Chalk-Ex: Calibration of the MODIS coccolith algorithm

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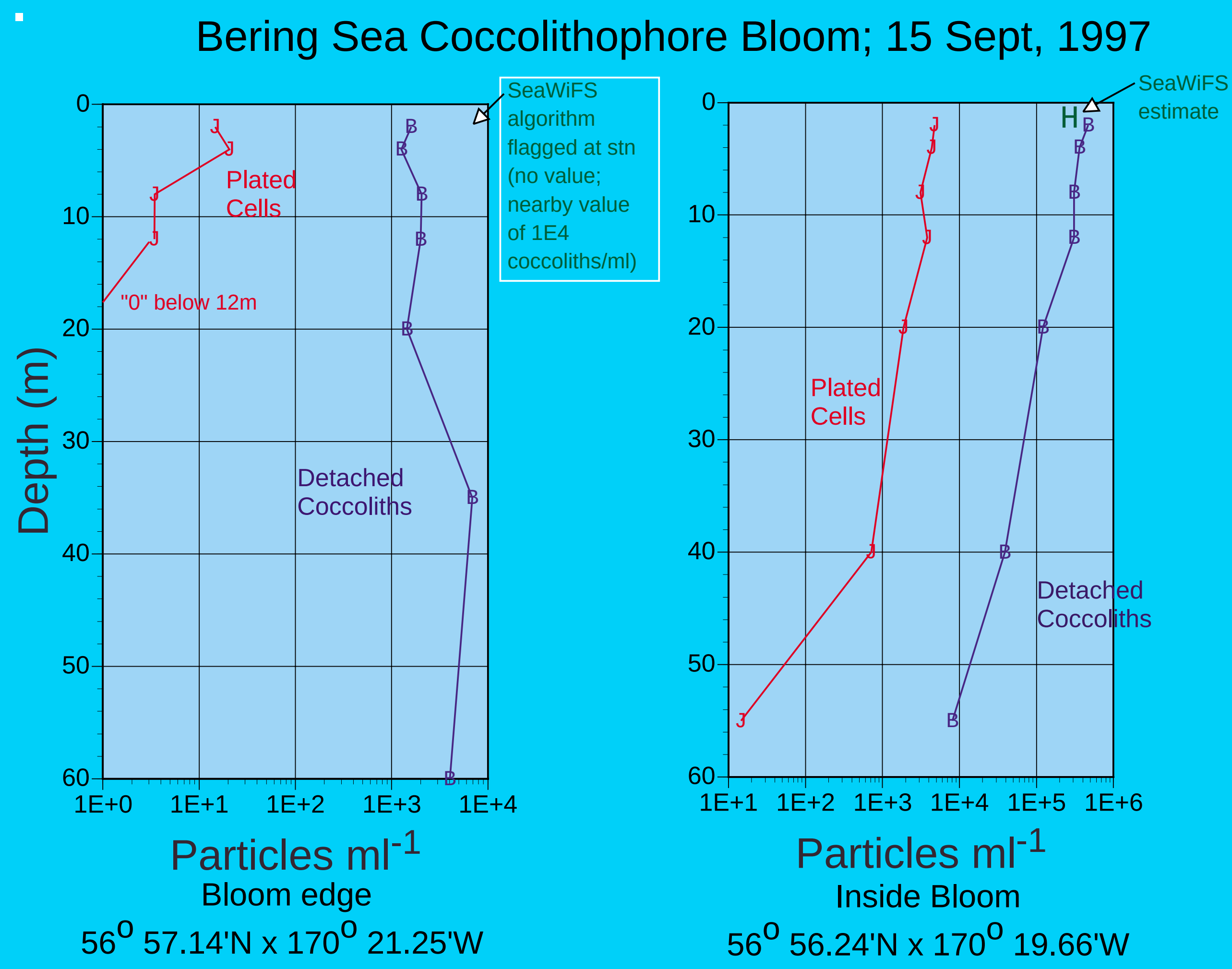
What does a coccolithophore bloom do to ocean color? Biogeochemical consequences?

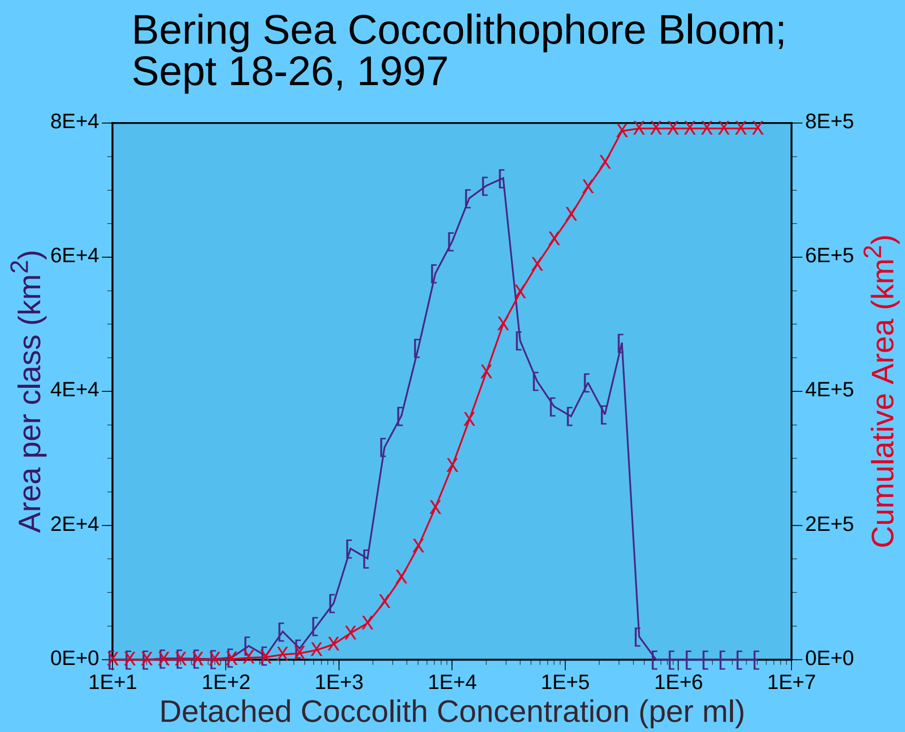
Gulf of Maine, June,1988

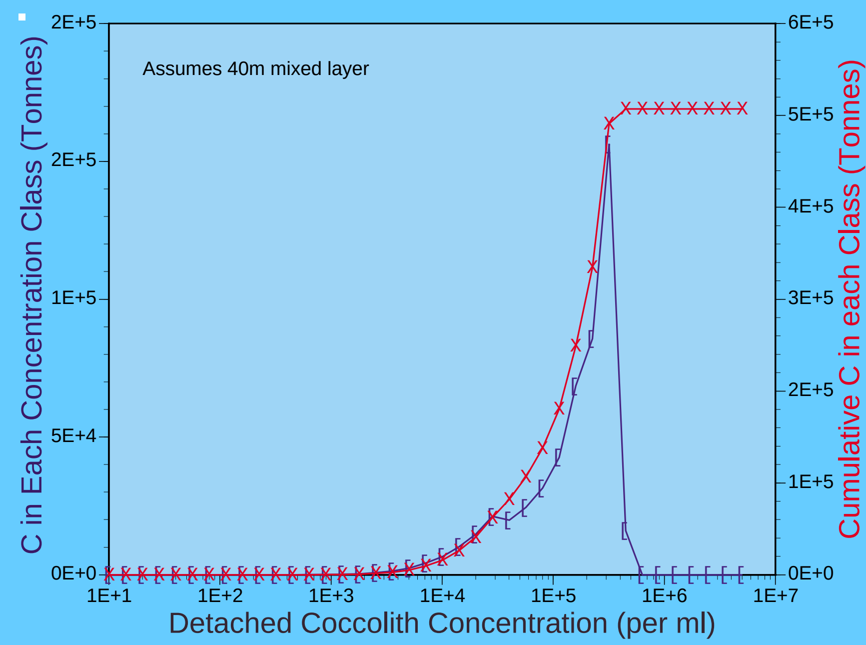
Speaker in navy-blue jacket

Pre-launch Algorithm results

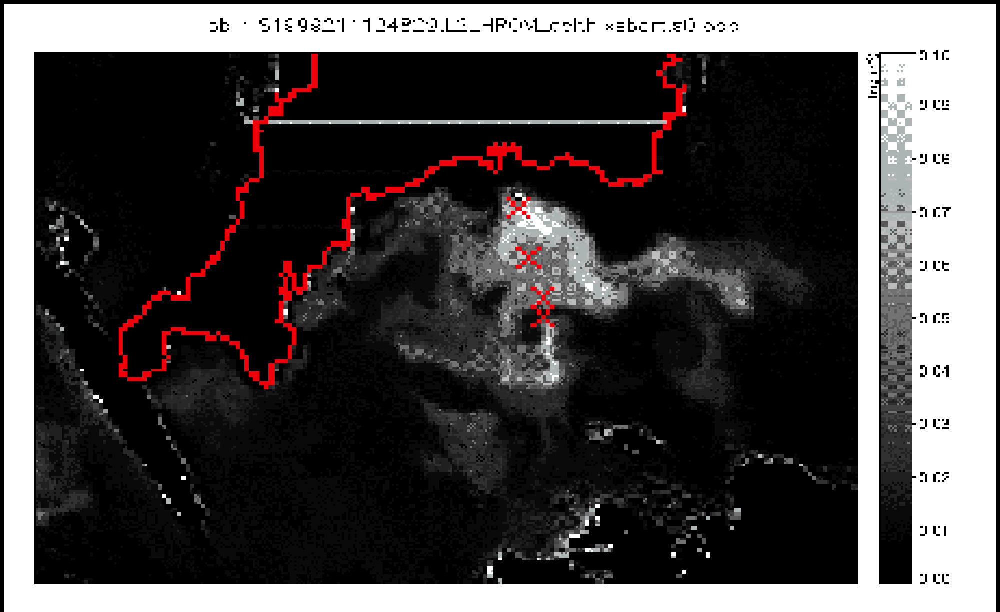


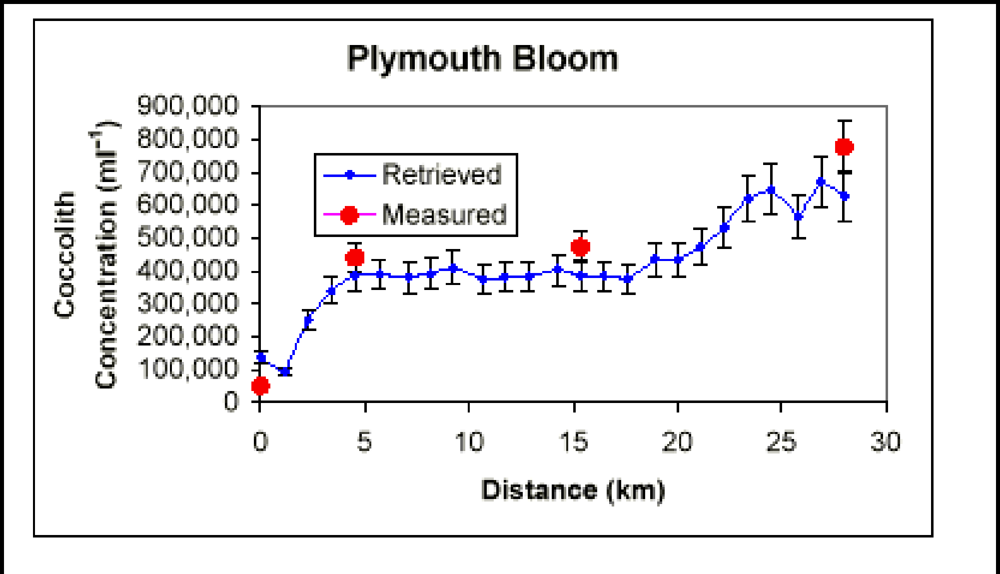
Algorithm applications:





New Algorithm Results



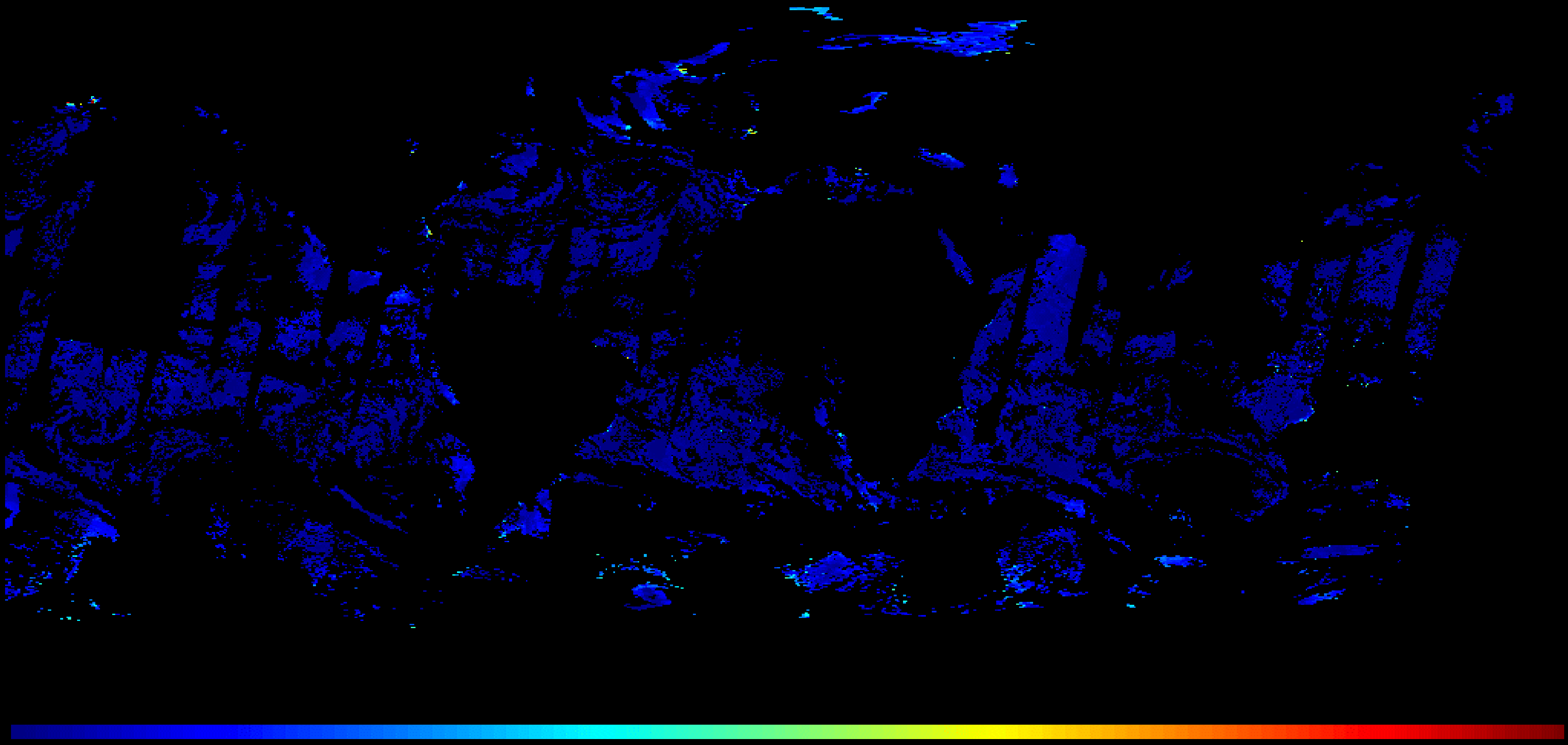


(Gordon, Boynton, Balch and Grooms), submitted

E. huxleyi bloom in English Channel, 1999

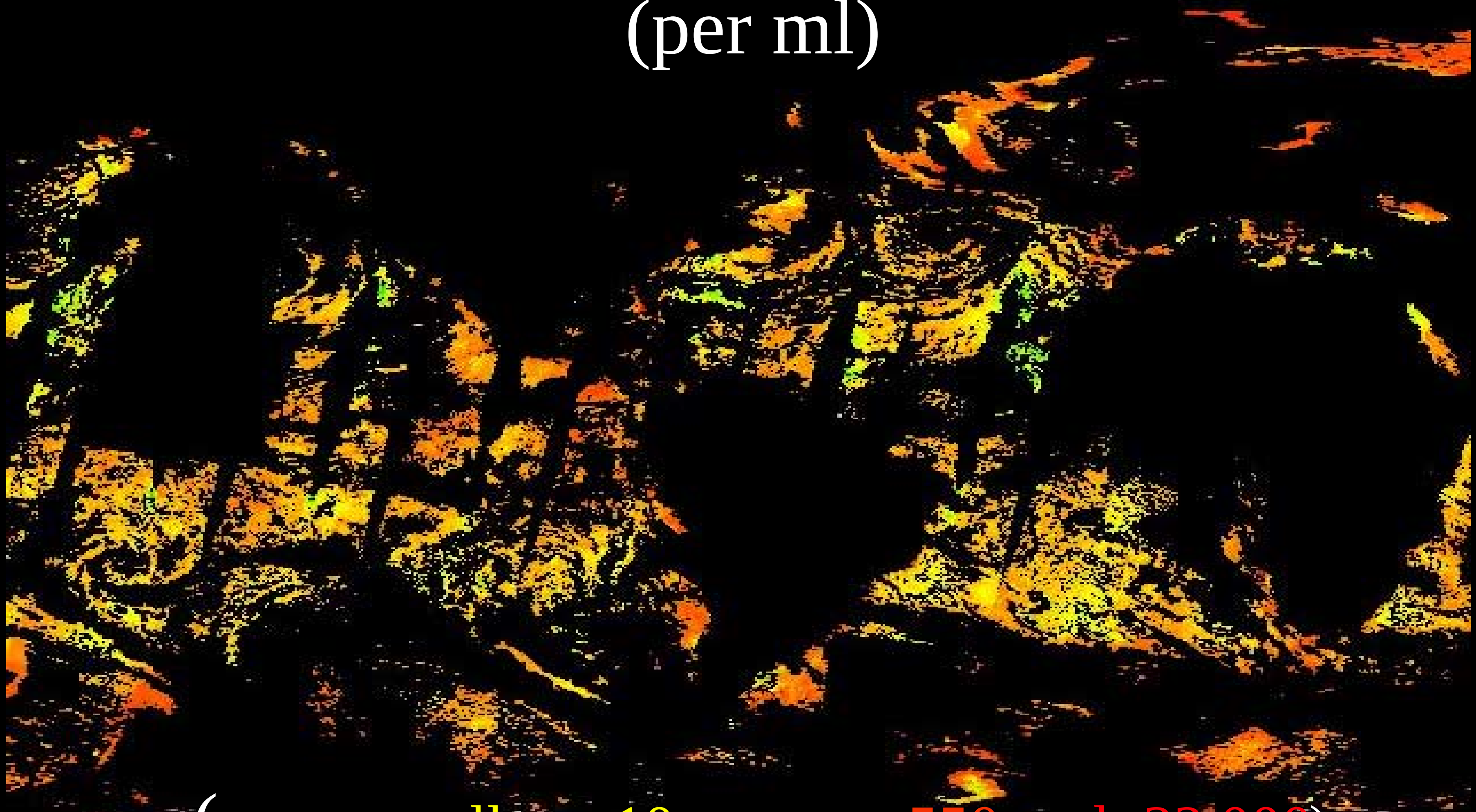
new 3 band algorithm; 670, 765, & 865

First look... MODIS coccolith concentration (2 band algorithm) April 11, 2000



Pretty much as expected…coccolithophore blooms are patchy in space and time!

Re-scaled MODIS coccolith concentration (per ml)



(4/11/00; yellow=10; orange=550; red=32,000)

These concentrations are very reasonable

..but how to sea truth a real bloom???

Challenges for Remote Sensing of Coccolithophores

- Find coccolithophore blooms
- Make sea-truth optical measurements under clear skies.
- Compare MODIS estimates to shipboard results for estimates of accuracy, precision and sensitivity
- Given occurrence of one coccolithophore bloom in the Gulf of Maine in the last decade, probability of predicting one in advance in order to schedule shiptime on clear days is almost nil!

Solution: “Make your own bloom”

- Ground Cretacious coccolith chalk is available with various grades of refinement
- Coccoliths are highly efficient scatterers (i.e. a little ground chalk goes a long way)
- One needs about 58g CaCO3 per m^2 to equal concentrations found in the spectacular N. Atlantic features, 8 g $CaCO_3$ m^{-2} will make a bright feature.

Calculations and assumptions

- Using standard wake dispersion calculations based on cross-sectional area of submerged hull, and speed.
- Final PIC concentration of 8g CaCO3 m^{-2} will be used with a target patch size of 3km^2.
- Total required PIC will be 25 metric tons
- With a horizontal eddy diffusion coefficient of 10^4 cm^2 s^{-1}, one 3 km line will diffuse to ~300m width in 1/2 d.

More calculations/assumptions

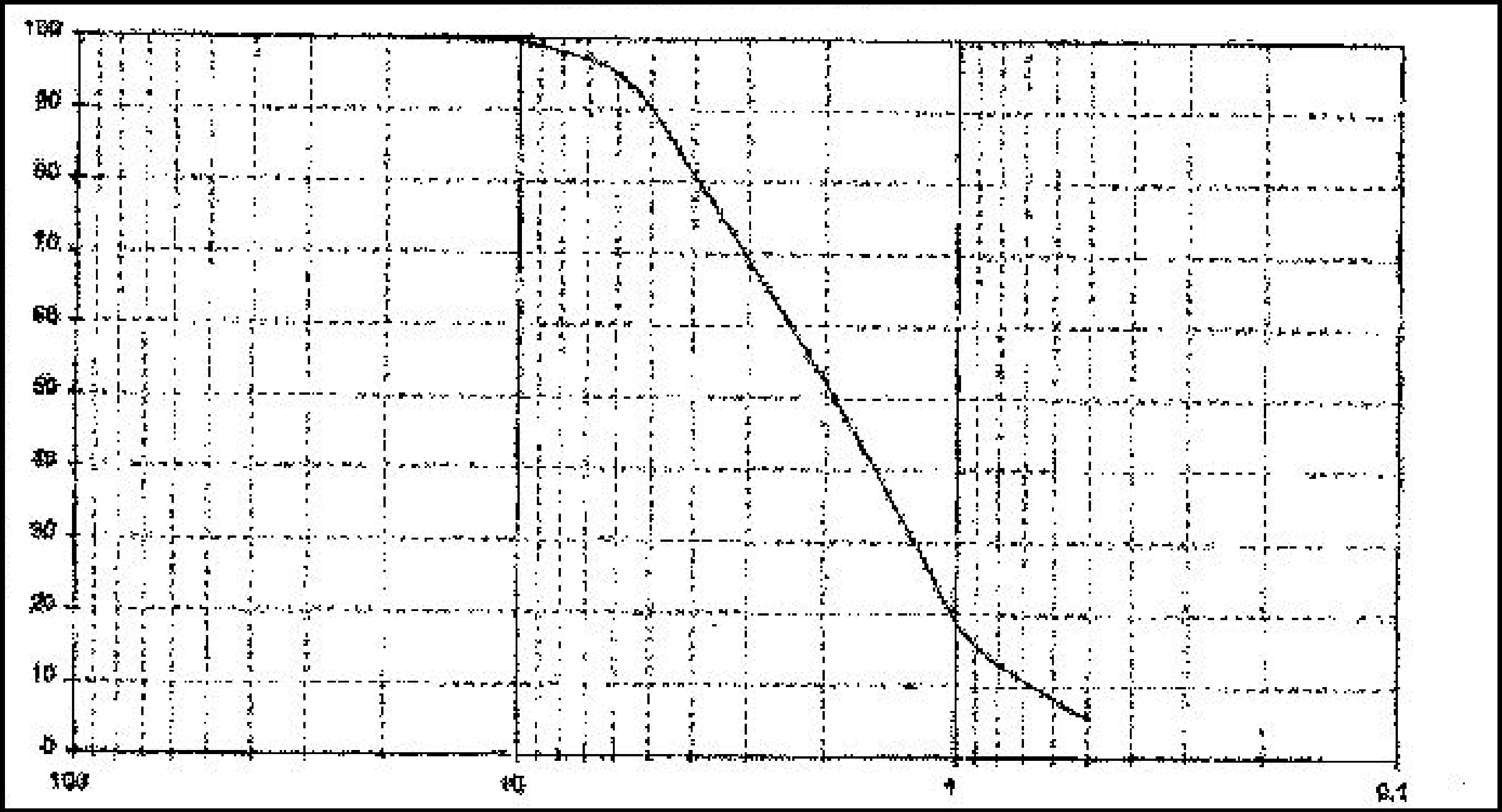
- Primary stock will be 210kg m^{-3} (21% by wt, or ~2M). Chalk slurries of 60% (~6M) are possible!
- PIC will initially be dispersed over top 3m (2.8 g $CaCO_3$ m^{-3})
- With a 30m mixed layer, when PIC is eventually dispersed homogeneously, final concentration will be ~0.3 g $CaCO_3$ m^{-3}.

Optical Consequences

- Chlorophyll *a* = 0.1 mg m^{-3}
- Initial expected optical properties in wake: $bb_{total\ 550}$ = ~0.1 m^{-1} ; R_{550} = ~0.26 (assume $Q=\pi$ and eqns of Gordon et al., 1988)

- Final optical properties (mixed over 30m):
  $bb_{total\ 550}$ = ~0.006 m^{-1} ; R_{550} = ~0.025
- The plan will be to provide sea-truth for overpass, and watch the optical evolution of the feature over time.

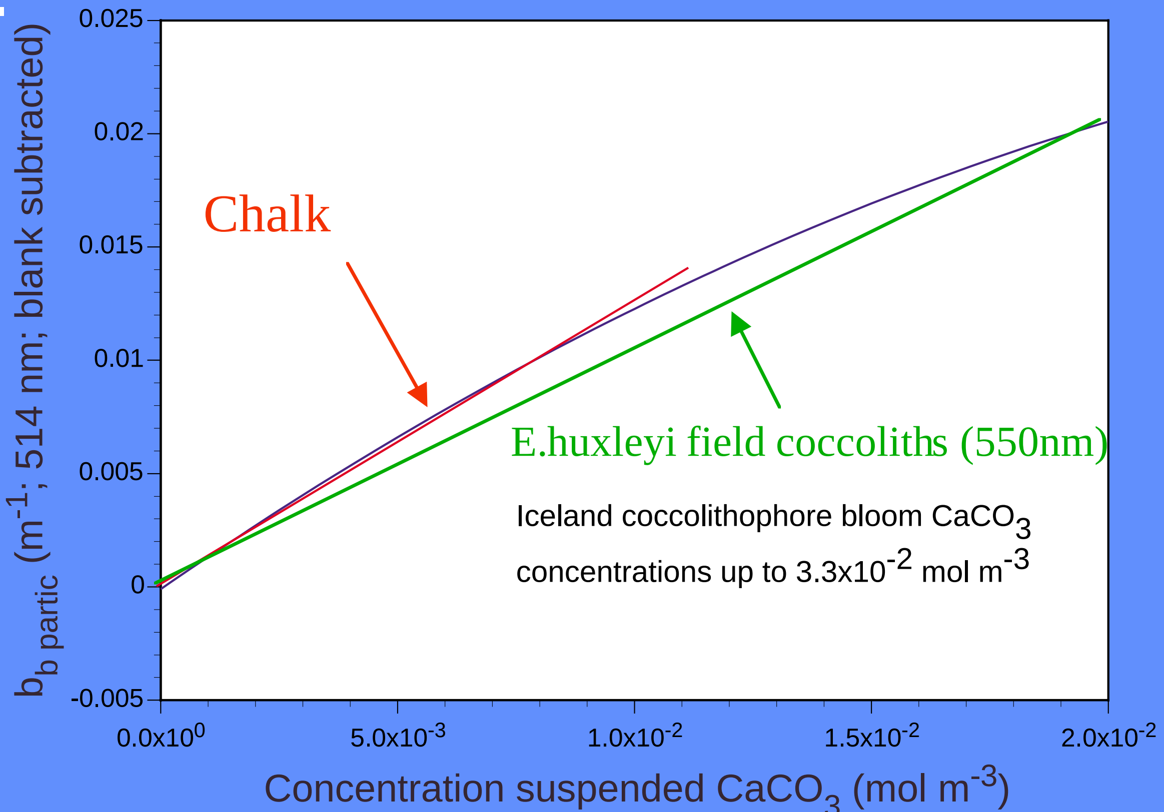
Size distribution of chalk



Percentage by weight finer than:

Particle diameter (µm)

Specific scattering coefficient of ground Cretacious chalk



Linear fit to lower 3 concentrations
f(x) = 1.246*x + 3.932E-5
R^2 = 0.9879

Polynomial fit to full range of concentrations:
f(x) = -20.520*x^2 + 1.441*x + -9.4815E-5
R2^2 = 0. 838,R1^2 = 0.9753,R0^2 = 0.9895

Proof of concept:
Purchase 1 Ton of Chalk

Adding 25 kg of chalk to mixer

$CaCO_3$ seawater slurry prior to release

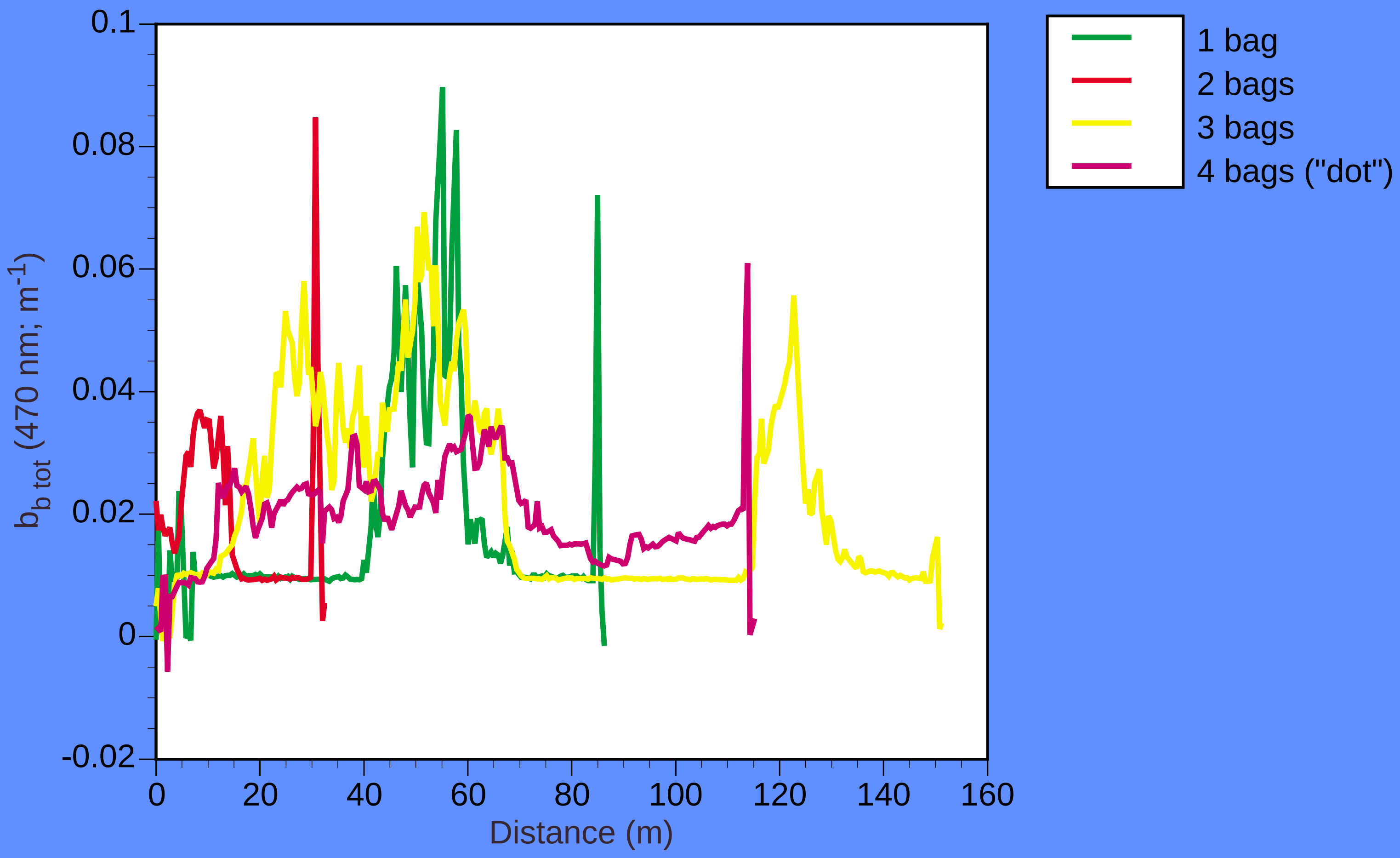
Dispersing chalk

Patch after 1/2 h

Patch after 1.5h

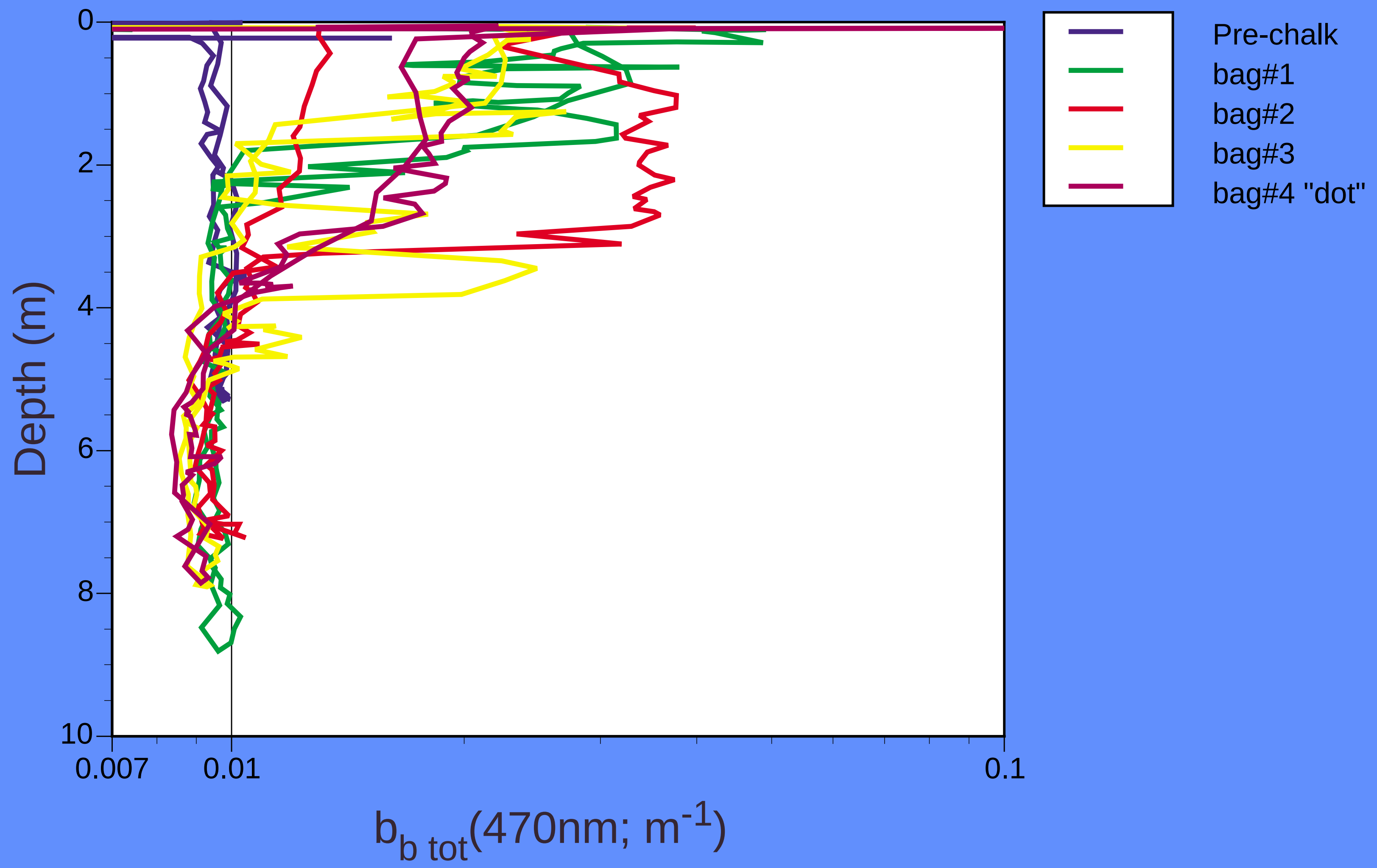
Horizontal Distribution of Patch

- Chalk-ex #1; 4/19/00



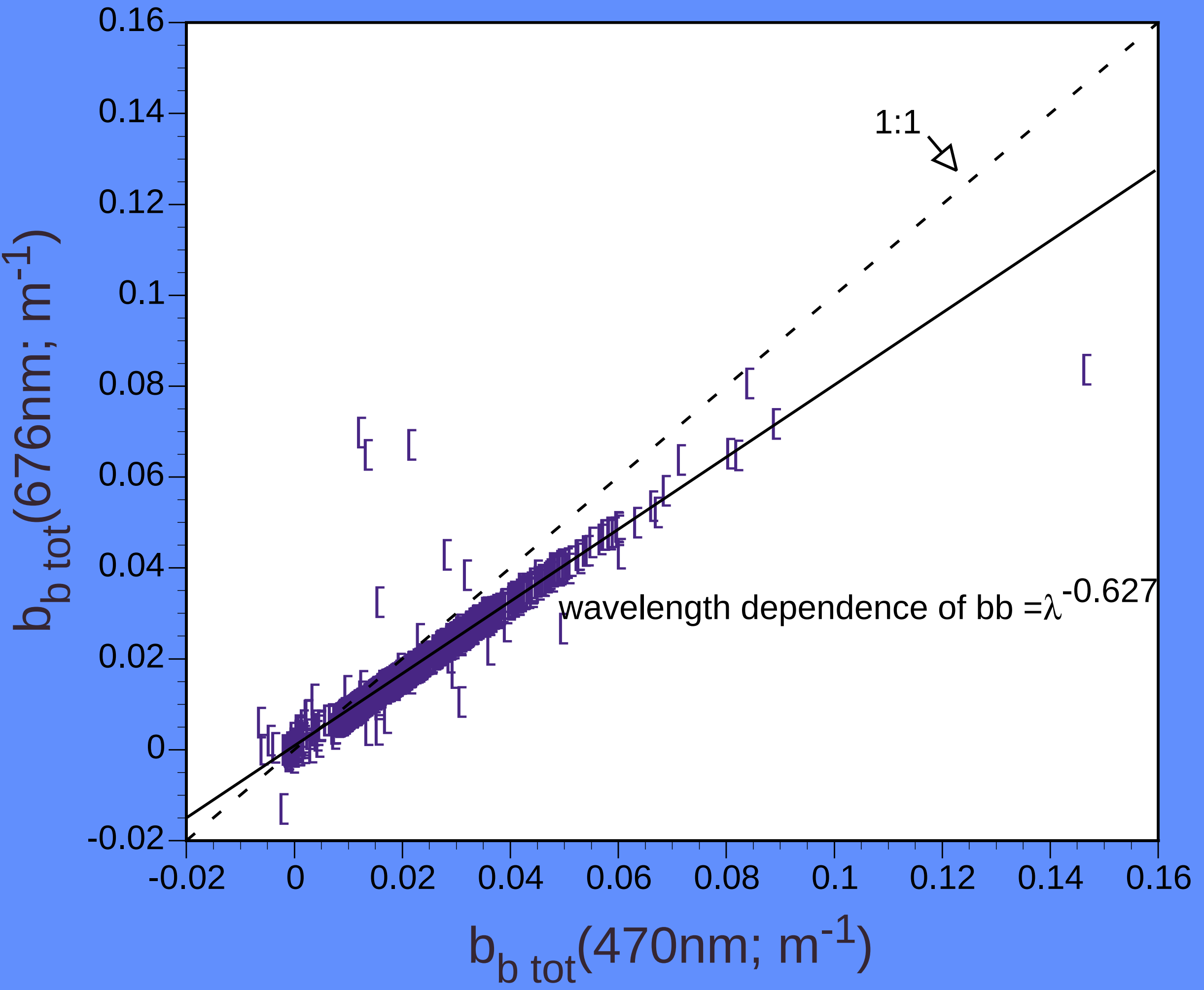
Vertical profiles bb470 in patch

- Chalk-ex #1; 4/19/00



Wavelength dependence of bb

- Chalk-ex #1; 4/19/00



Next step

- Need for a scaled-up experiment
  - Define mixing scales
  - Optical scales
  - Time scales
  - Space scales
- 0.9 Tons of chalk left...

Initial Deployment of 0.9T chalk in offshore waters

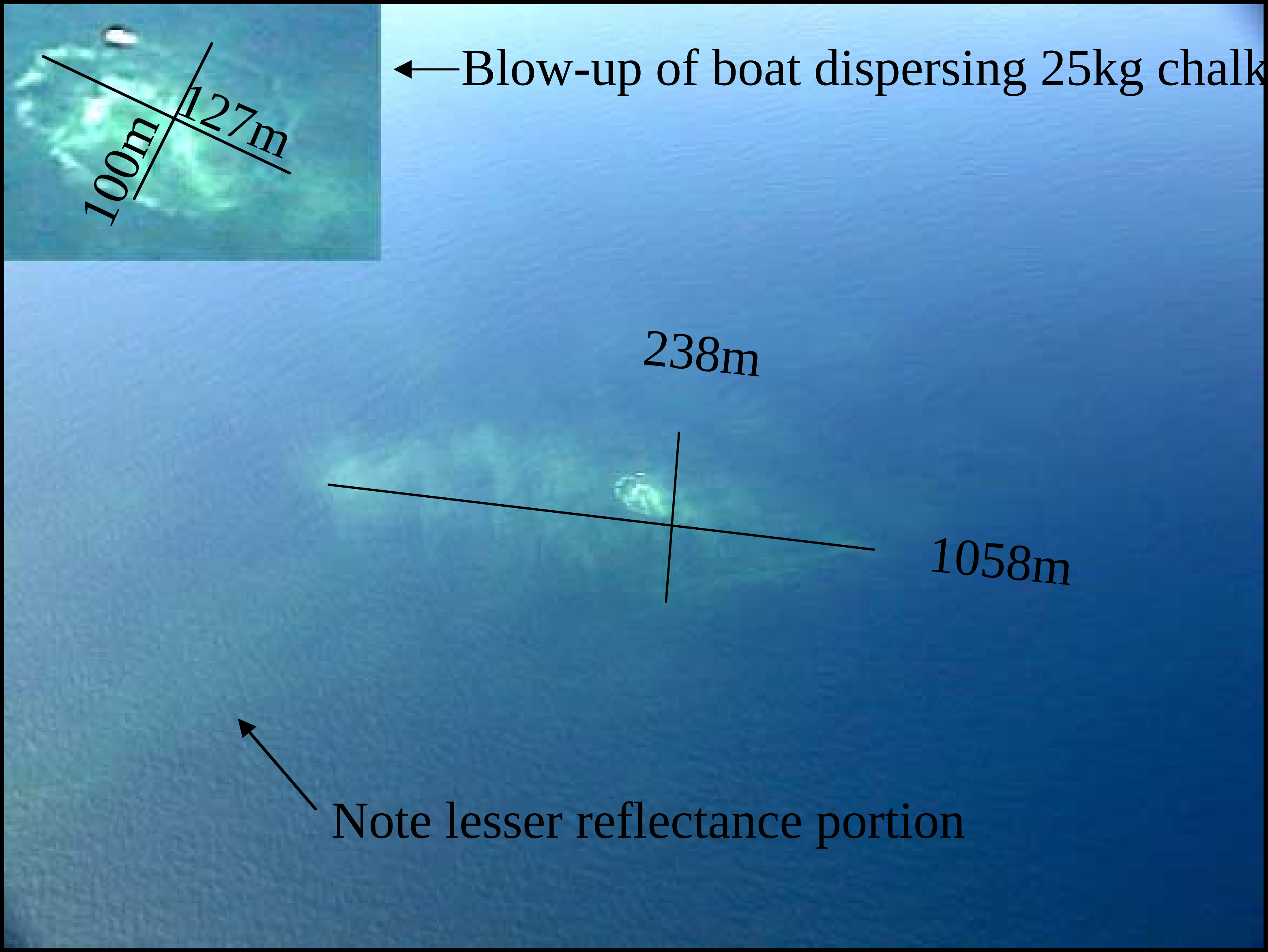
Spreader

Hosing down between chalk batches

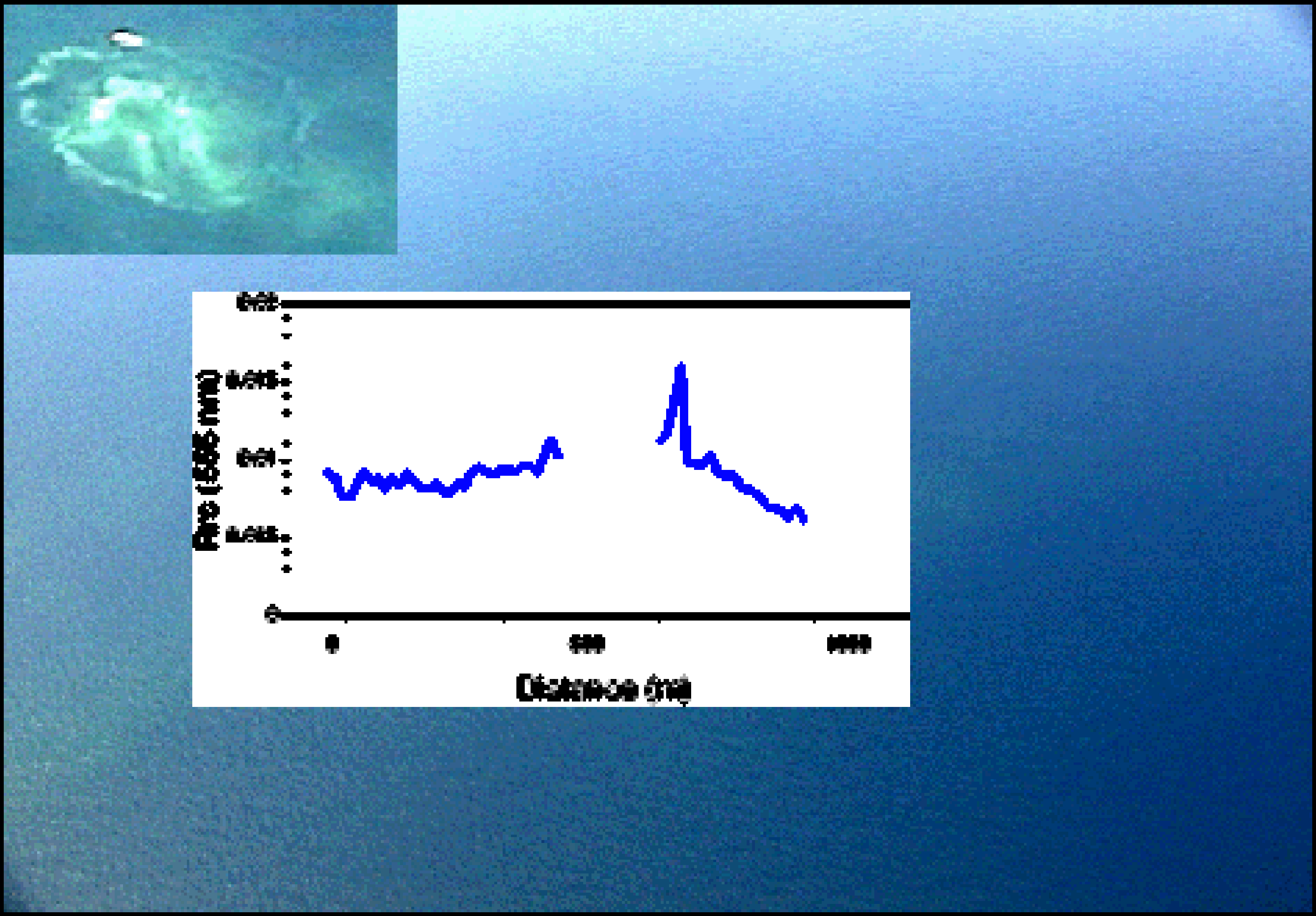
Finishing 0.9T patch

Vertical bb profiles in patch

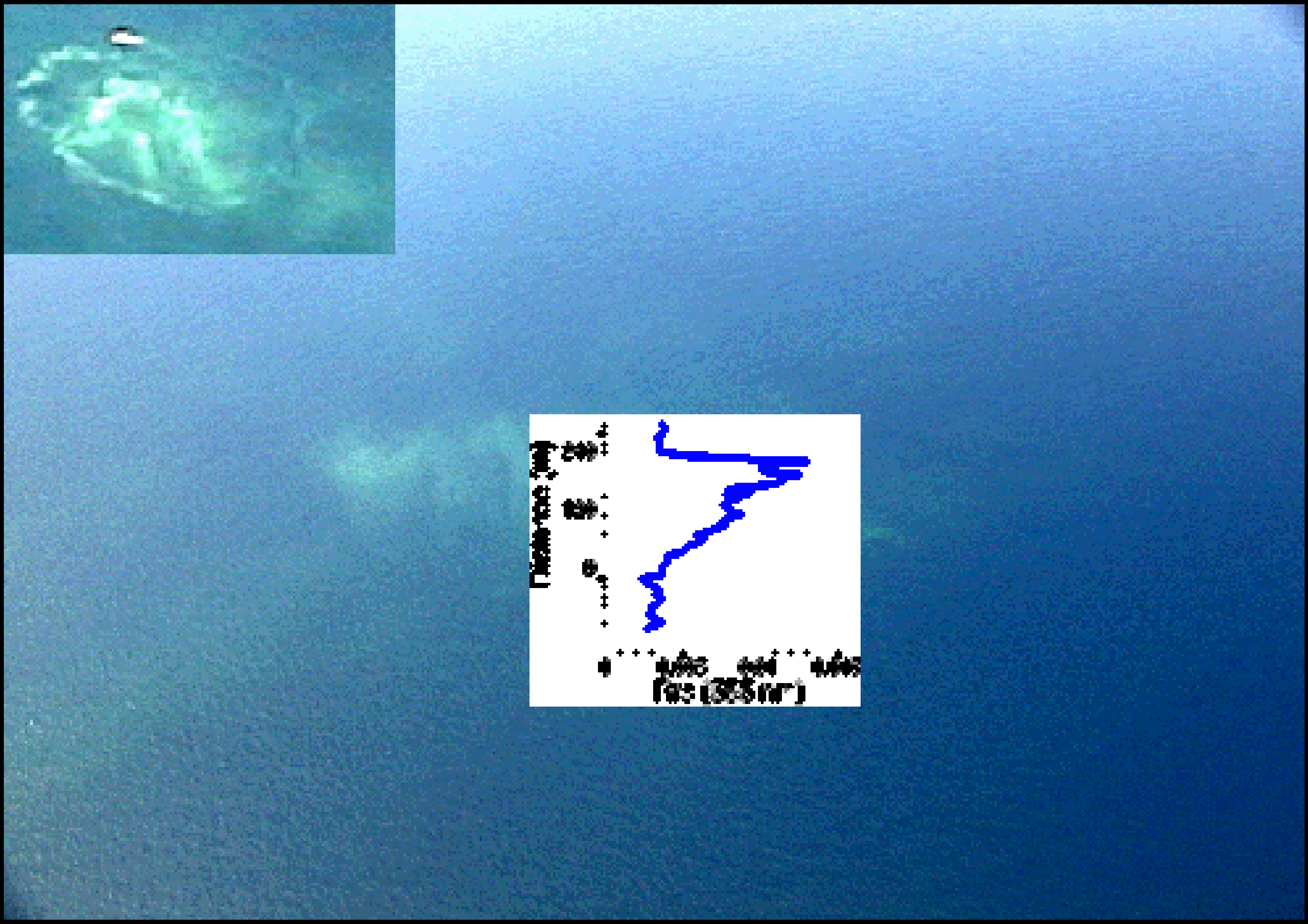
View of 0.9T patch from 6,500ft



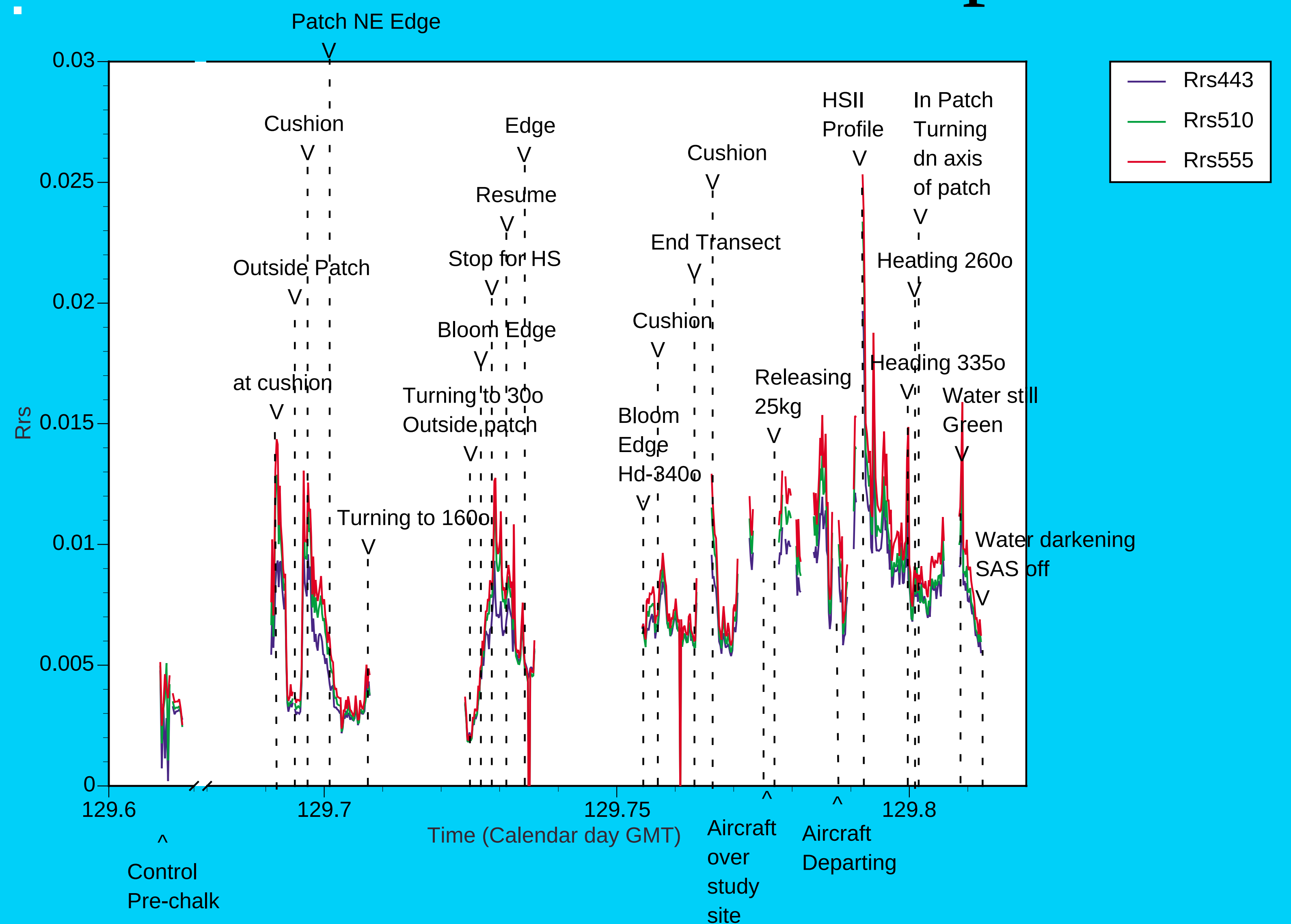
555nm reflectance measured from boat



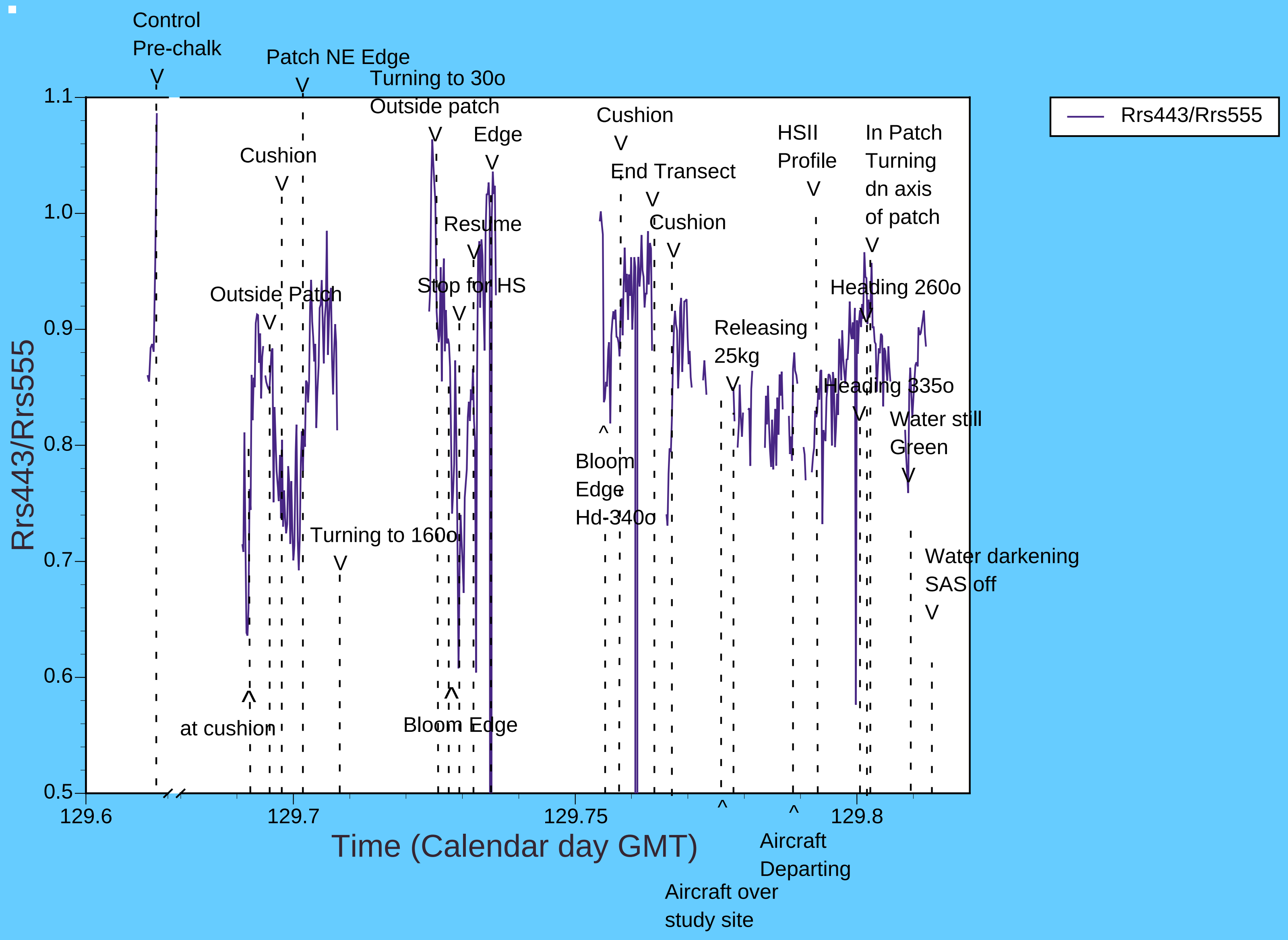
555nm reflectance across patch



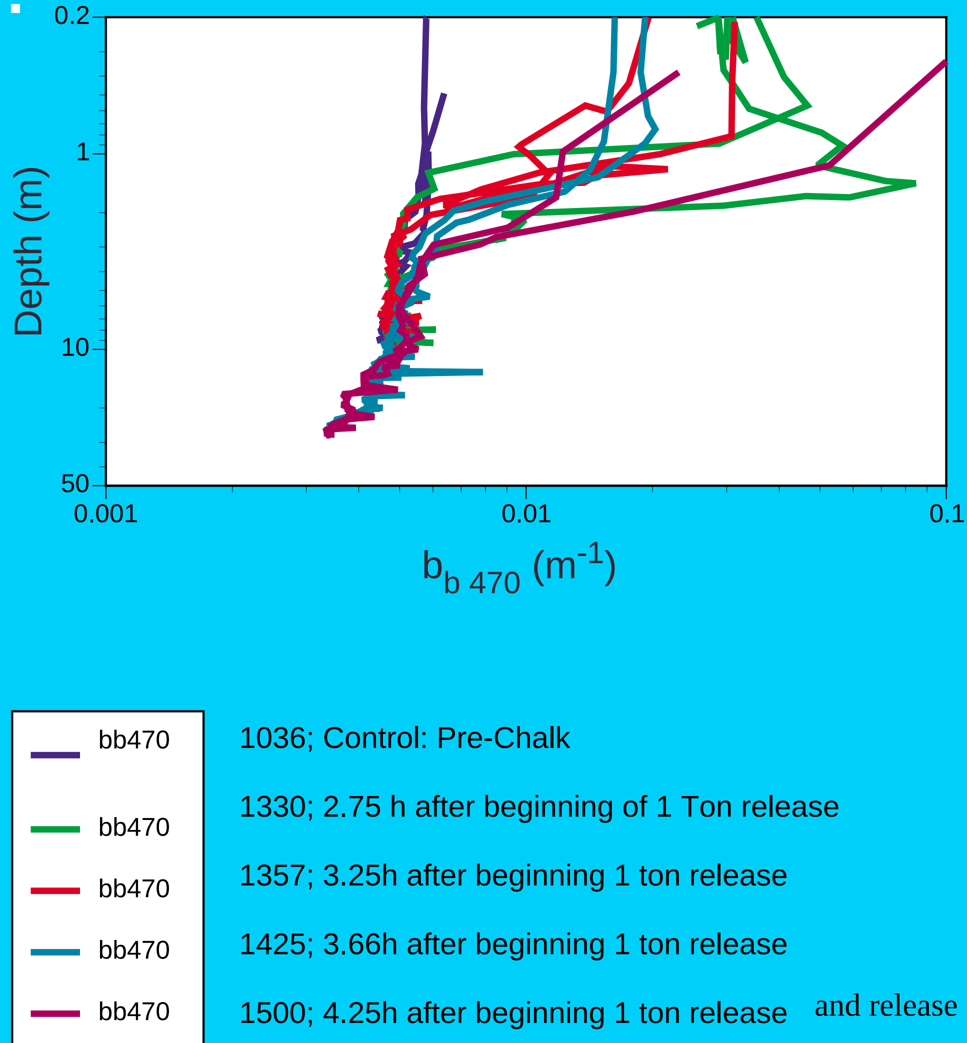
Rrs data from 0.9T patch



Rrs443/Rrs555 in 0.9T patch



Profiles of $b_{b\ 470}$ in 0.9T patch



1036; Control: Pre-Chalk

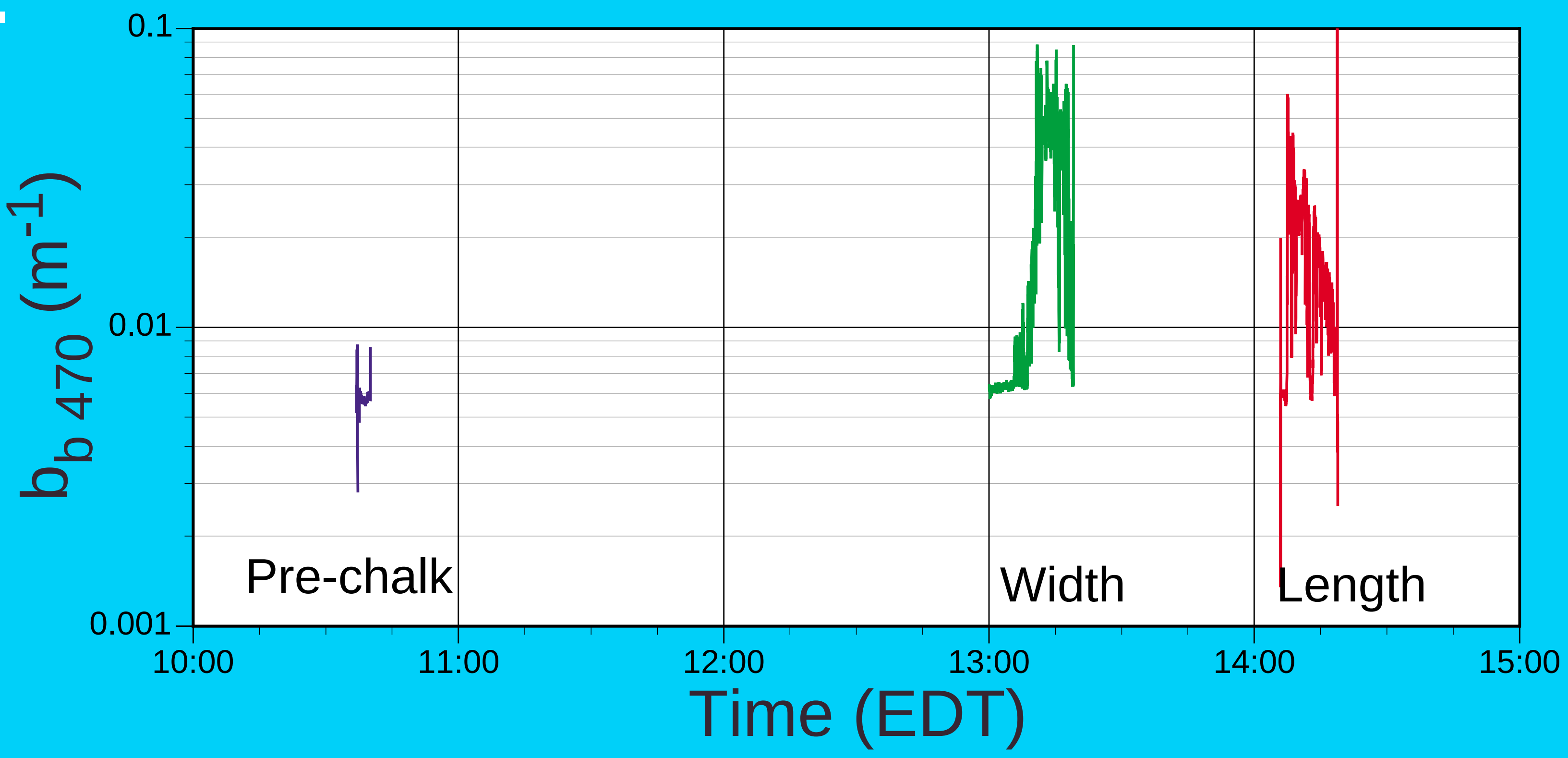
1330; 2.75 h after beginning of 1 Ton release

1357; 3.25h after beginning 1 ton release

1425; 3.66h after beginning 1 ton release

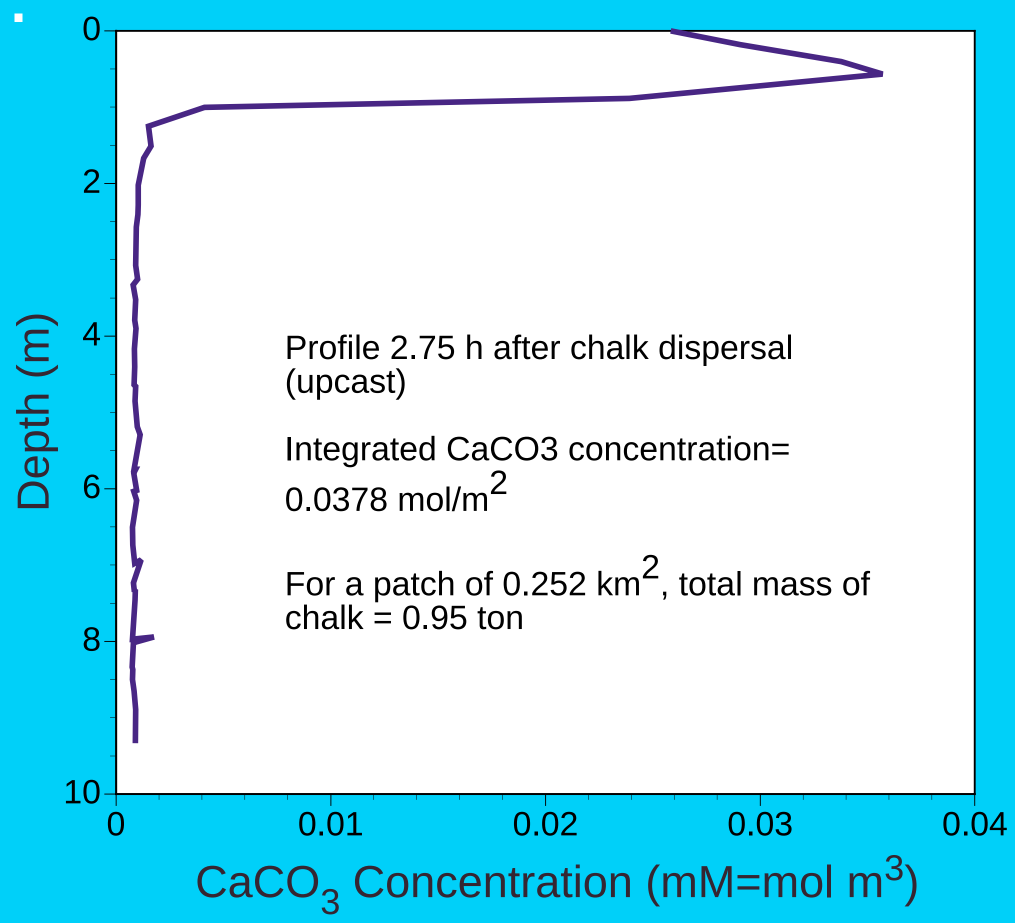
1500; 4.25h after beginning 1 ton release and release of additional 25kg

Surface $b_{b\ 470}$ transects through 0.9T patch



Is there mass balance?

$$M=\Sigma_{depth}[(bb-bb_{blank}) \times bb^*_{CaCO3}] \times [\text{patch area}]$$



Plans

- First full-scale Chalk-Ex August 3-14, 2000 we will take 25 tons of chalk aboard *R/V Cape Hatteras* to blue oligotrophic waters to create a 3 km^2 patch.
  - 9d window for a clear day, and 3d of 9d to lay patch, and follow the optical evolution.
  - Will collect IOP’s and AOP’s, discrete samples.
  - Hoping Frank Hoge can provide aircraft coverage.
  - US Coast Guard, Army Corps, and US EPA have all been consulted in planning this experiment!
- Barring any real coccolithophore blooms, we will repeat experiment in 2001. Thank you!