Using AQUA MODIS PIC concentration to determine coccolithophore bloom phenology

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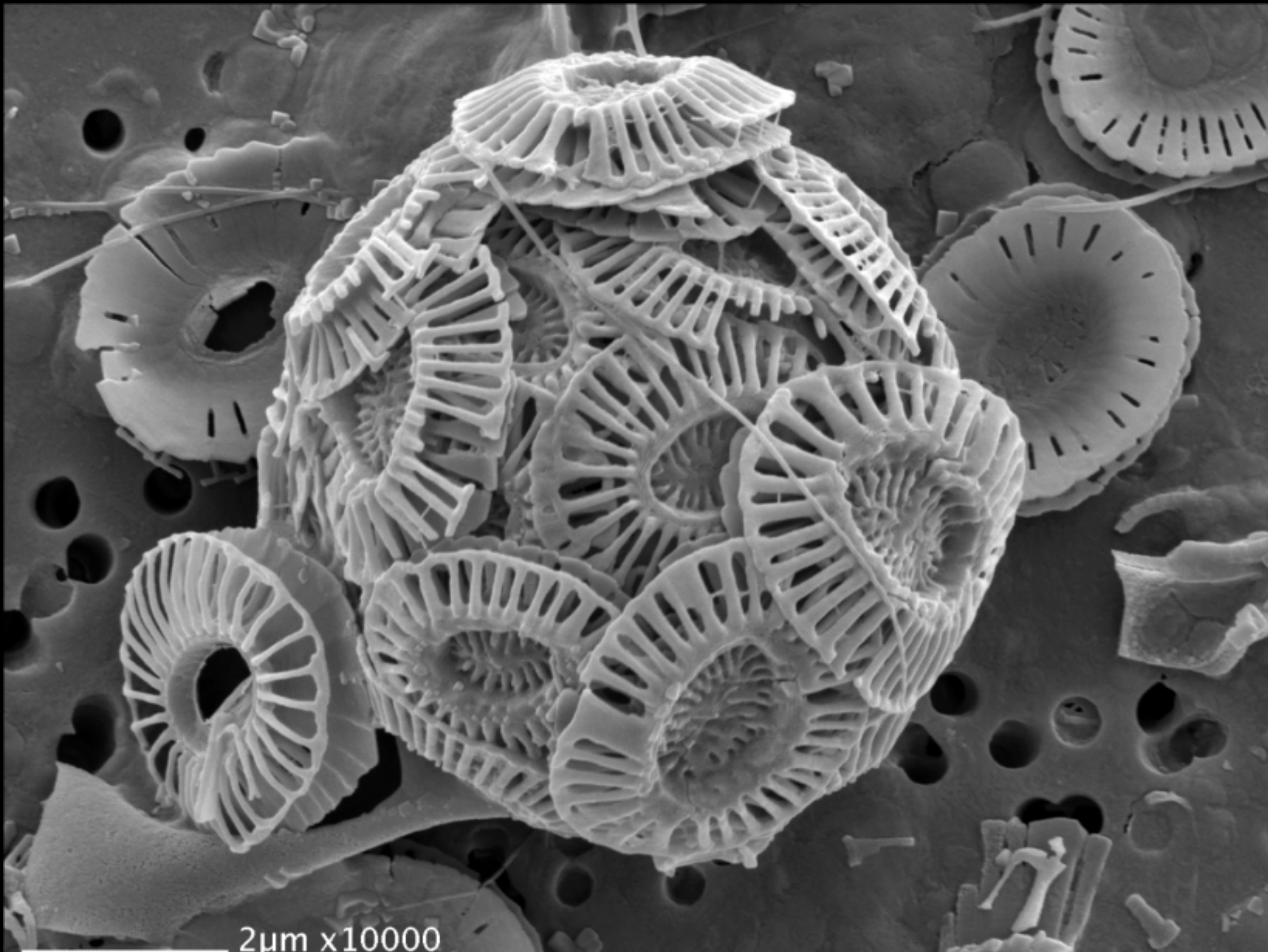


Image: A Poulton, NOCS

Coccolithophore blooms from space

http://earthobservatory.nasa.gov/

http://visibleearth.nasa.gov

Why are we interested in PIC?

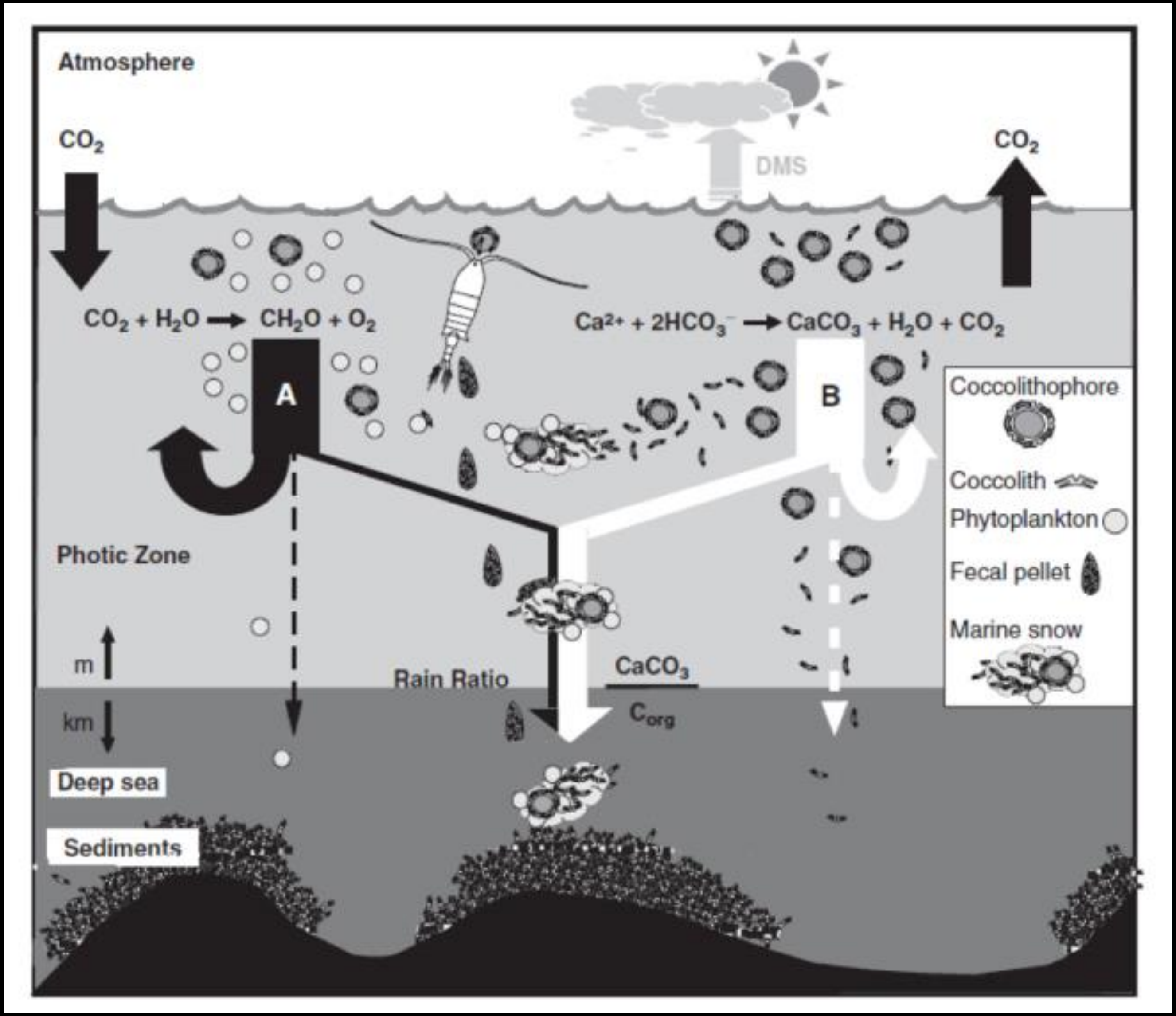


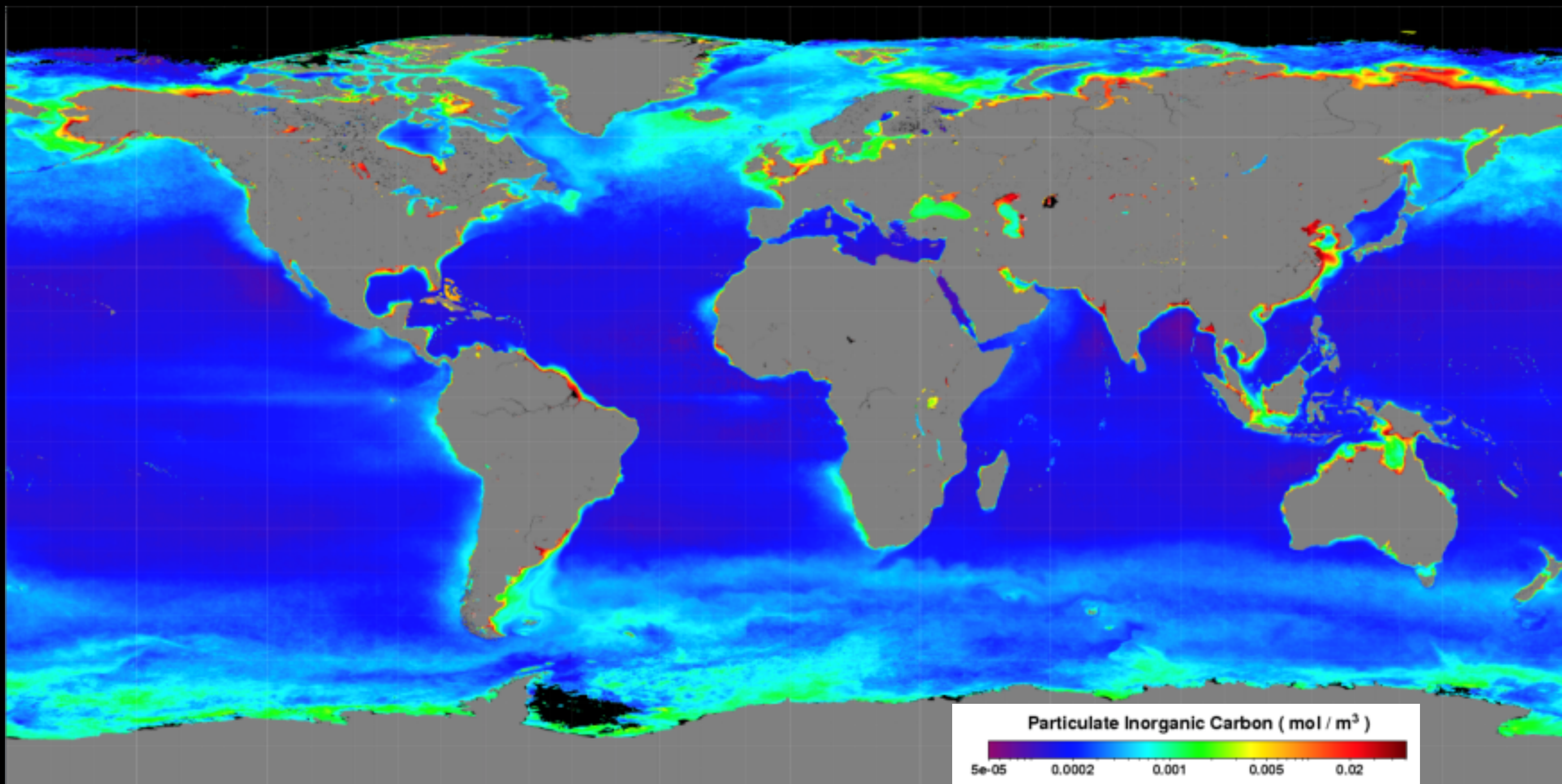
Image adapted from de Vargas et al., 2007

The merged PIC algorithm

Balch et al., 2005 - Two-band algorithm. Uses LUT generated from forward modelling of the optical properties of chlorophyll-a and PIC. Good in relatively low PIC concentrations.

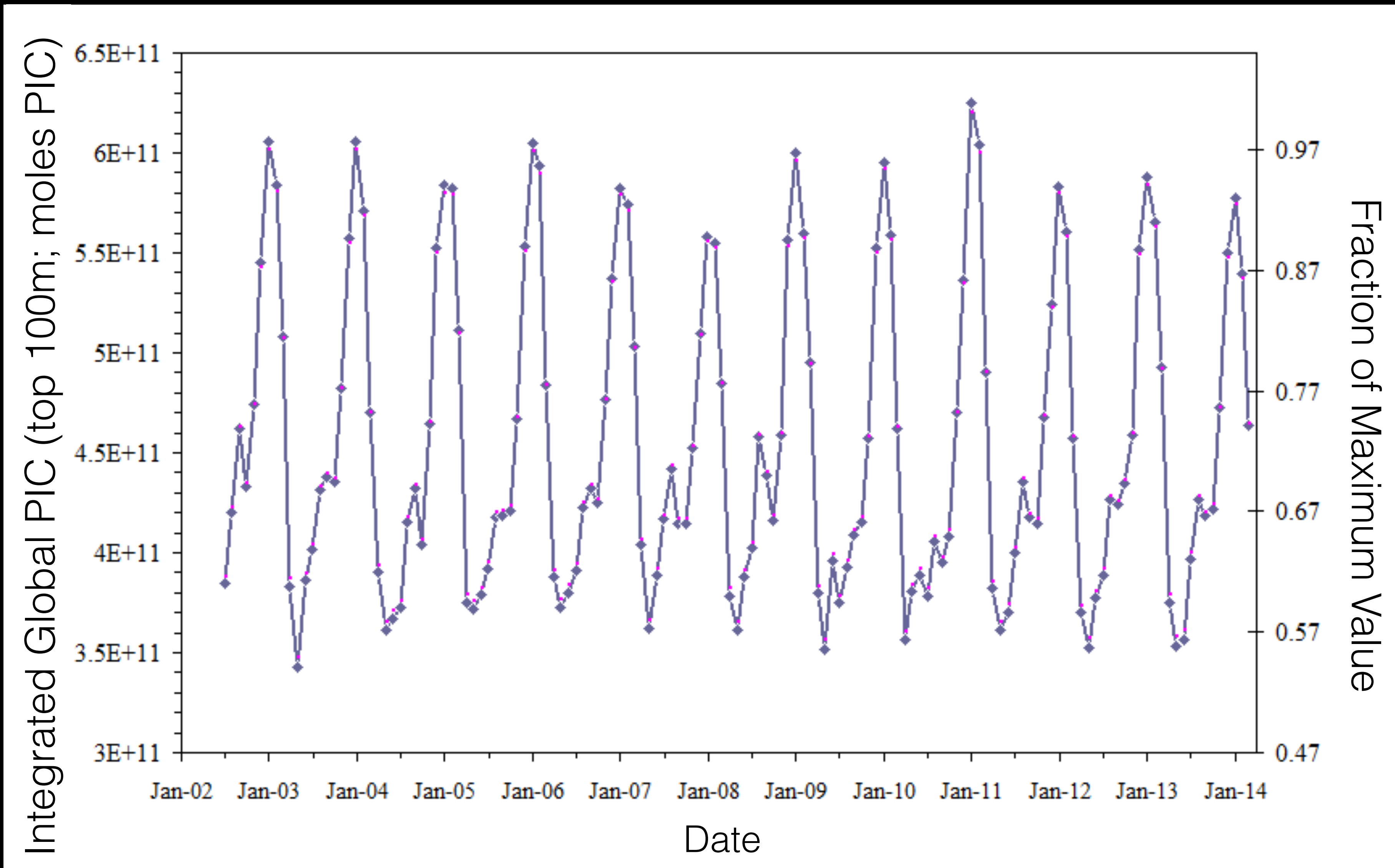
Gordon et al., 2001 - Three-band algorithm. Uses 3 NIR wavebands to estimate atmospheric effects and backscatter from coccolithophores. Good in relatively high PIC concentrations.

Global PIC

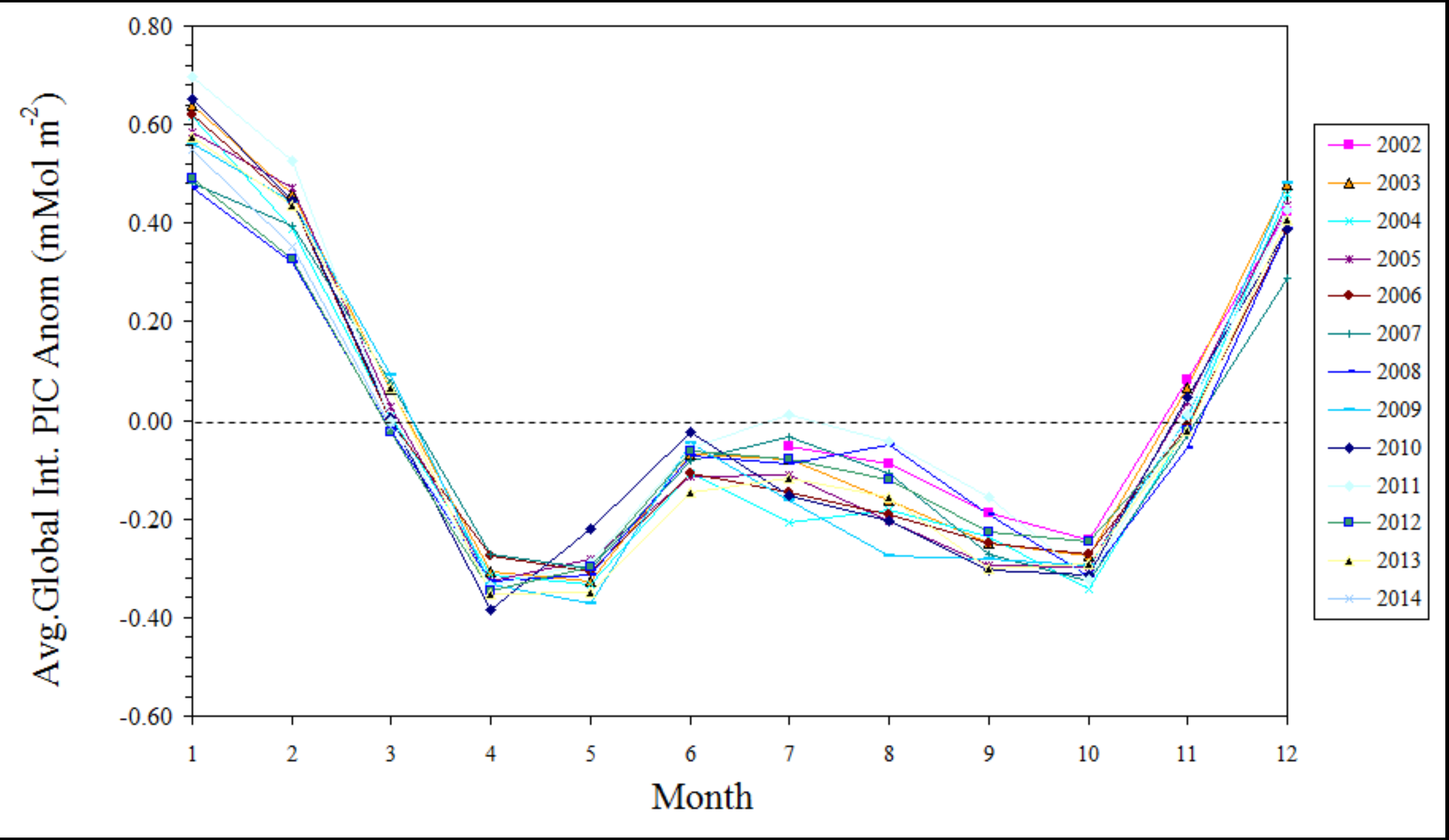


Mission composite PIC from http://oceancolor.gsfc.nasa.gov

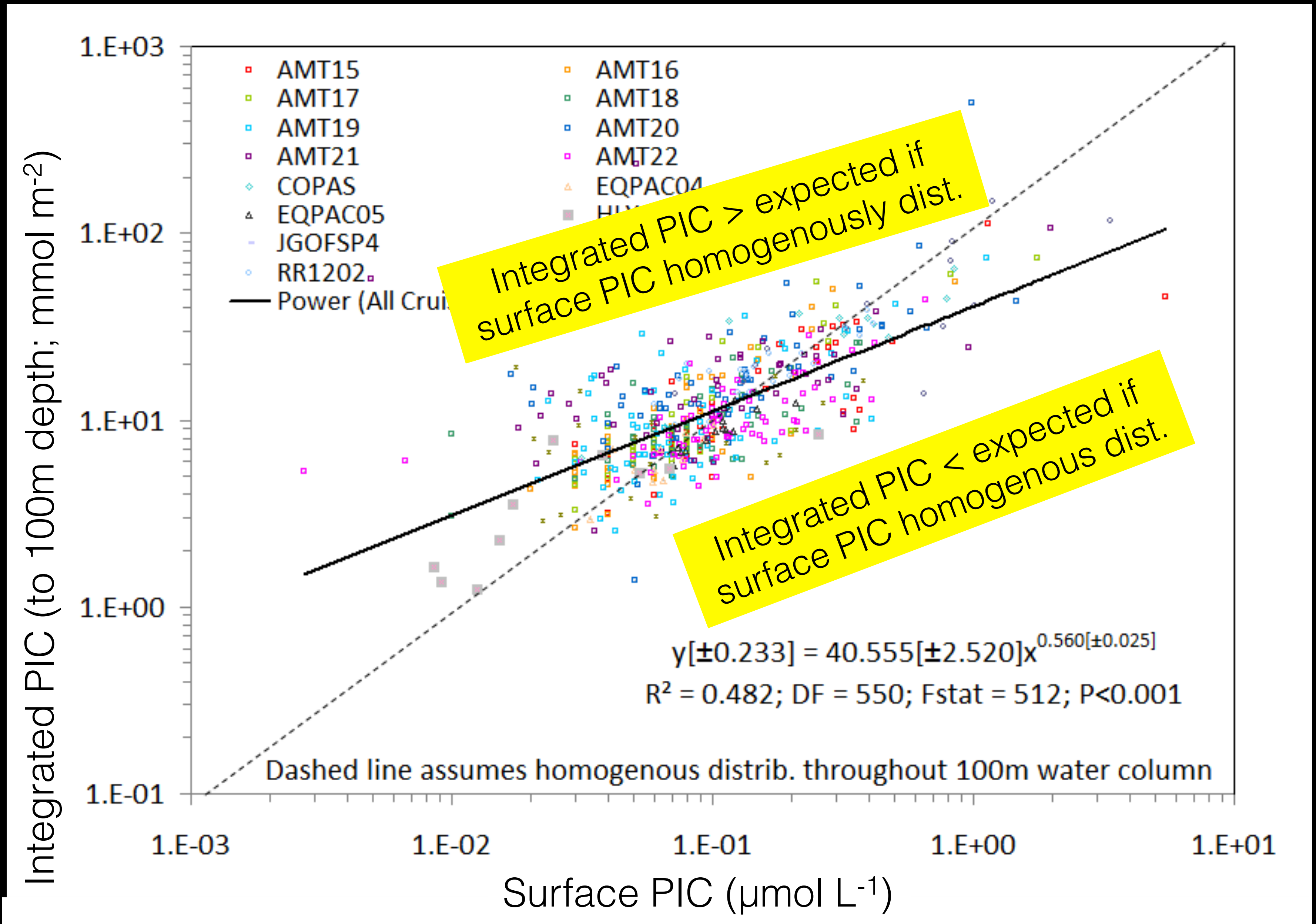
PIC Global Time Series (MODIS-Aqua)
Mission record- Highest PIC during austral summer



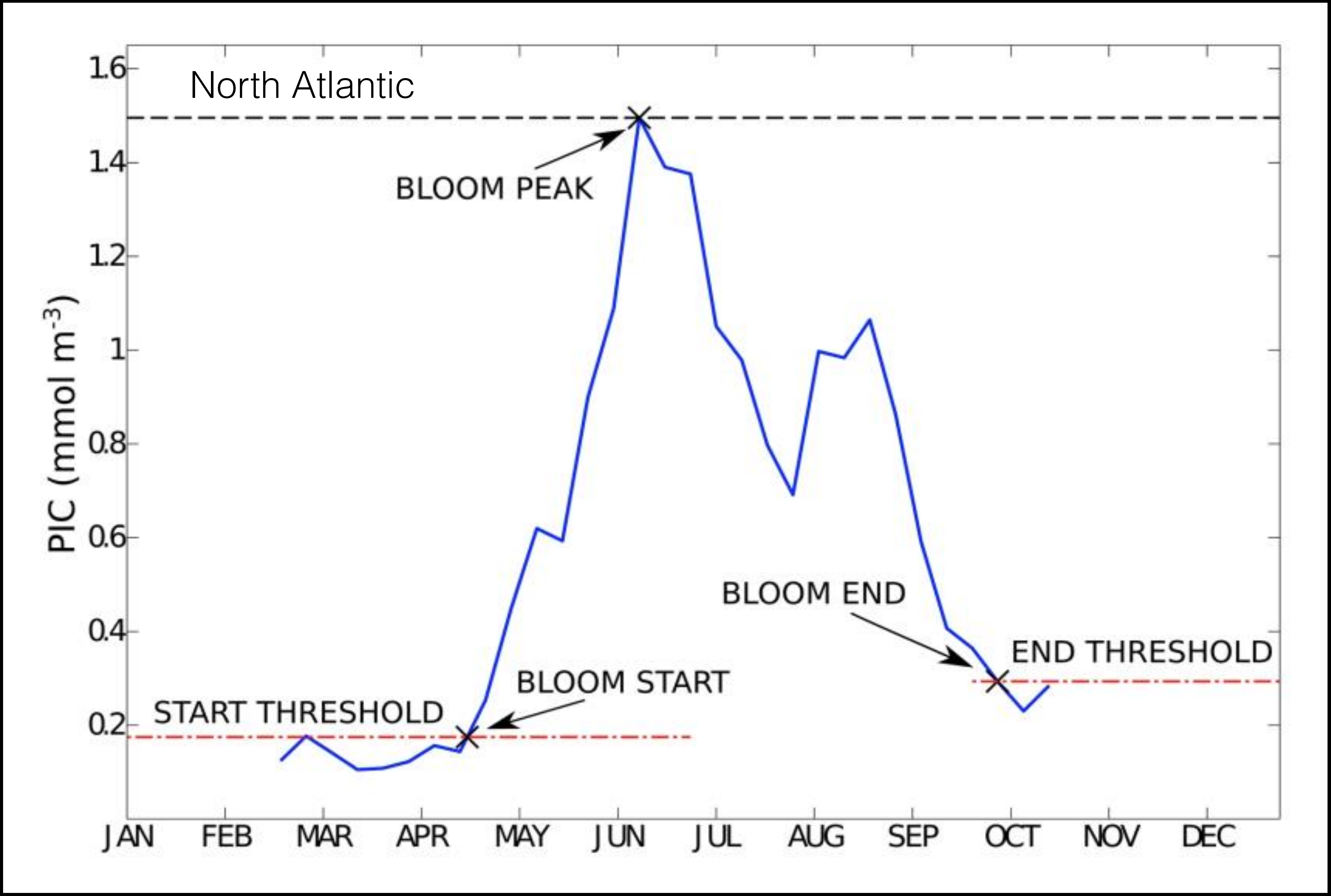
PIC Global Time Series (MODIS-Aqua)
Annual coccolithophore phenology



Relating surface to integrated PIC

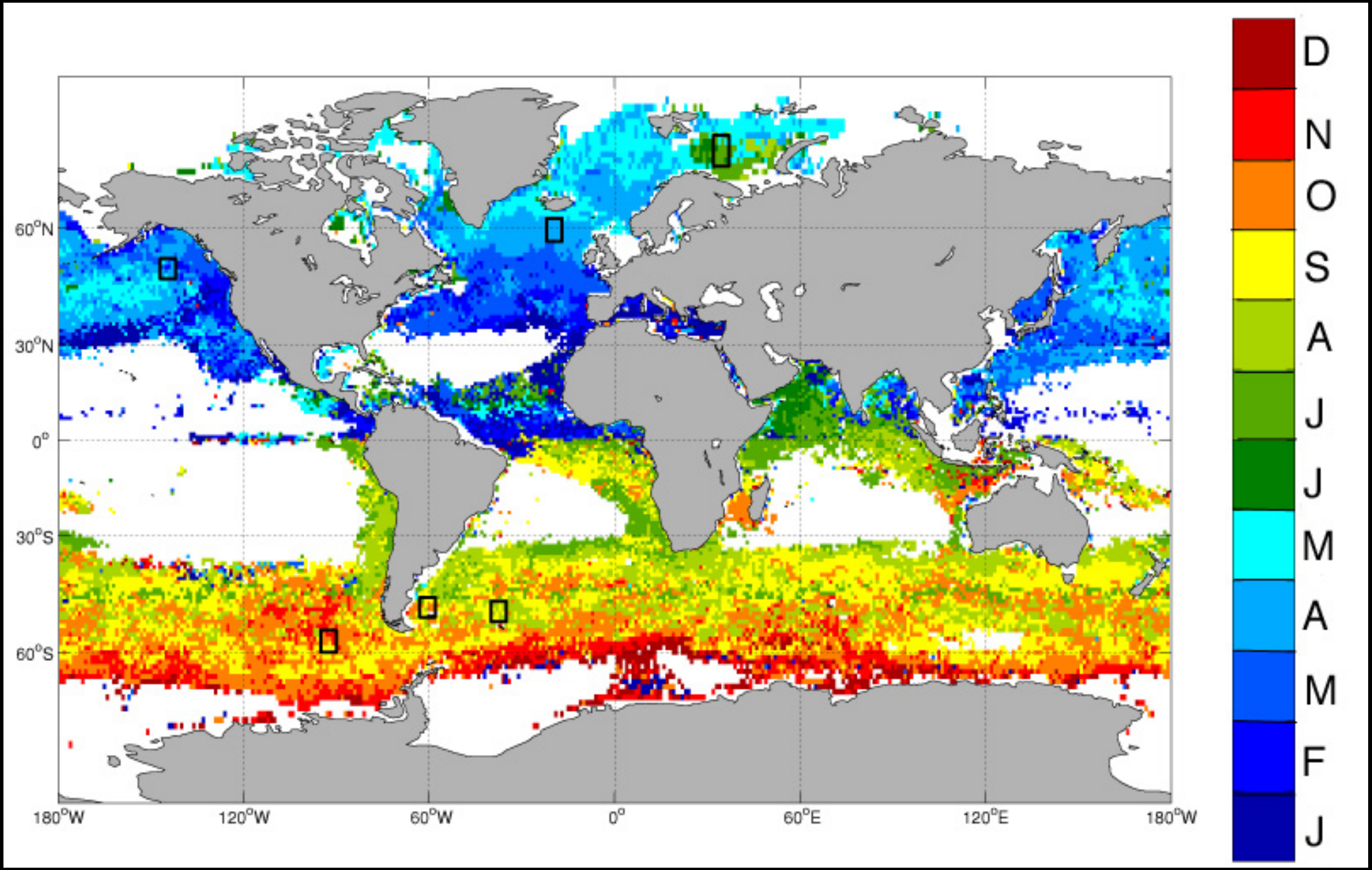


Coccolithophore bloom phenology



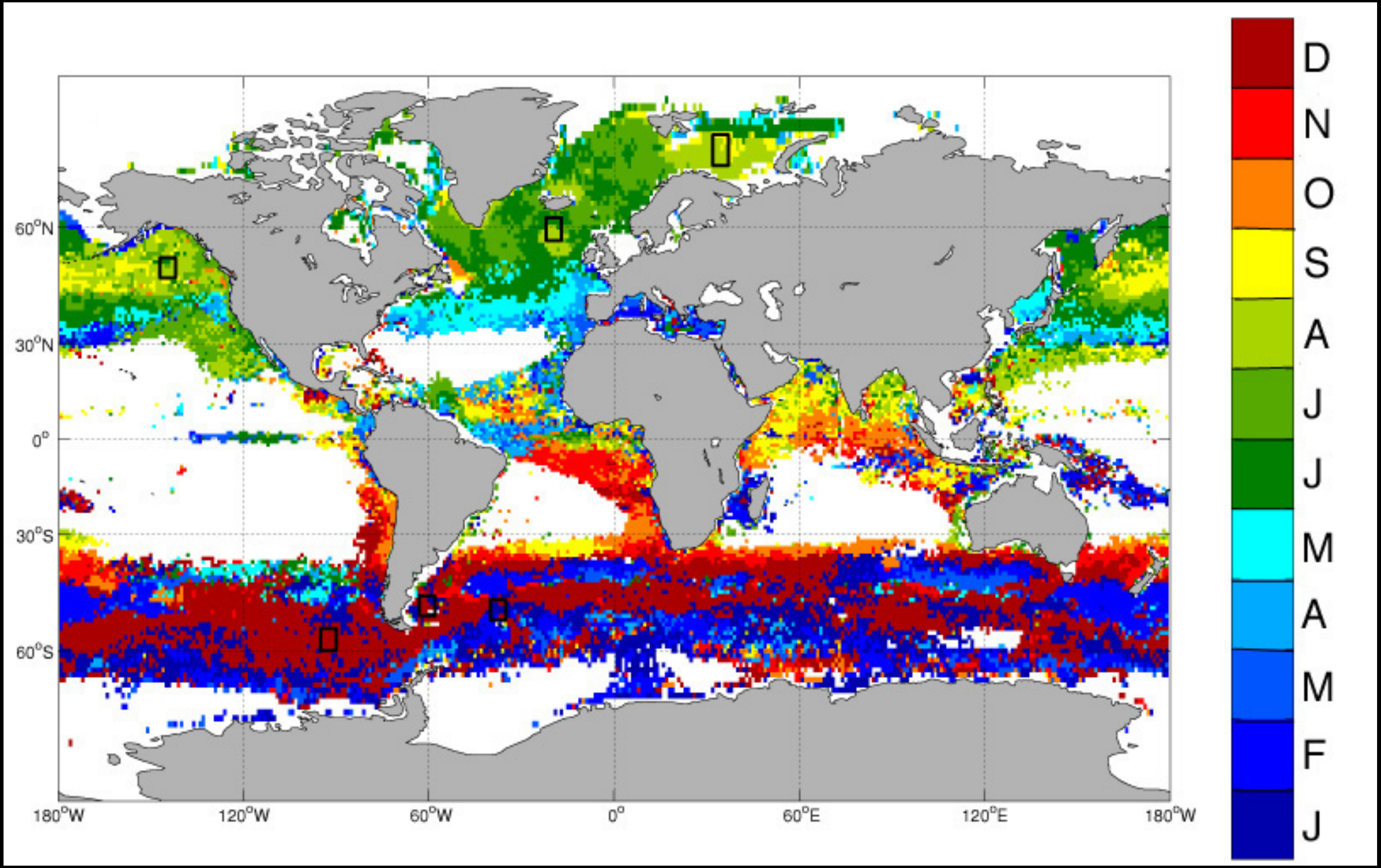
Hopkins et al., 2015, GBC

Bloom start date



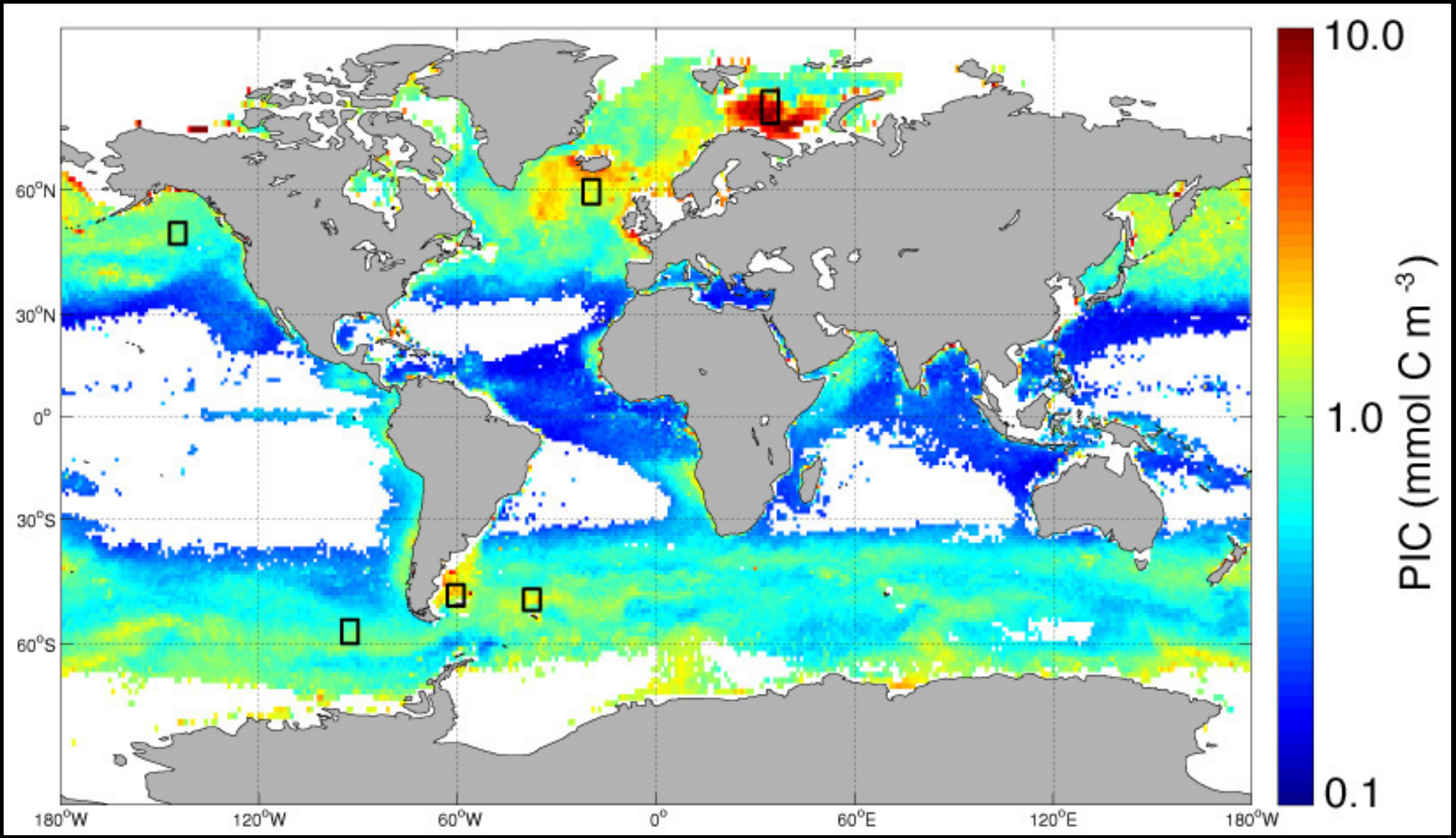
Hopkins et al., 2015, GBC

Bloom peak date



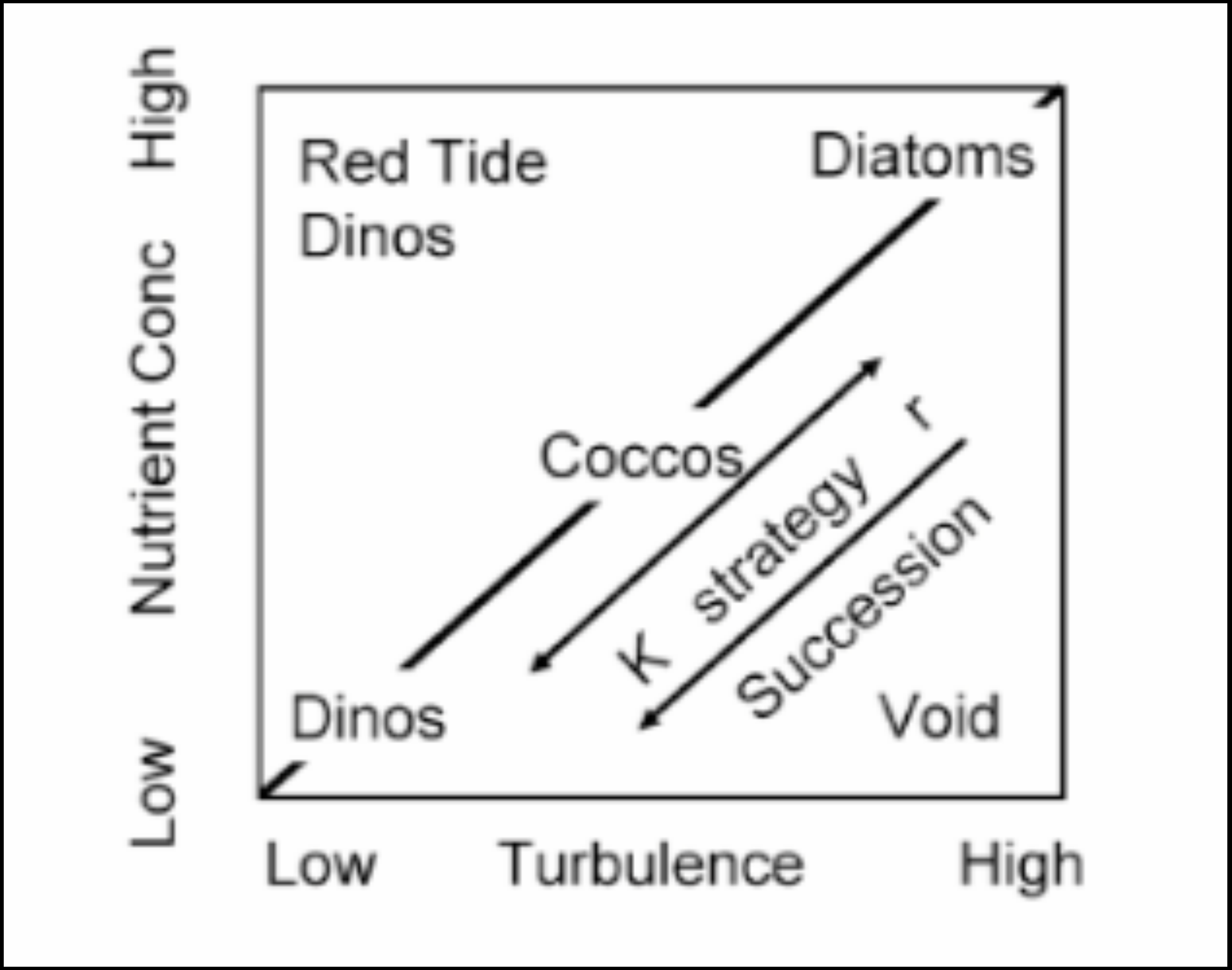
Hopkins et al., 2015, GBC

Bloom peak concentration



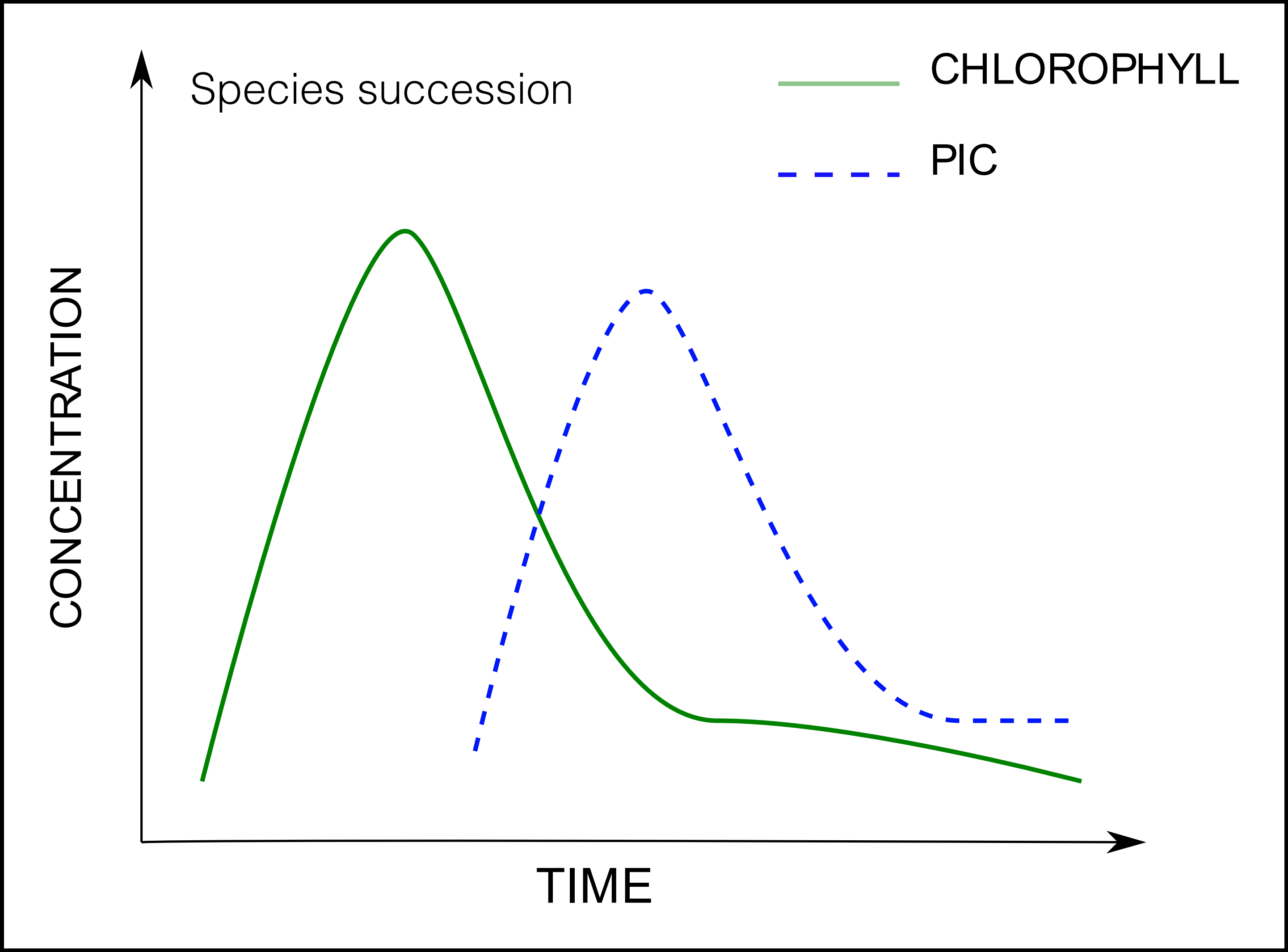
Hopkins et al., 2015, GBC

Phytoplankton succession

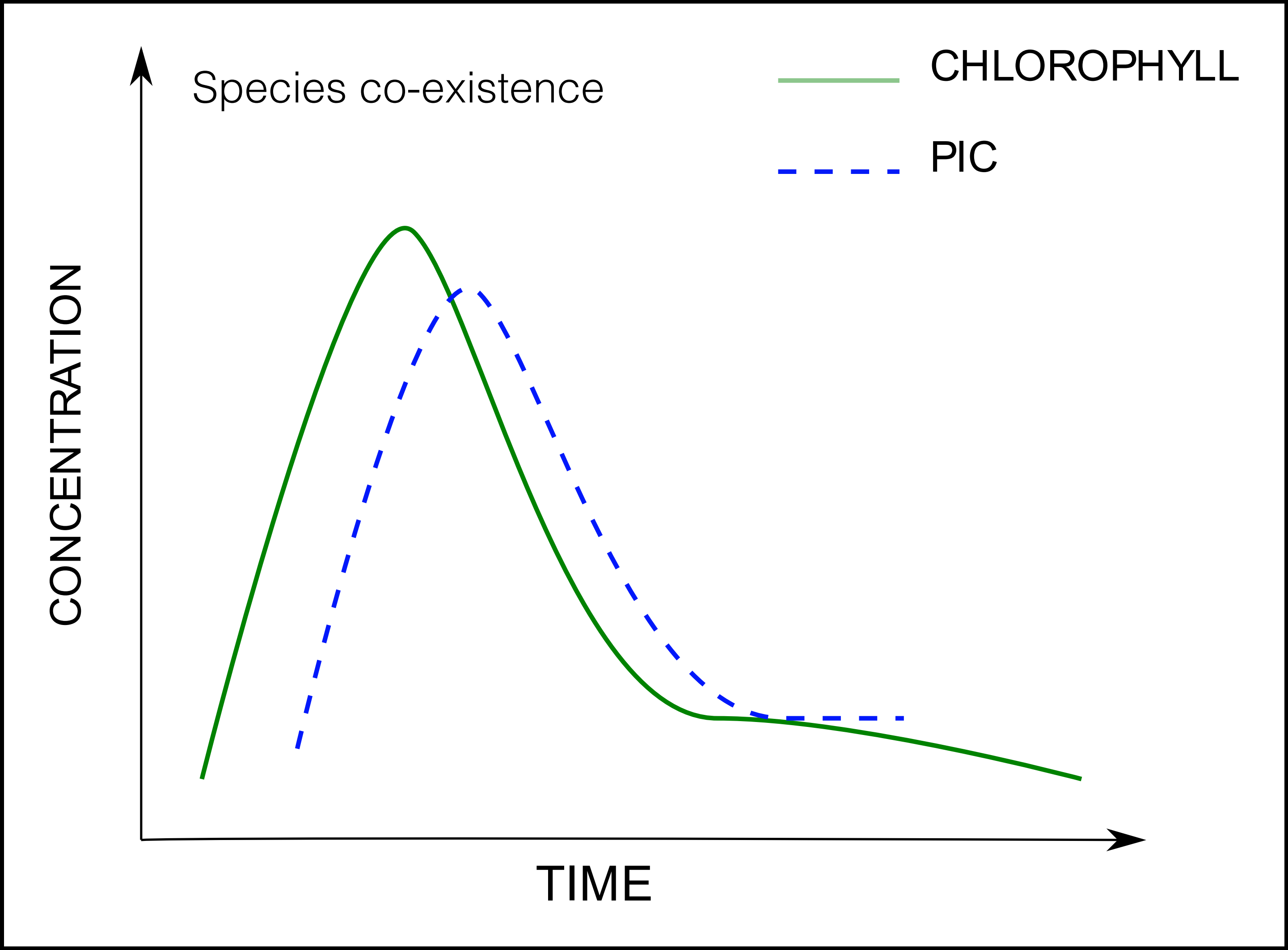


Margalef, Oceanologica acta.,1978 (Image: Balch, 2004)

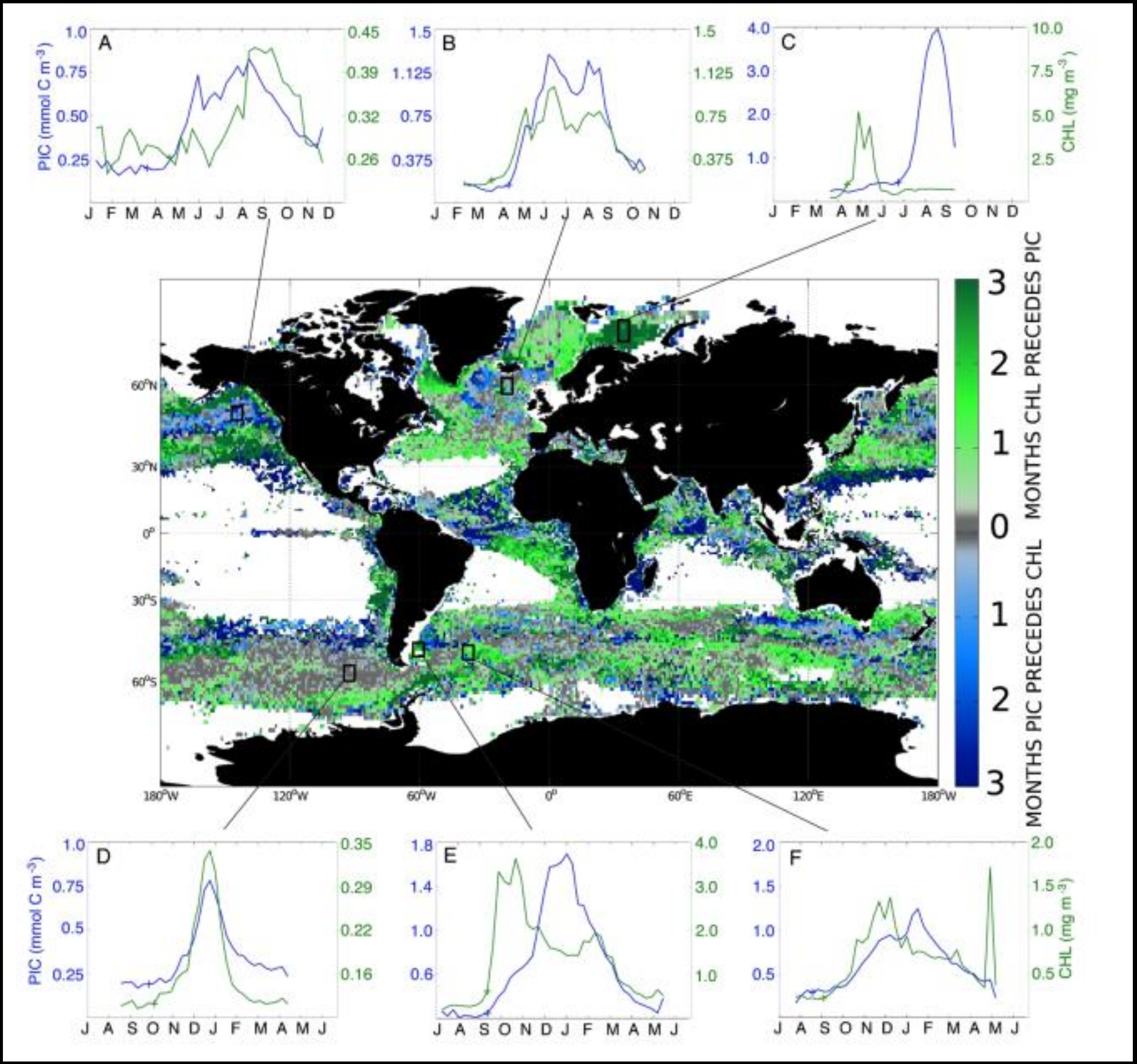
Succession in peaks



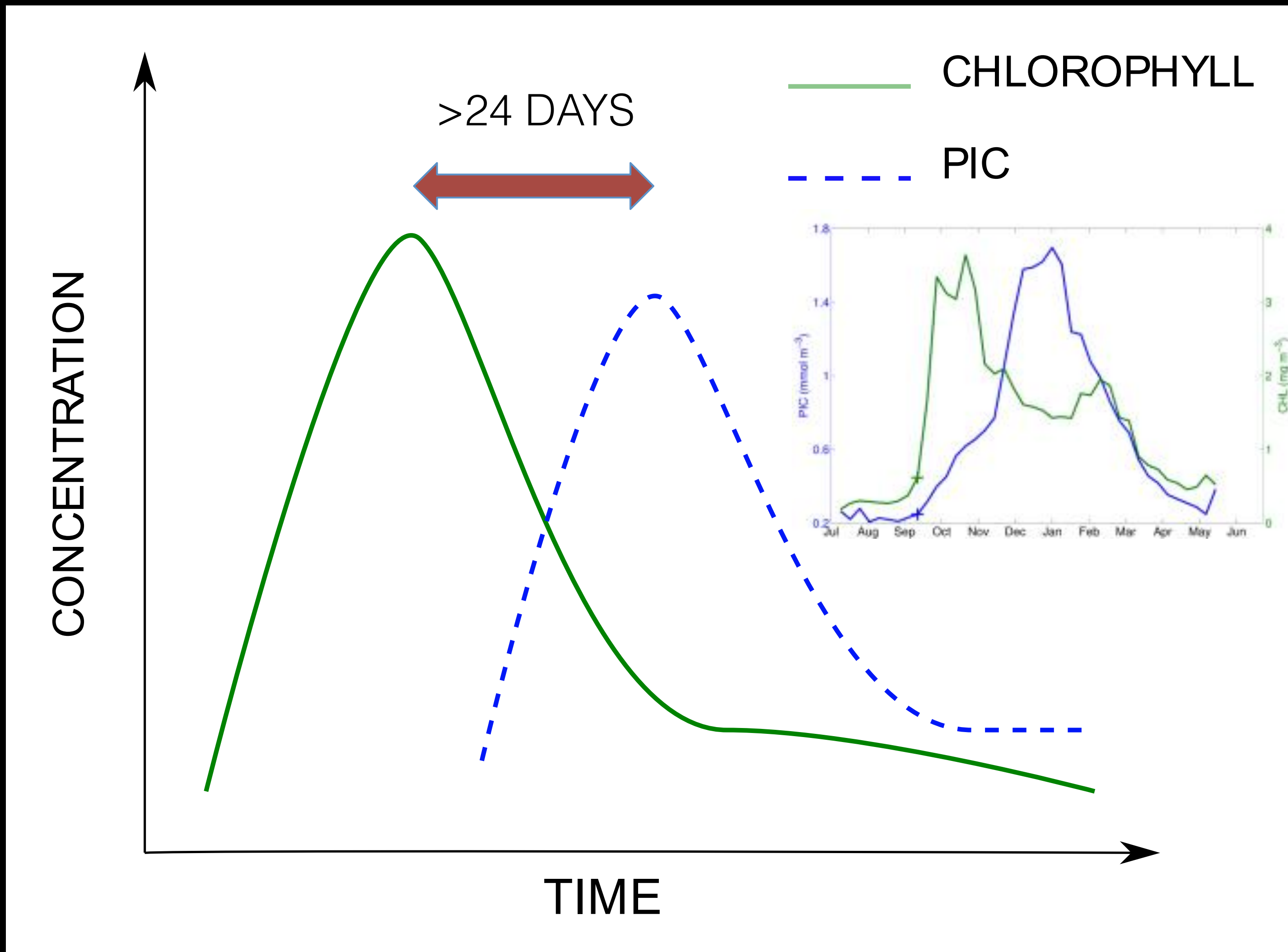
Co-occurrence of peaks



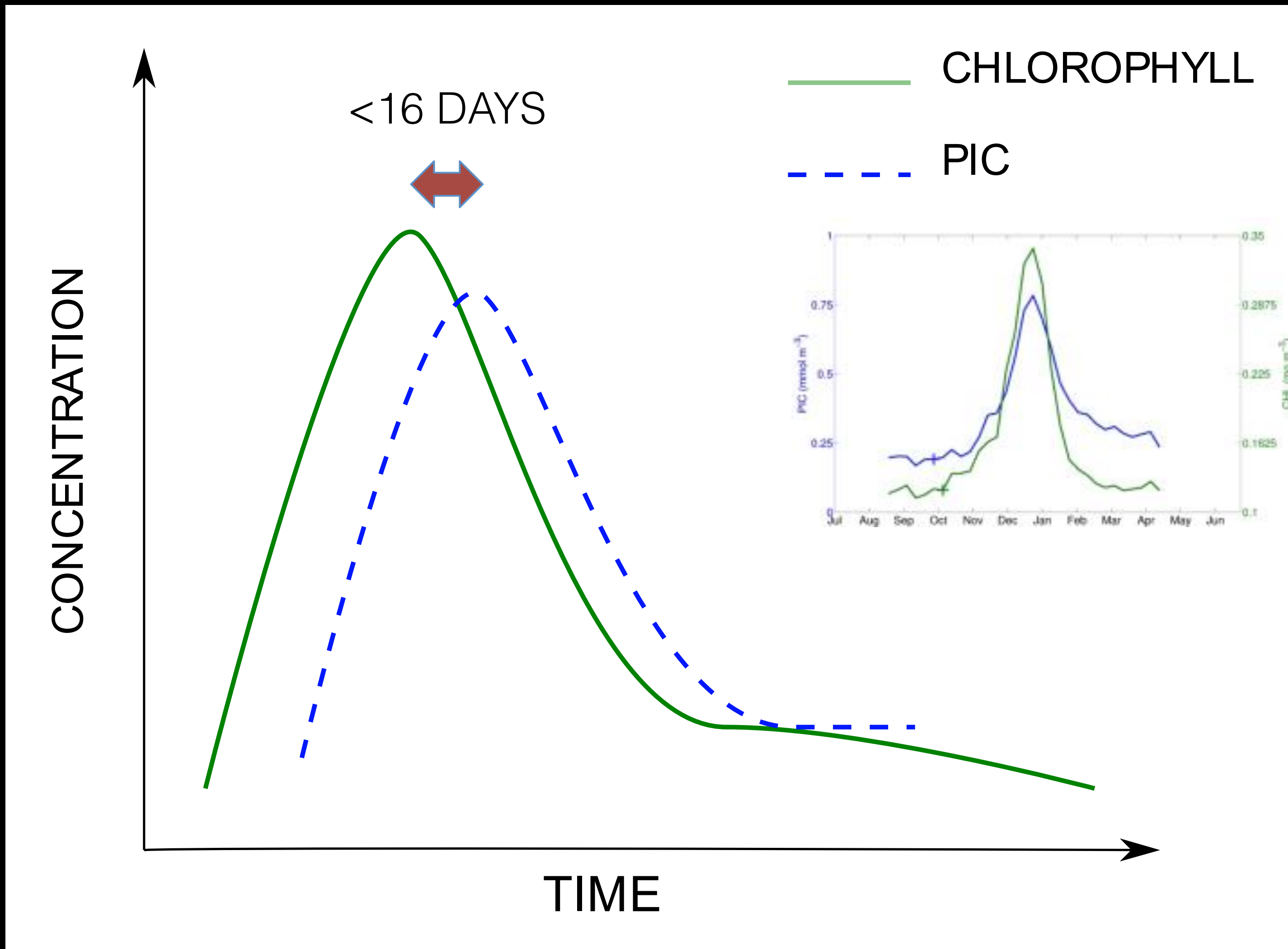
PIC and chlorophyll time-series



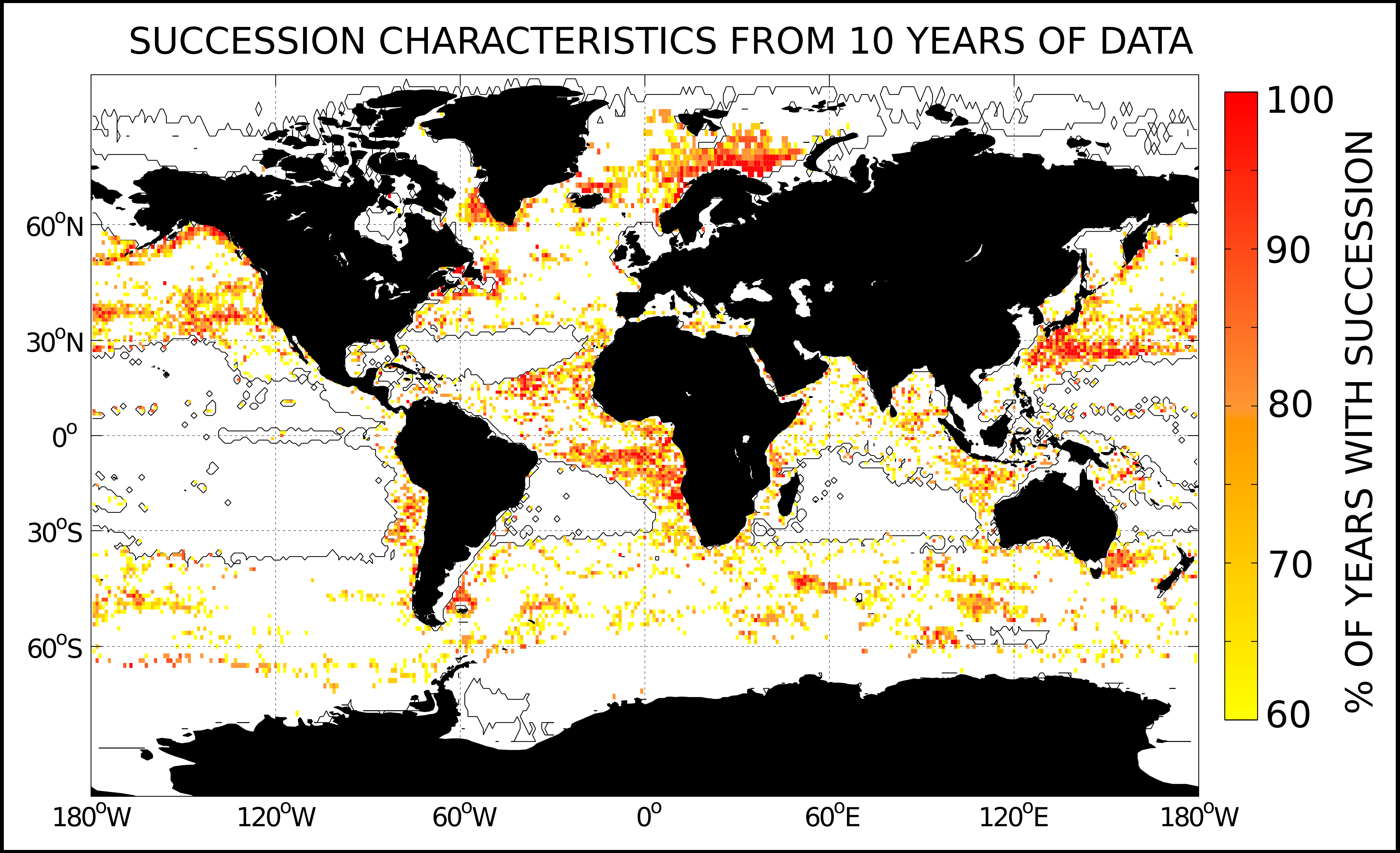
Succession in peaks



Co-occurrence of peaks

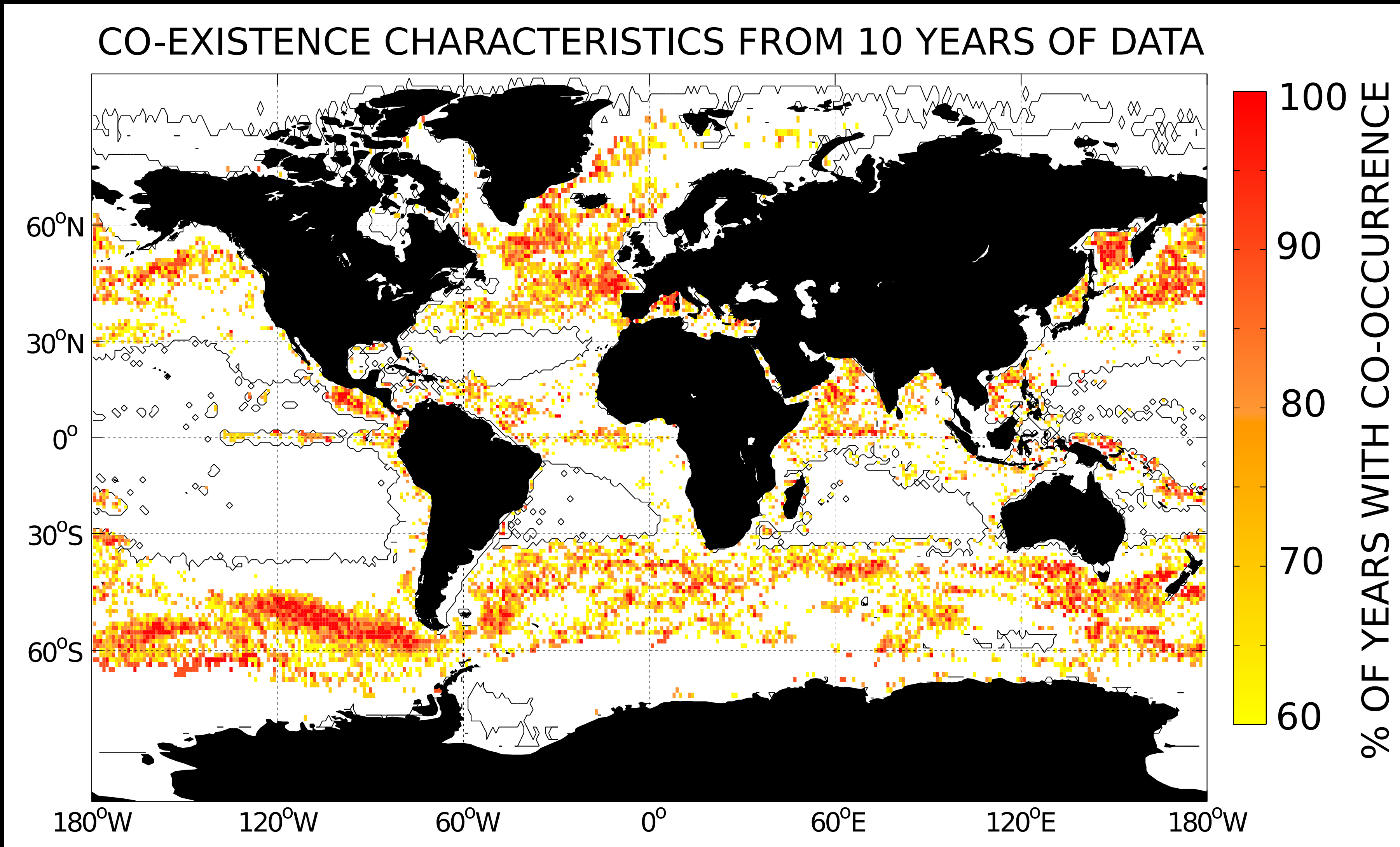


Pixels with succession in peaks



White bounded areas represent regions with low variability, persistent periods of missing data or water column depths <150 m

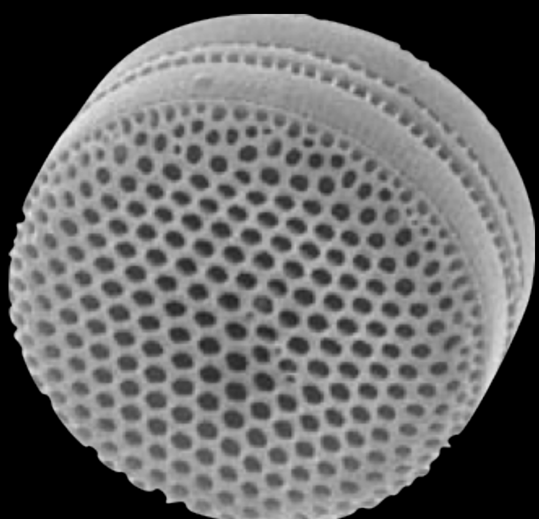
Peaks that co-occur

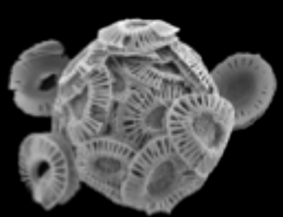


White bounded areas represent regions with low variability, persistent periods of missing data or water column depths <150 m

Coccolithophores and diatoms

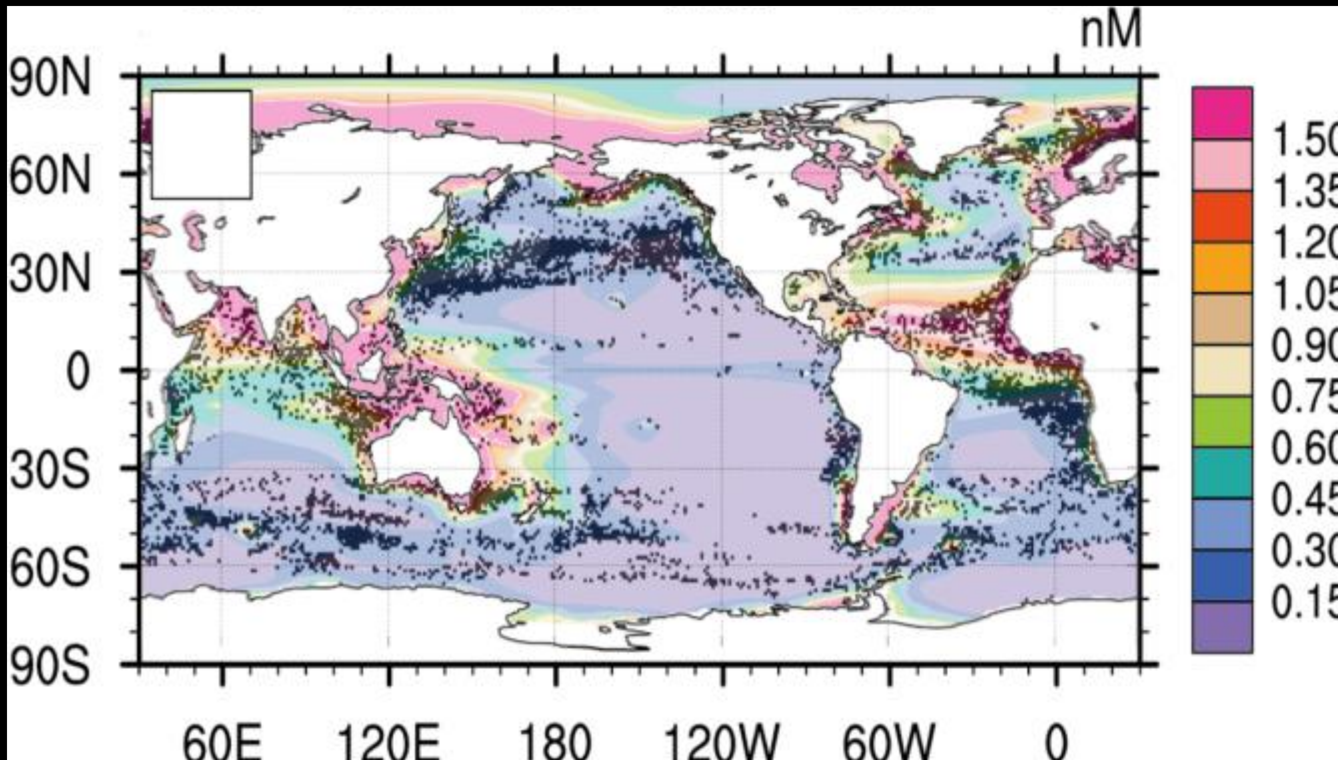
LARGE	**SMALL**
Silicate	No silicate
Relatively high Fe	Relatively low Fe





The case for Fe?

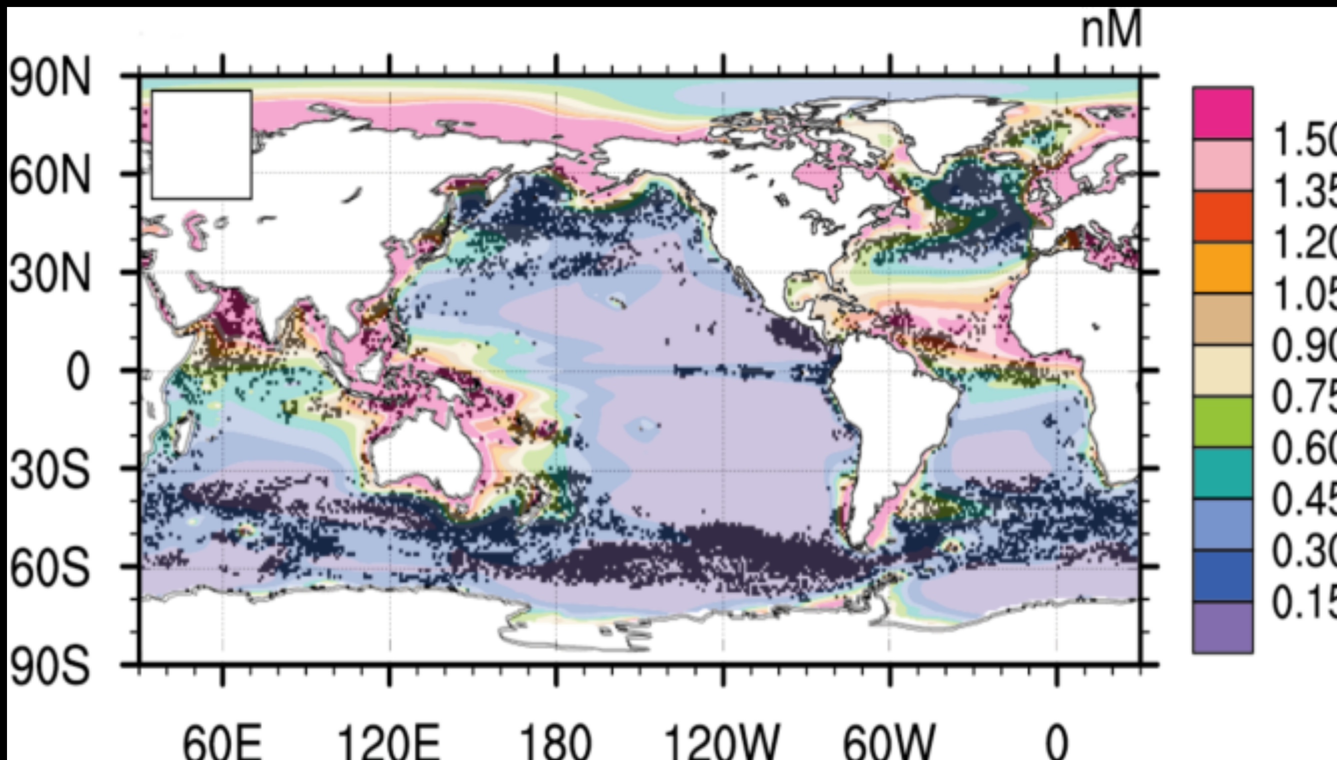
Timing gap between chlorophyll peak and PIC peak



Misumi et al., 2014 Biogeosciences

The case for Fe?

No timing gap between chlorophyll peak and PIC peak



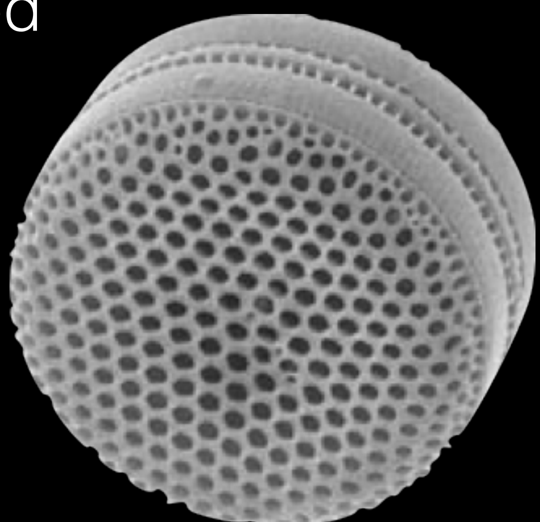
Misumi et al., 2014 Biogeosciences

Coccolithophores and diatoms

HIGH Fe

Large diatoms dominate

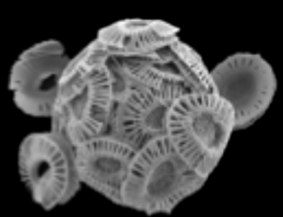
Coccolithophores have to wait until diatom population has diminished



LOW Fe

Large diatoms unable to establish dominance in bloom

Coccolithophores can bloom with other phytoplankton taxa



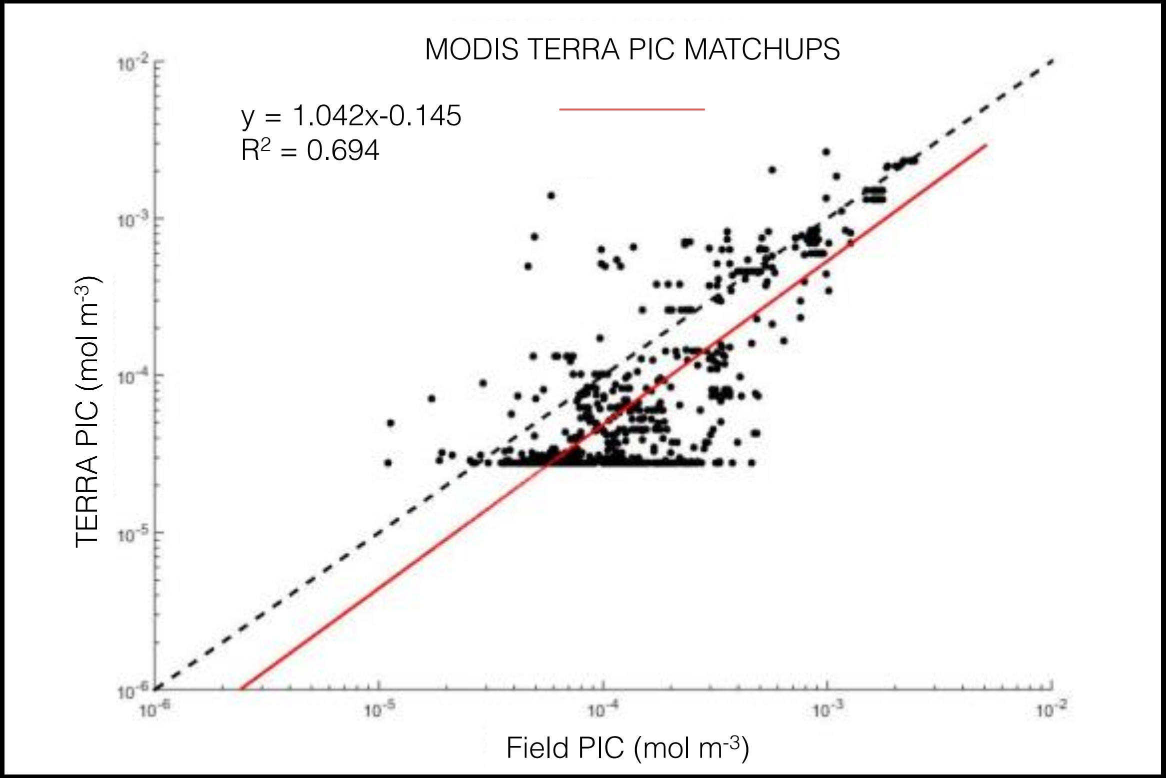
Ongoing work

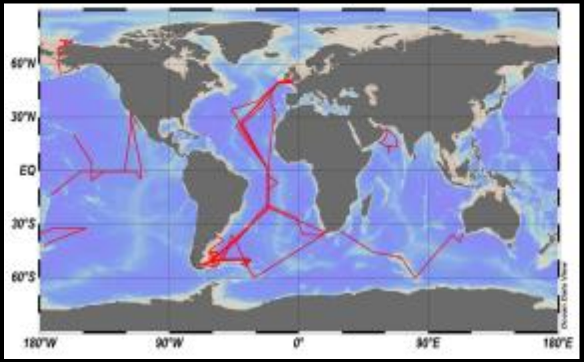
The merged PIC algorithm

Recent changes to PIC algorithm

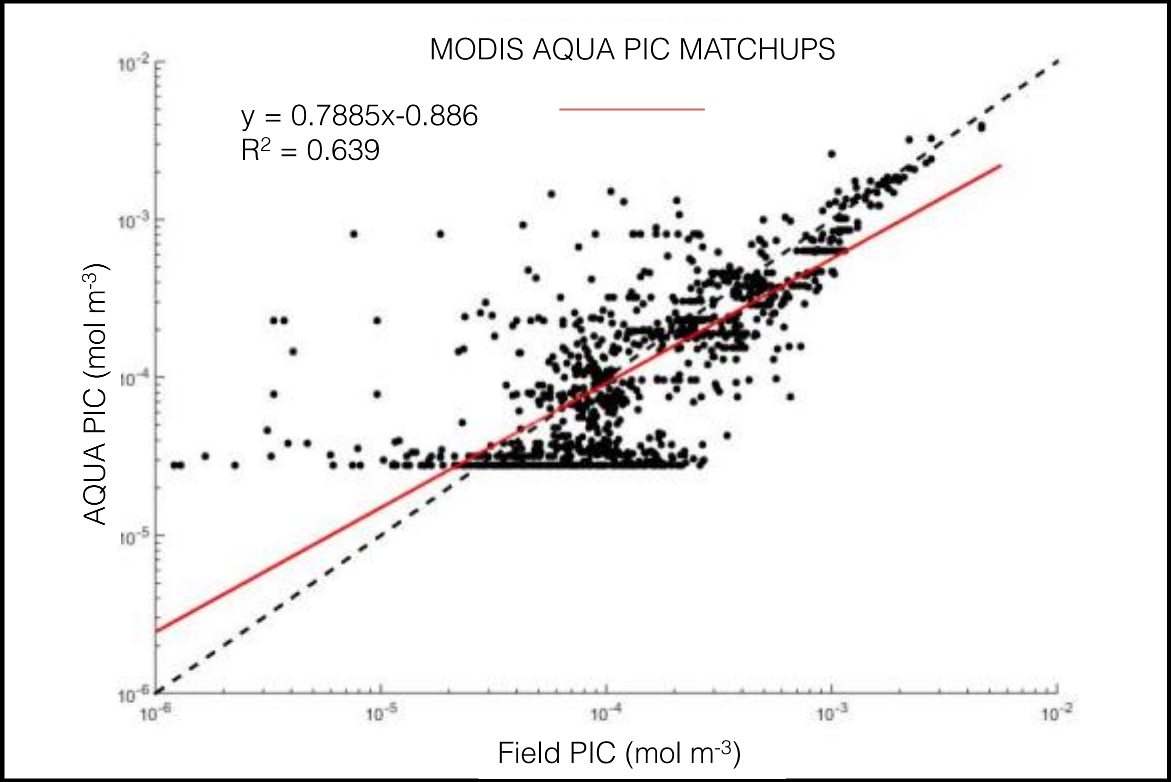
- LUT modified to reflect data from increased number of in-situ acid labile b_b measurements
- New b_b* implemented (now 1.628 m^2 mol^{-1})

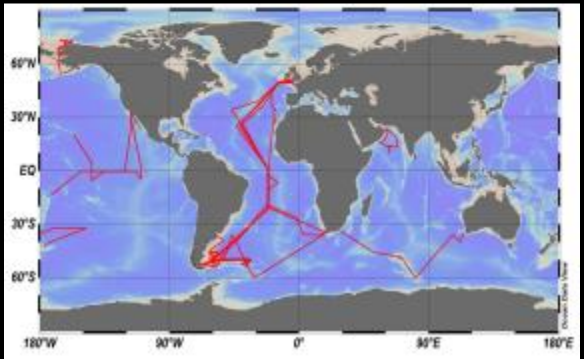
Satellite PIC and in-situ PIC matchups –Terra MODIS



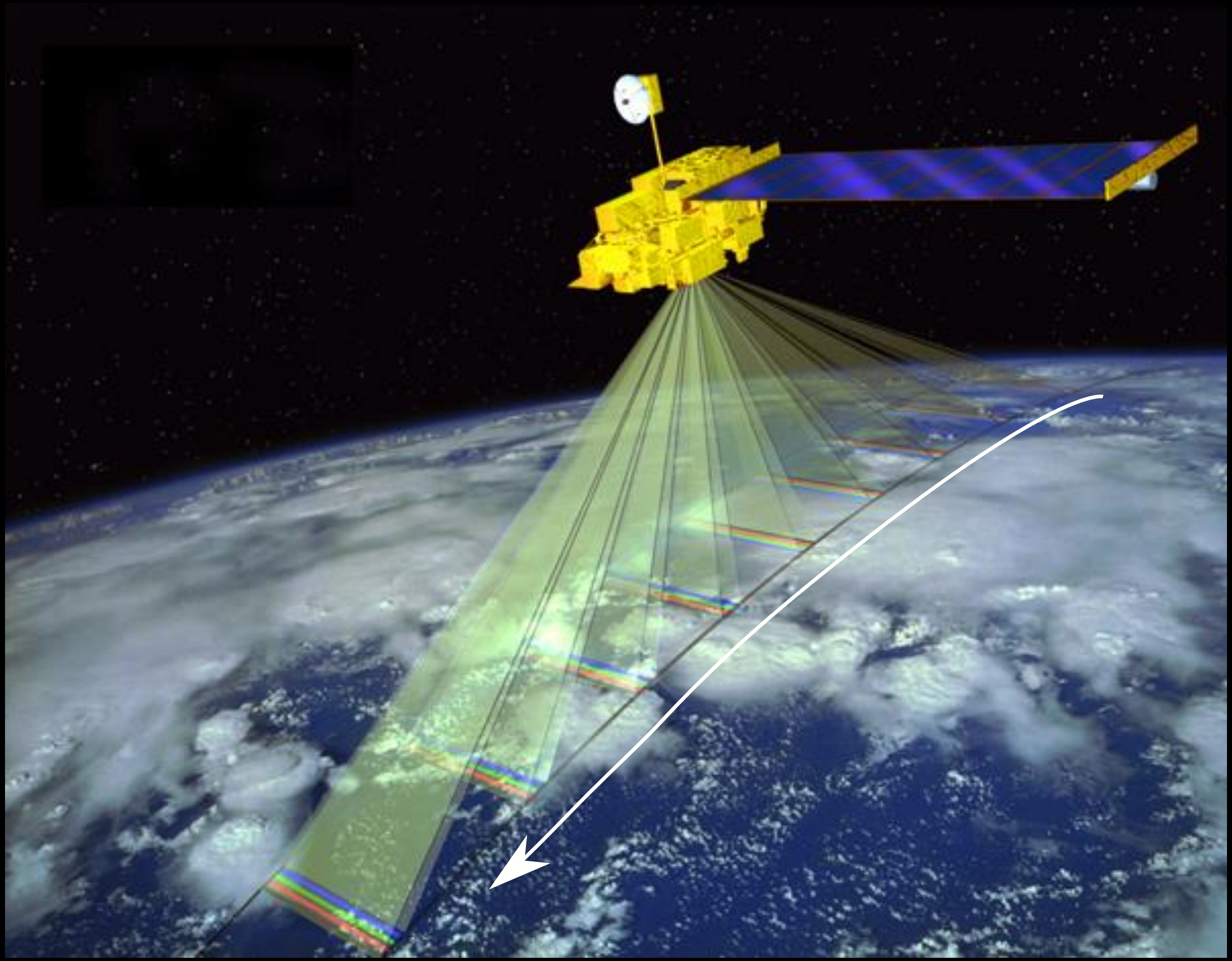


Satellite PIC and in-situ PIC matchups –Aqua MODIS





Ongoing work - MISR

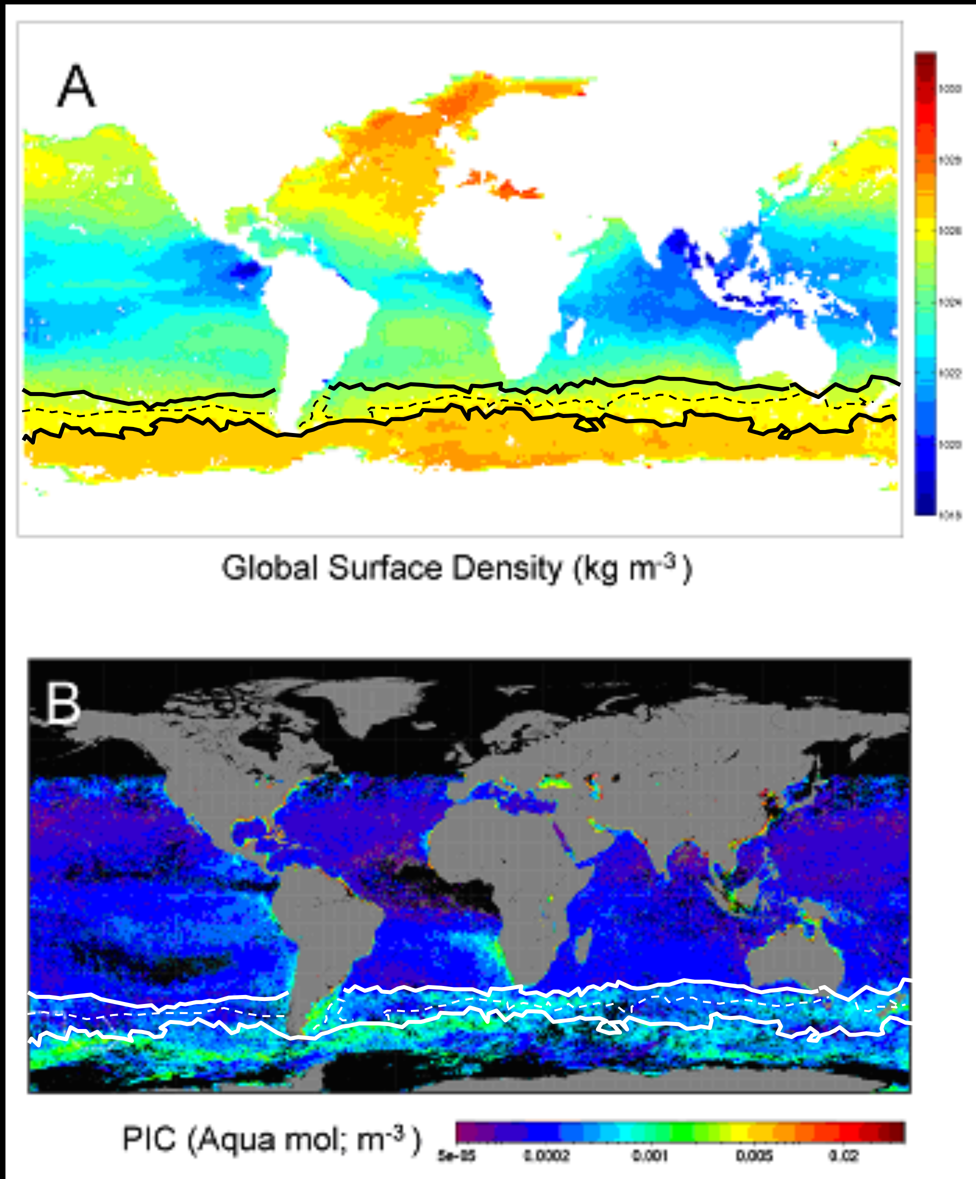


https://www-misr.jpl.nasa.gov/

Ongoing work – PIC at sub-kilometer resolution

http://earthobservatory.nasa.gov

Ongoing work – Edge detection algorithm



Density

T from MODIS
S from Aquarius

Edge Detection

Cayula & Cornillon, 1991

Thank you

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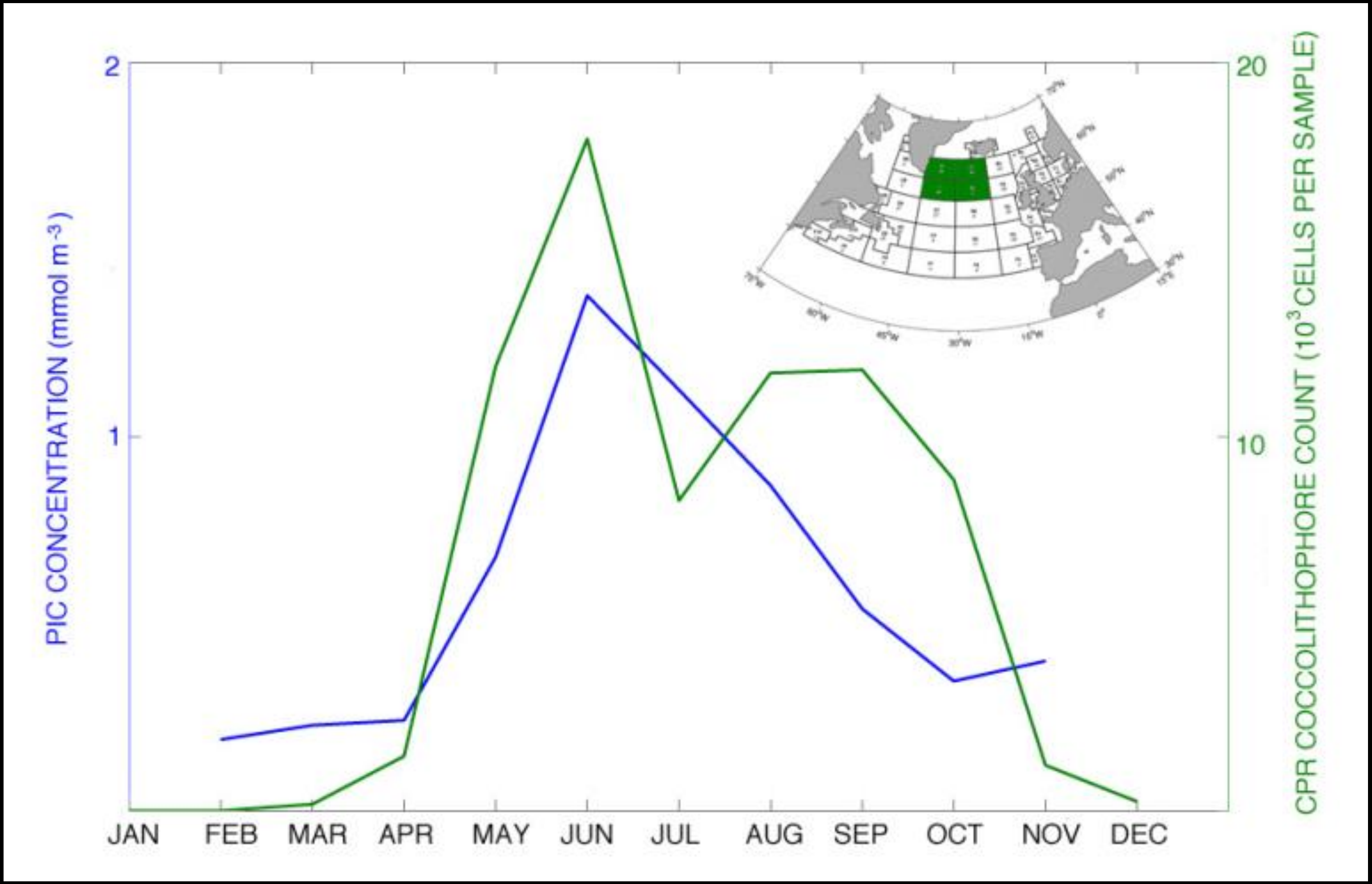
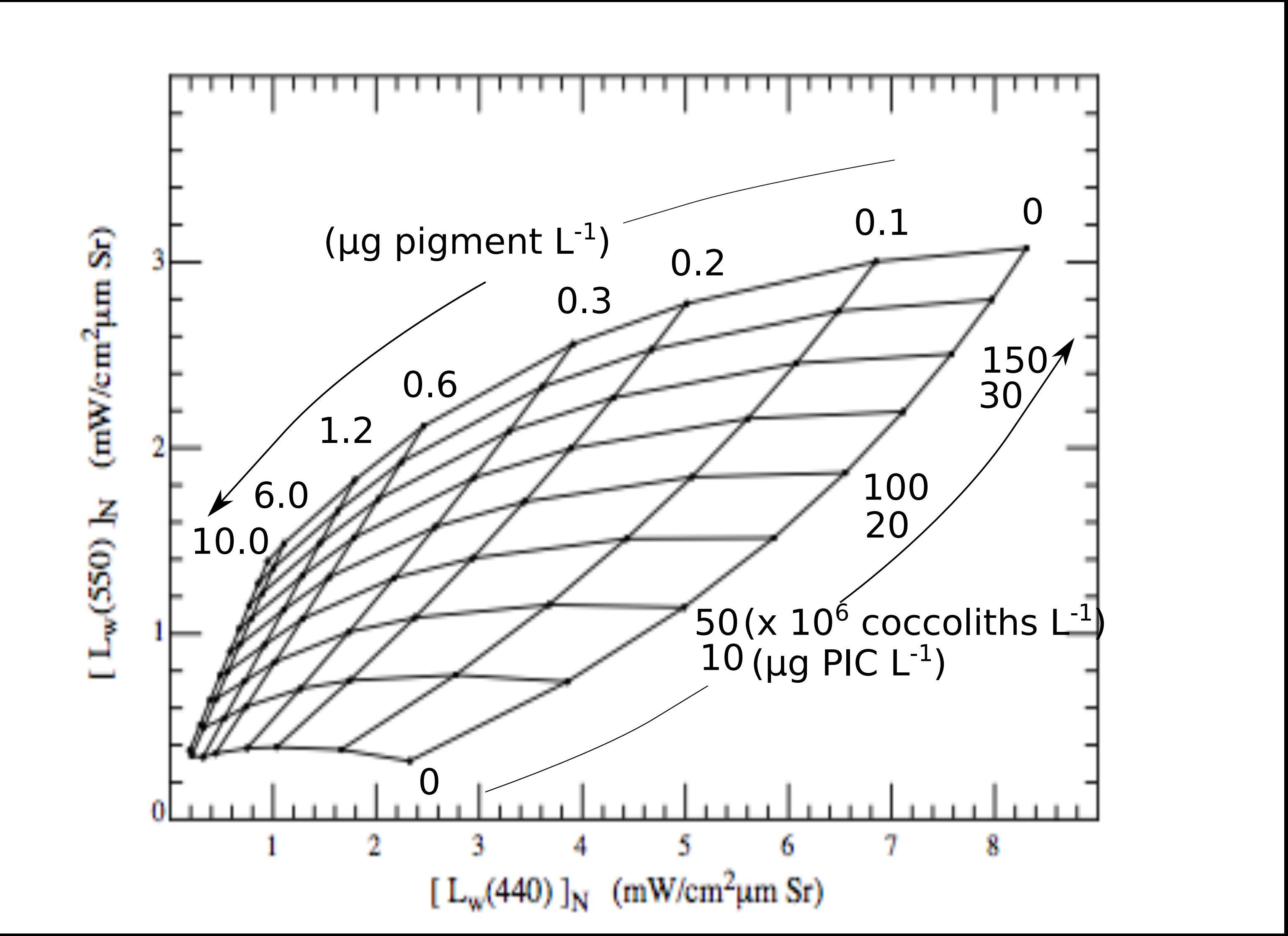
PIC and coccolithophores



Two band LUT



Adapted from Balch et al, 2005, *JGR*

Coccolithophores and chlorophyll

Bloom PIC content = 0.75 mmol m^{-3}

Coccolith PIC content = 0.016 pmol C [*Poulton et al, 2011*]

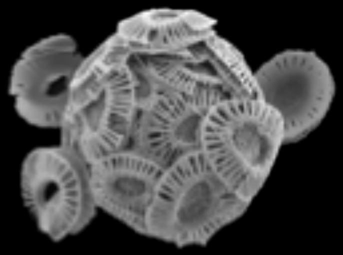
Bloom coccolith total = $0.75 \times 10^{-3} \div 0.016 \times 10^{-12}$ = 4.7×10^{10} coccoliths m^{-3} = 47000 ml^{-1}

Assuming 12 coccoliths per cell & 100 loose coccoliths per cell = 112 coccoliths for every cell

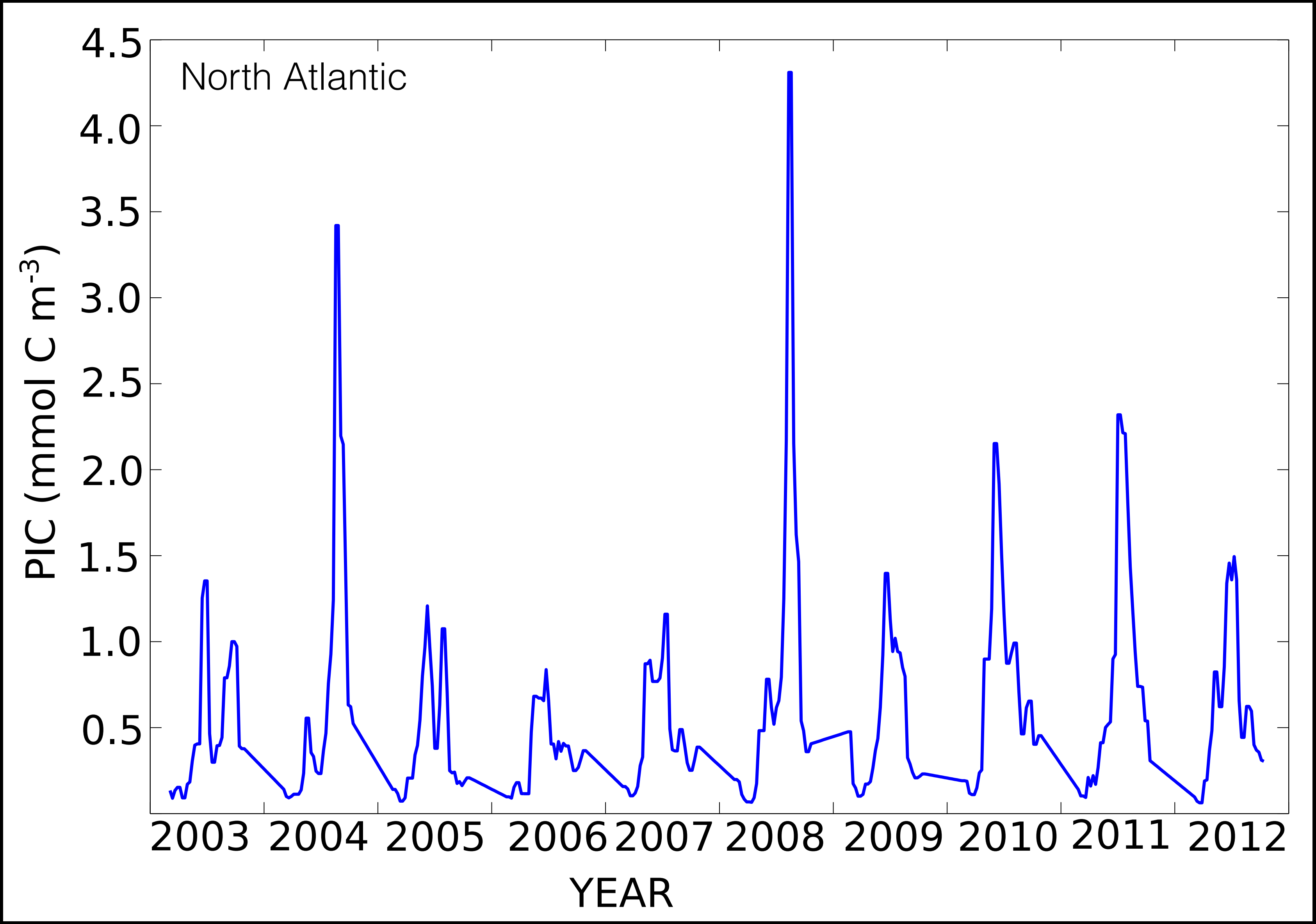
<u>No. of cells in bloom = 420 cells ml^{-1}</u>

Assuming chl content per cell = 0.1pg [Stolte et al, 2000]

<u>Chl contribution to bloom = 0.04 mg m^{-3}</u>



PIC concentration seasonality



MODIS PIC data; 8-day, 9km composites for 2003-2012