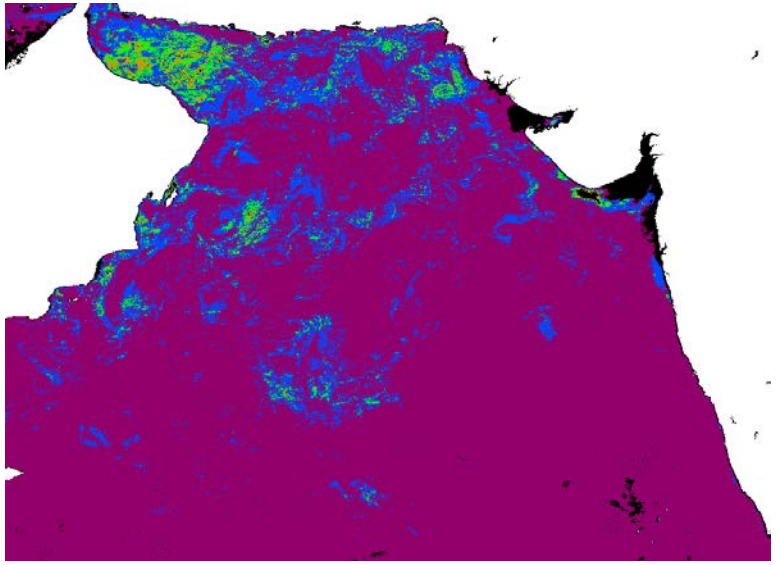
$b_{bp}(443)$



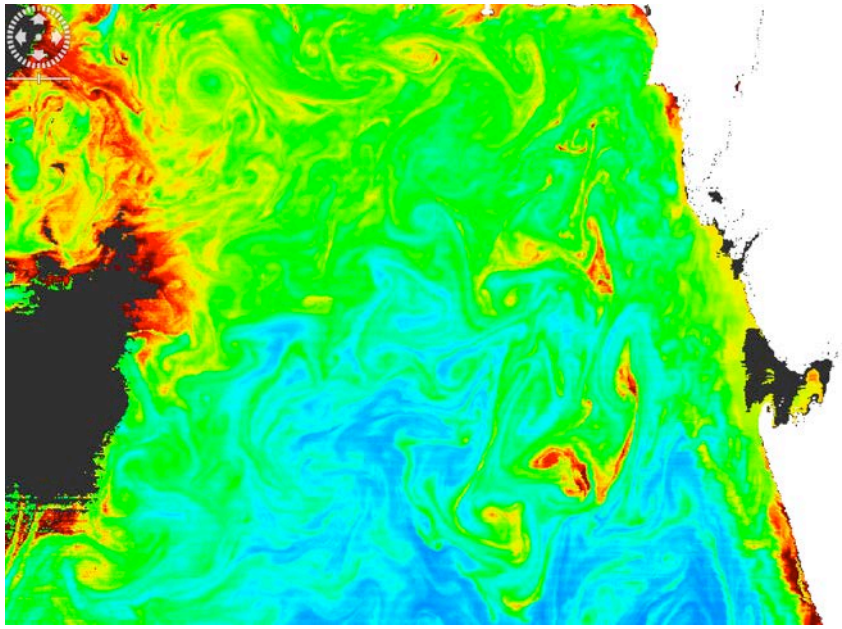
$b_{bp}(443)$ / Chl



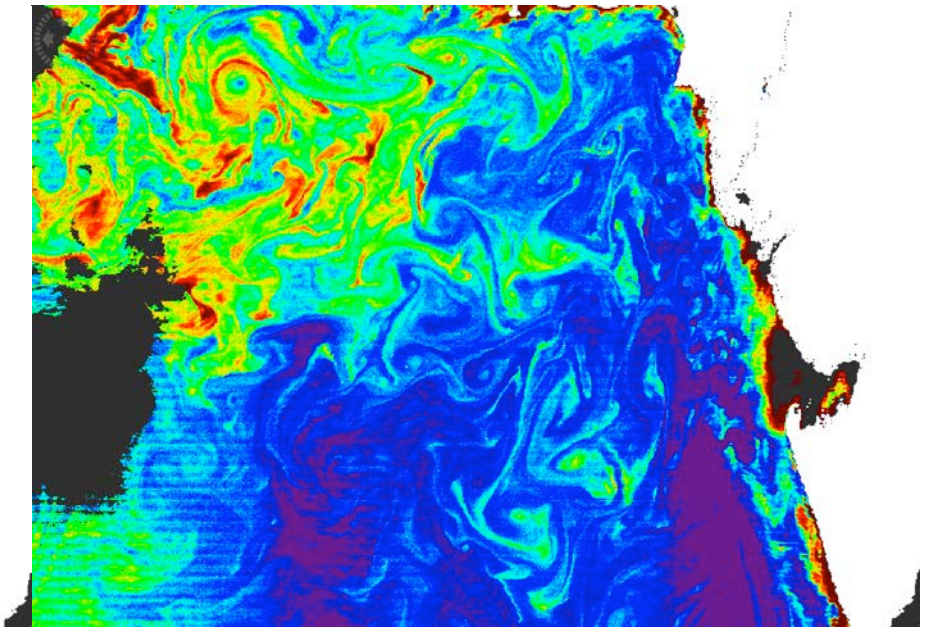
# of N. miliaris



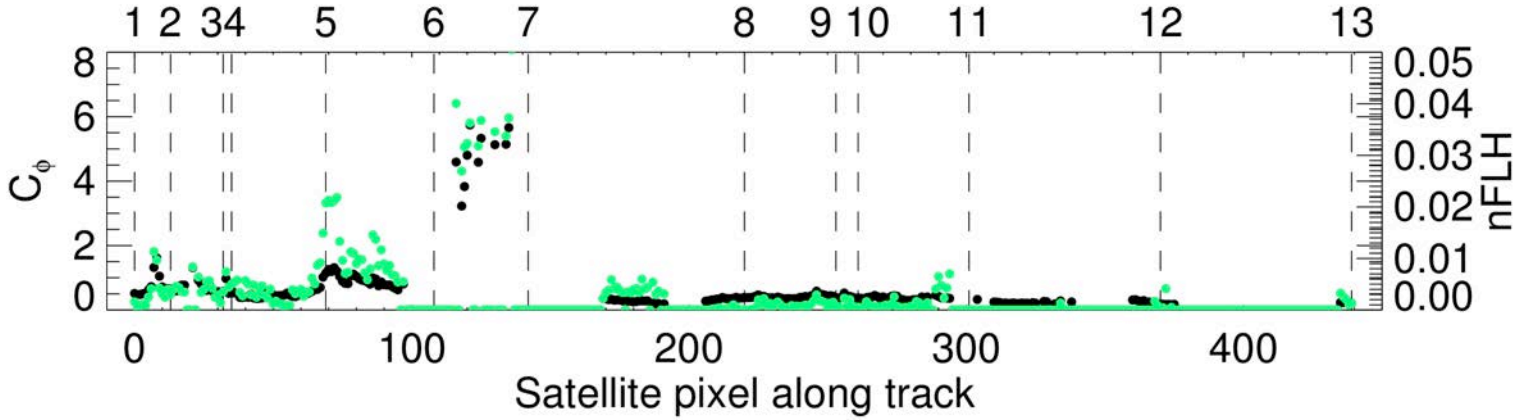
Fluorescence



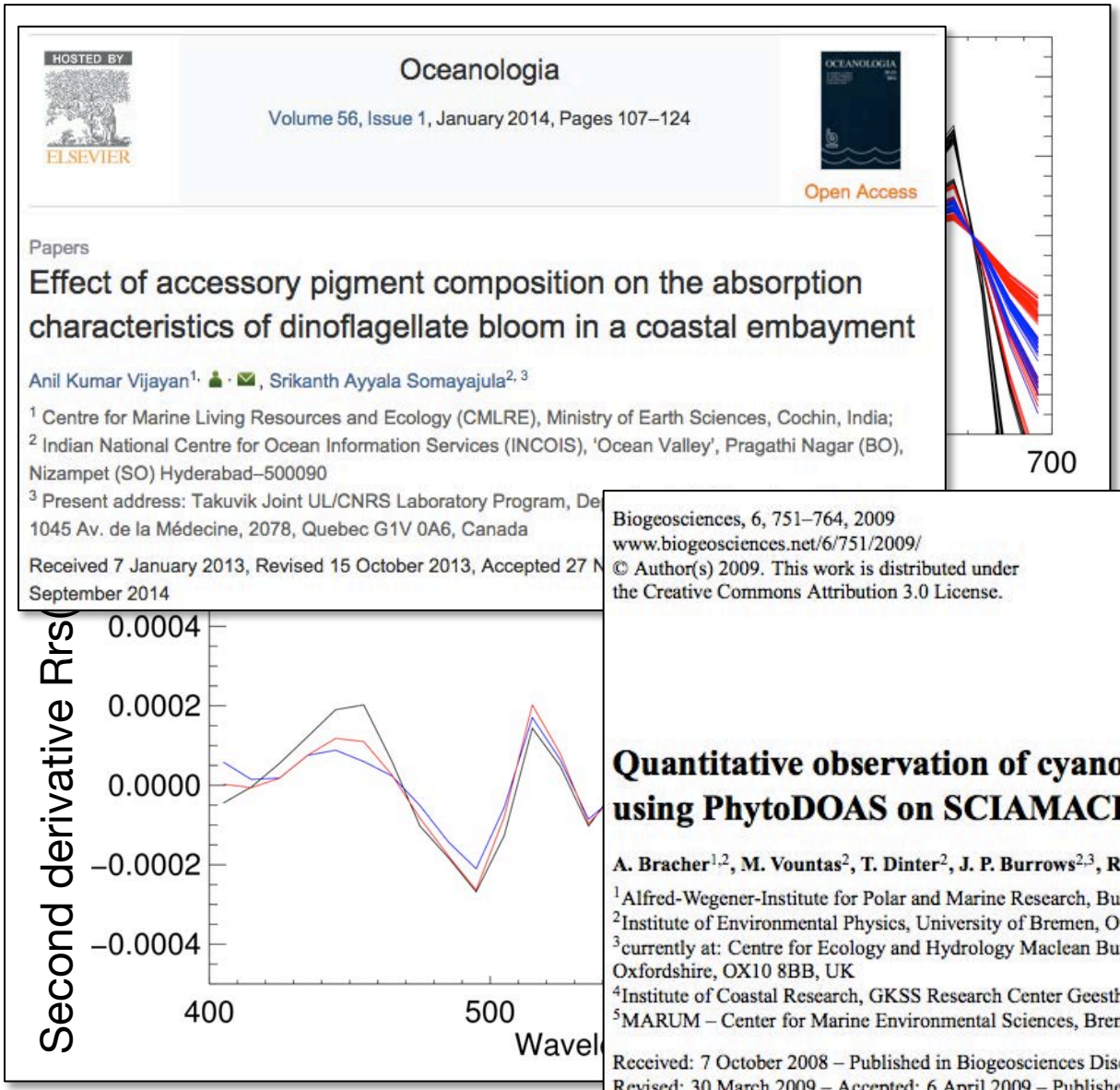
OC3 0.05 to 50 mg m^{-3}



nFLH 0 to 0.04 μW cm^{-2} nm^{-1} sr^{-1}



Moving towards hyperspectral information



Derivative analyses

of Rrs(λ) may reveal community composition based on differences in phytoplankton absorption

Legend:

Noctiluca only