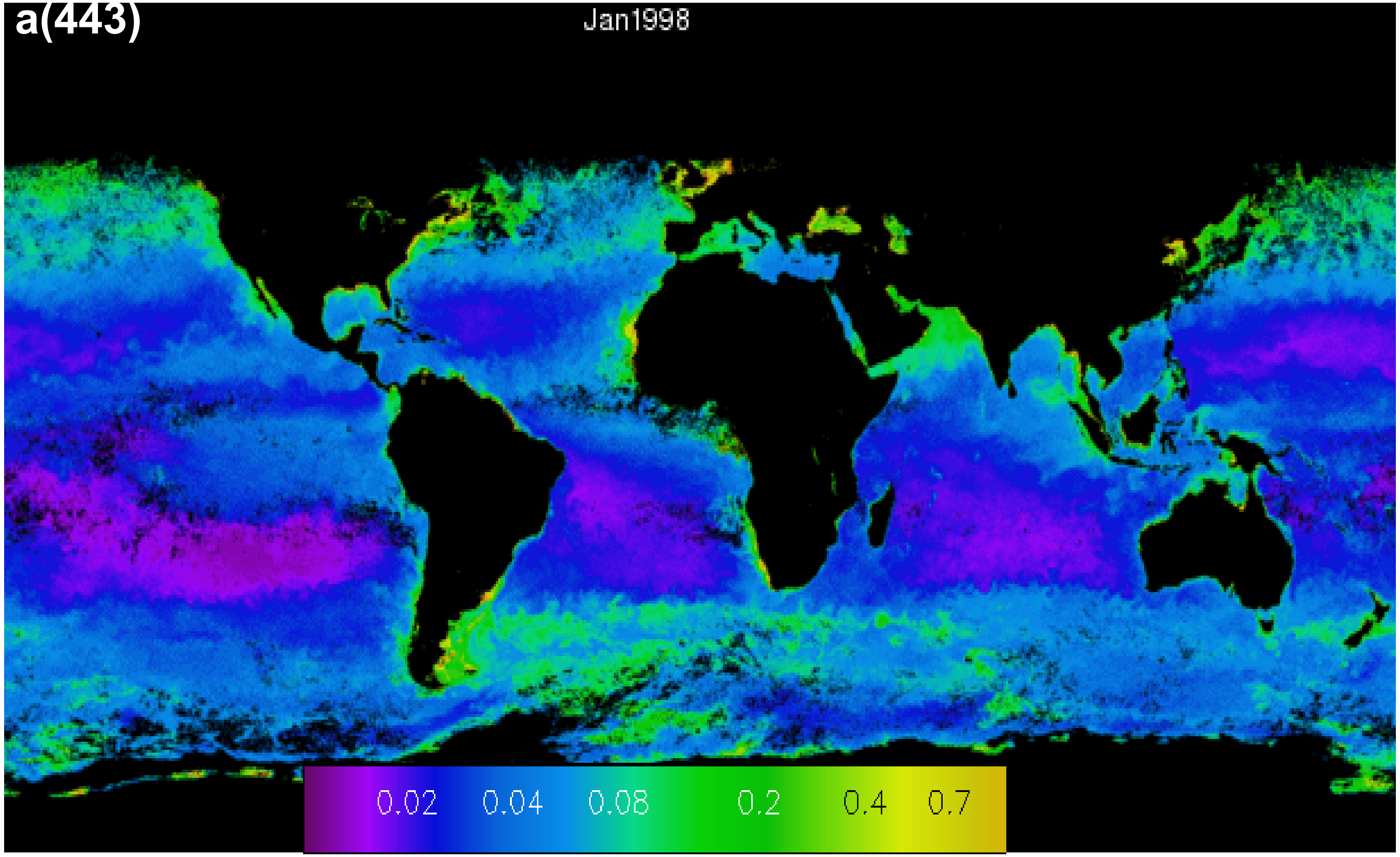
Changes in global phytoplankton community structure from satellite observations

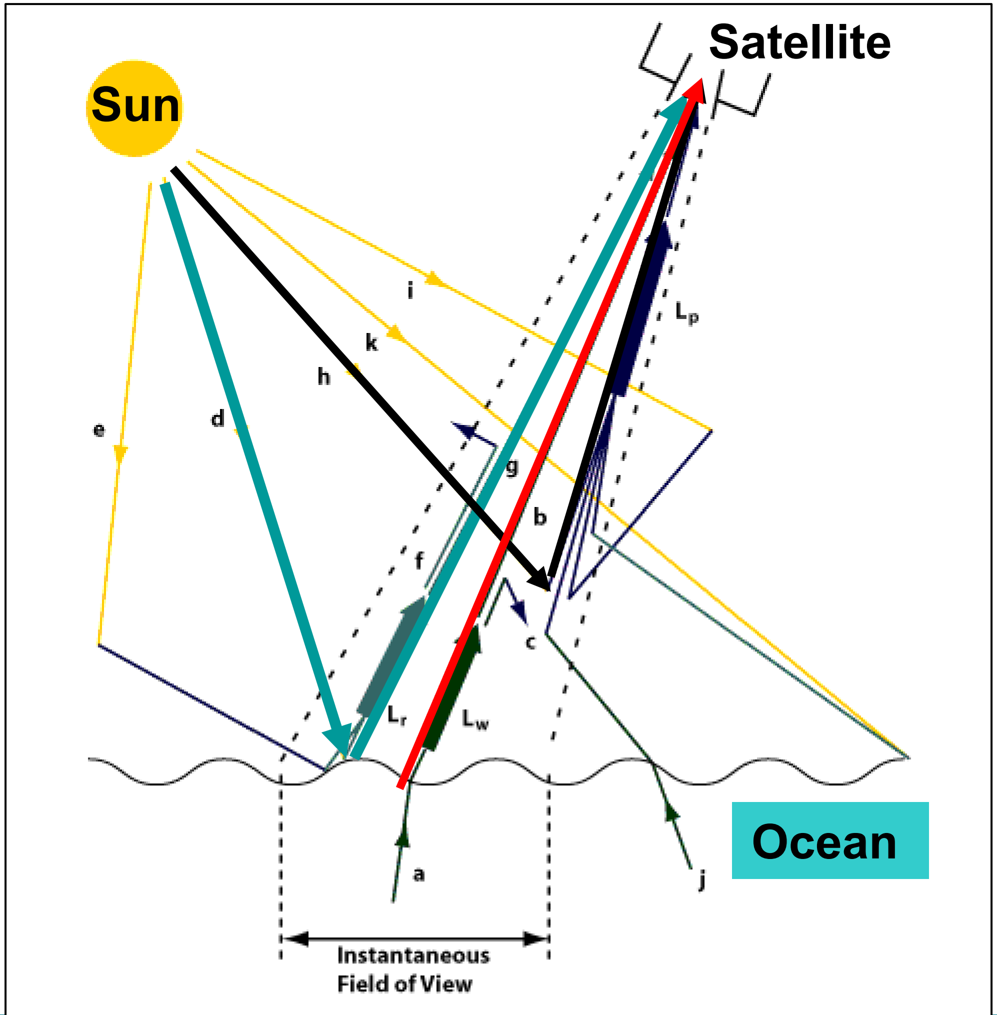


Tim Smyth, Jim Aiken, Takafumi Hirata, Nick Hardman-Mountford

Overview

- Introduction: What are we actually measuring from space using ocean colour?
- The PML Inherent Optical Property model;
- Application of the IOP model within the context of global change;
- Determination of phytoplankton community structure;
- What are the (short) time-series showing?

Introduction: What are we actually measuring from space?



Myth: we are measuring chlorophyll.

Reality: we are measuring top-of-atmosphere radiances with a small (5%) water leaving component.

So what? Lw is closely related to ***absorption*** and ***scattering*** within the water column.

Who cares? Gives us better parameters to decompose into bio-geochemical partitioning.

The PML Inherent Optical Property (IOP) model

- Water leaving radiance directly related to absorption (a) and backscatter (b_b)

$$\rho_w(\lambda) = \Re_\lambda F_\lambda \left[\frac{b_{bw}(\lambda) + b_{bp}(\lambda)}{a_w(\lambda) + a(\lambda)}\right]$$

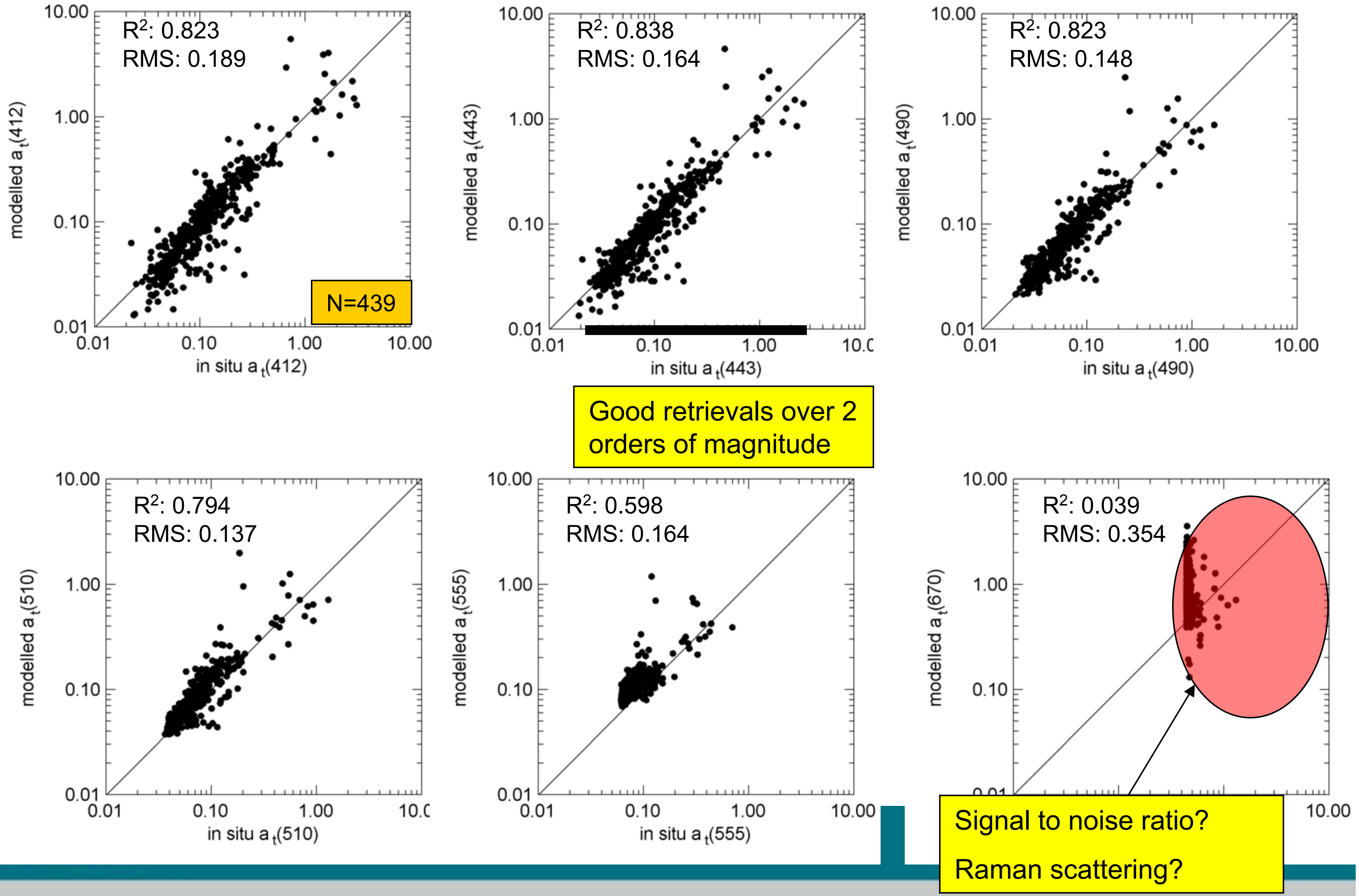
Water interface terms

Total absorption:

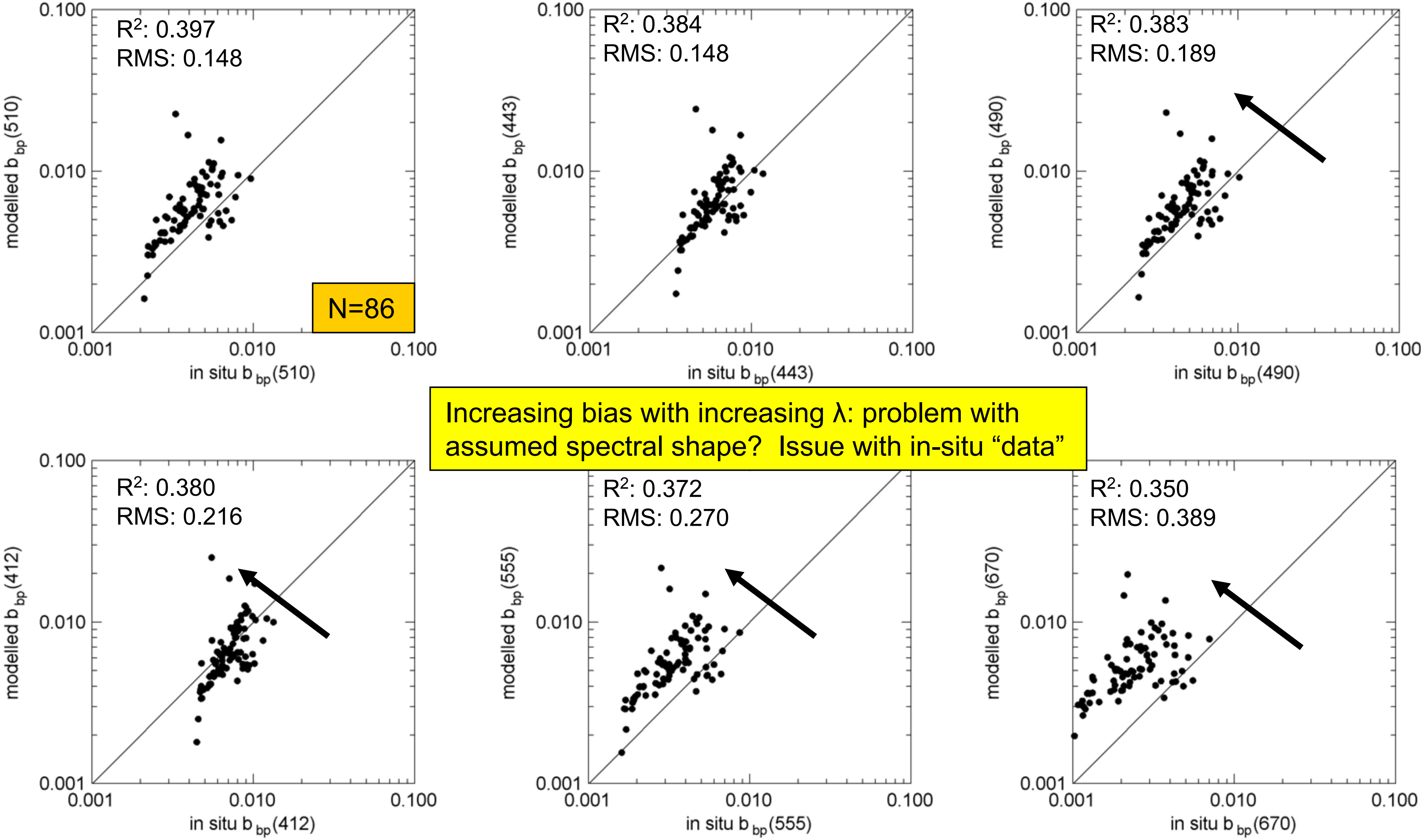
$a_{ph}(\lambda)$, $a_d(\lambda)$, $a_y(\lambda)$

- Two unknowns of $b_{bp}(\lambda)$ and $a(\lambda)$: therefore require two equations …
- Achieve this using:
    - two neighbouring wavelengths;
    - and empirically derived spectral slopes.
- Can then go on to partition absorption into component parts: phytoplankton (ph), detrital (d), coloured dissolved organics (y).
    - again use neighbouring wavelengths and field data.

PML IOP model validation: total absorption, $a_t(\lambda)$

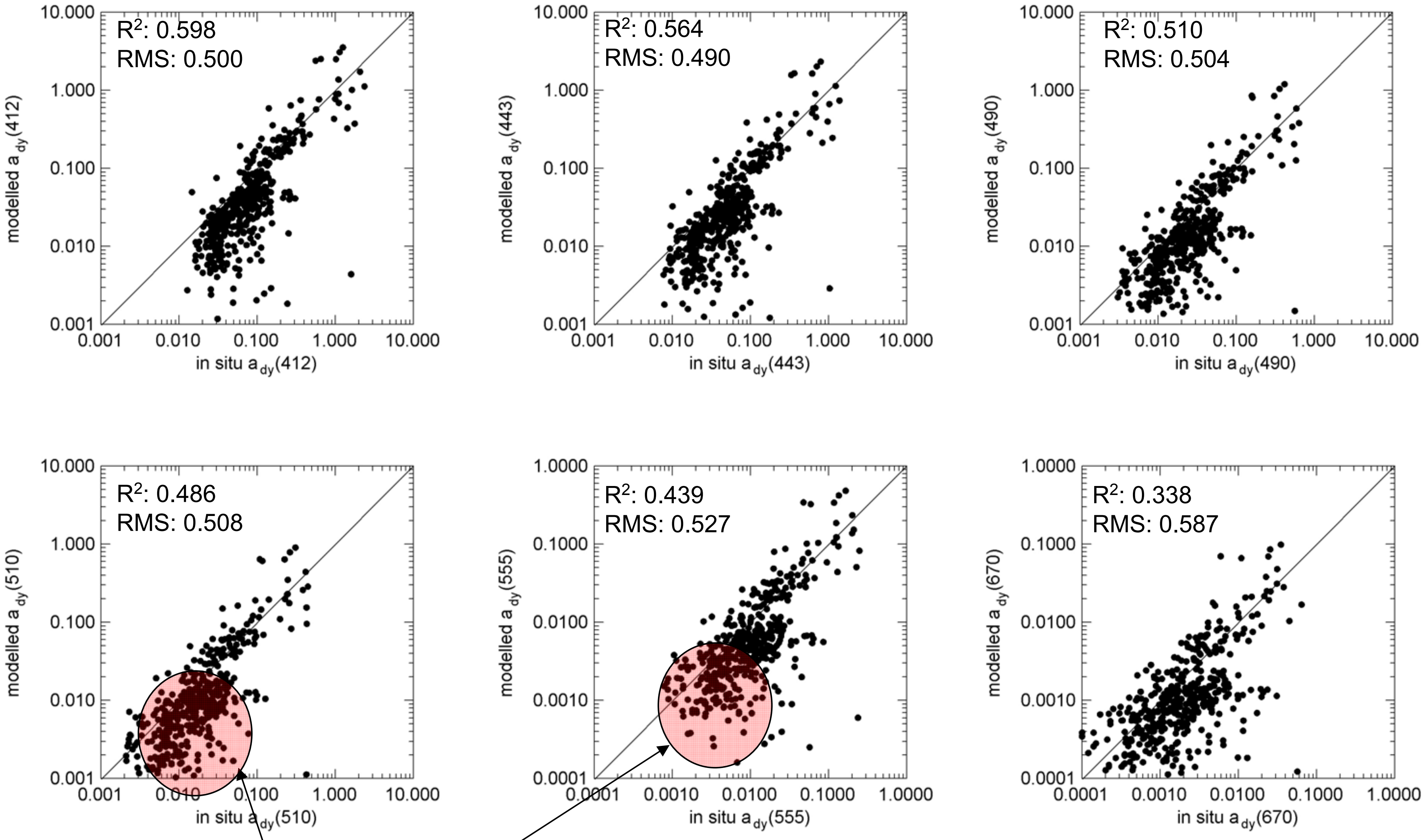


PML IOP model validation: Total backscatter, $b_b(\lambda)$



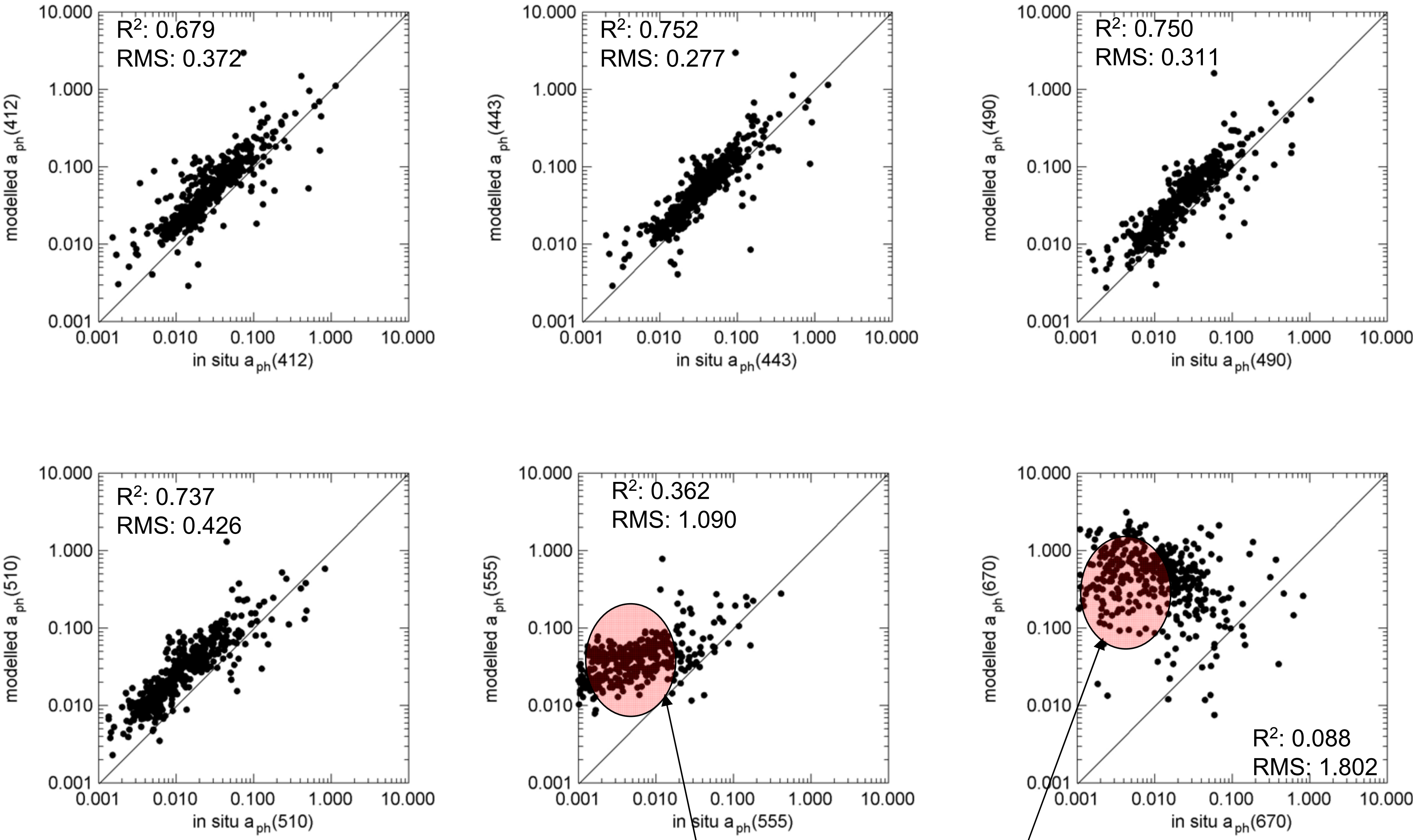
Increasing bias with increasing λ: problem with assumed spectral shape? Issue with in-situ "data"

PML IOP model validation: CDOM absorption, $a_{dy}(\lambda)$



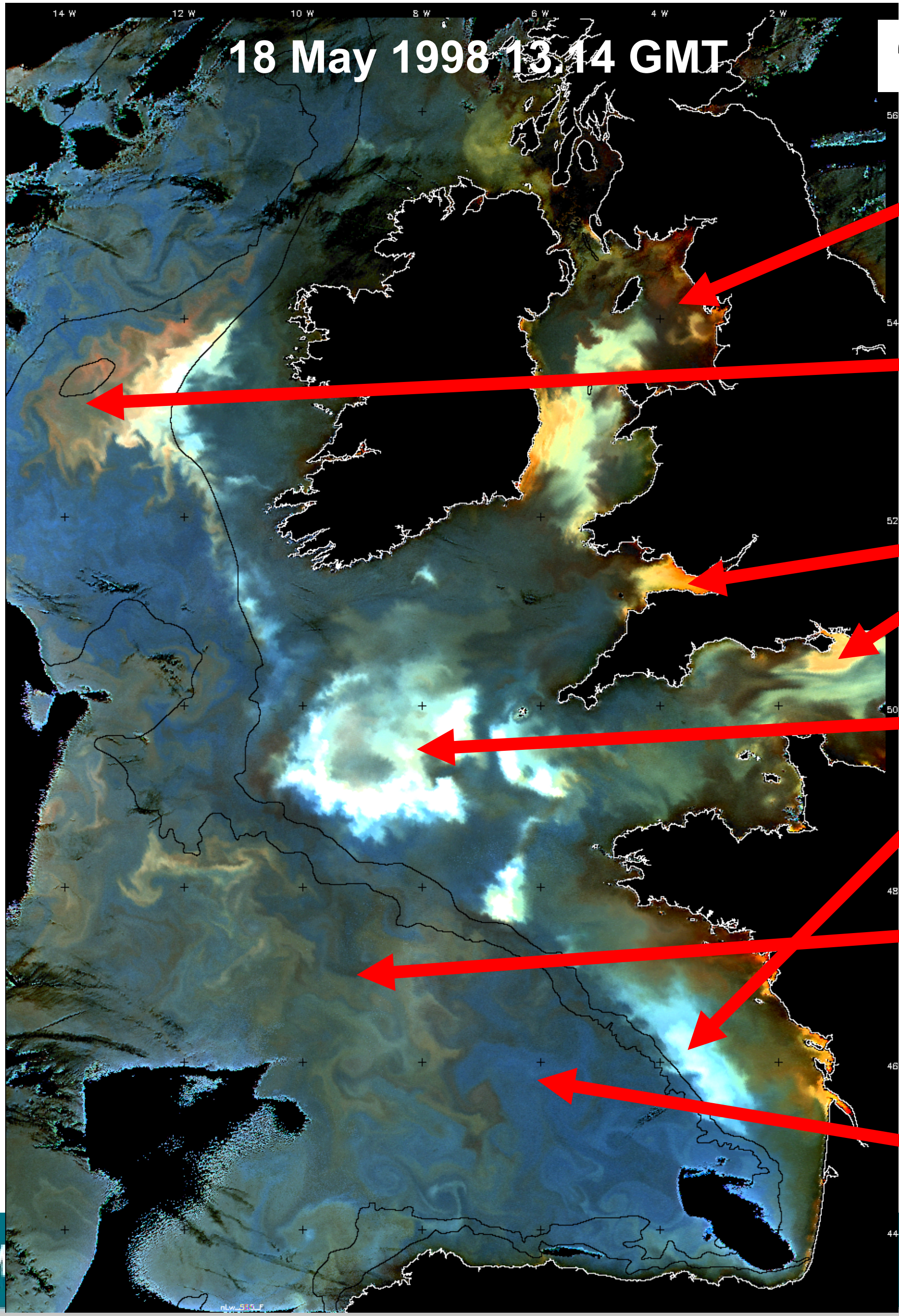
Noisy at low $a_{dy}(\lambda)$: possible measurement error?

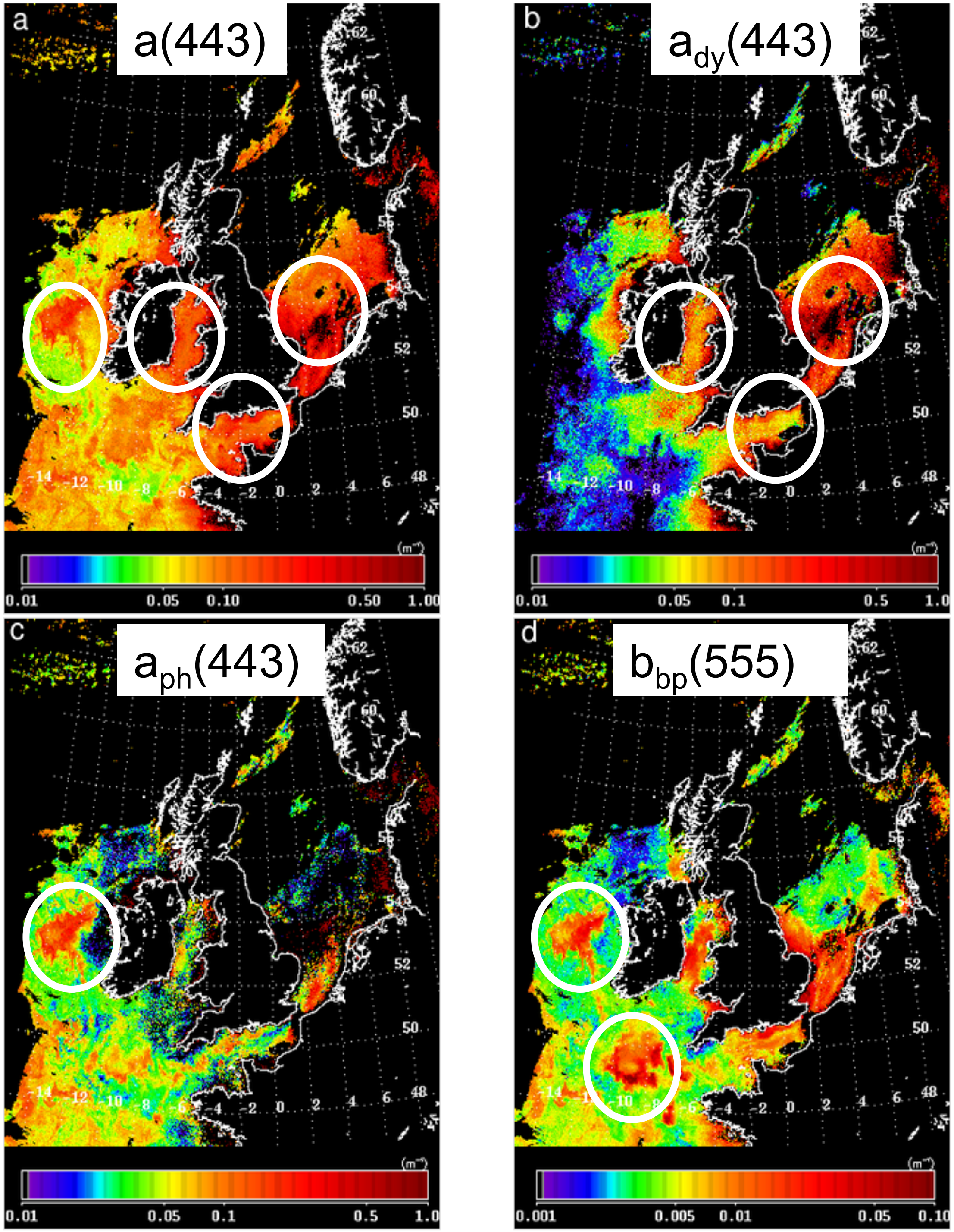
PML IOP model validation: phytoplankton absorption, $a_{ph}(\lambda)$



Problems with retrievals at 555 and 670

"True color" composite - qualitative





a) a(443): high values (0.2 – 0.5 m^{-1}) in coastal seas; ca. 0.3 m^{-1} in bloom.

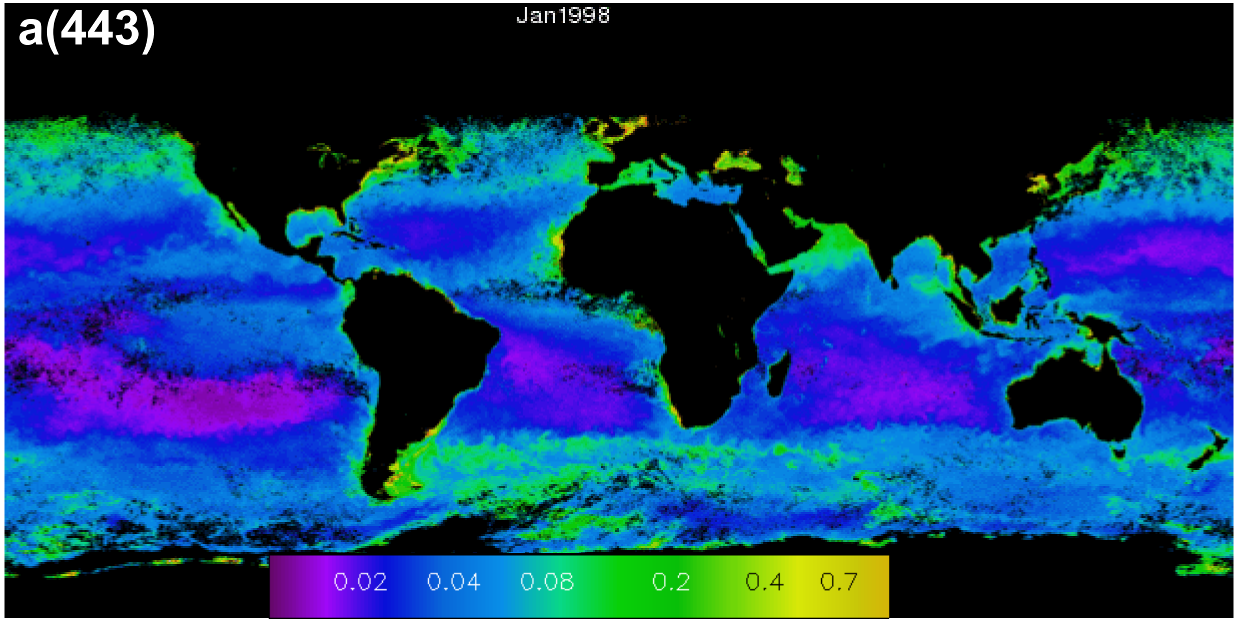
b) a_{dy}(443): coastal seas dominated by CDOM;

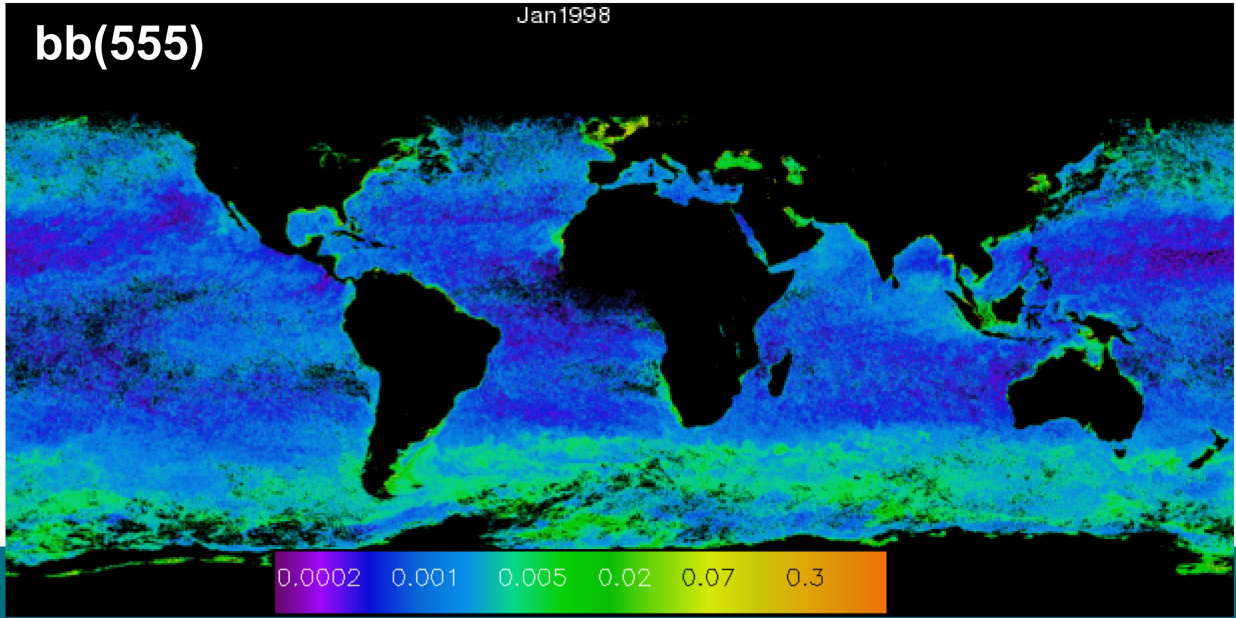
c) a_{ph}(443): phytoplankton bloom off W. Ireland;

d) b_{bp}(555): *Emiliana huxleyi* bloom in Western Approaches (*in situ* confirmed this)

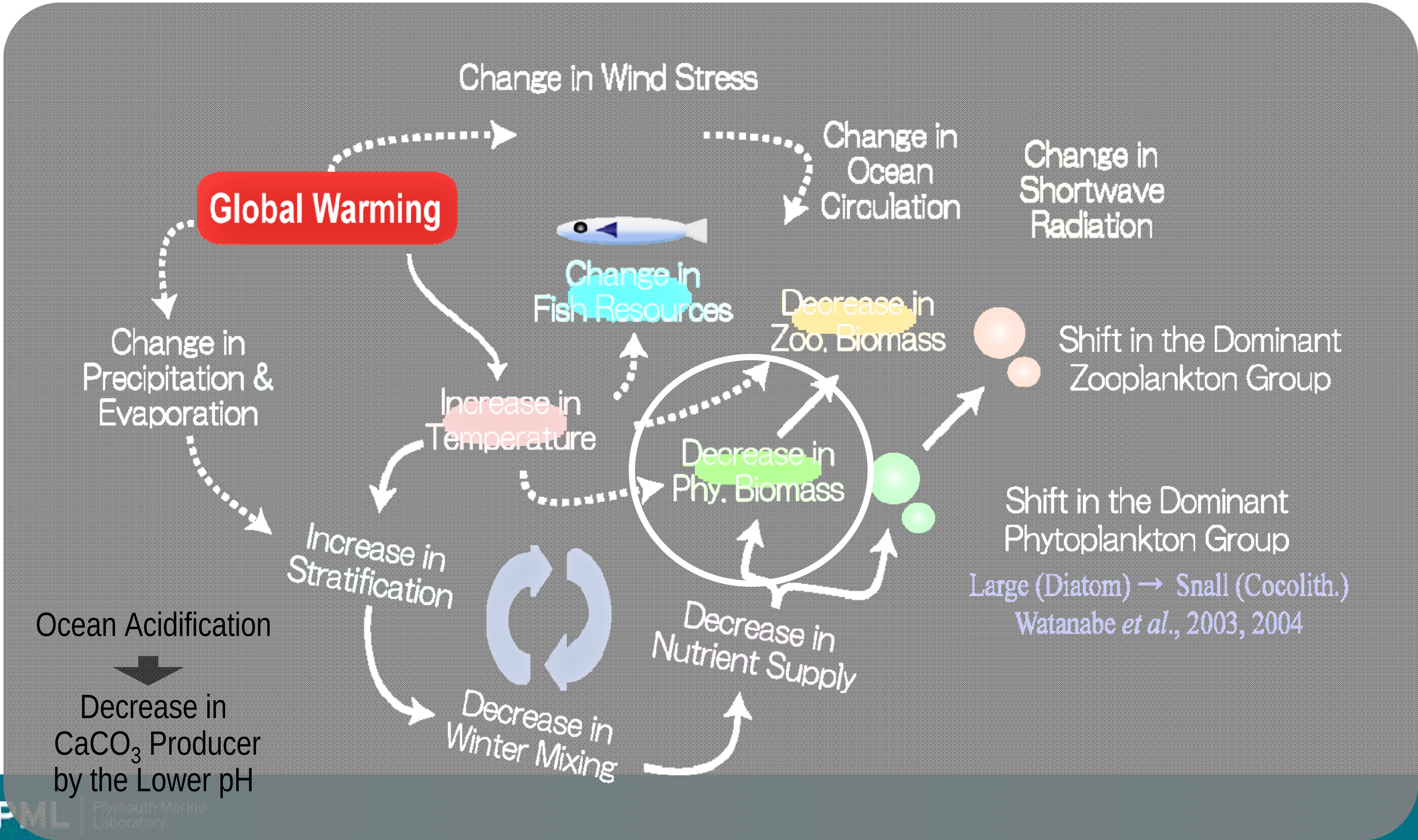
IOP model allows us to **quantify** these features.

Global IOP time-series (SeaWiFS)



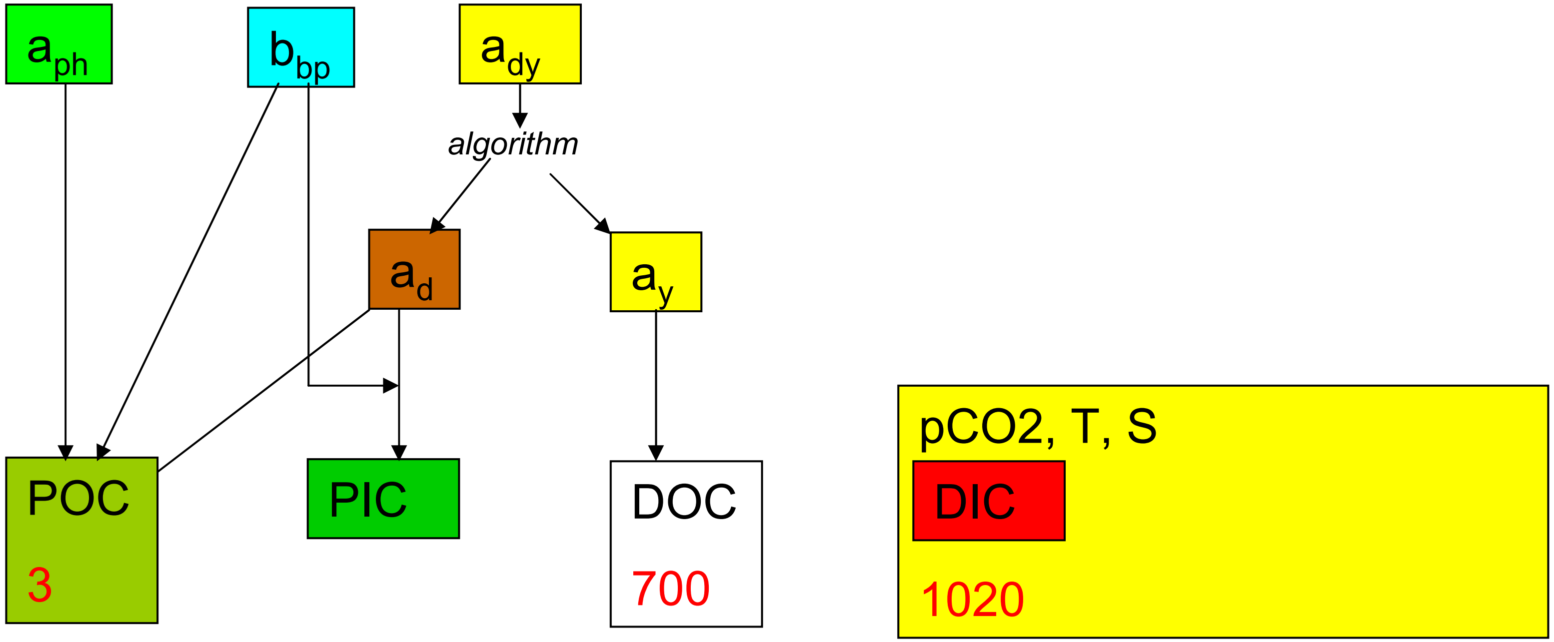


Application of the IOP model within the context of global change. (Or how can we answer the bigger questions?)



Application of the IOP model within the context of global change.

- Assimilation of IOPs into POLCOMS – improved sea-surface temperature (Holt et al., Sathyendranath et al.)
- Further partitioning of IOPs into “real” components of the carbon “pools” (future work under NCEO)

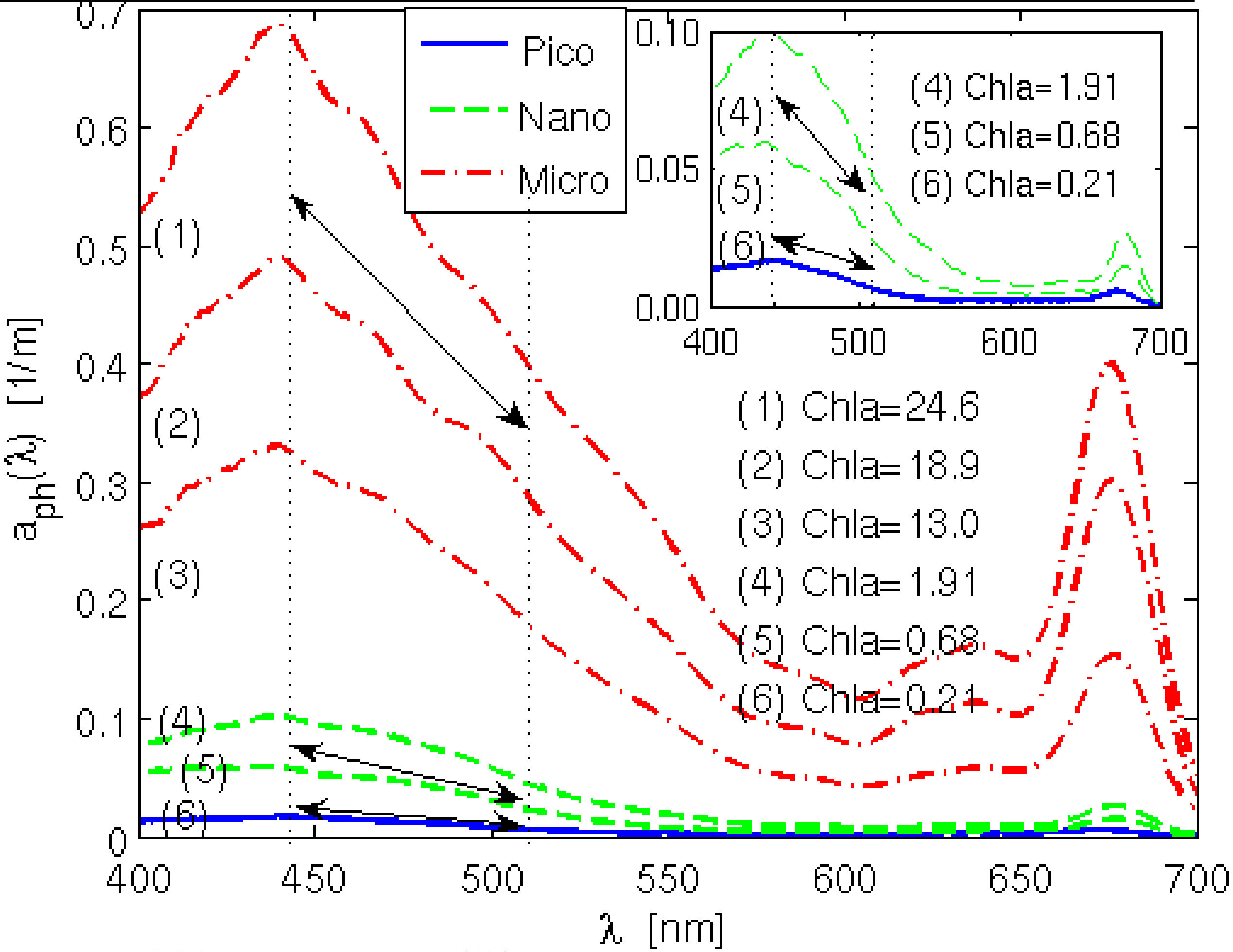


- Determination of primary productivity – direct route … ongoing
- **Determination of phytoplankton community structure**

Determination of phytoplankton community structure

Hirata et al., (2008), *Rem. Sens. Environ.*, **112**, 3153-3159

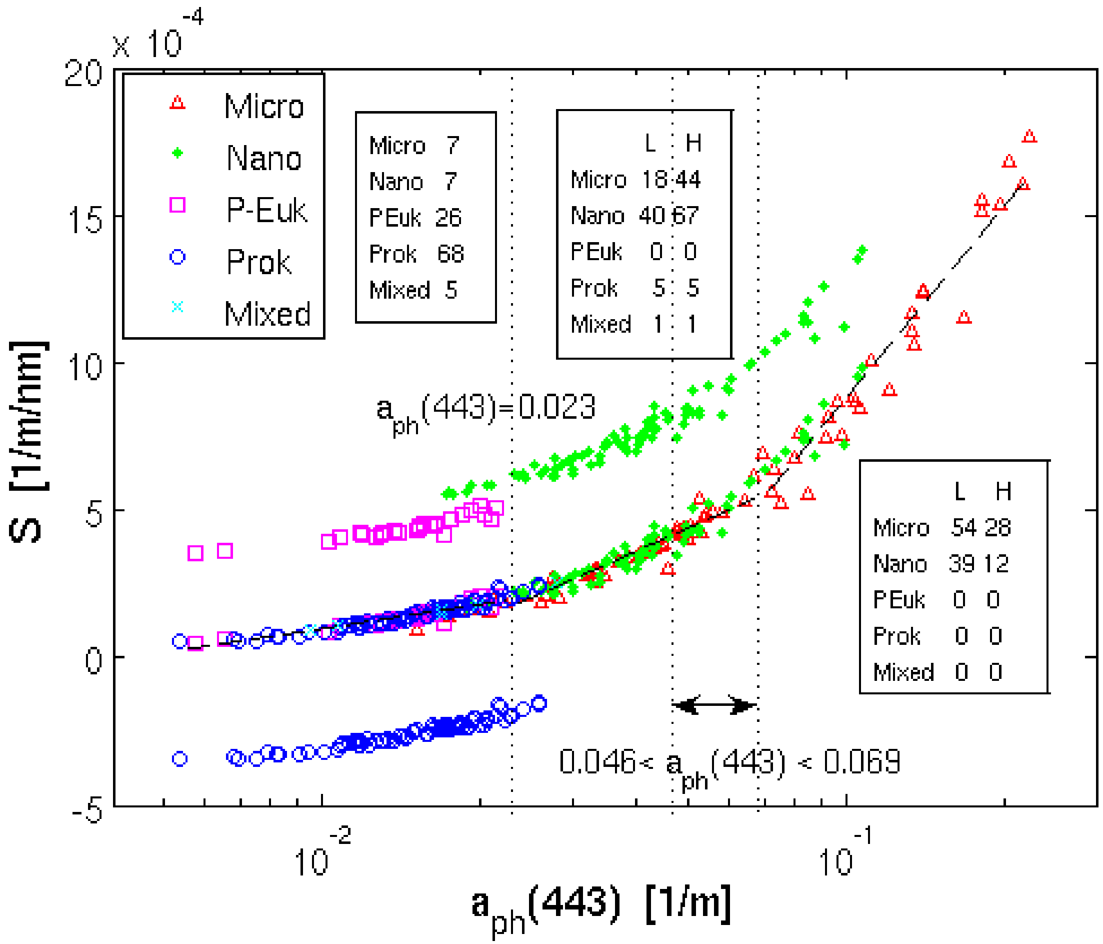
$a_{ph}(\lambda)$: range of Chla concentrations and size classes



Observations: **a_{ph}443** and **slope** (S) increase with increasing **chlorophyll** and **phytoplankton size class**.

Magnitude of a_{ph}443 is signature of phytoplankton community structure

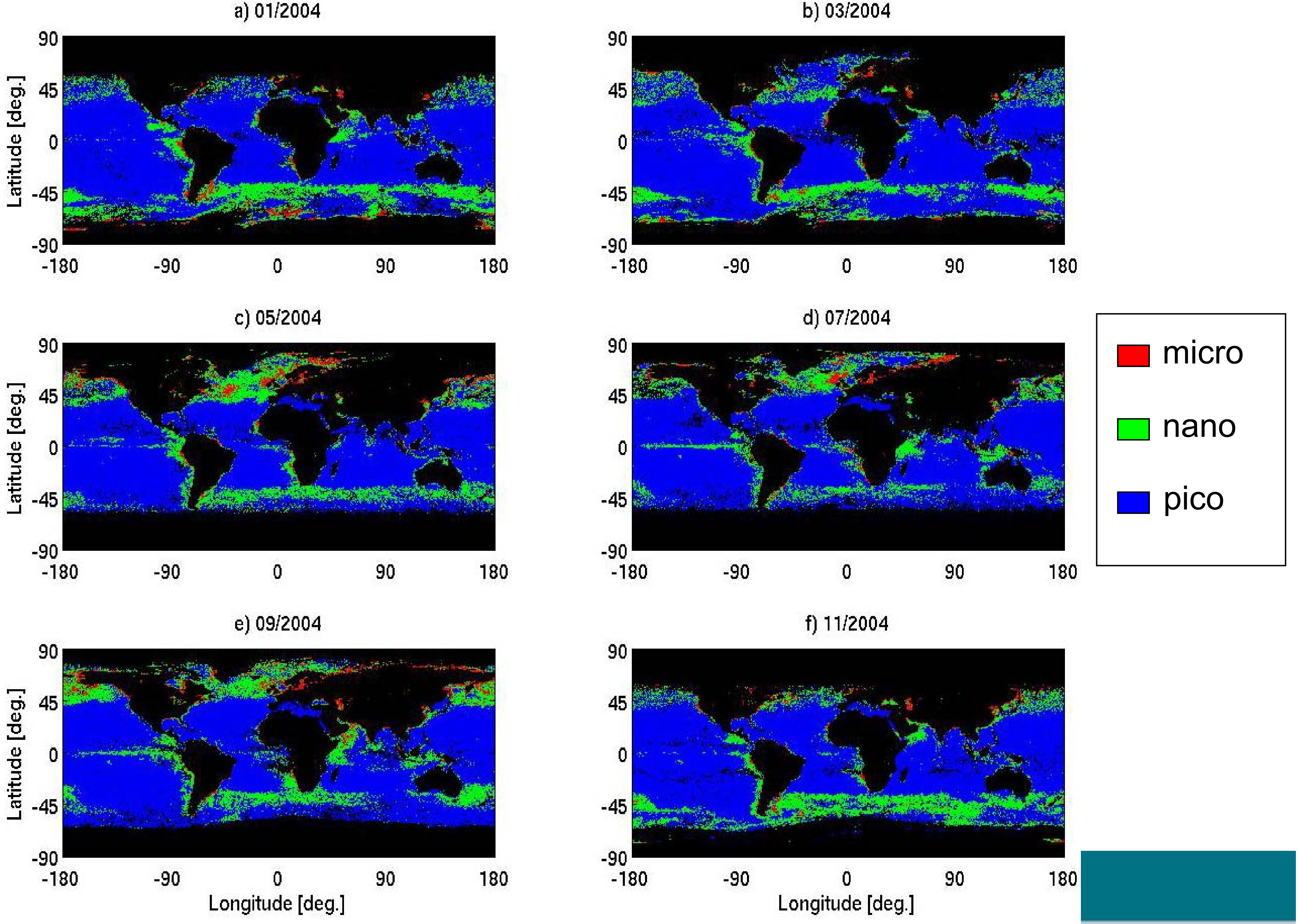
Determination of phytoplankton community structure



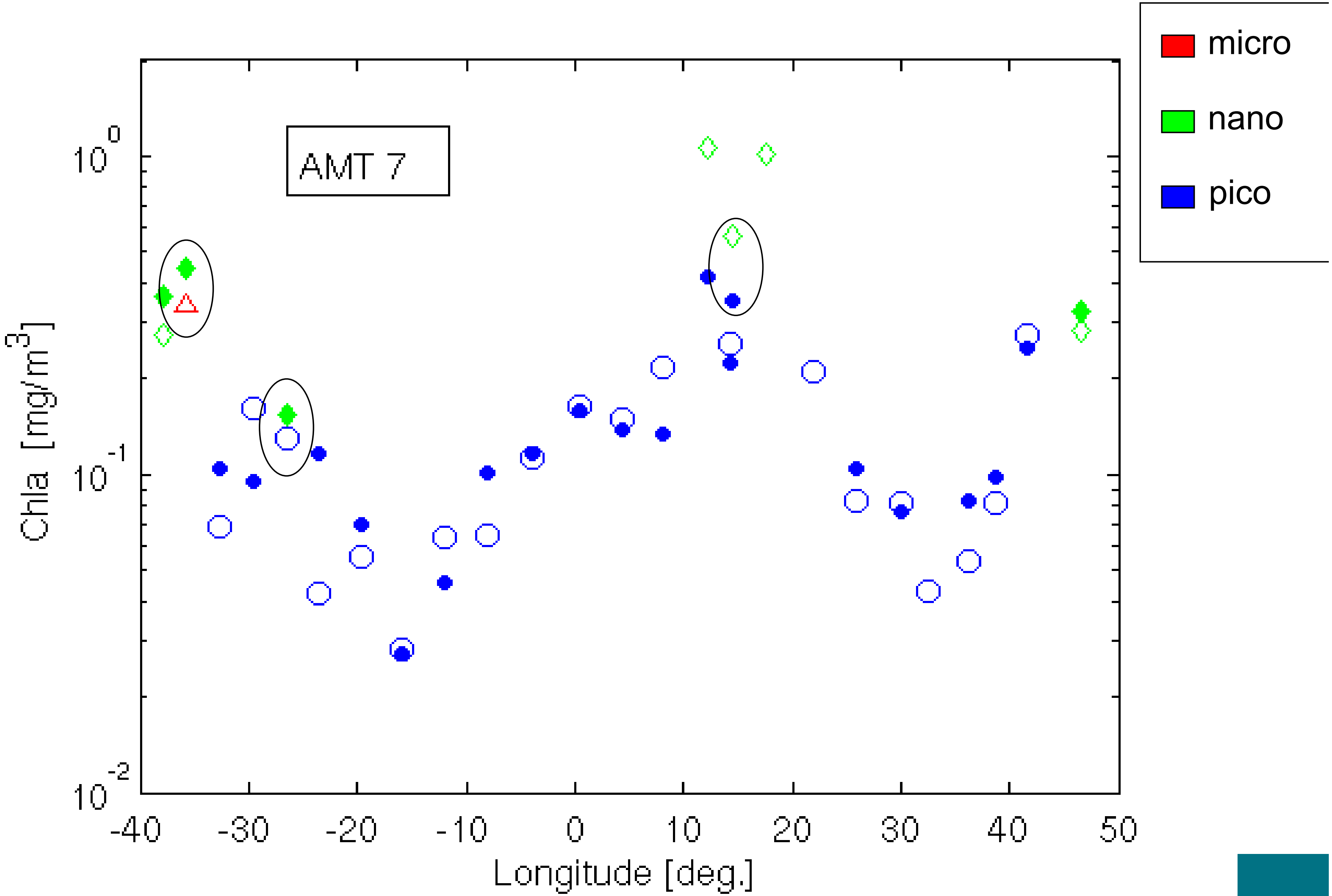
Well defined cut-offs:

- **aph443 < 0.023: dominated by prokaryotes and pico-eukaryotes**
- **aph443 > 0.069: dominated by microplankton**
- **intermediate region less defined – but nanoplankton in majority**

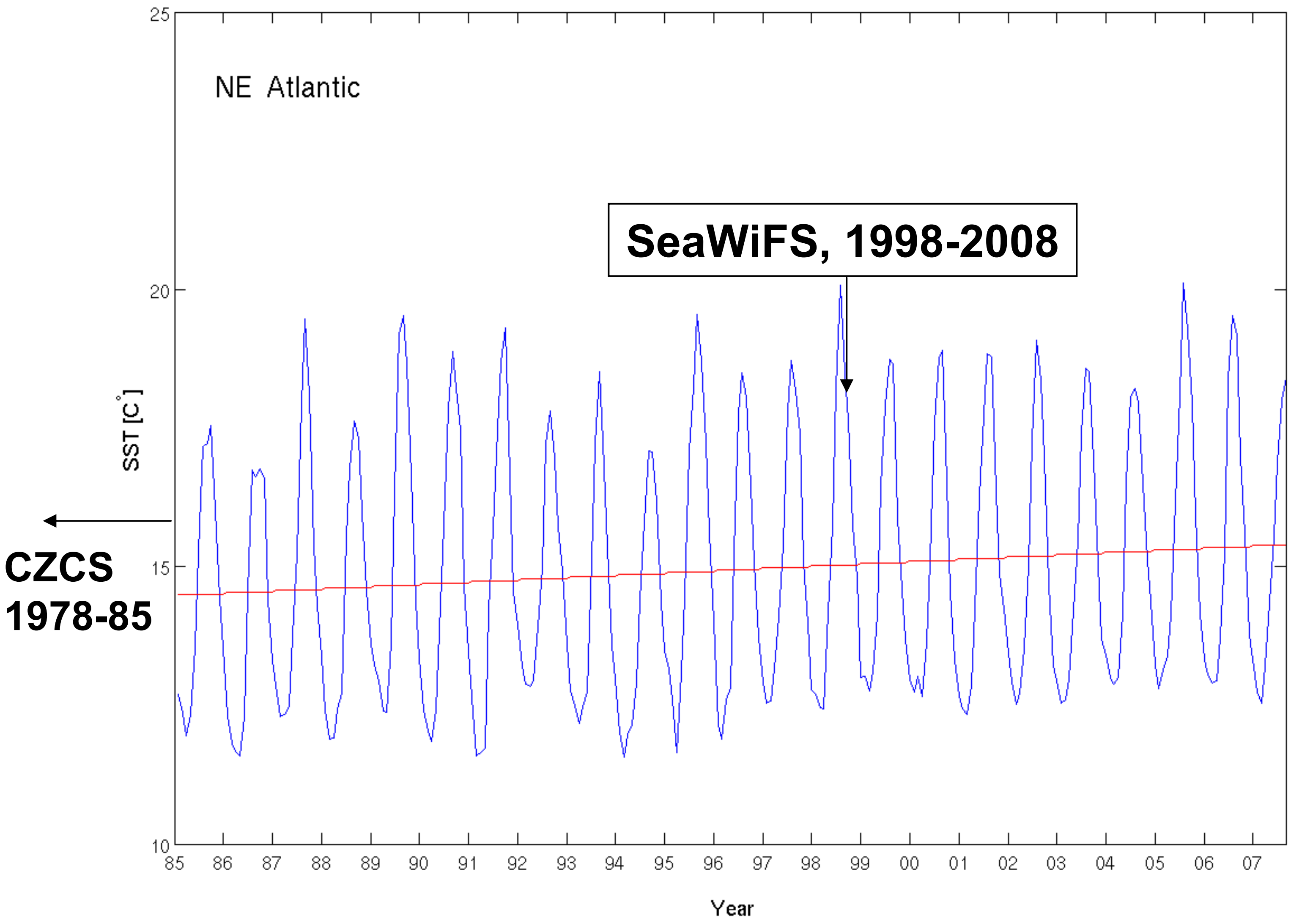
Determination of phytoplankton community structure



Determination of phytoplankton community structure: validation

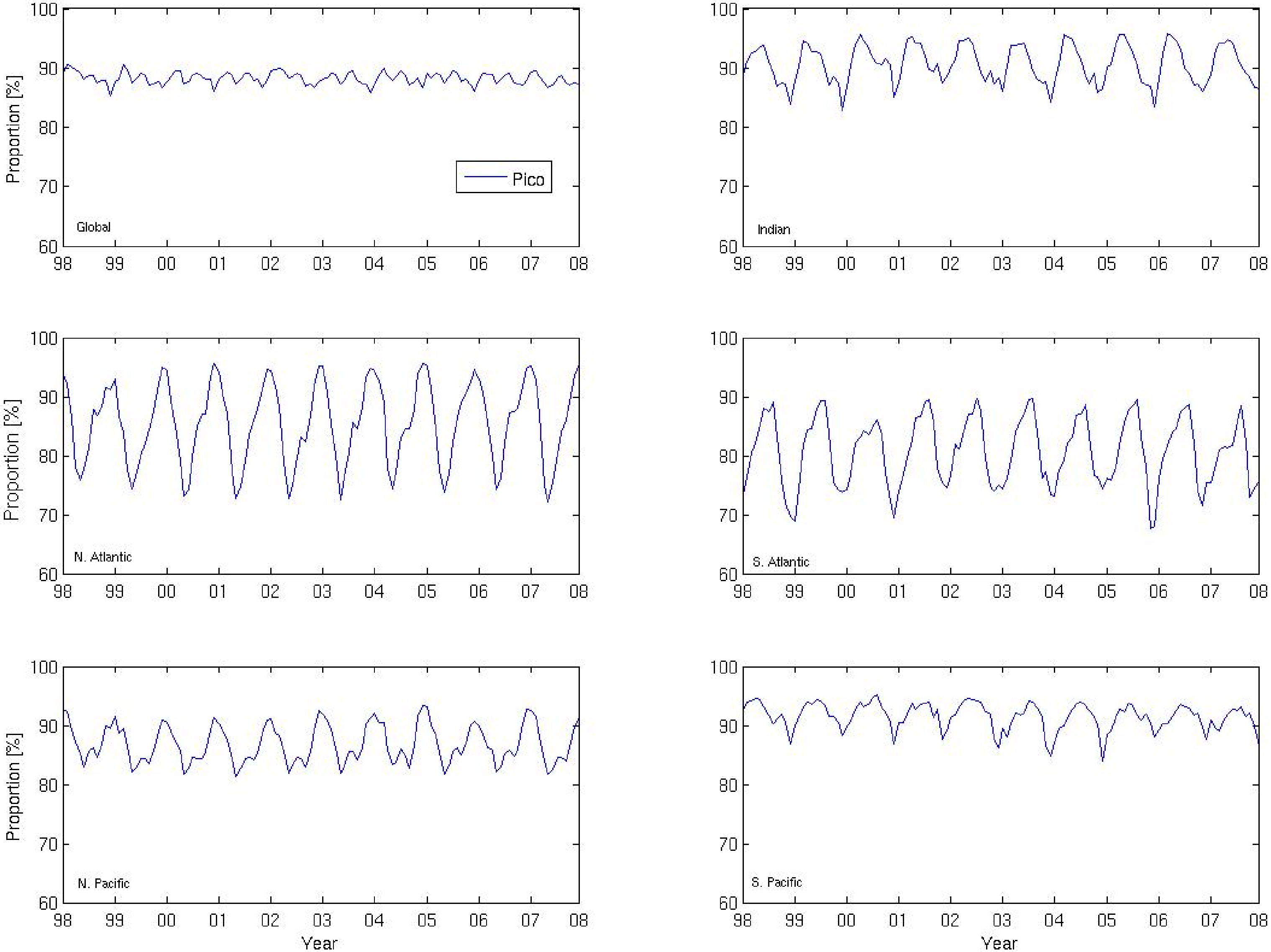


What are the (short) time-series showing?



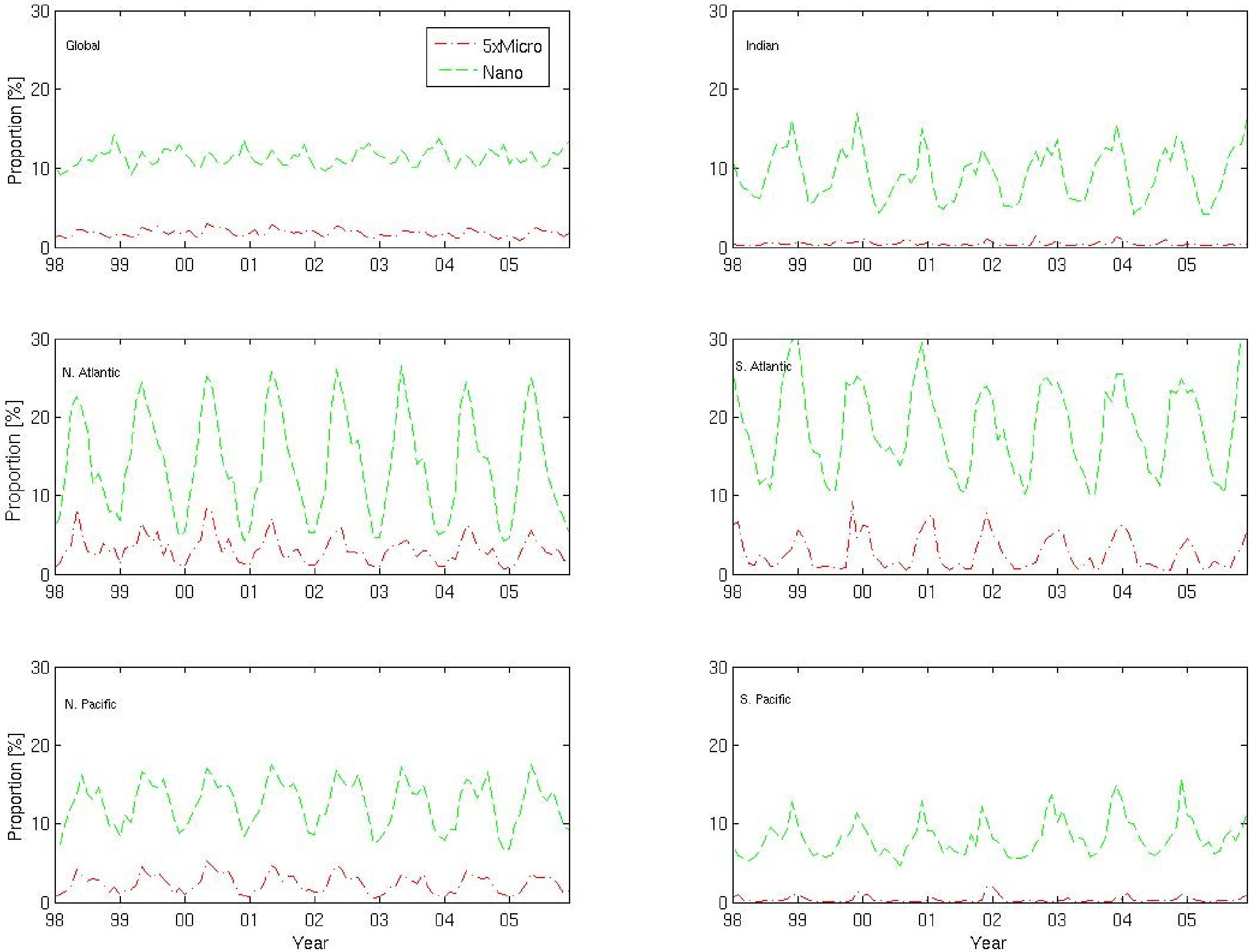
N. Atlantic average monthly temperature – AVHRR Pathfinder

What are the (short) time-series showing?



- **Pico plankton in oligotrophic gyres – little or no trend.**
- **More biomass or larger gyres, greater area of permanent stratification**

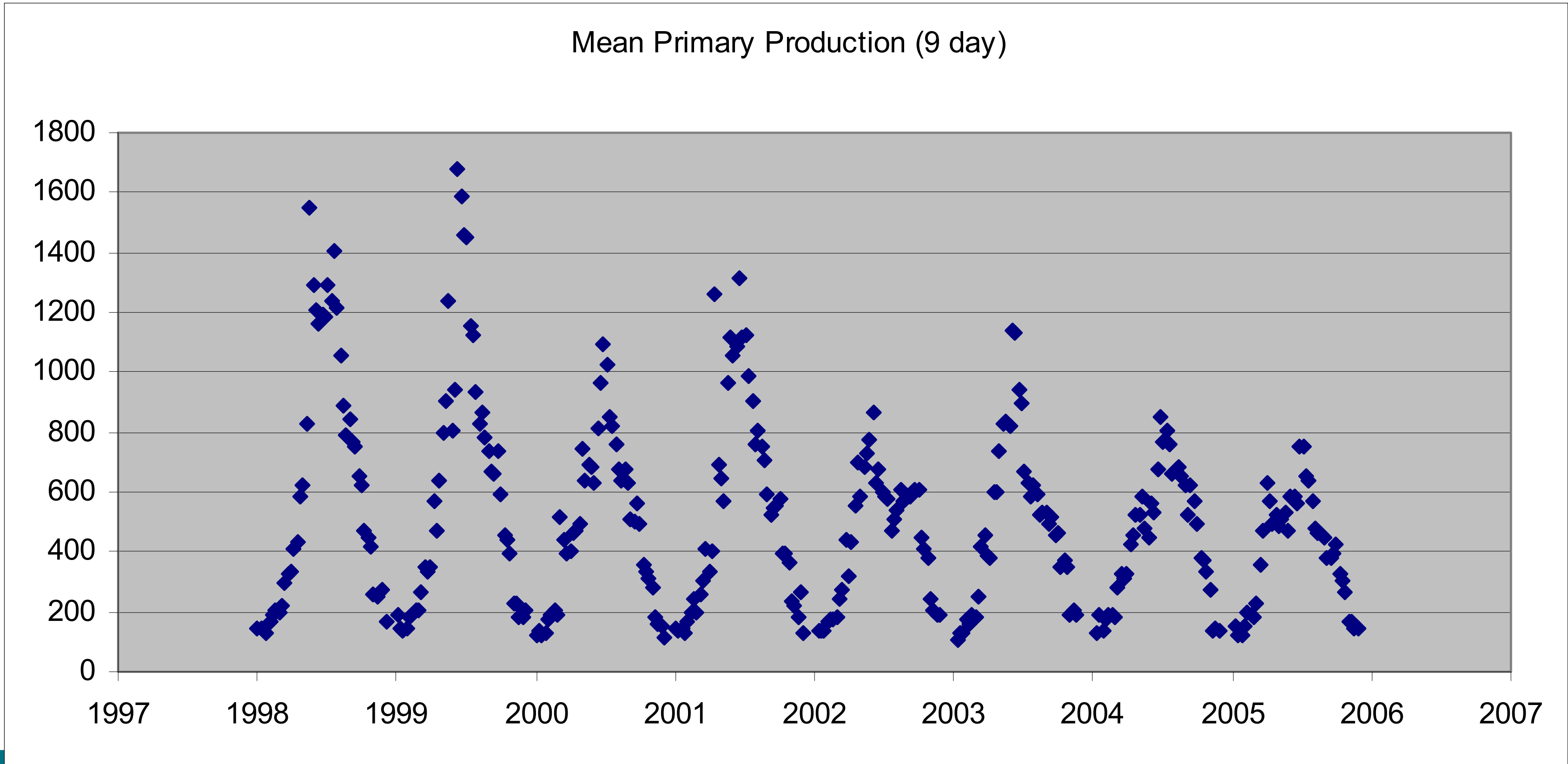
What are the (short) time-series showing?



- Nanoplankton and microplankton (x5); N. Atlantic - downward trend??

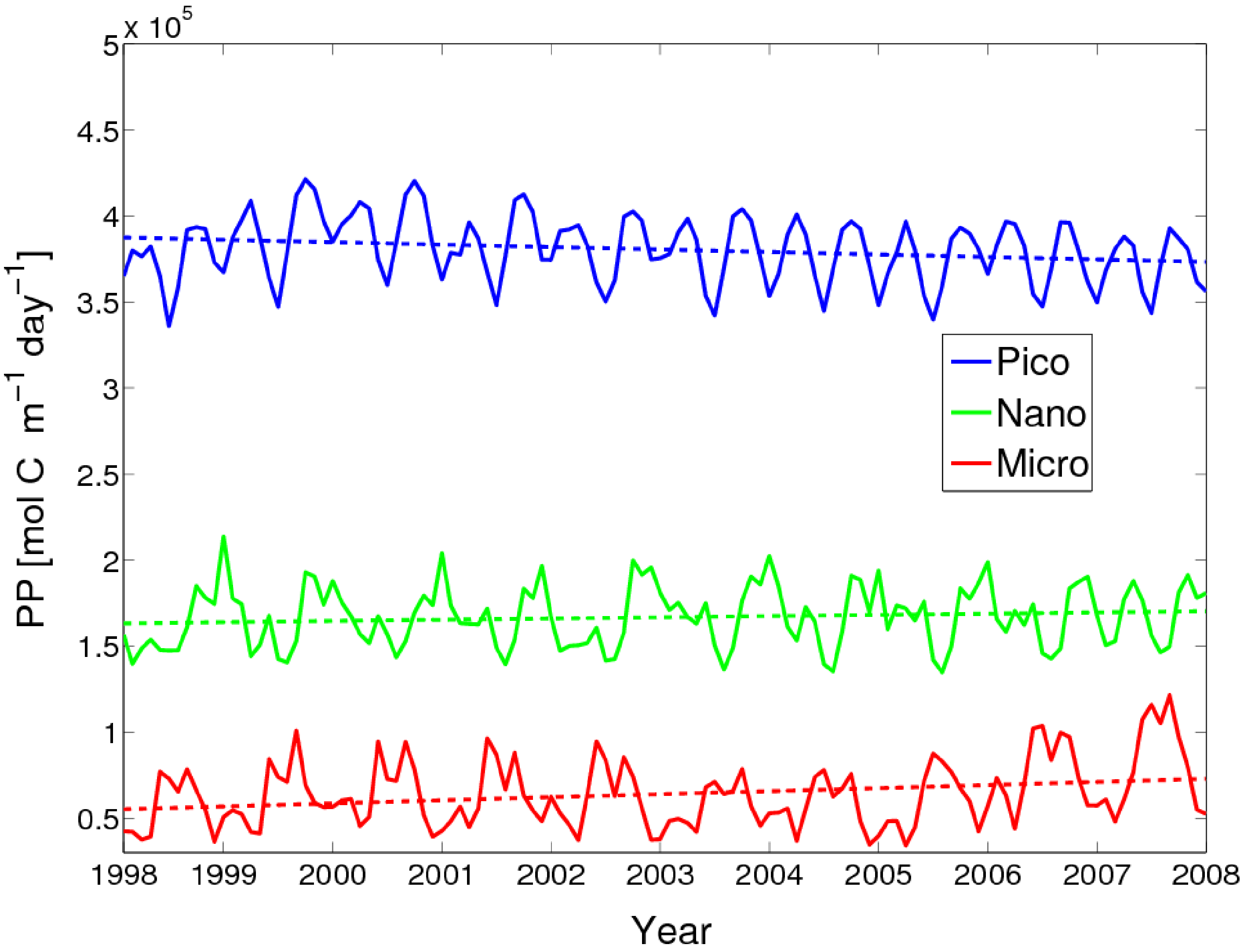
What are the (short) time-series showing?

- Behrenfeld et al., (2006) **decrease in global primary production** – attributed to expansion of stratified regions (gyres);
- Porcupine Abyssal Plain (PAP) site: Primary Production derived from satellite data (Smyth et al., 2005). **Marked reduction** – especially at peak.



What are the (short) time-series showing?

- Primary Production: derived using IOP model via Marra (2007); use size classes to give size discriminant PP.



Conclusions

- Presented a powerful method for determining the primary measurands of ocean colour from space;
- Application: data assimilation, PCS, primary production;
- Presented method for determining PCS from space;
- Possible decrease in global primary production;
- Reduction in smaller phytoplankton biomass and increase in micro plankton.