Remote Sensing Reflectance Inversion of Phytoplankton Community Size Structure and Ecological Implications

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RTE and Remote Sensing Course - DMC

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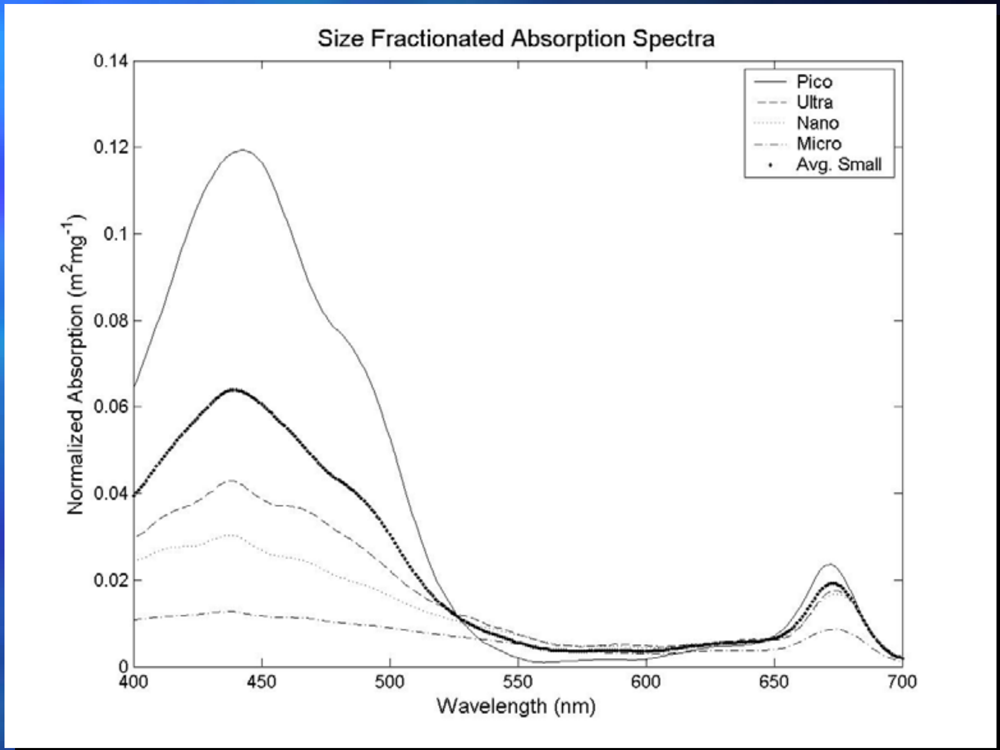
Ecological Importance

- Many biogeochemical processes are directly related to the distribution of phytoplankton size classes in a given environment or time (Longhurst, 1998), and size distribution is a major biological factor that governs the functioning of pelagic food webs (Legendre and Le Fevre, 1991).

Absorption and Cell Size

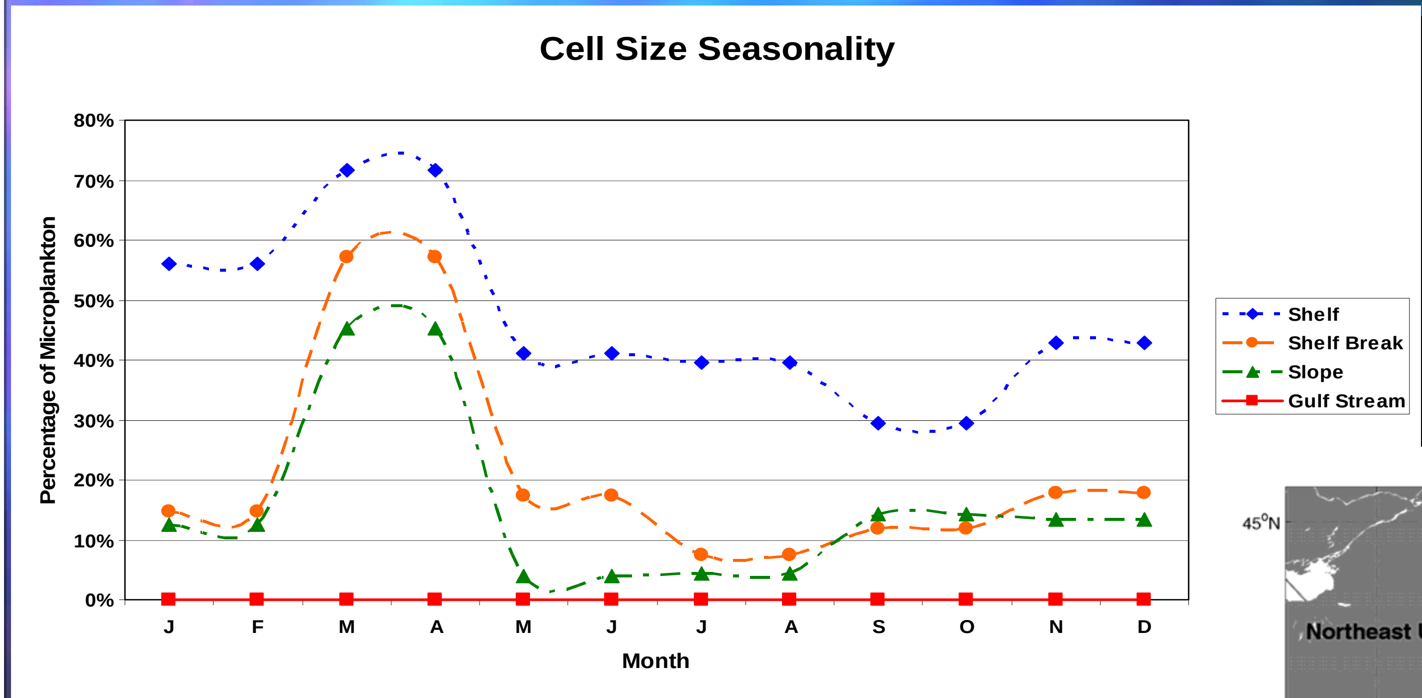
- Variation in spectral shape can be defined well by changes in the dominant cell size due to pigment concentration and packaging.
- No direct dependence on chlorophyll *a*.

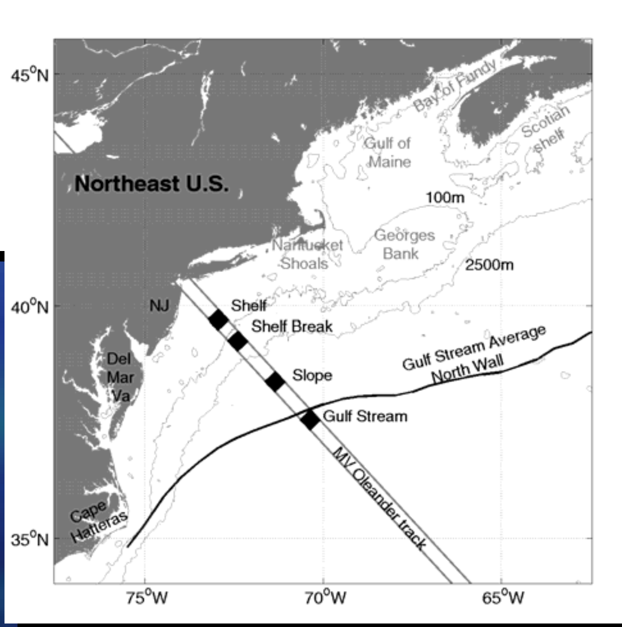


$$\bar{a}^*_{ph} = [(S) * \bar{a}^*_{pico}] + [(1-S) * \bar{a}^*_{micro}]$$

(Ciotti *et al.*, 2002)

Cell Size Seasonality





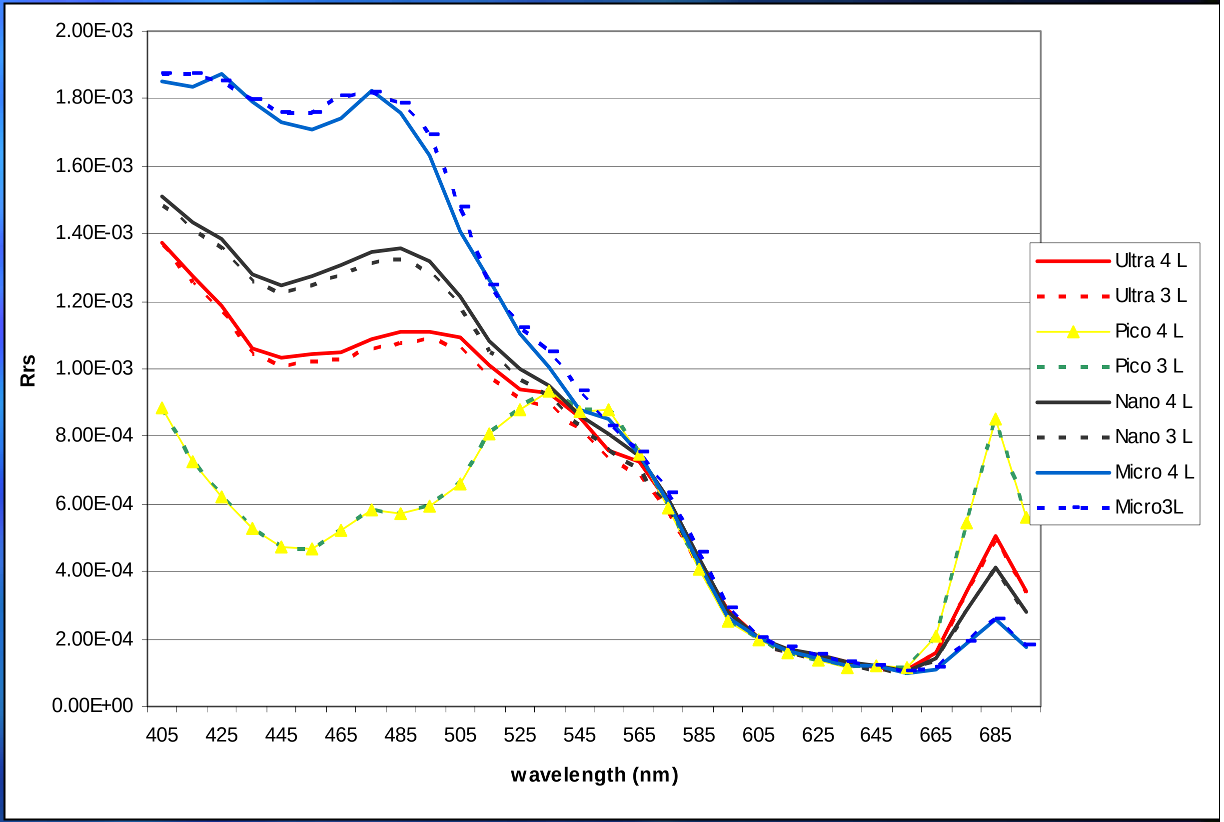
O'Reilly and Zetlin, 1998; Olson *et al.*, 1985; Olson *et al.*, 1990; Cavender-Bares *et al.*, 2001

Forward Model

- Ciotti et al., 2002 $a_{\phi}^{*}(\lambda)$
- Mie calculations to obtain $b_{b\phi}^{*}(\lambda)$ and phase function
  - Varied the slope between -3 and -4
  - Spectral calculation for numerous cell sizes within each size fraction.
- Hydrolight
  - ABCASE2
  - Constant chlorophyll (2 μg/L)
  - Low [CDM]
  - NAP set to zero
  - R_{rs} calculated for each size fraction with varying slopes.

Forward Model

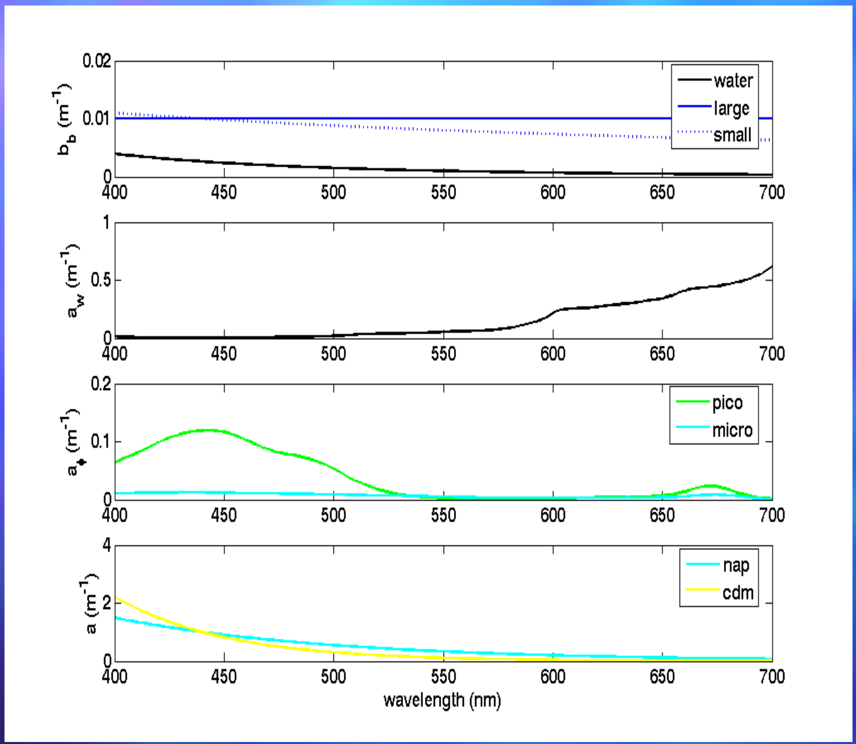
- Investigate influences of packaging and particle size distribution (PSD) on R_{rs}.
- Constant slope, vary size ⇒ packaging
- Constant size, vary slope ⇒ PSD

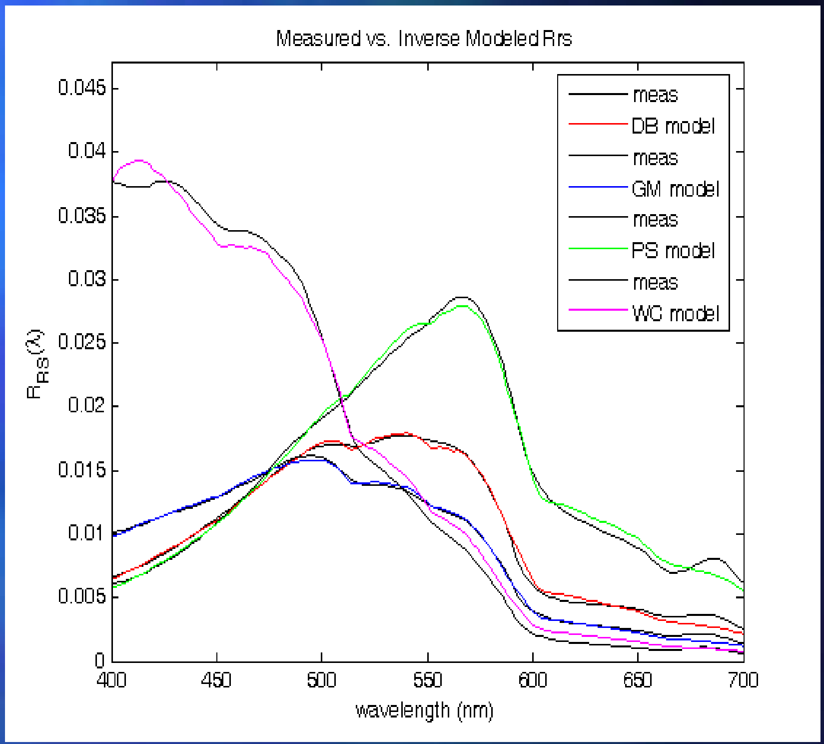


Inverse Model

- Roesler and Perry, 1995 Inversion Model
- Ciotti et al., 2002 phytoplankton chlorophyll specific absorption size fractionated basis vectors.
- $R(\lambda) = G \dfrac{b_b}{a + b_b}$.
- $b_b = b_{bw}(\lambda) + C_{bbp}\, b_{bp}{}^{*}(\lambda)$
- $a = a_w(\lambda) + C_{a\phi}\, a_\phi{}^{*}(\lambda) + C_{CDM}\, a_{CDM}{}^{*}(\lambda) + C_{NAP}\, a_{NAP}{}^{*}(\lambda)$
- $a_\phi{}^{*}(\lambda) = [S(f)\, a_{pico}(\lambda)] + [(1-S(f))\, a_{micro}(\lambda)]$ (Ciotti et al., 2002)

Preliminary Results



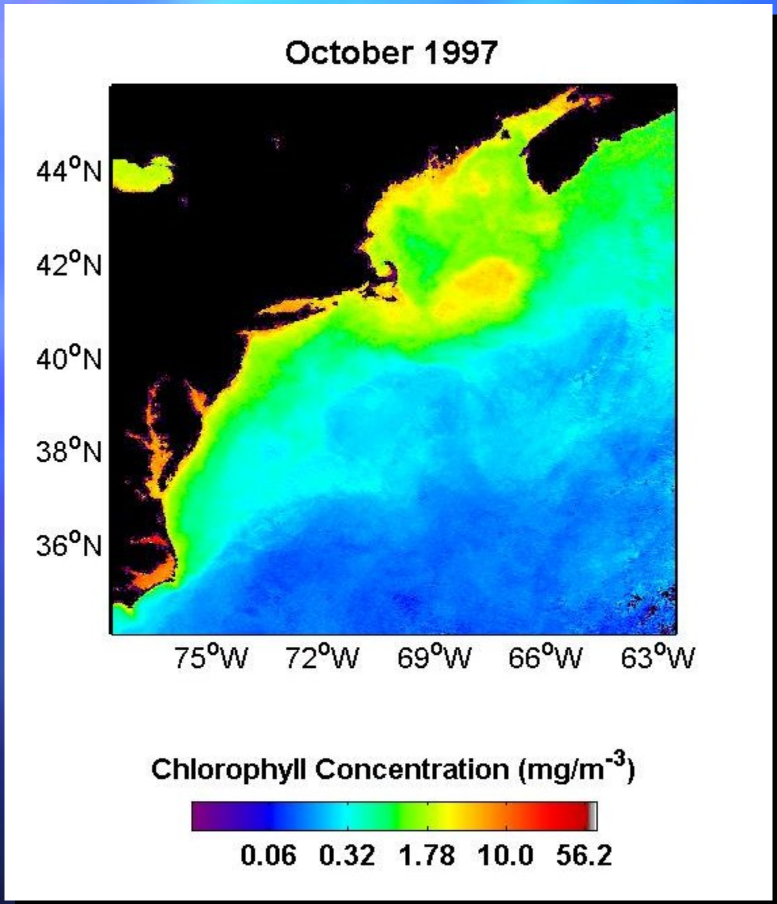


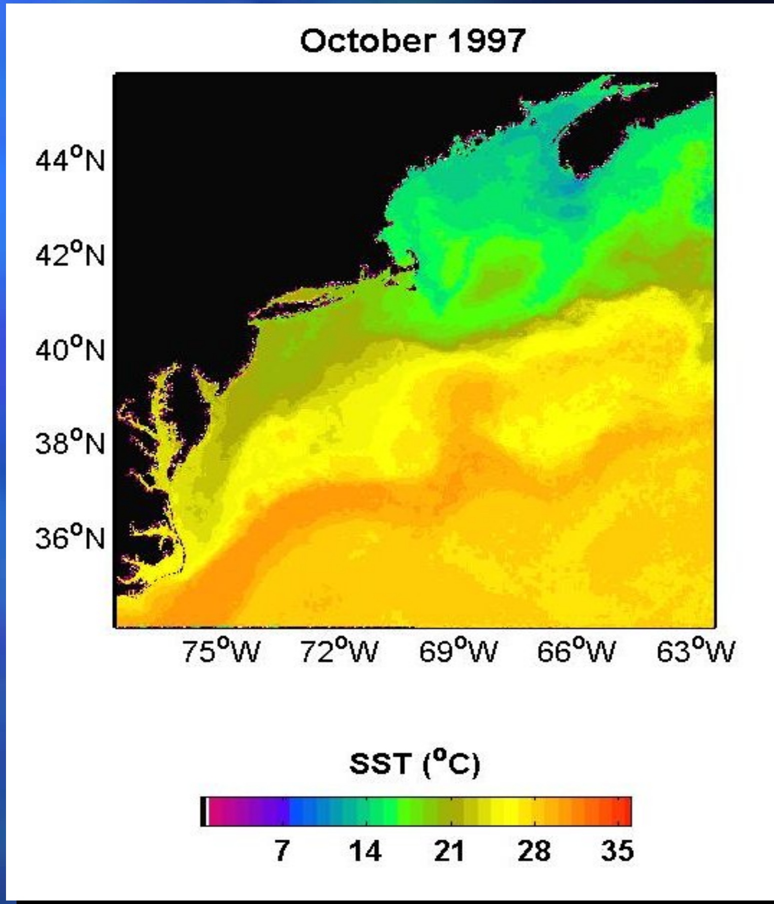
	DM	GM	PS	WC
% pico	16.5%	10.9%	9.2%	8.3%
pico chl. (ug/L)	0.11	0.13	0.20	0.10
micro chl. (ug/L)	0.54	1.06	1.20	1.06

Application to Imagery

- $R_{rs} = L_w/E_d$
- Calculate R_{rs} from nL_w for each band and invert to obtain relative community size structure.

Current View of the Ocean Surface





COMING SOON… maps of cell size distribution and IOPs

Application to Ecology

Production Model

$$PP = \int a^{*}_{ph} * \Phi * E_k * \tanh(E_z/E_k) * chl\, dz$$

(Mouw and Yoder, submitted)

Production Model

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$$\Phi = \Phi_{max} * f_a * f_\Delta * f_{c(N)} * f_{c(\tau)} * f_{c(PAR,inh)} * f_{E,t}$$ (Woznaik *et al.*, 2002)

Production Model

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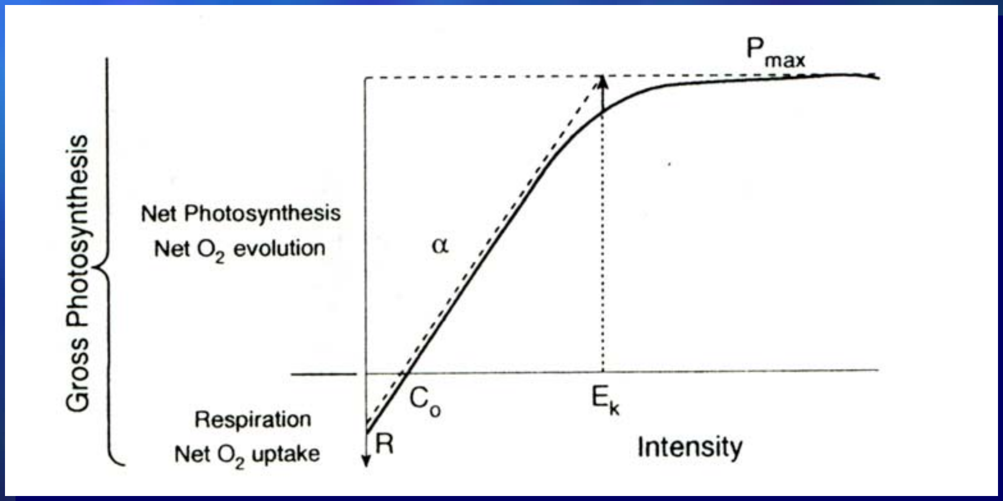
$$E_k = P^b_{max}/\alpha$$ (Sakshaug *et al.*, 1997)



Production Model

$$PP = \int \bar{a}^*_{ph} * \Phi * E_k * \tanh(E_z/E_k) * chl\ dz$$

$$\bar{a}^*_{ph} = [(1-S) * \bar{a}^*_{pico}] + [(S) * \bar{a}^*_{micro}]$$ (Ciotti *et al.*, 2002)

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$$P^b_{max} = f(T)$$ (Behrenfeld and Falkowski, 1997)

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$E_k = P^b_{max}/\alpha$ (Sakshaug *et al.*, 1997)

$P^b_{max} = f(T)$ (Behrenfeld and Falkowski, 1997)

$\alpha = \bar{a}^*_{ph} * \Phi$ (Sakshaug *et al.*, 1997)

Future Directions & Conclusions

- Future Directions:
  - Check inversion at multispectral resolution
  - Apply to satellite imagery
  - Sensitivity analysis
  - More insight into differences in packaging and species composition
  - Compare to ocean times series and historical surveys.
- Conclusions:
  - Theoretically, cell size can be mapped from ocean color.
  - Lead to greater understanding of ecological structure, function, and dynamics important in carbon cycling and global climate studies.

Acknowledgements

- CM - for helping clarify my fuzzy intuition that mapping cell size was possible from inversion models, idea of the investigation of packaging and PSD with Mie Theory and Hydrolight; and modifying inversion code.
- EB - Mie Theory
- CM - Hydrolight and comic relief
- NASA, ONR, UMaine
- The rest of the gang!!