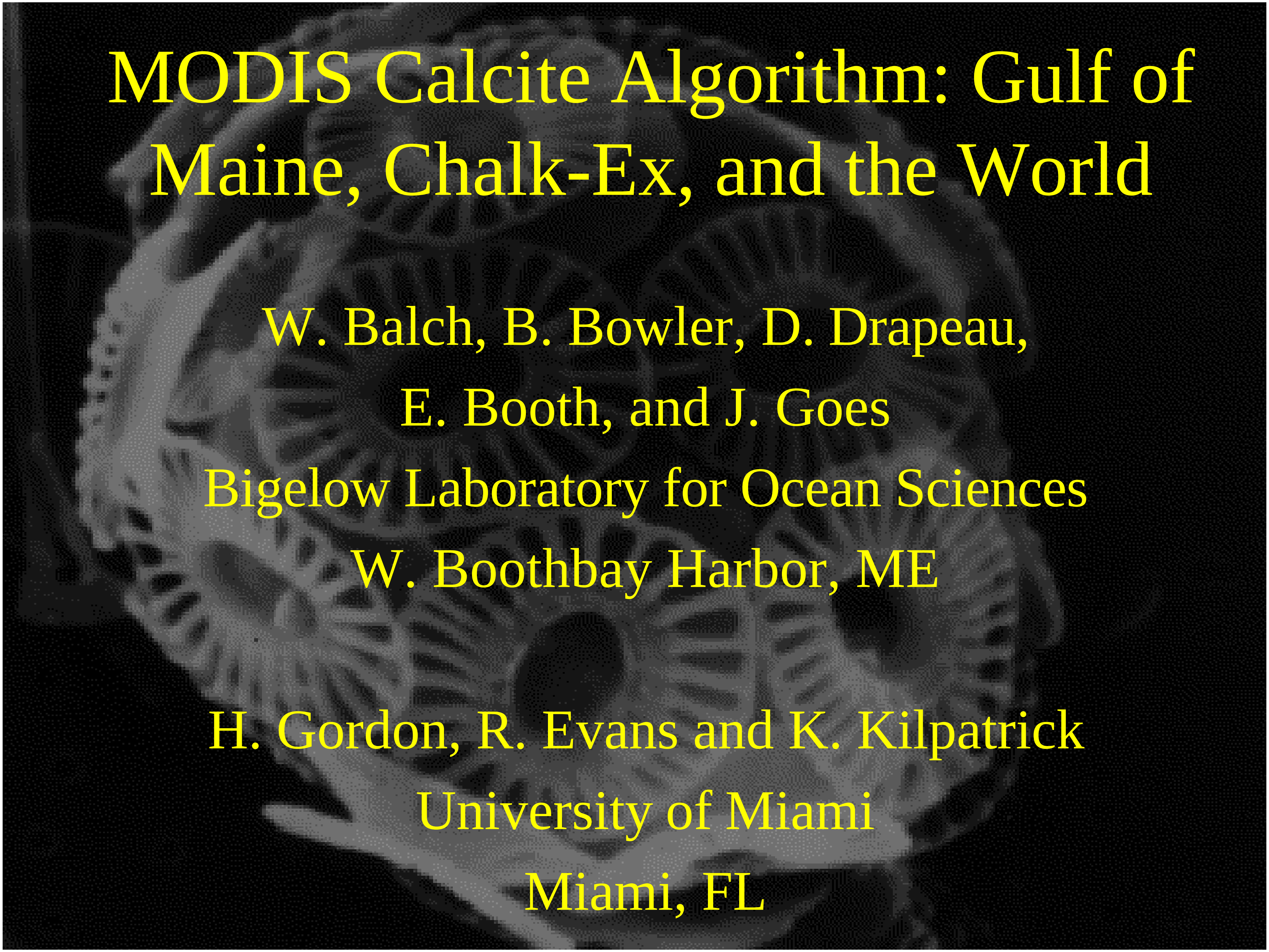
MODIS Calcite Algorithm: Gulf of Maine, Chalk-Ex, and the World
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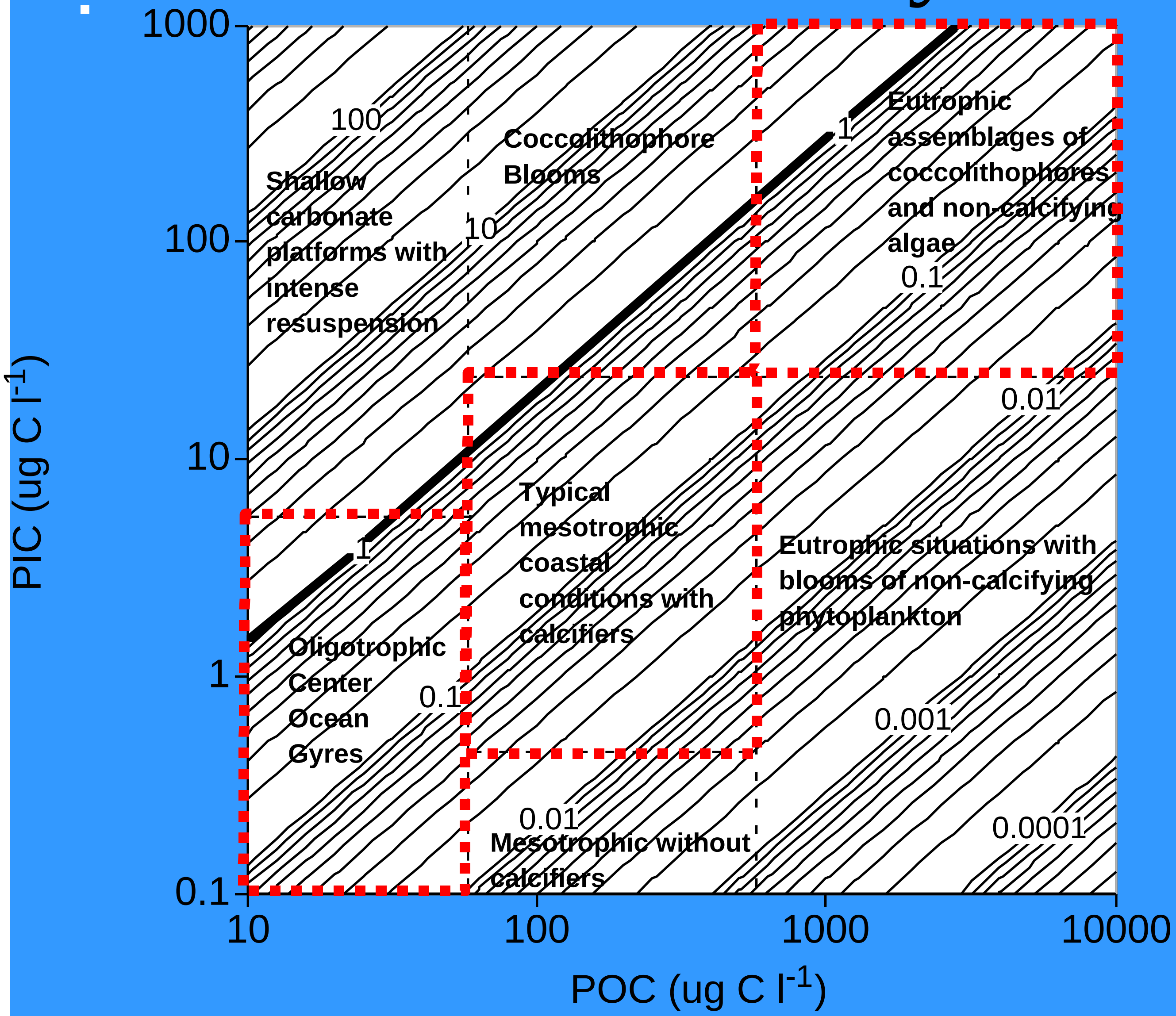
Brief Review

- Calcium carbonate (calcite= $CaCO_3$ = particulate inorganic carbon=PIC) is ubiquitous in the global ocean The major oceanic source is coccolithophores, phytoplankton with $CaCO_3$ scales
- Due to high refractive index, PIC plays a disproportionately large role in the backscattering of light from the sea (relative to the small amount of PIC present).
- PIC plays a first-order role in water-leaving radiance (accounting for a baseline of 10-20% of backscattering, routinely 30-40%, and in coccolithophore blooms, up to 99%)

Who cares about PIC?

$bb_{PIC}:bb_{POC}$ ratios vary w/ PIC & POC



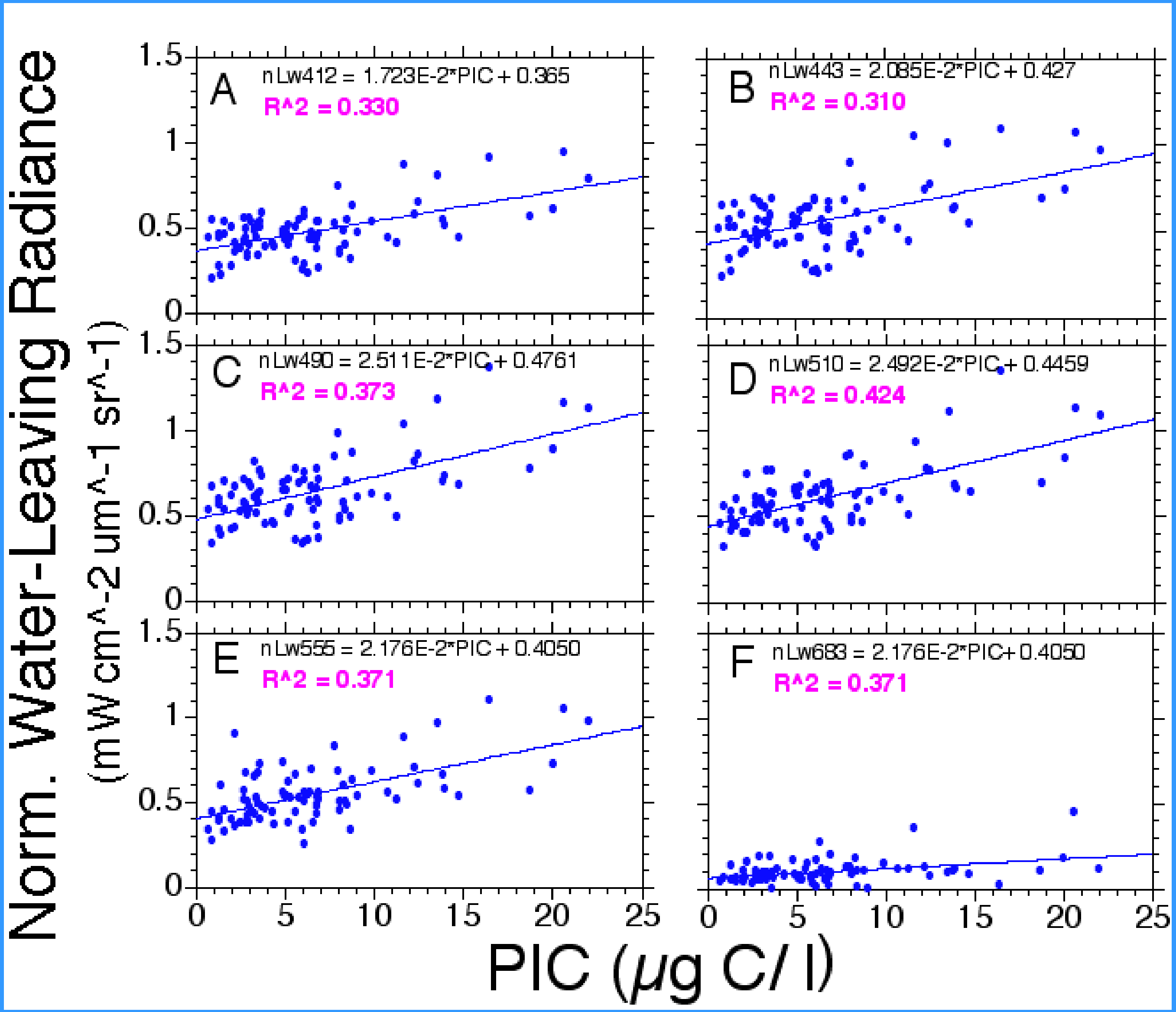
Note, in eutrophic to oligotrophic environs, bb_{PIC} can easily reach 10-100% of bb_{POC}.

Contours of bb550PIC:bb550POC (water not included; typical values characteristic of specific environments shown with dashed lines; bb550PIC based on Balch et al, 2001; bb550POC based on Stramski et al 1999 data from APFZ shown in his Fig. 1, wavelength corrected from 510 to 550nm assuming λ exponent of -1.4)

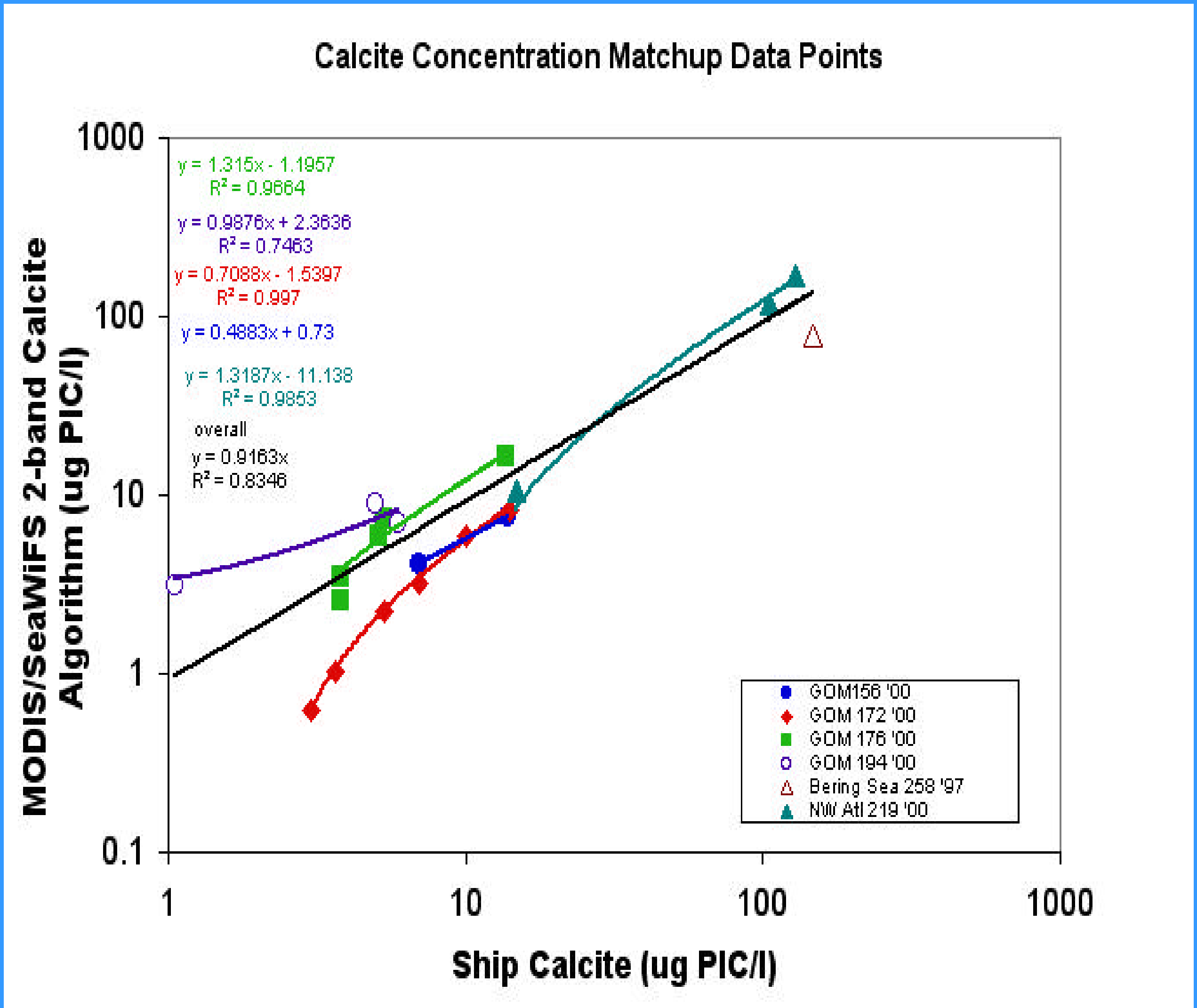
Overall Goals of MODIS Work

- Validation of Gulf of Maine PIC concentrations (in assoc. w/ SeaWiFS/SIMBIOS ferry sampling)
- Chalk-Ex-Testing the 2 band calcite algorithm under simulated bloom conditions
- Application of 2-band (443, 551nm) algorithm to global 36 km monthly imagery a) to make first estimates of global calcium carbonate standing stock, and b) compare to published estimates

Relationship of nLw to suspended PIC



Algorithm validation



- For a single day, sat-derived PIC good to ±0.2 ugC/l
- For pooled data, PIC good to ±2 ugC/l
- Samples for 2001 still being processed

Validation

-Caveat: current validation results use data only from east side of swath.

-Expect full validation of the product after reprocessing with new code (v.3.4) which will remove the east/west bias

Chalk-Ex November10-19, 2001

- Coccolithophore blooms (containing millions of tons of PIC, covering 100's of thousands km^2) are almost impossible to predict in space and time
- GOAL- Validation of calcite algorithm under simulated bloom conditions
- Made two 13T coccolith chalk patches:
  - a) Jordan Basin (Gulf of Maine)
  - b) SE of Great South Channel (250miles SE of Cape Cod over Continental Slope)

Other Chalk-Ex Goals

- Achieve mass balance of PIC using multi-optical sensor approach:
  - Freefall rad/irrad, above-water rad/irrad, Undulating Scanfish (bb, c, T, S), continuous surface IOP measurements (spectral a, b, c, & bb; horizontal and vertical)
  - Surveillance balloon (used for high altitude view of patch shape, and deriving optimal survey strategy)
  - MODIS/SeaWiFS observations
- Multi-investigators to determine fate of the 2µm PIC chalk particles as they disperse/sink.

Other Investigators in Chalk-Ex '01

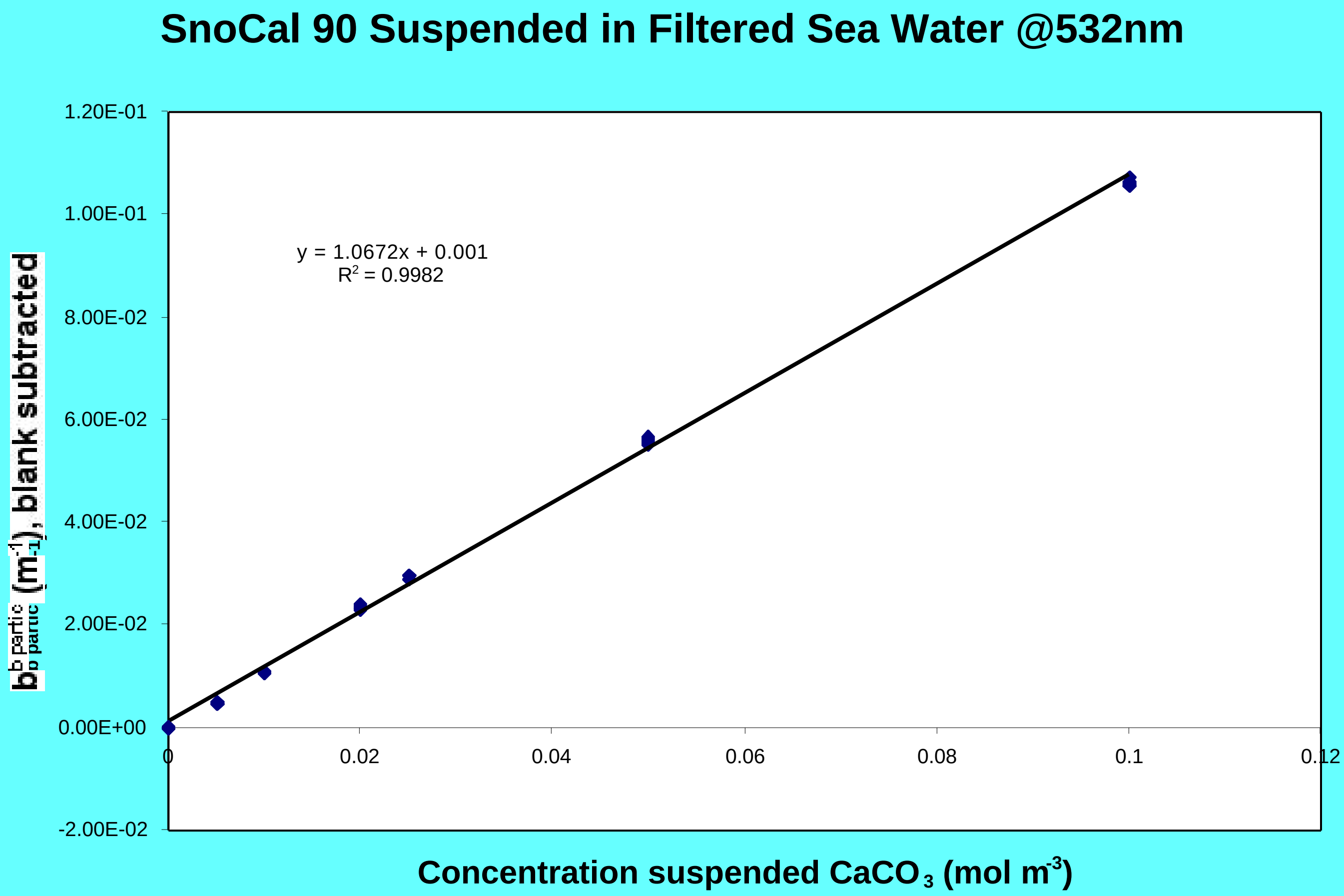
Pilskaln; Bigelow;
Drifting Sed. traps

Plueddemann; WHOI;
Physics of patch

Dam &McManus; UCONN;
Aggregation; Partic. Size Dist/
Zooplankton Grazing

Goes; Bigelow;
Sub-µm Partic. Size Distributions/DOC

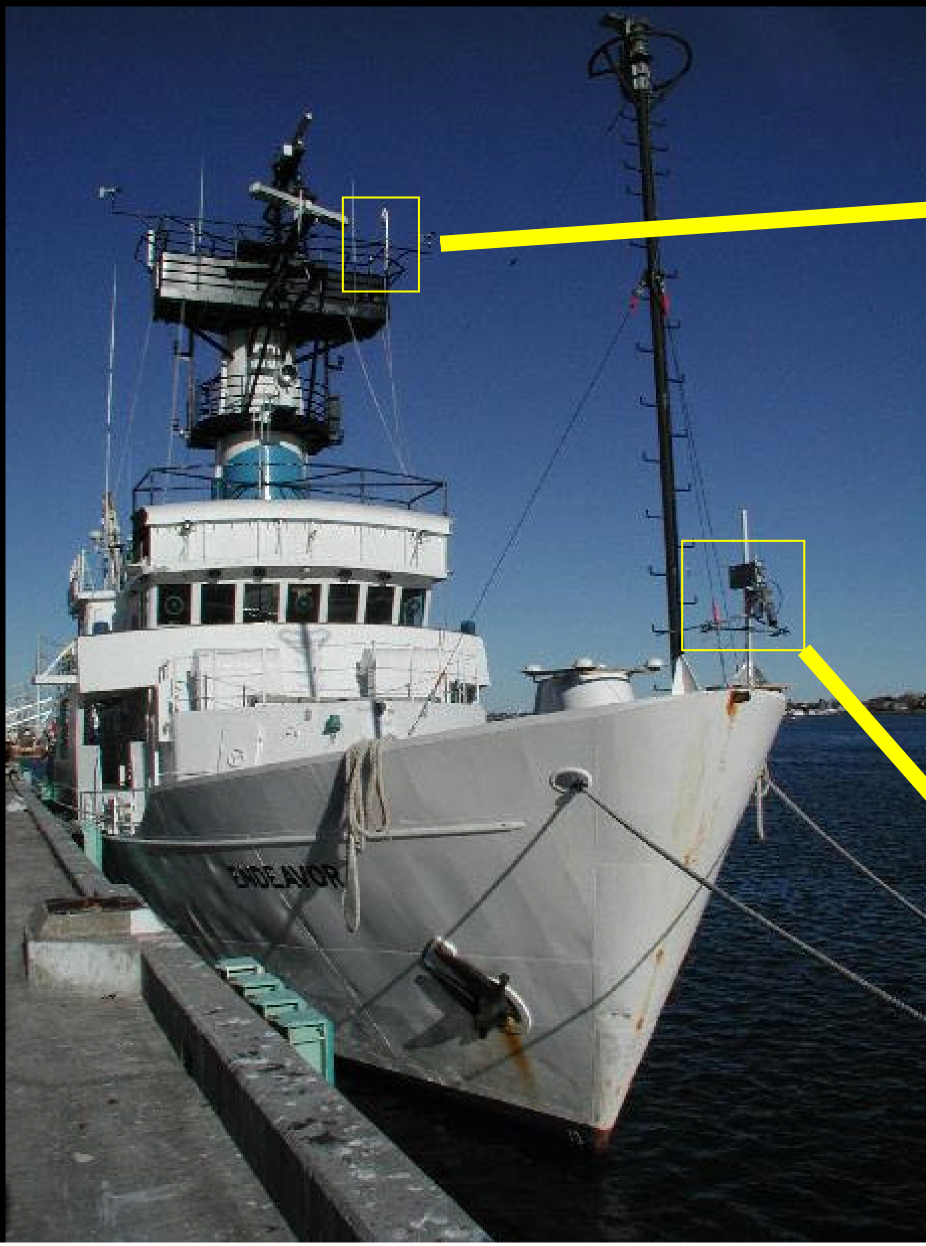
Chalk concentration is highly correlated to its backscattering

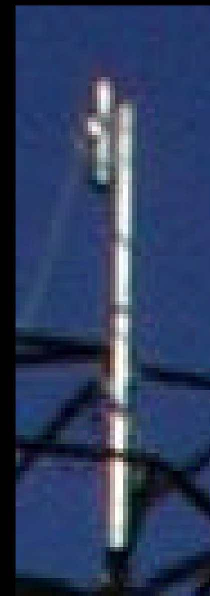


Loading Chalk In Portland

Installation of the "Sky Box"

Satlantic radiometers on R/V Endeavor





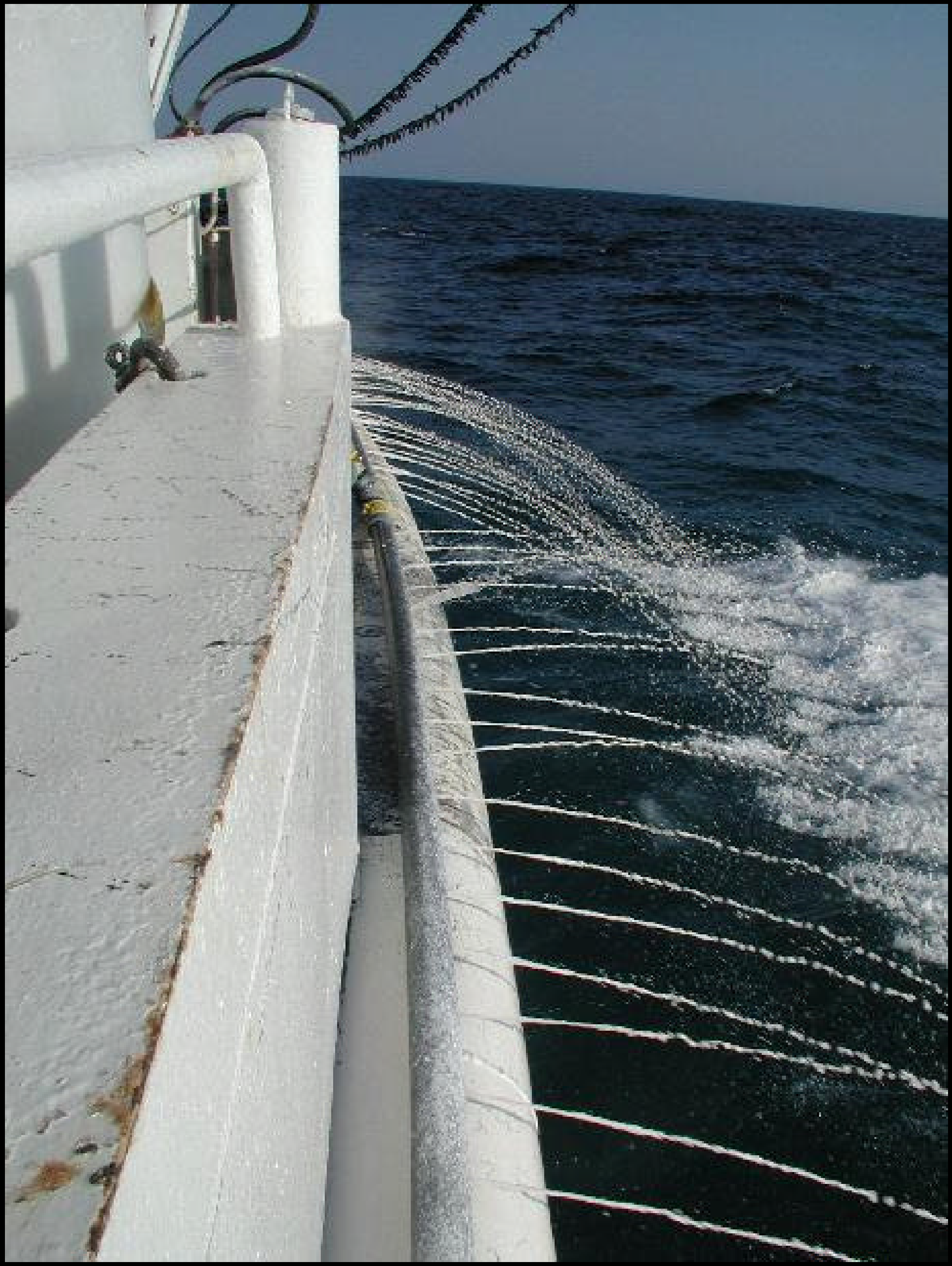
Ed (λ) sensor

Lu(λ) and Lsky (λ) sensors

Laying Patch #1; Jordan Basin

Logistics of handling chalk at sea

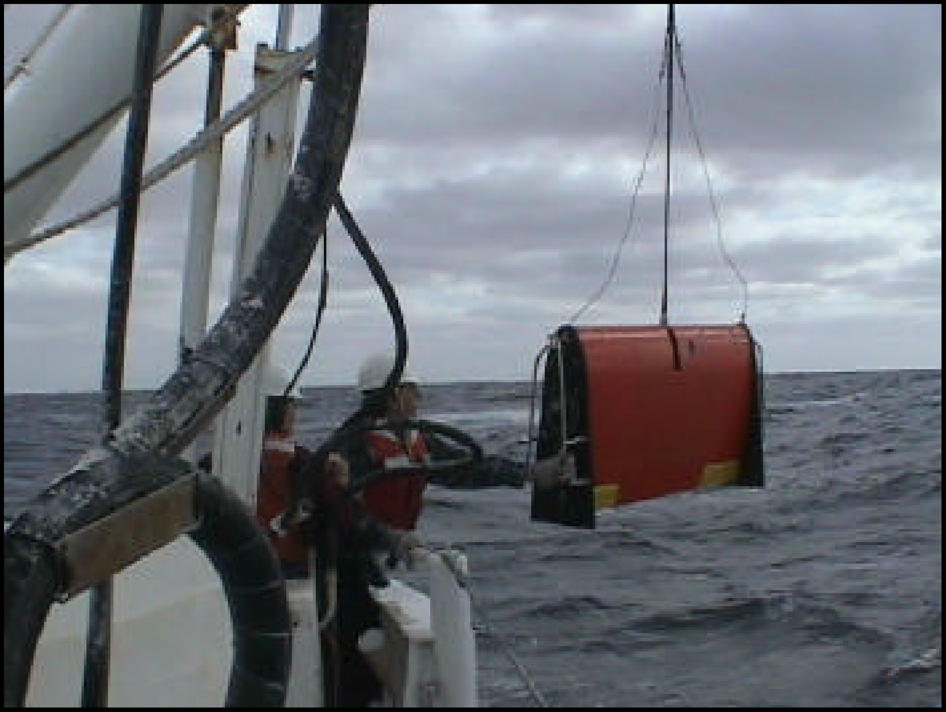
Chalk Dispersal

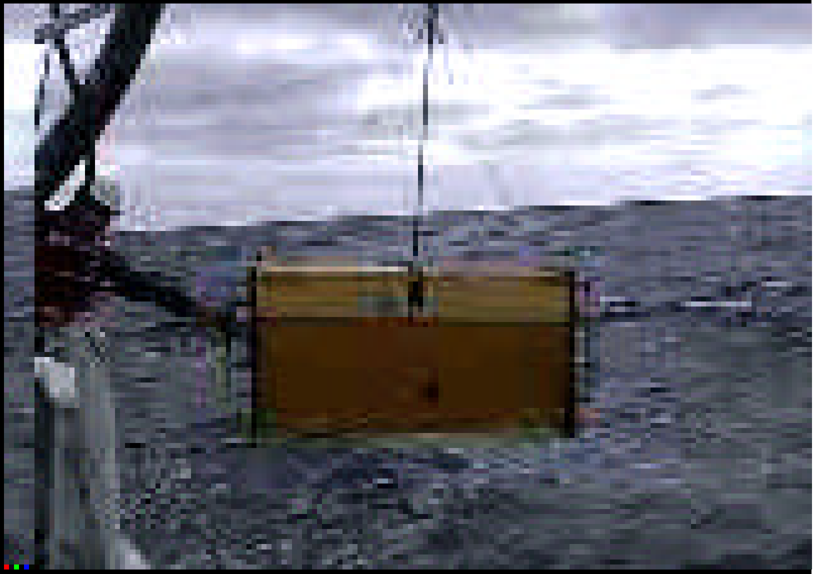


Spreading 0500h-0930h, steaming in an expanding ellipse, 1.5 x 0.5 km

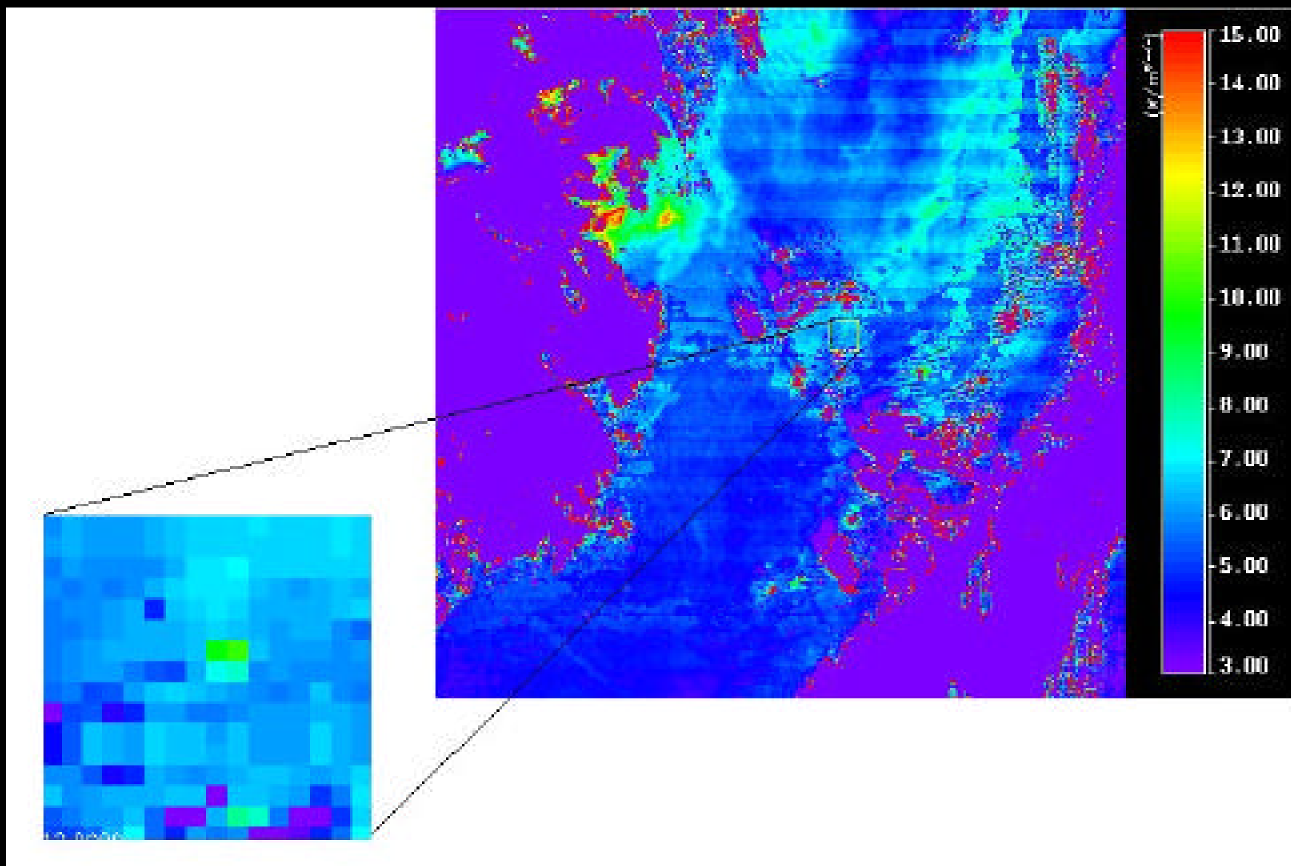
Southern patch (#2) complete

Scan Fish for undulating measurements of bb, c, T, S; top 100m



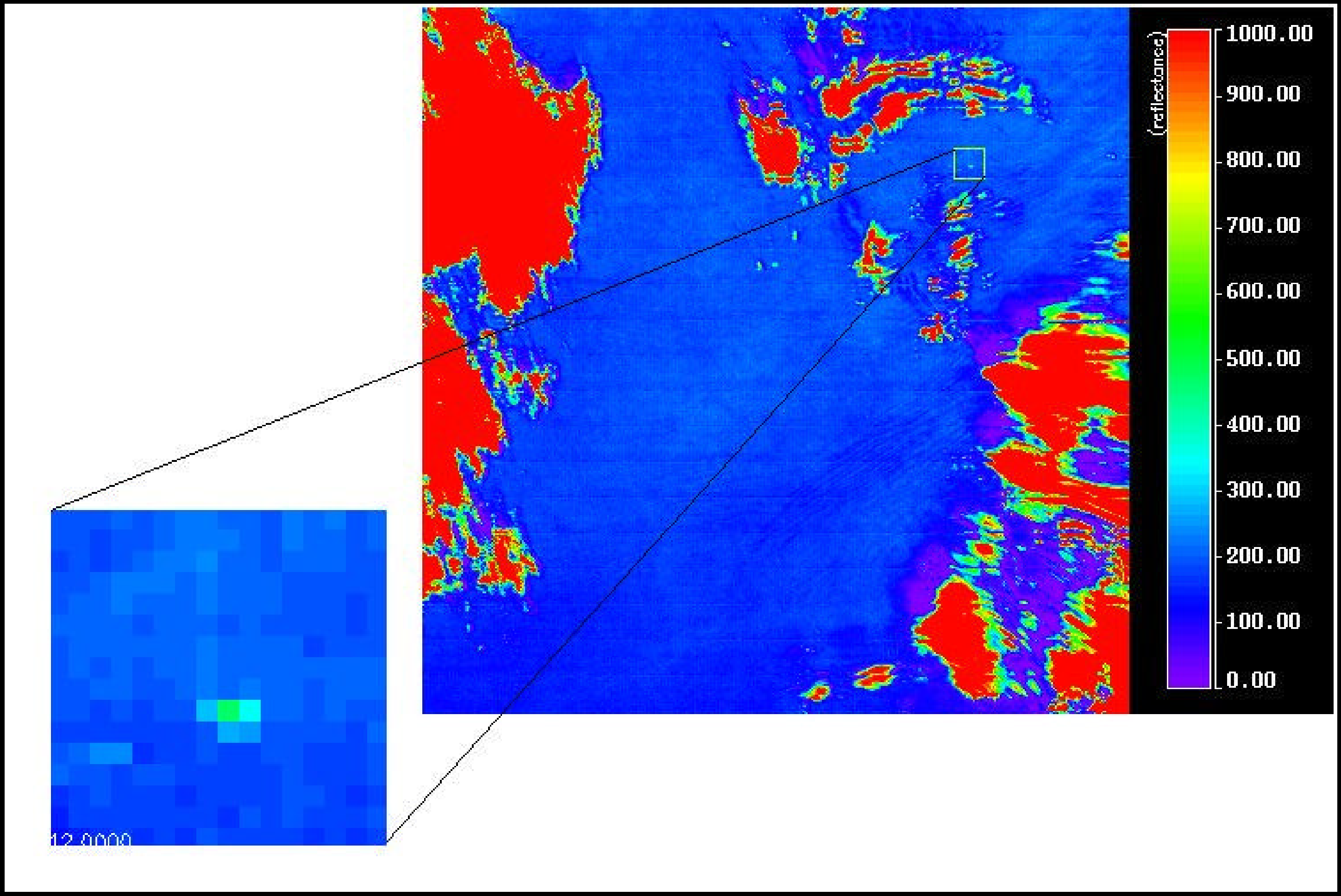


MODIS view of Chalk-Ex Patch #2: 551nm, 1Km data, 15 November 2001

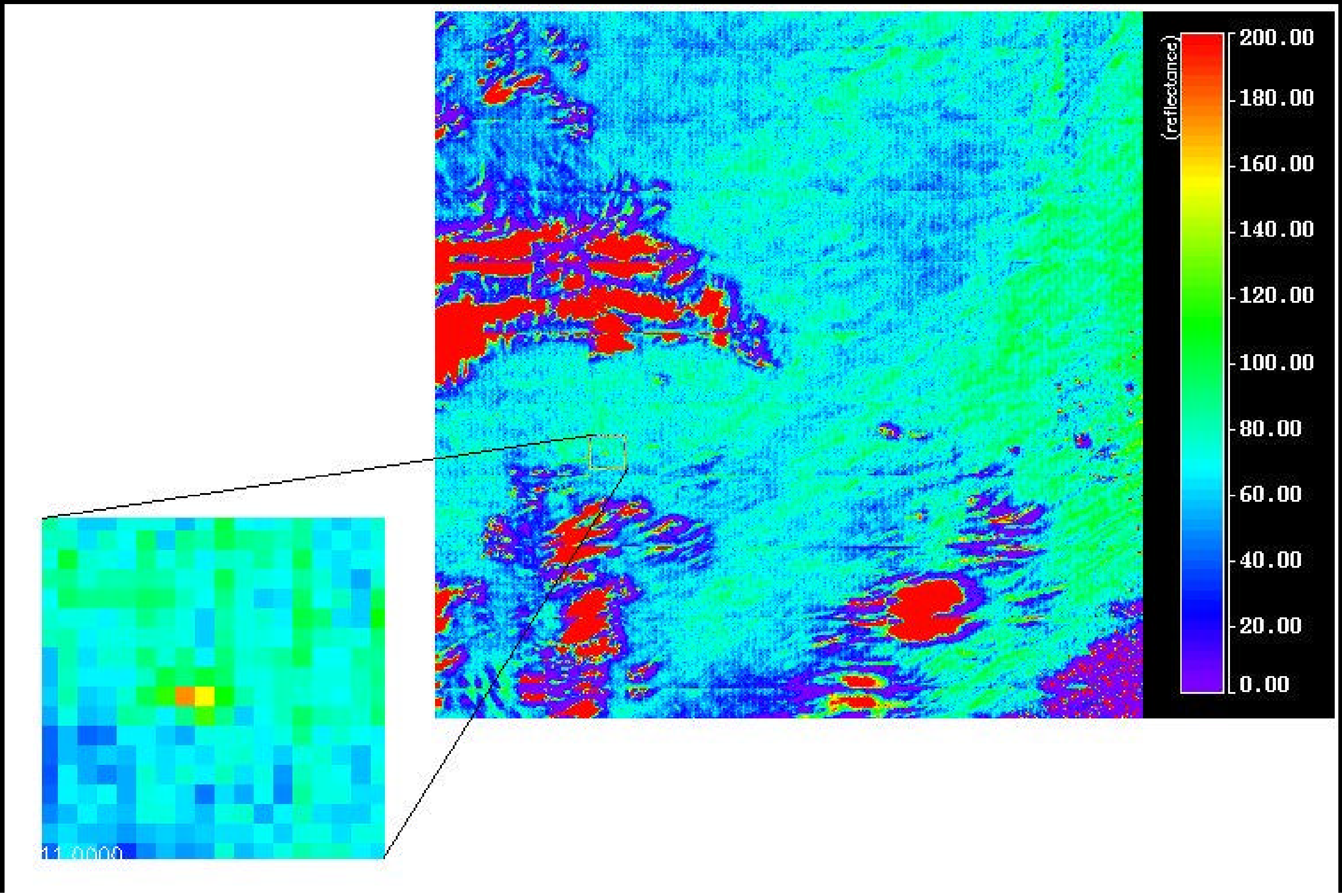


Two patch pixels: 39.81°N x 67.78°W (9.73 W m^{-2} um^{-1} sr^{-1})
39.80°N x 67.76°W (10.24 W m^{-2} um^{-1} sr^{-1})

MODIS view of Chalk-Ex Patch #2: 555nm, 500m resolution 15 November 2001



MODIS view of Chalk-Ex Patch #2: 648nm, 250m resolution 15 November 2001



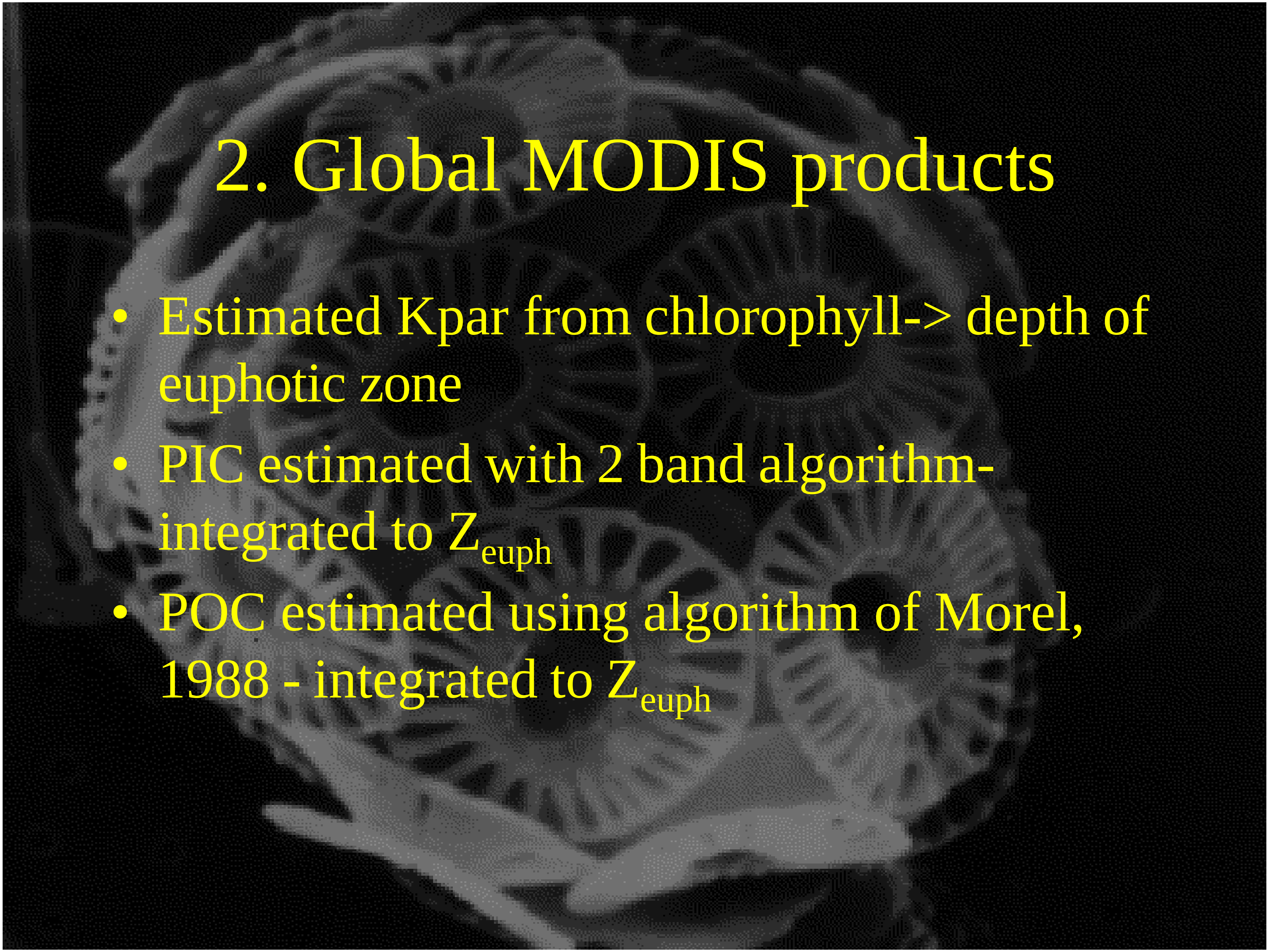
Balloon Ops

- 15’ diameter surveillance He balloon
- Video camera w/fisheye lens, 2.4 GHz transmitter for live video feed, remote shutter release, towed from ship at ~1500ft altitude

Aerial images from patch#2

Results

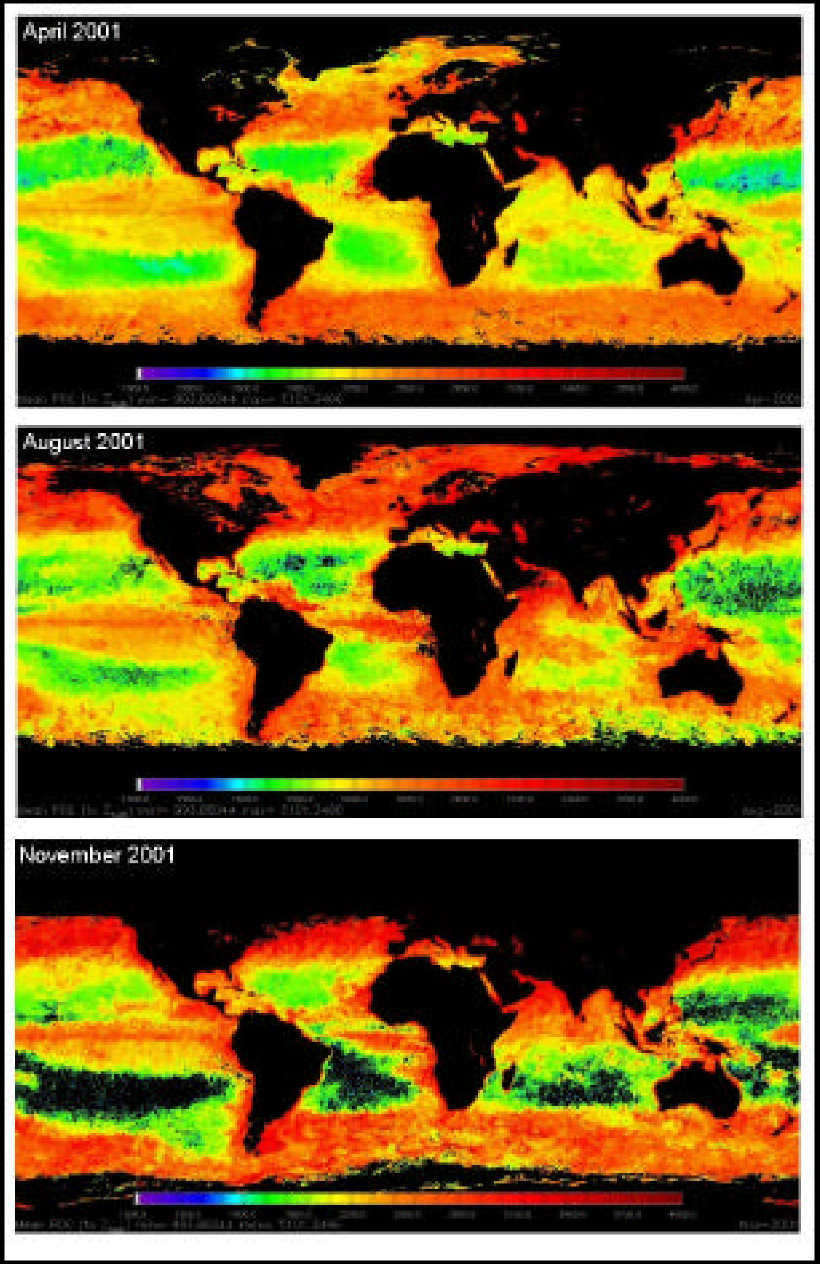
- Active mixed layer in Jordan Basin dispersed chalk downwards quickly. No image.
- b_b values as high as 0.08 per m in patch (=0.08 mol PIC m^{-3})
- Second patch was observed by MODIS
- Physics dominated biology in dispersal at both sites- relative importance yet to be determined
- Much data to work up!



2. Global MODIS products

- Estimated Kpar from chlorophyll-> depth of euphotic zone
- PIC estimated with 2 band algorithm- integrated to Z_{euph}
- POC estimated using algorithm of Morel, 1988 - integrated to Z_{euph}

Global Euphotic POC ($\mu g\ C\ m^{-2}$)



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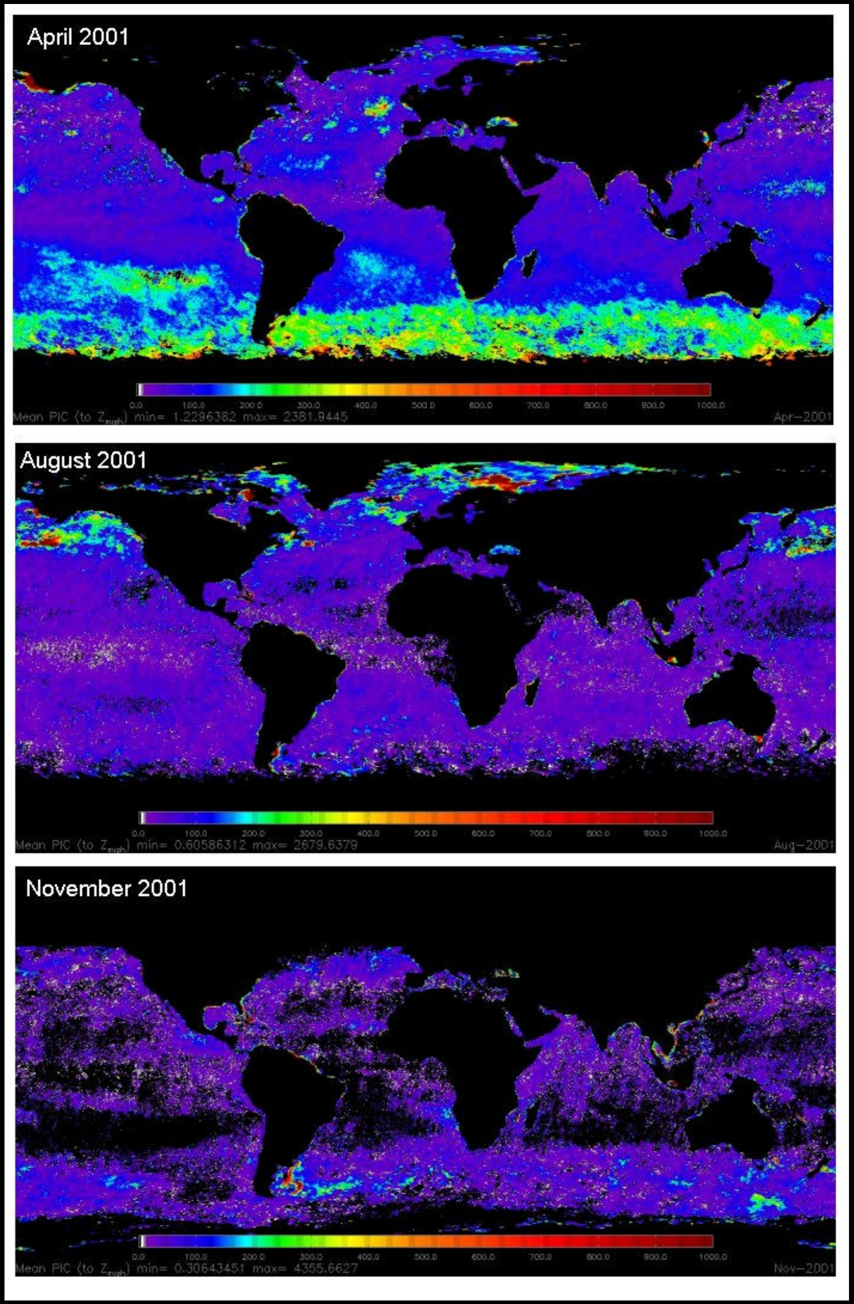
1000 2500 4000 µgC/m²

Global Euphotic PIC ($\mu g\ C\ m^{-2}$)



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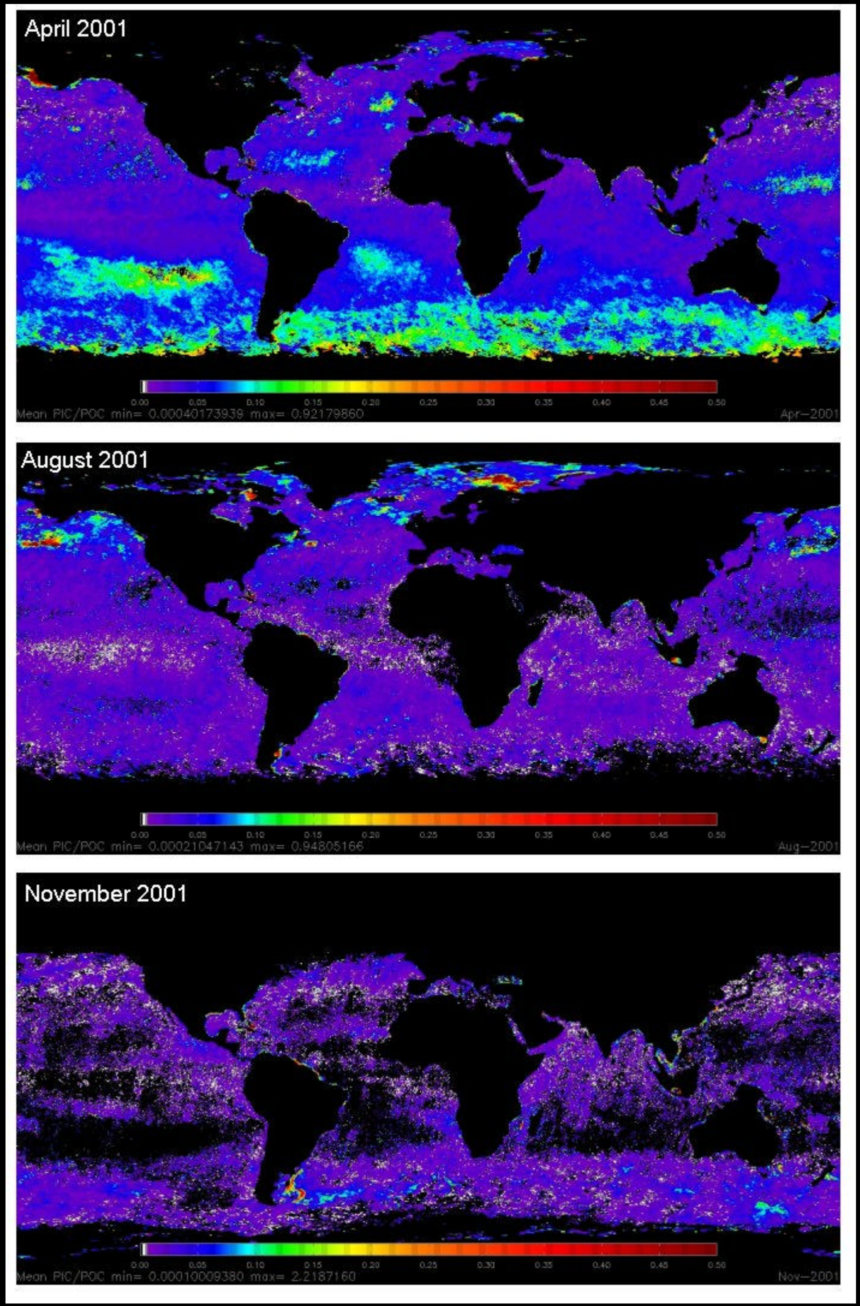
0 500 1000µgC/m²

Global PIC:POC



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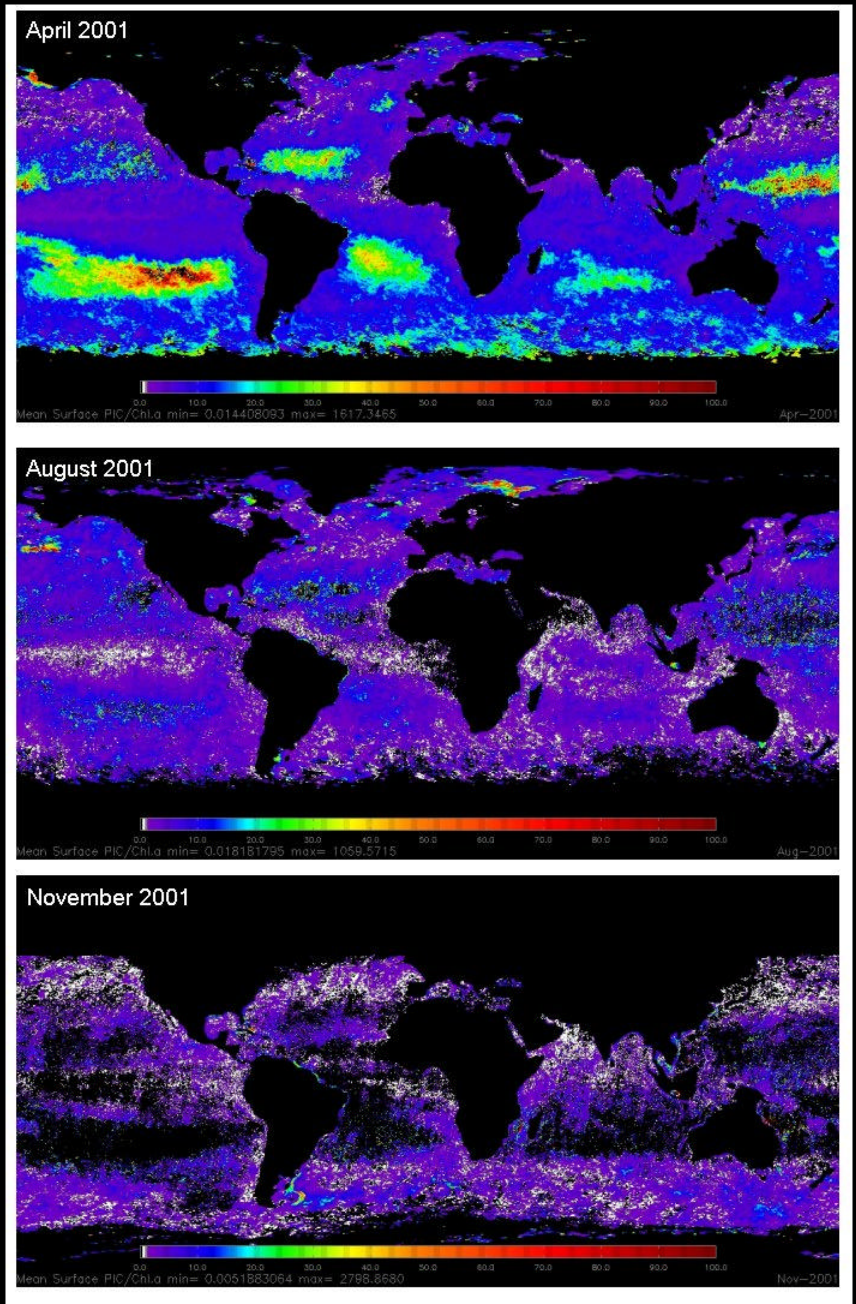
0 0.25 0.50

Global PIC:Chl µgC:µg Chl



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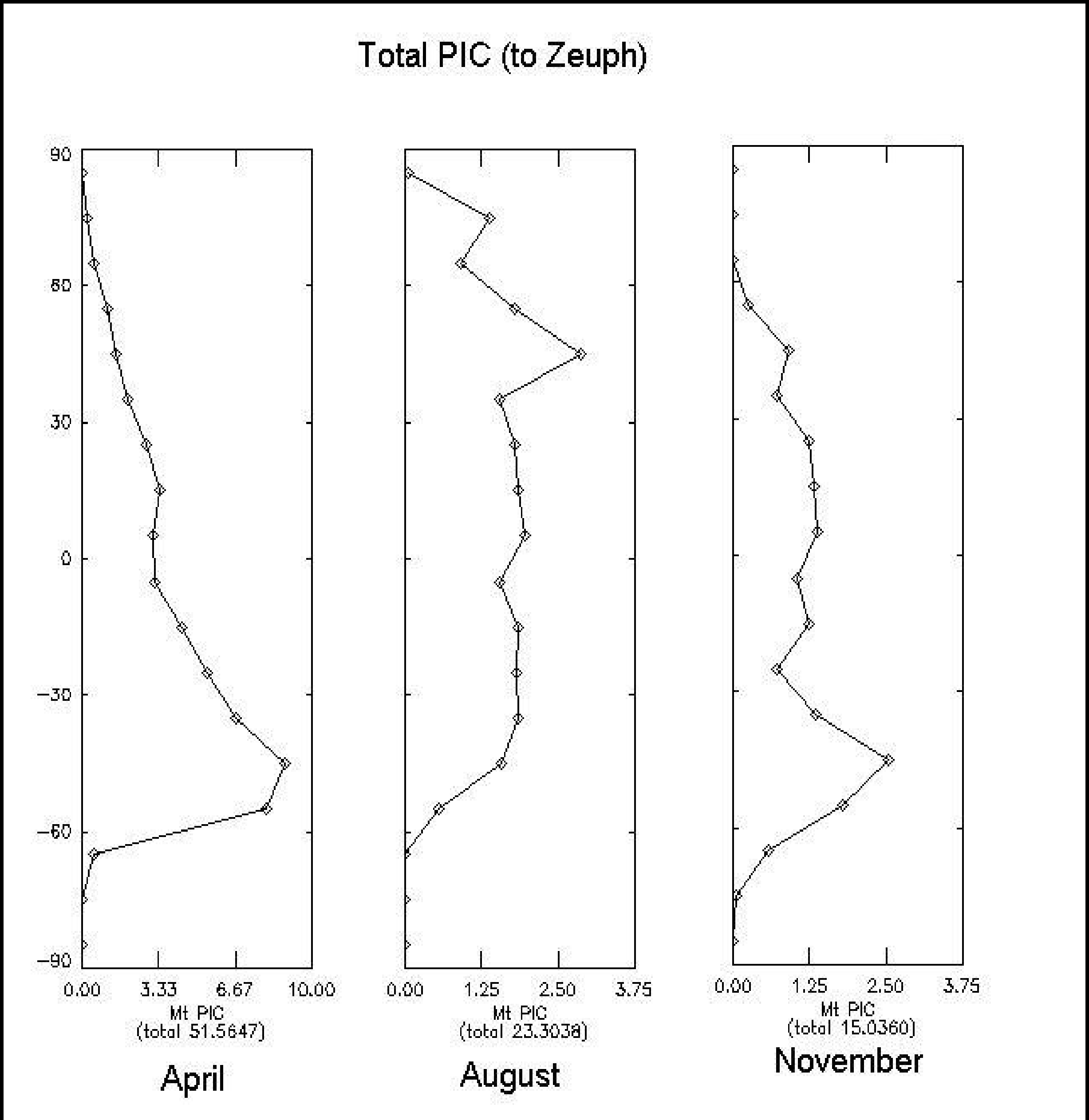
0 50 100 µgC:µgChl

Table of global POC and PIC standing stocks

	PIC (Mt)	POC (Mt)	PIC/POC
April	51.56	1030.75	5.00%
May	52.42	958.83	5.47%
August	23.30	1028.14	2.27%
October	15.90	990.54	1.61%
November	15.04	955.89	1.57%
Average	31.64	992.83	3.19%

Latitudinal distribution of PIC (Mega-tons per 10^{o} Lat)



Global Totals (Mt) 51.6 23.3 15.0

How do these numbers compare to other independent estimates?

- Global average PIC = 1.8 mg C m^{-3} (Milliman et al., 1999)…**<u>estimated global suspended PIC = ~65Mt</u>**. Order of magnitude confidence on these estimates!
- Published **<u>global ocean POC standing stock= 1000Mt</u>** (Whitaker, 1975). Carbon cycle science plan (Sarmiento et al., 1999) **<u>decadel average POC= 3000Mt</u>**.

Summary

- Validation data for 2 band PIC algorithm shows ±2μg PIC/l overall; ±0.2 μgPIC/l within an image.
- November ‘01 Chalk-Ex experiment was successful for making synchronous measurements of high [PIC] by MODIS and ship. Now examining subsequent imagery
- Global applications of 2-band algorithm show strong seasonal variability in PIC in S latititudes and in central gyres. This is of major significance for global carbon models.