Particle Aggregation & Disaggregation

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1785

A Tale of Two Bacons

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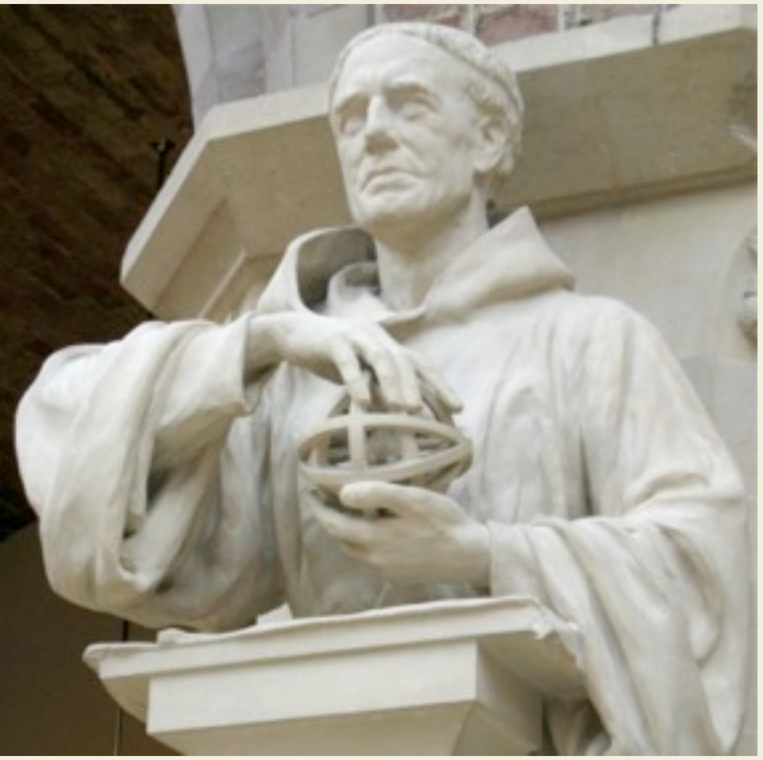
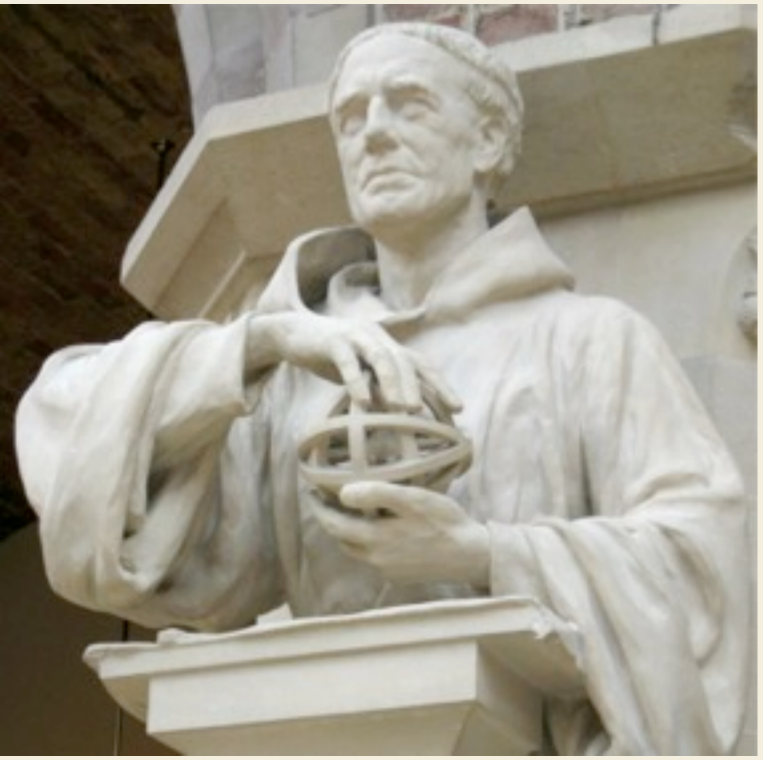


A Tale of Two Bacons



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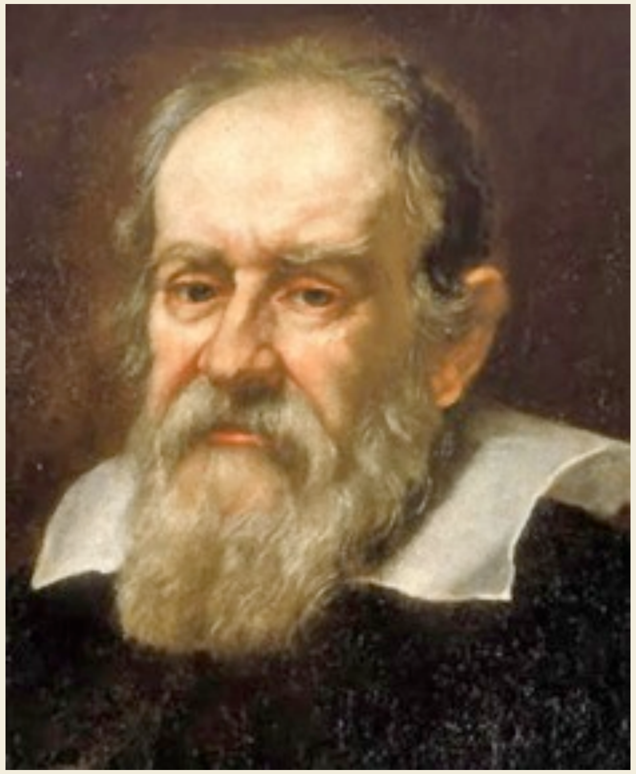
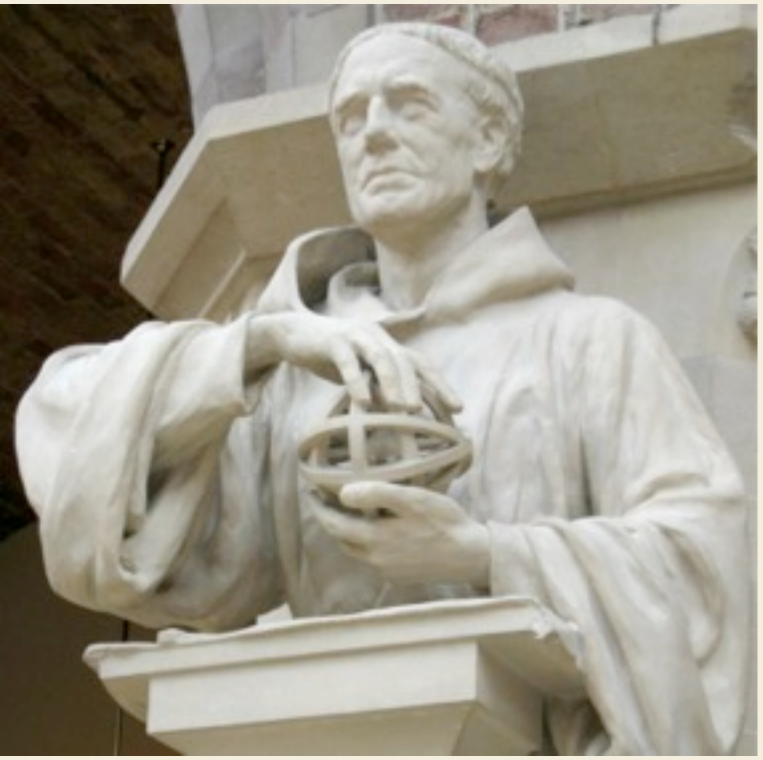
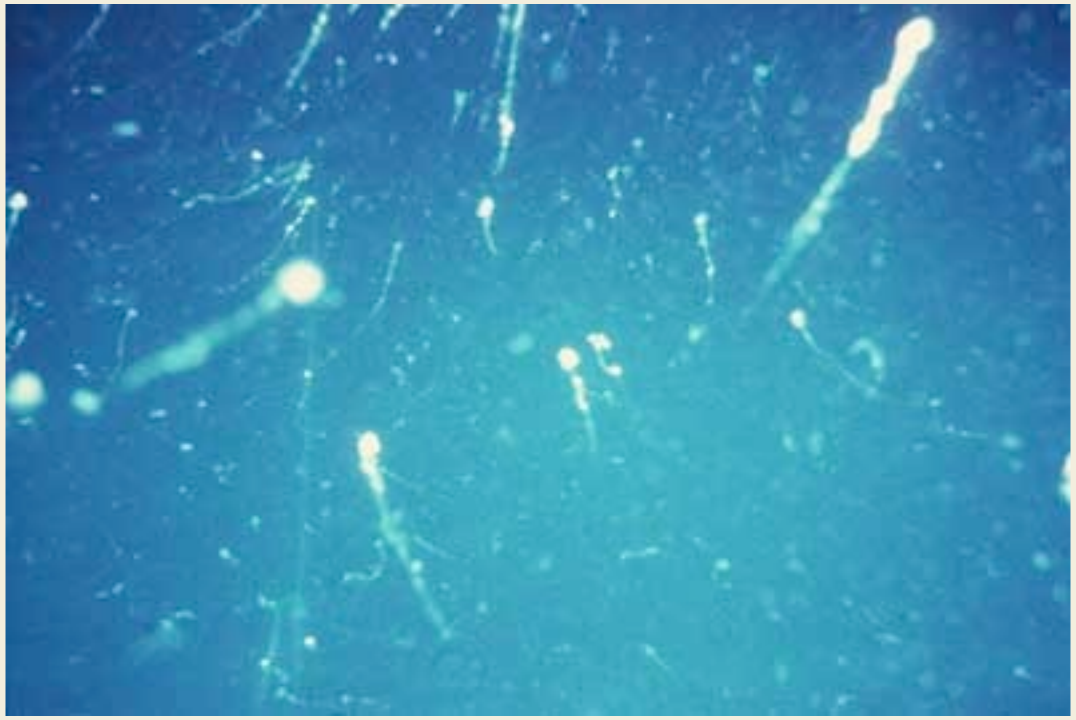


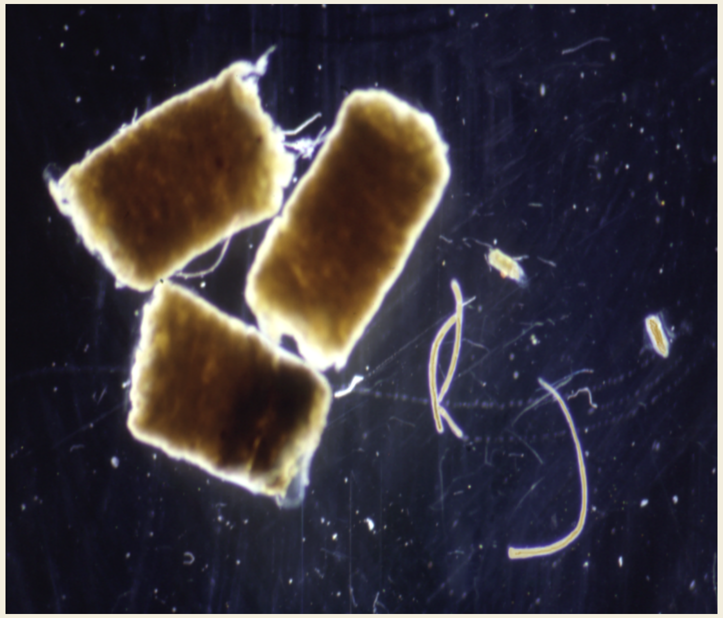


Aggregates

Alice Alldredge



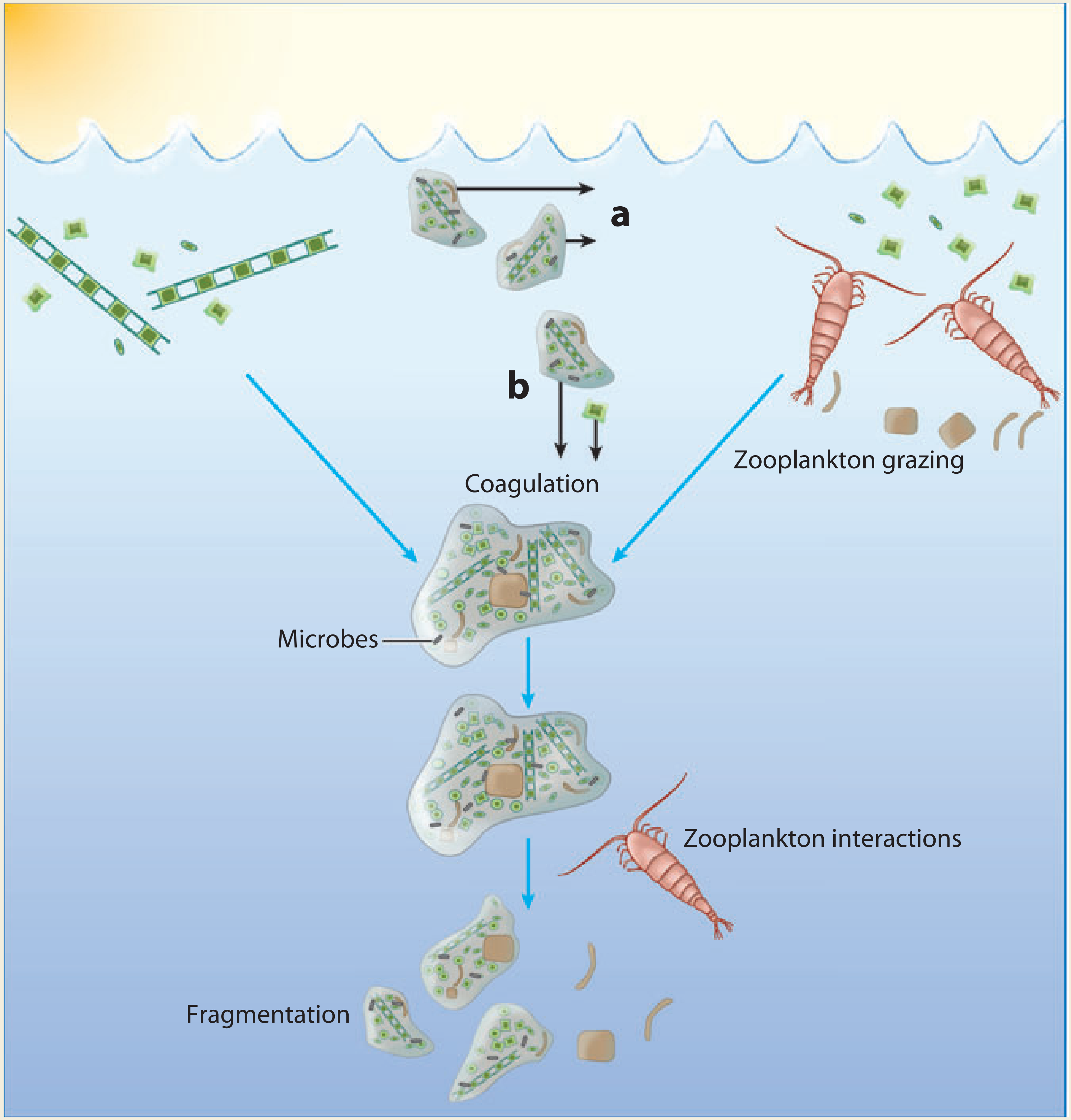
Alice Alldredge



Debbie Steinberg

Richard Lampitt

Processes affecting particles

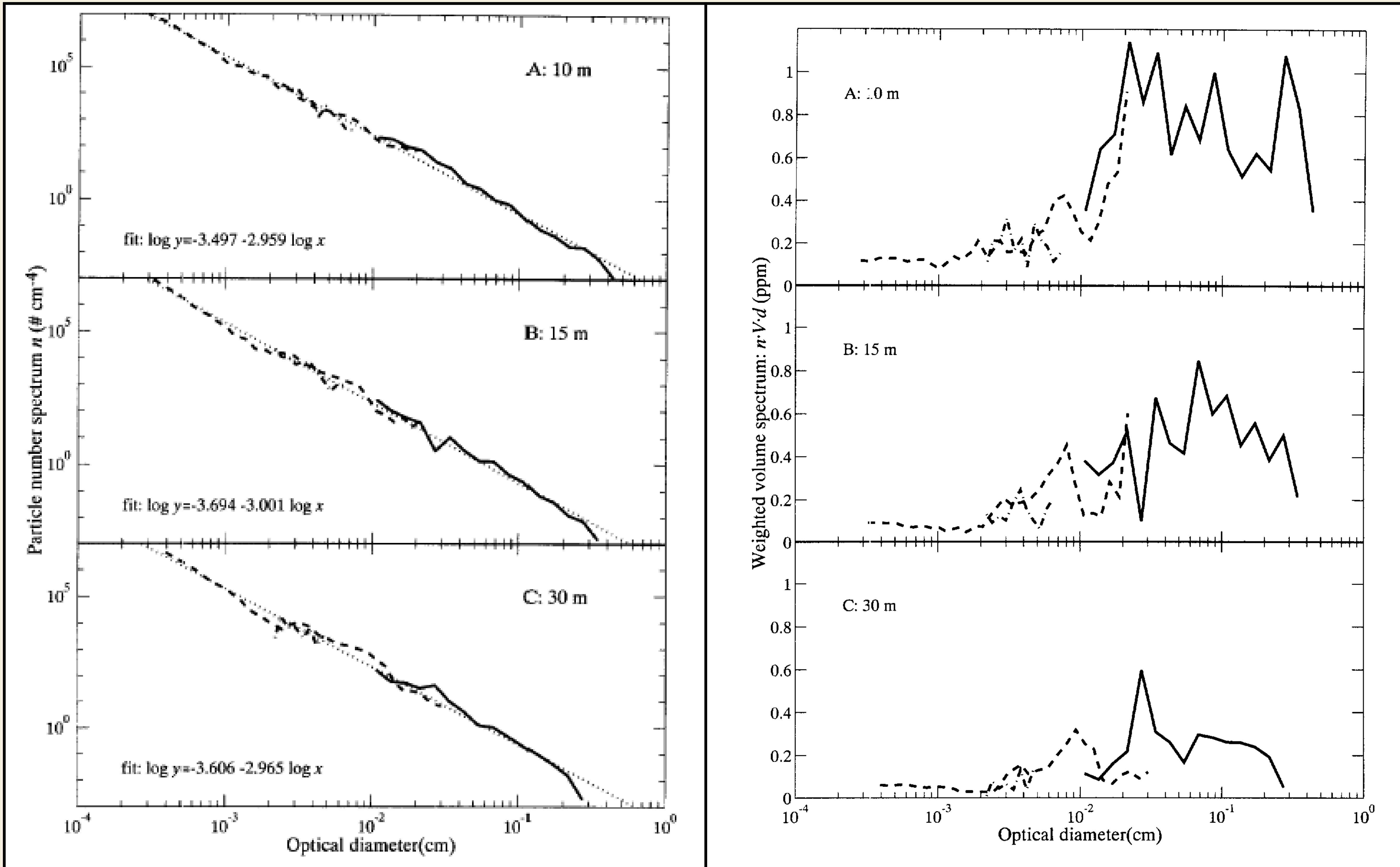


Burd & Jackson, *Ann. Rev. Mar. Sci.*, 1, 65–90 (2009)

Coagulation Theory

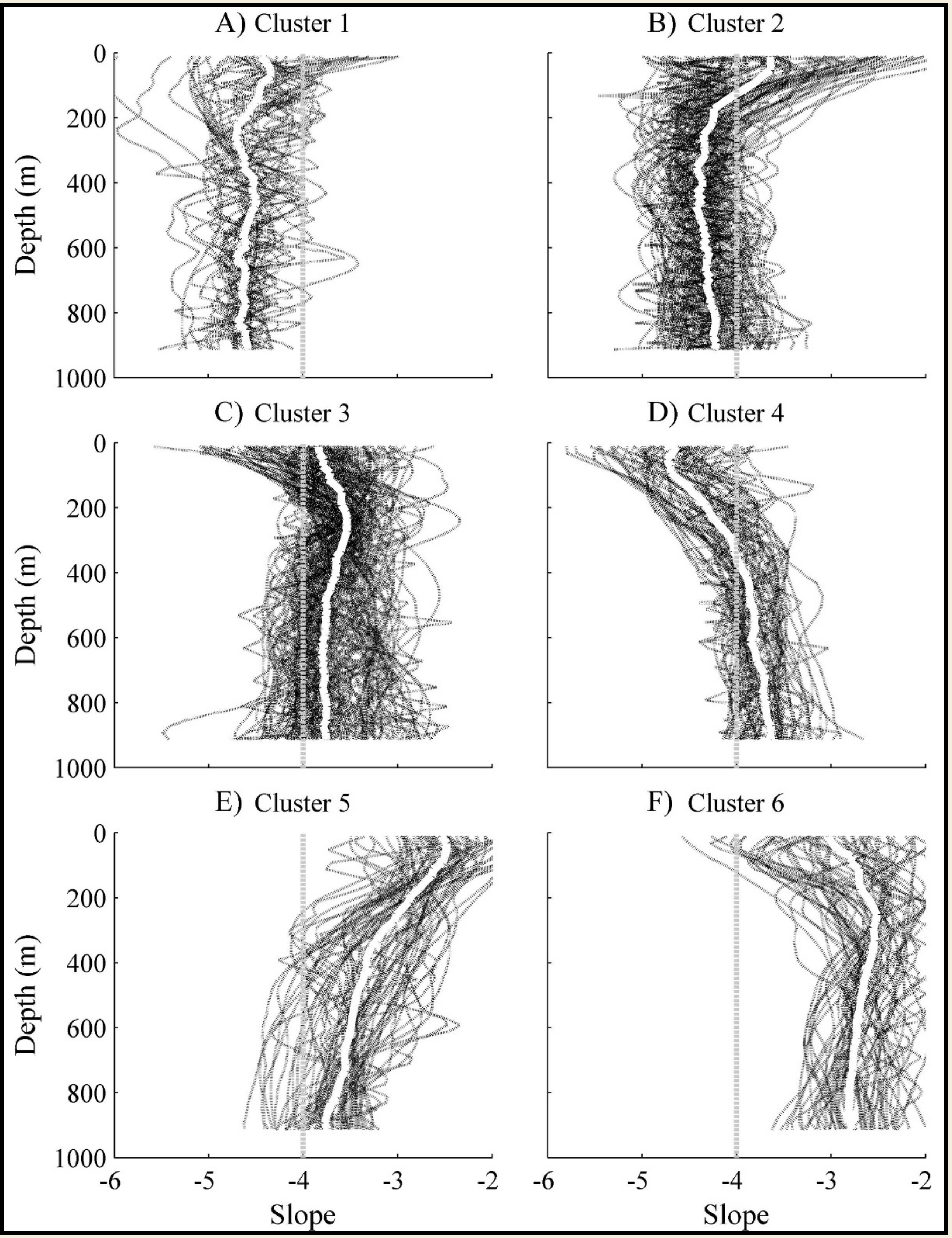
$$
\begin{aligned}
\frac{dn(m,t)}{dt} &= \frac{\alpha}{2}\int_0^m \beta(m_j,\ m-m_j)n(m-m_j,\ t)n(m_j,\ t)\,dm_j \\
&- \alpha n(m,\ t)\int_0^\infty \beta(m,\ m_j)n(m_j,\ t)\,dm_j \\
&- n(m,t)\frac{w_s(m)}{z} + I(m,t)
\end{aligned}
$$

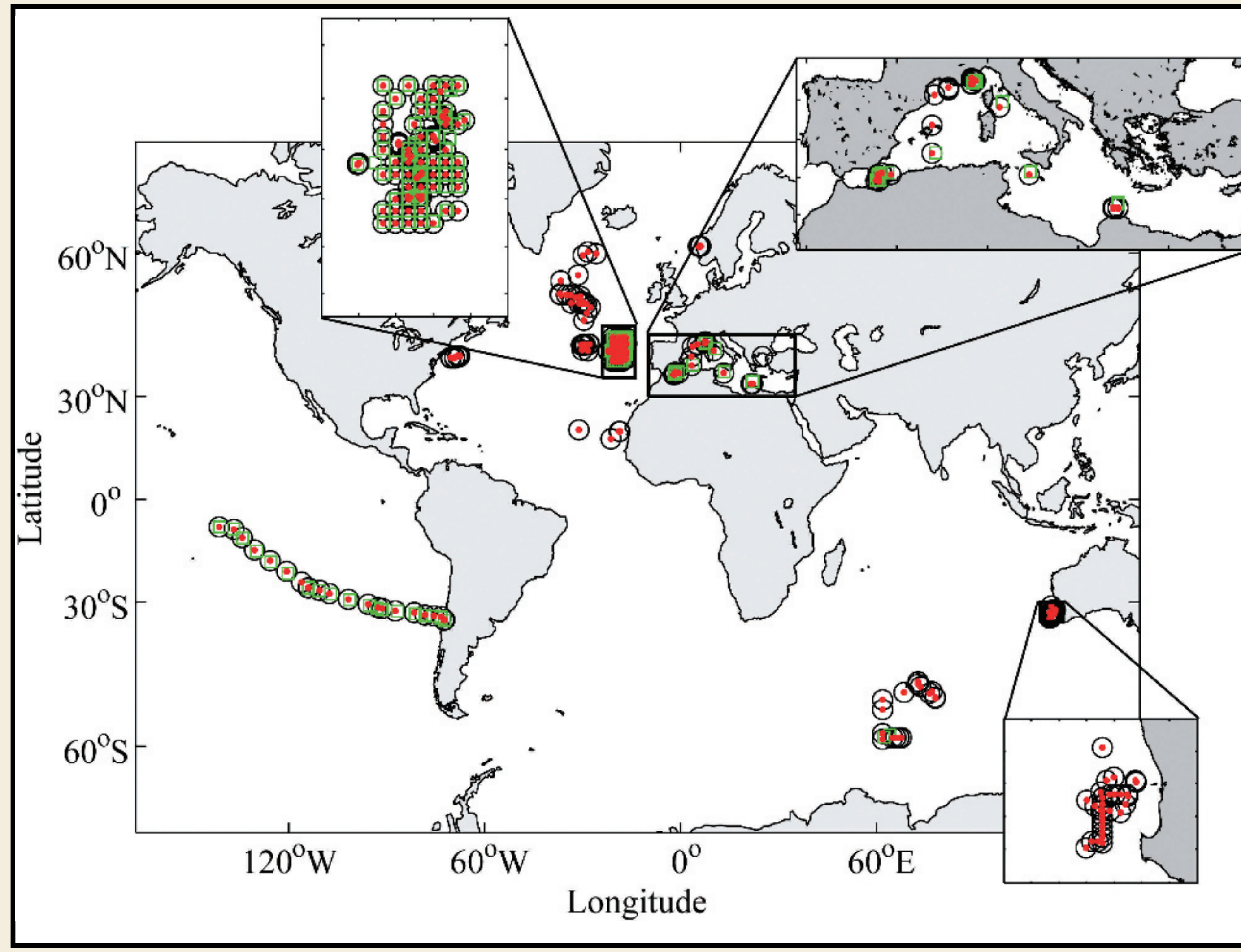
Particle Size Spectra



Jackson et al., *Deep-Sea Res I*, 44, 1739–1767 (1997)

Variations in spectral slope



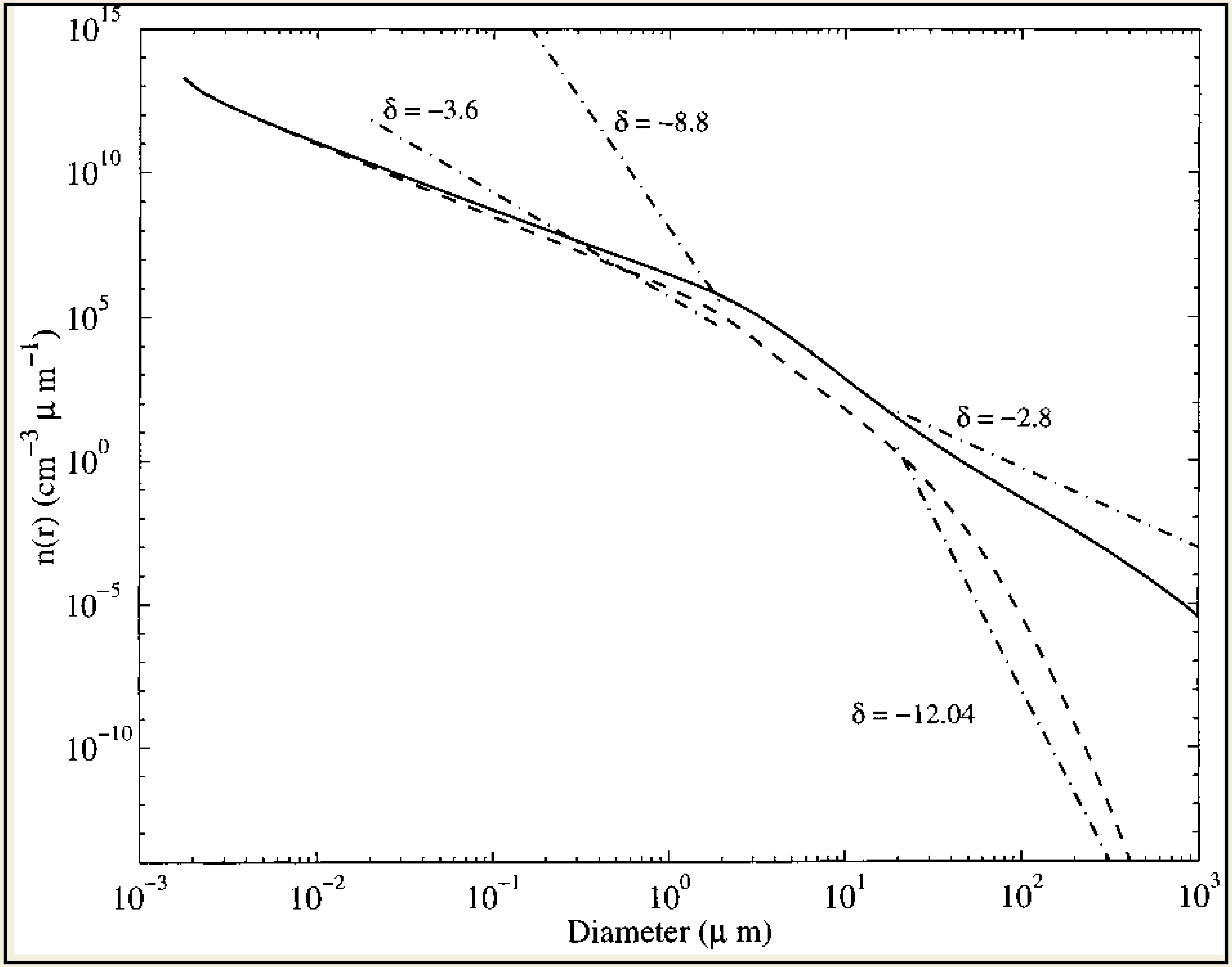


Guidi et al., *Limnology & Oceanogr., 54, 1951–1963* (2009)

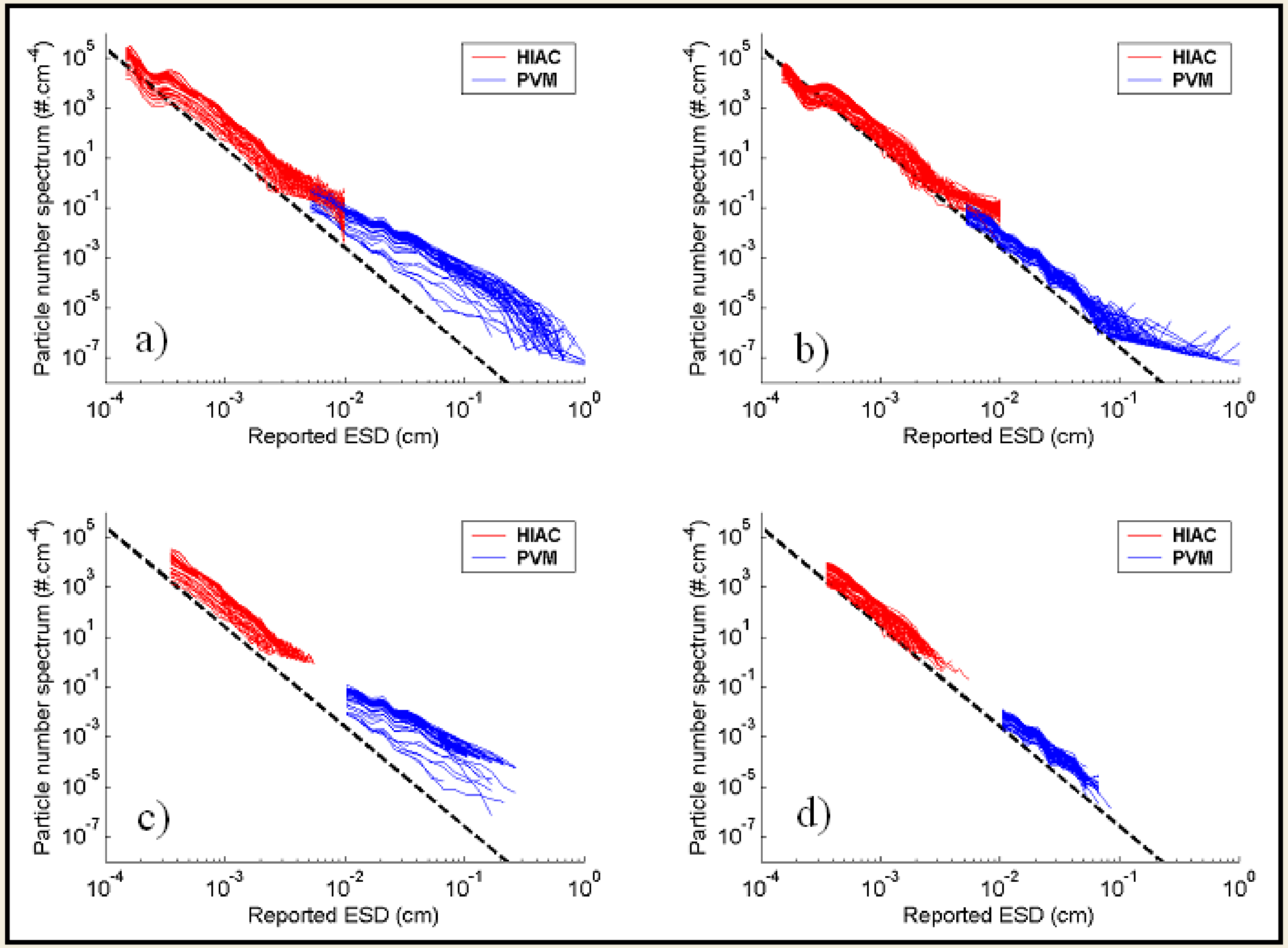
$$n(r) = ar^{-b}$$

Modeled Size Spectra

Jackson & Burd., *Env. Sci. Technol*, 32, 2805–2814 (1998)



Stemmann et al., *Biogeosciences, 5:299–310, 2008*

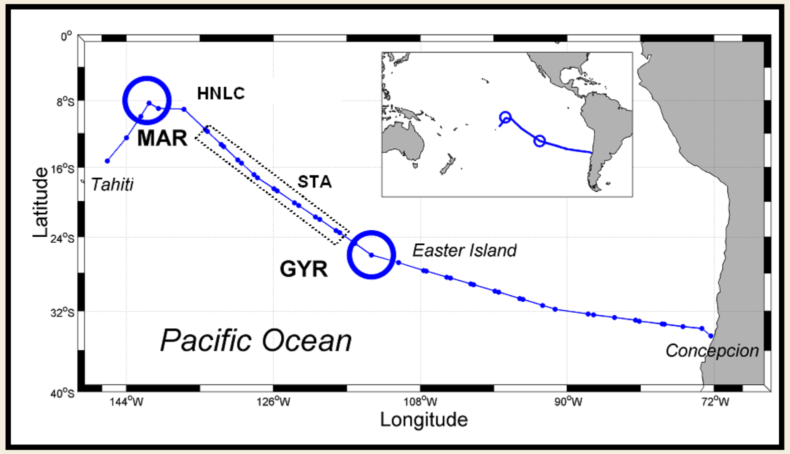


Raw Spectra

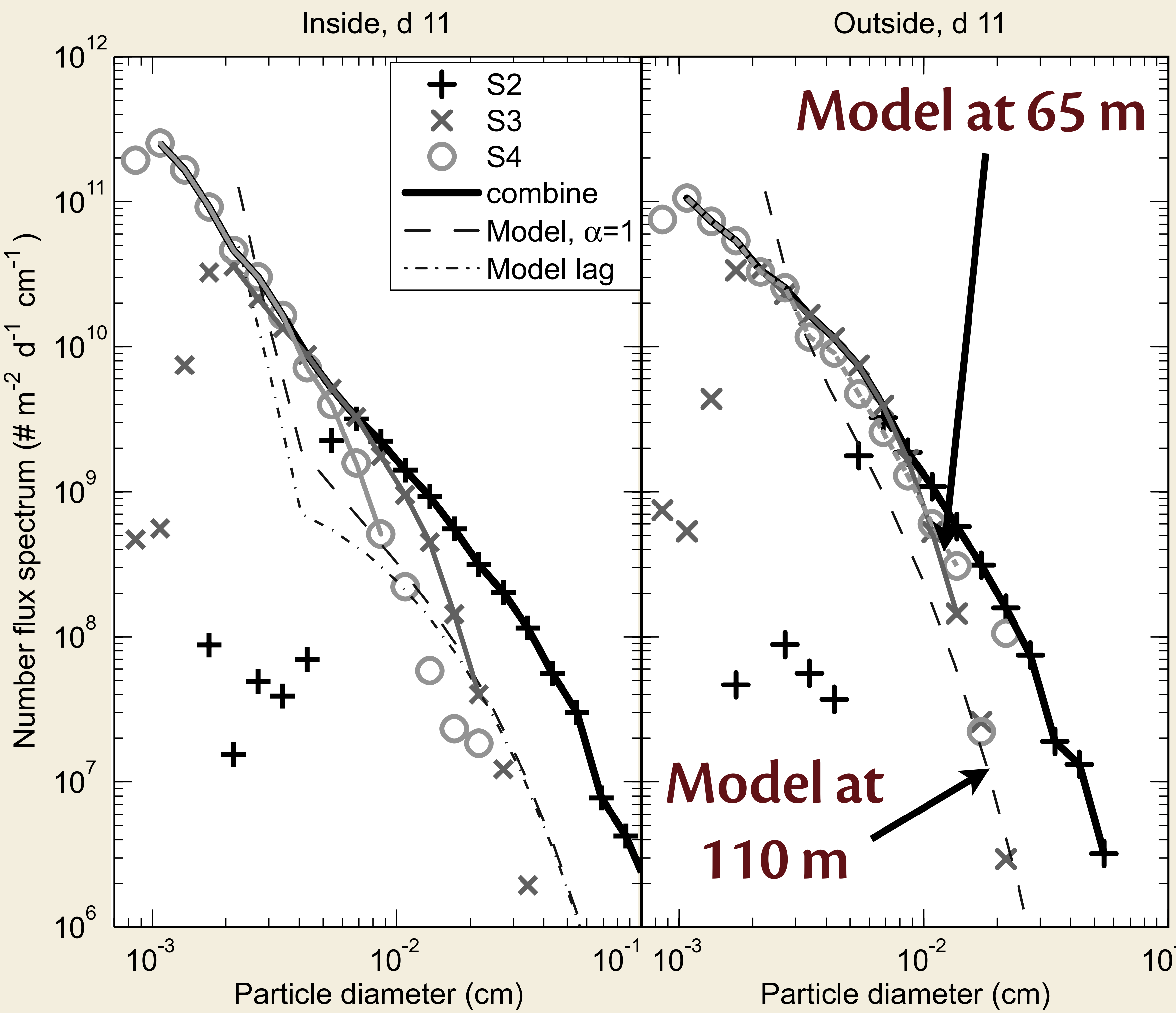
Corrected Spectra

MAR

GYR

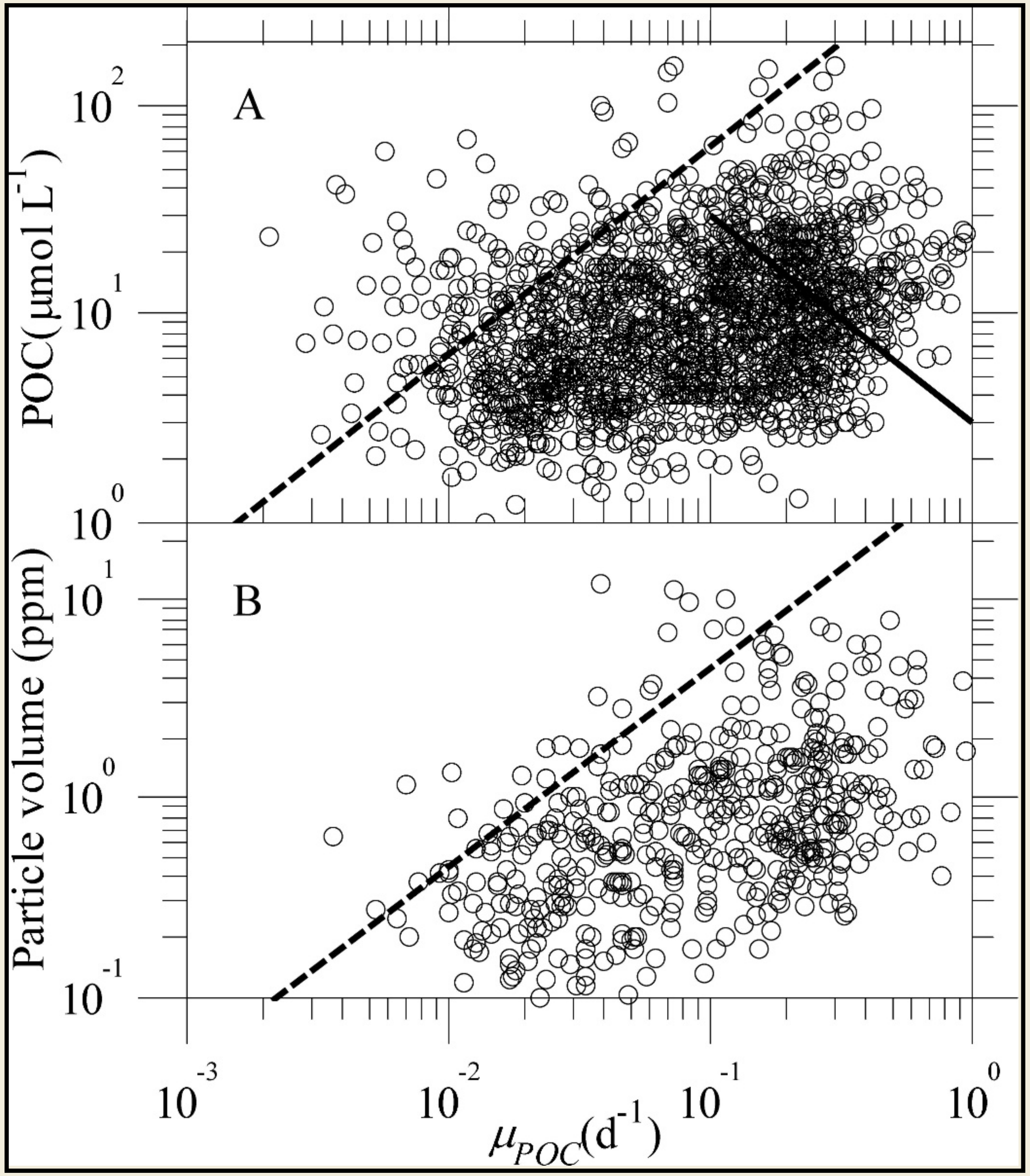


Size spectrum



Jackson et al., *Geophys. Res. Lett.*, 32, L13607 (2005)

Maximum Cell Concentrations



Jackson & Kiørboe, *Limnol. Oceanogr.*, 53, 395–399 (2008)

Coagulation kernels

$$\frac{dn(m,t)}{dt} = \frac{\alpha}{2}\int_0^m \boxed{\beta(m_j,\, m - m_j)}\, n(m - m_j,\, t)\, n(m_j,\, t)\, dm_j$$

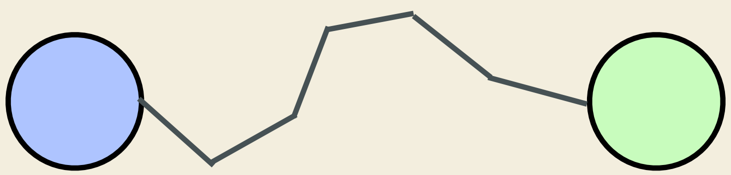
$$- \alpha n(m,\, t) \int_0^\infty \boxed{\beta(m,\, m_j)}\, n(m_j,\, t)\, dm_j$$

$$- n(m,t)\frac{w_s(m)}{z} + I(m,t)$$

Determines the rate of collisions between particles — we have good theories for these

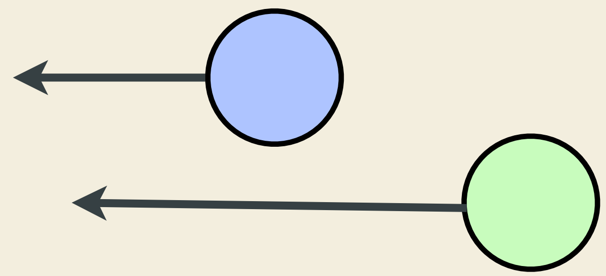
Physical Coagulation

Brownian Motion



$$\beta(r_i, r_j) = \frac{2}{3}\frac{kT}{\mu}\frac{(r_i + r_j)^2}{r_i r_j}$$

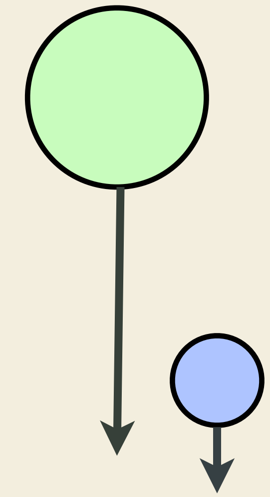
Fluid Shear



$$\beta(r_i, r_j) = 1.3\left(\frac{\epsilon}{\nu}\right)^{1/2}(r_i + r_j)^3$$

$$\beta(r_i, r_j) = \frac{p^2}{1 + 2p^2}\left(\frac{\epsilon}{\nu}\right)^{1/2}(r_i + r_j)^3$$

Differential Sedimentation



$$\beta(r_i, r_j) = \pi(r_i + r_j)^2 |w_j - w_i|$$

$$\beta(r_i, r_j) = 0.5\pi r_j^2 |w_j - w_i|$$

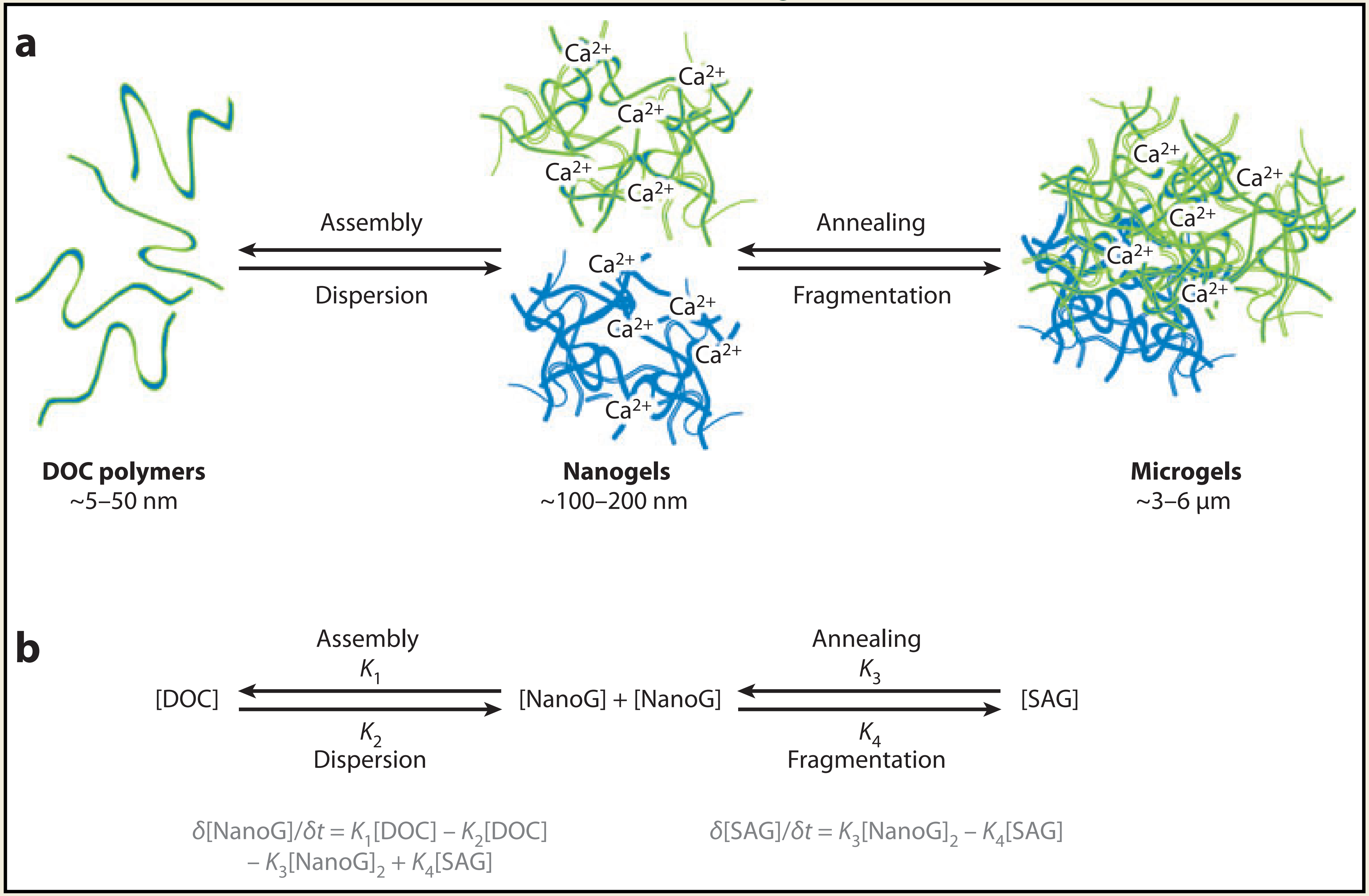
Stickiness

$$\frac{dn(m,t)}{dt} = \frac{\alpha}{2}\int_0^m \beta(m_j,\, m-m_j)n(m-m_j,\, t)n(m_j,\, t)\, dm_j$$
$$-\alpha n(m,\, t)\int_0^\infty \beta(m,\, m_j)n(m_j,\, t)\, dm_j$$
$$-\, n(m,t)\frac{w_s(m)}{z} + I(m,t)$$

Determines the probability that particles will adhere once they have collided.

Nanoparticles

Verdugo, *Ann. Rev. Mar. Sci.*, 4, 375–400 (2012)

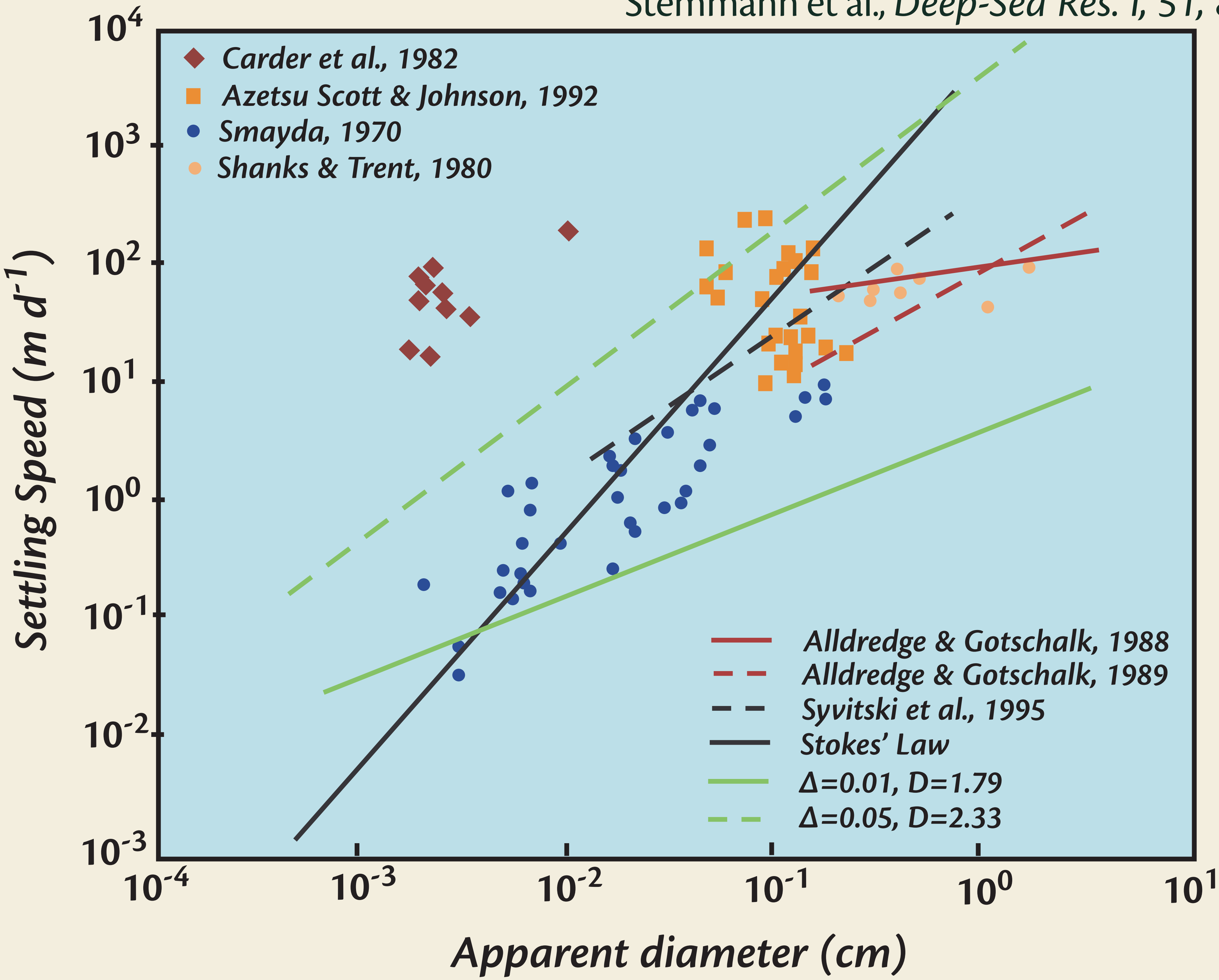


Settling

$$\frac{dn(m,t)}{dt} = \frac{\alpha}{2}\int_0^m \beta(m_j,\, m - m_j)n(m - m_j,\, t)n(m_j,\, t)\, dm_j$$
$$- \alpha n(m,\, t)\int_0^\infty \beta(m,\, m_j)n(m_j,\, t)\, dm_j$$
$$- \boxed{n(m,t)\frac{w_s(m)}{z}} + I(m,t)$$

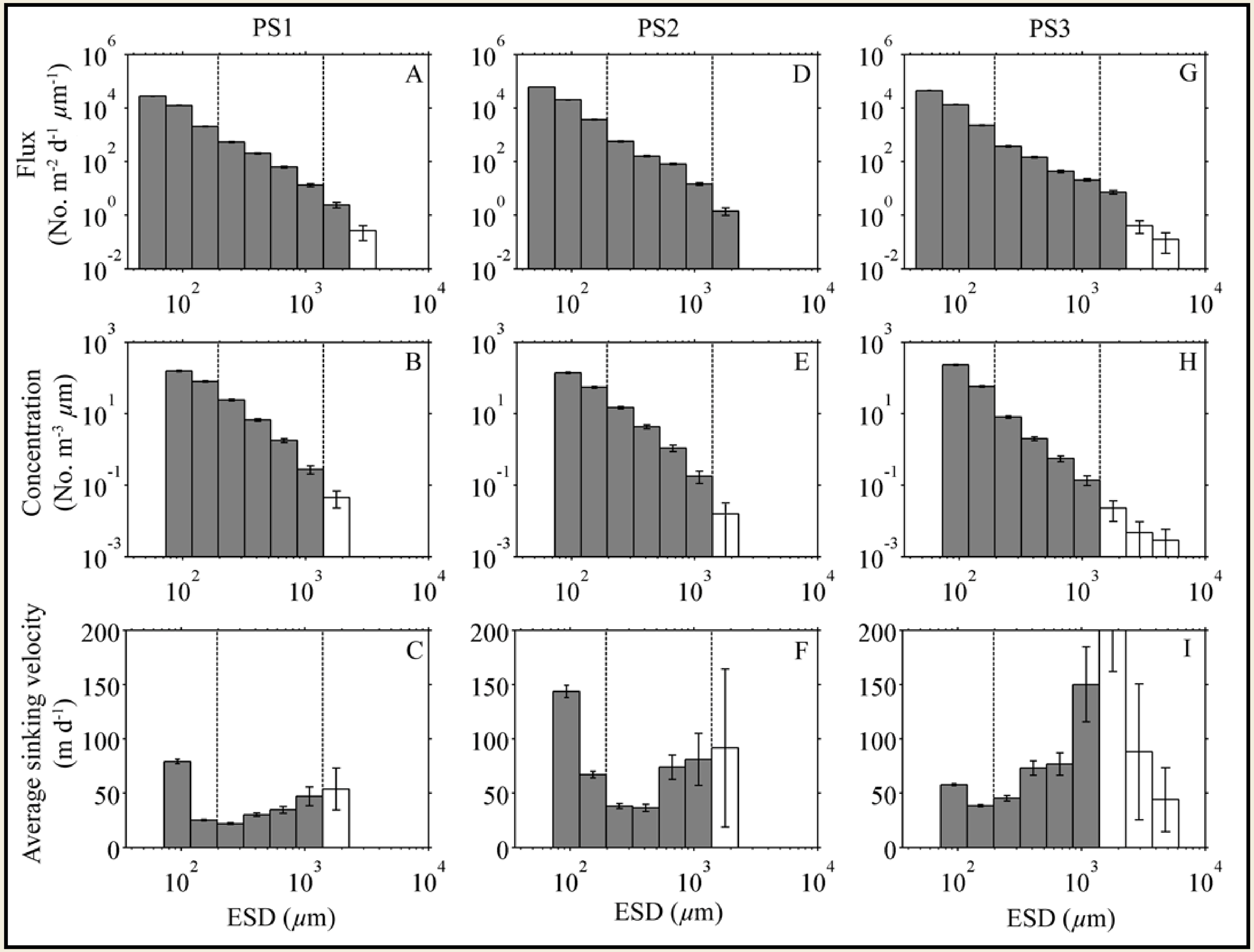
Settling Velocity

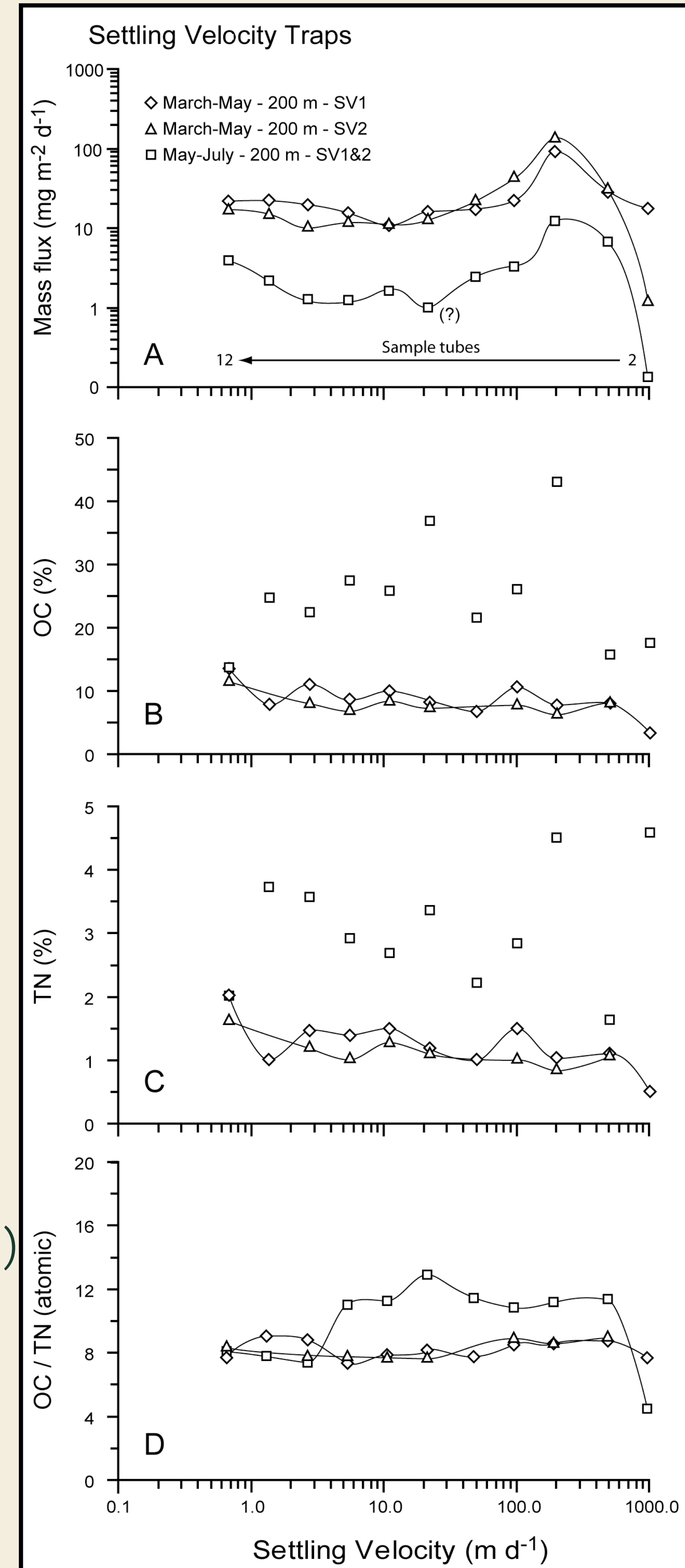
Stemmann et al., *Deep-Sea Res. I, 51, 865–884* (2004)



Tuesday, July 22, 14

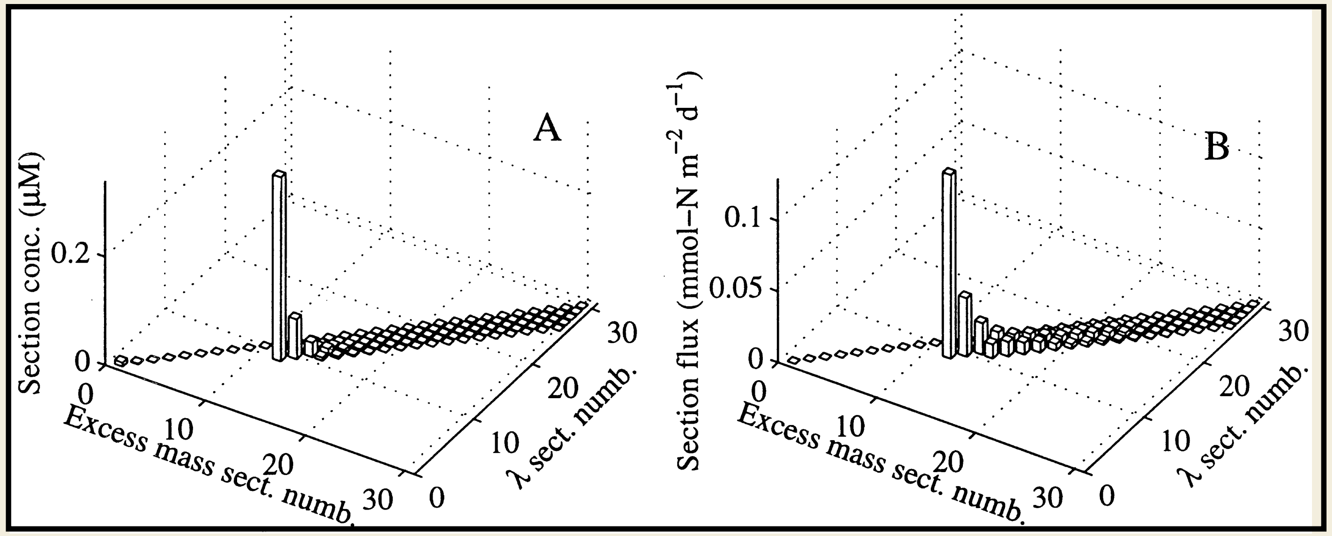
McDonnell & Buesseler, *Limnol. Oceanogr., 55, 2085–2096* (2011)

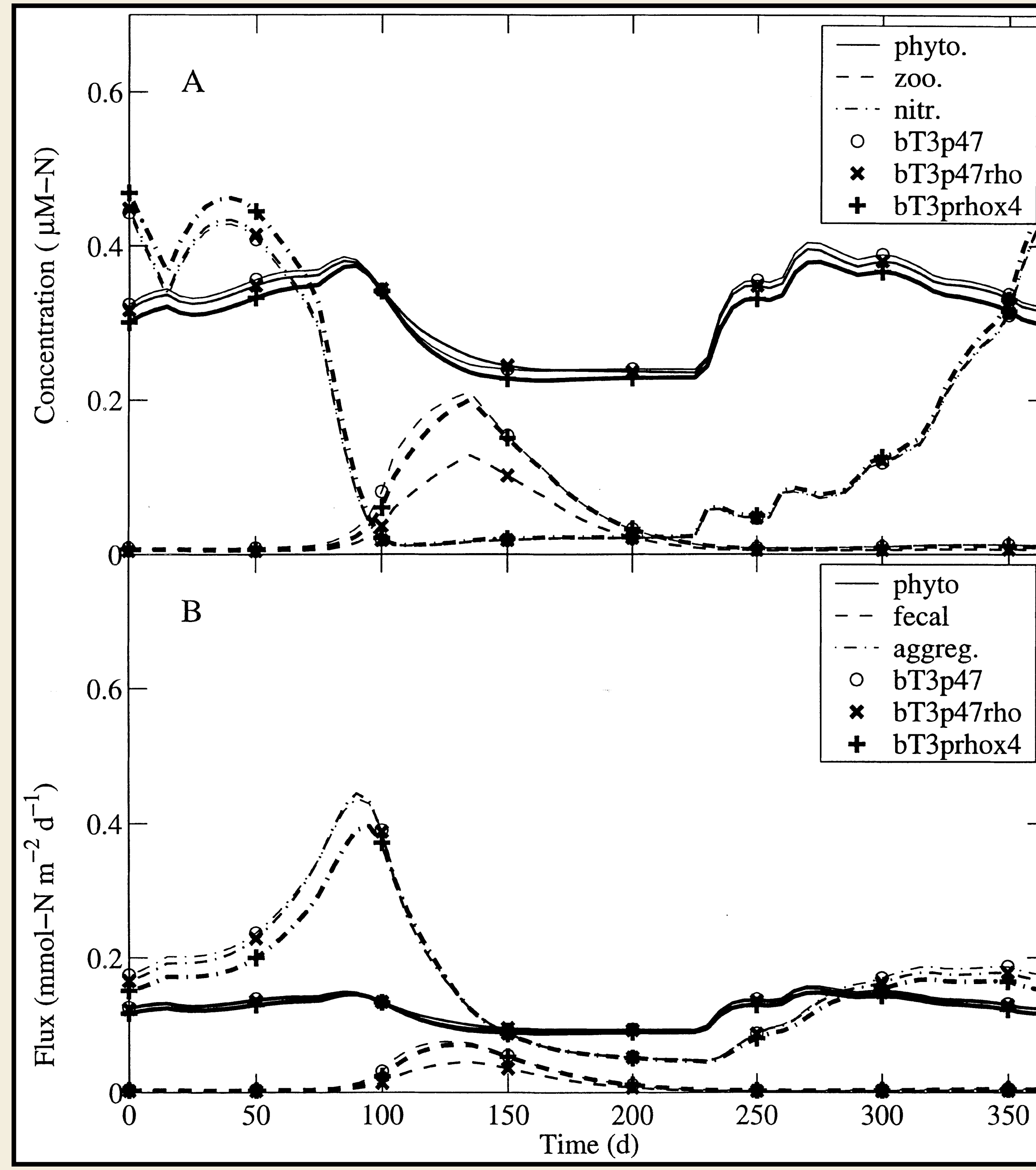




Peterson et al., *Limnol. Oceanogr. Methods, 3, 520–532* (2005)

Biological Aggregation





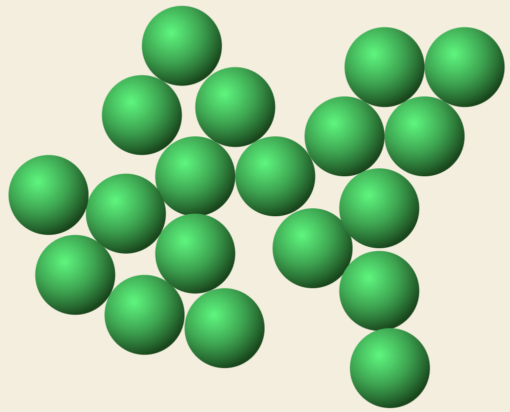
Jackson, *Deep-Sea Res. I, 48, 95 – 123* (2001)

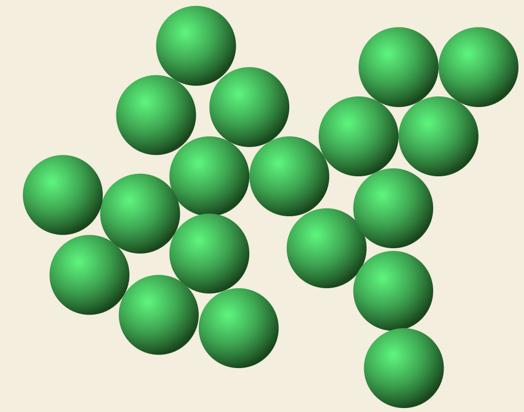
Disaggregation

$$
\begin{aligned}
\frac{\mathrm{d}Q_i(t)}{\mathrm{d}t} = &- Q_i(t)\sum_{j=1}^{i-1}\int_{v_{j-1}}^{v_j}\int_{v_{i-1}}^{v_{i-1}+w}\frac{(v-w)p_\mathrm{e}(w)g_\mathrm{e}(v)}{v(v_i-v_{i-1})P_\mathrm{e}(v_{i-1})}\mathrm{d}v\mathrm{d}w \\
&- Q_i(t)\sum_{j=1}^{i-1}\int_{v_{j-1}}^{v_j}\int_{v_{i-1}}^{v_i}\frac{wp_\mathrm{e}(w)g_\mathrm{e}(v)}{v(v_i-v_{i-1})P_\mathrm{e}(v_{i-1})}\mathrm{d}v\mathrm{d}w \\
&+ \sum_{l=i+1}^{m} Q_l(t)\sum_{j=1}^{l-1}\int_{v_{j-1}}^{v_j}\int_{v_{i-1}+w}^{v_i+w}\frac{(u-w)p_\mathrm{e}(w)g_\mathrm{e}(u)}{u(u_l-u_{l-1})P_\mathrm{e}(u_{l-1})}\mathrm{d}u\mathrm{d}w \\
&+ \sum_{l=i+1}^{m} Q_l(t)\int_{v_{i-1}}^{v_i}\int_{v_{l-1}}^{v_l}\frac{vp_\mathrm{e}(v)g_\mathrm{e}(u)}{u(u_l-u_{l-1})P_\mathrm{e}(u_{l-1})}\mathrm{d}u\mathrm{d}v \\
&- Q_i(t)\int_{v_{i-1}}^{v_i}\frac{g_\mathrm{s}(v)}{(v_i-v_{i-1})}\mathrm{d}v \\
&+ \sum_{l=i+1}^{m} Q_l(t)\int_{v_{i-1}}^{v_i}\int_{u_{l-1}}^{u_l}\frac{vp_\mathrm{s}(v,u)\upsilon(u)g_\mathrm{s}(u)}{u(u_l-u_{l-1})}\mathrm{d}u\mathrm{d}v \\
&+ Q_i(t)\int_{v_{i-1}}^{v_i}\int_{u_{i-1}}^{v}\frac{vp_\mathrm{s}(v,u)\upsilon(u)g_\mathrm{s}(u)}{u(u_l-u_{l-1})}\mathrm{d}u\mathrm{d}v.
\end{aligned}
$$

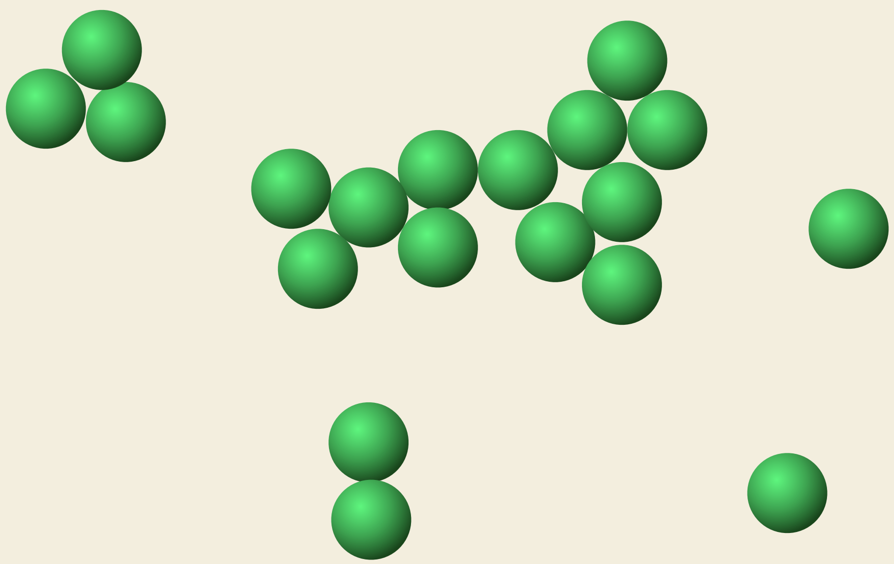
Hill, *Deep-Sea Res. I, 43, 679–702 (1996)*

Disaggregation

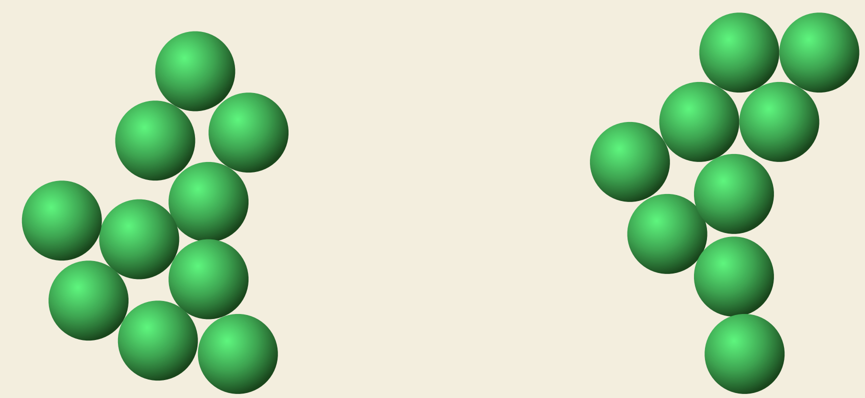




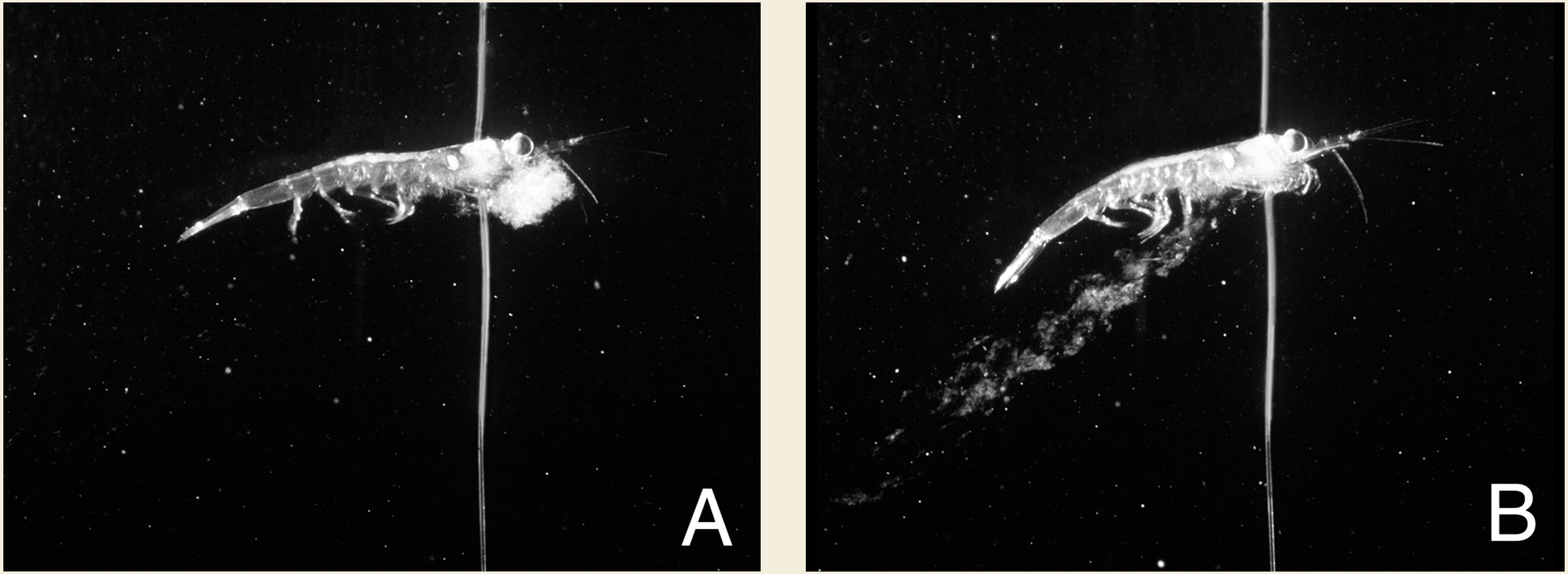
Erosion of Fines



Splitting into approximately equal particles



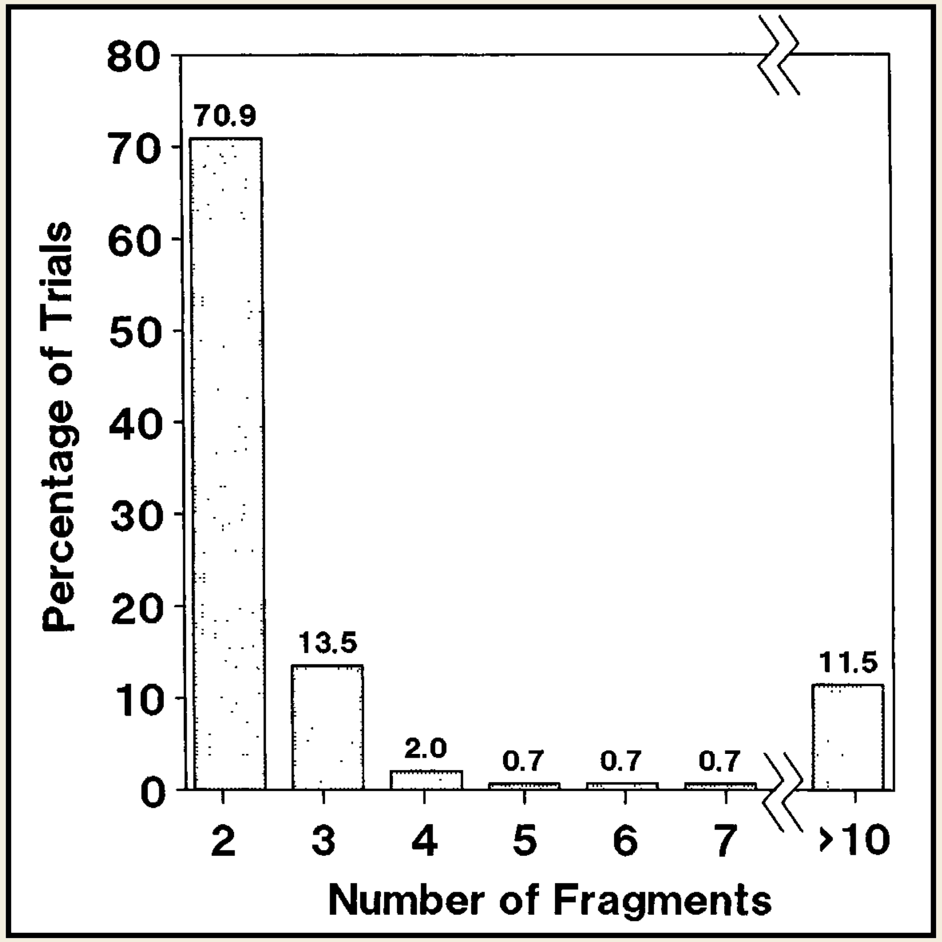
Bio-disaggregation

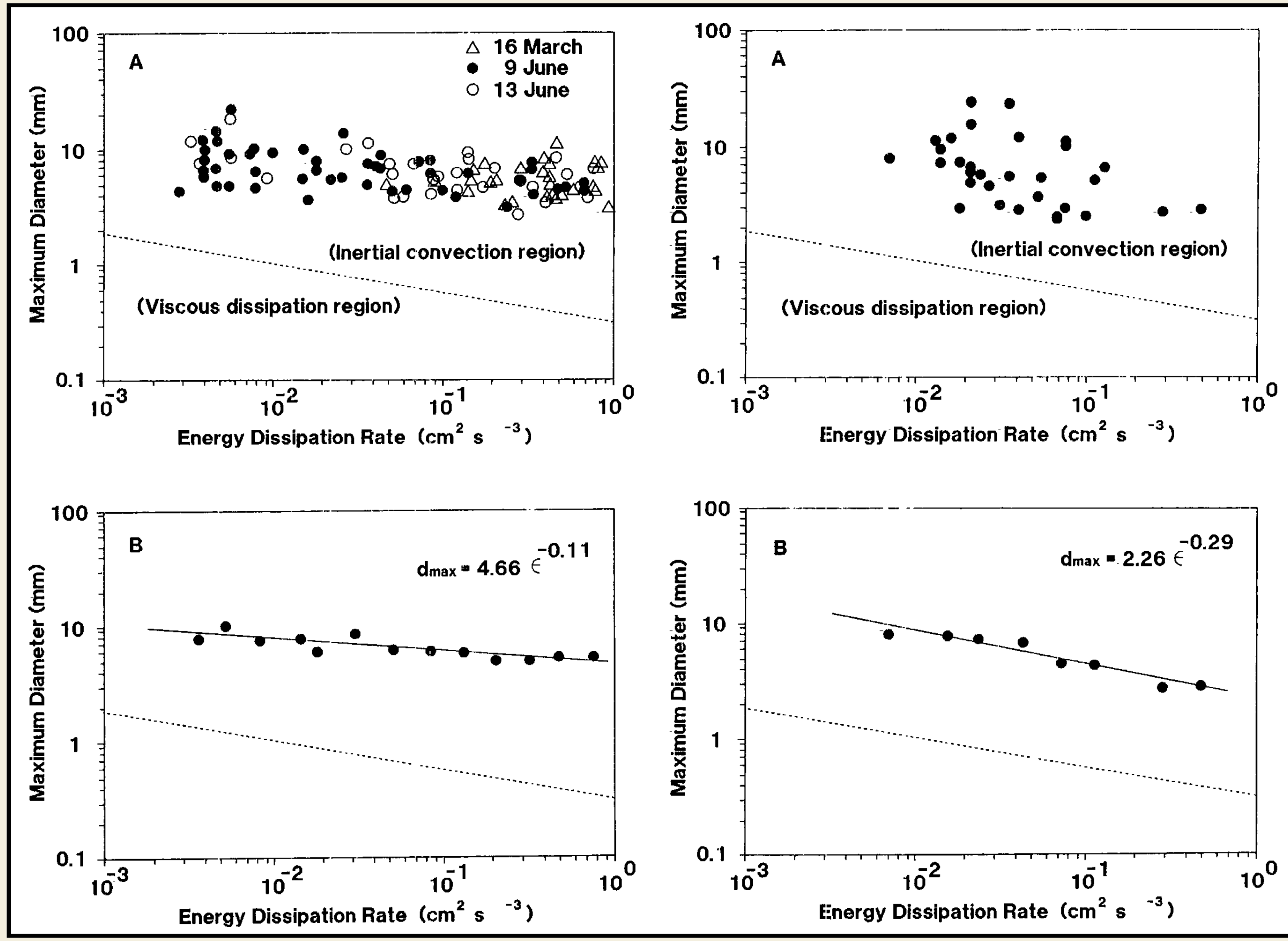


Dilling & Alldrege, *Deep-Sea Res. I, 47, 1227–1245 (2000)*

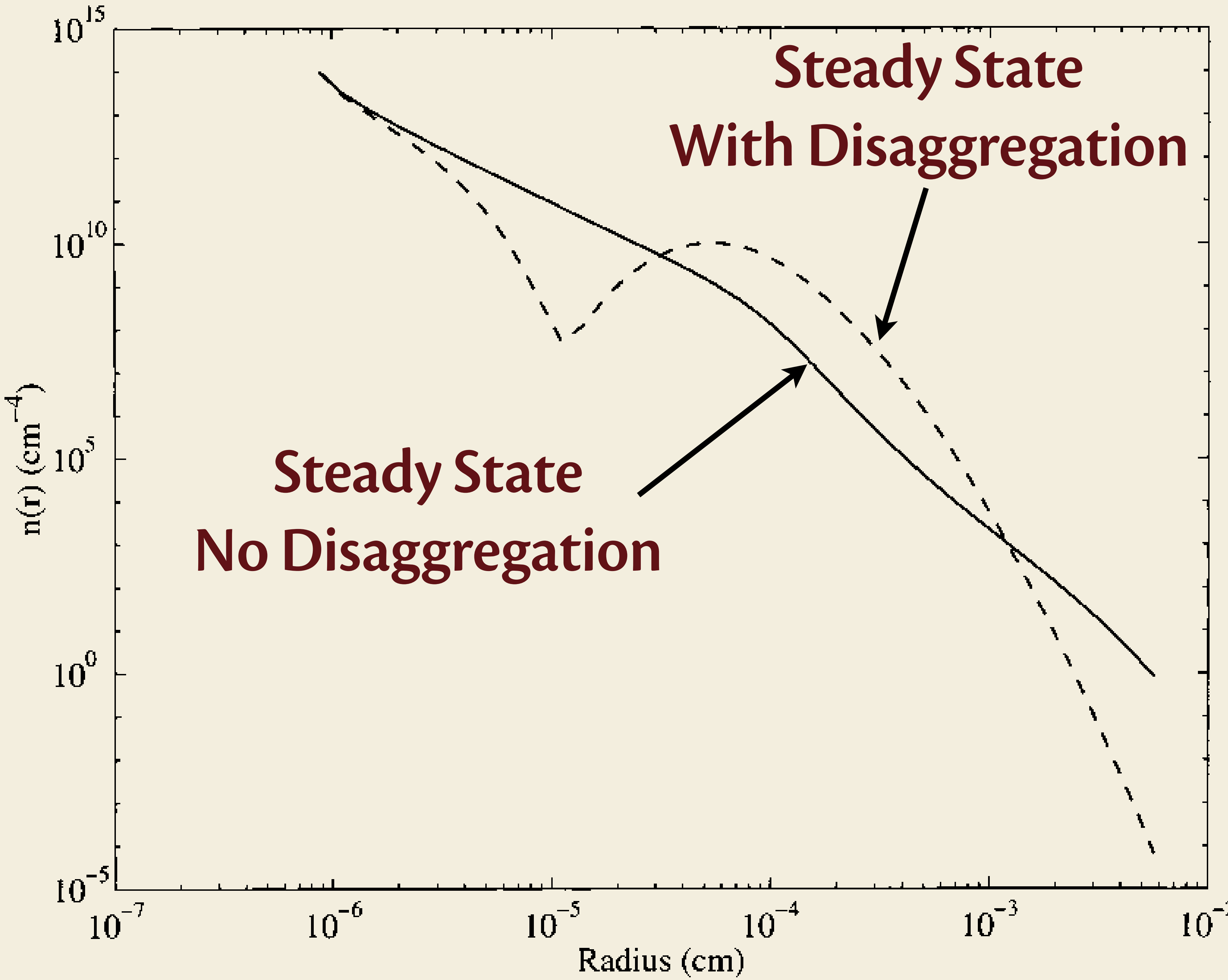
Physical Disaggregation

Alldrege et al., *Limnol. Oceanogr., 35, 1415–1428 (1990)*





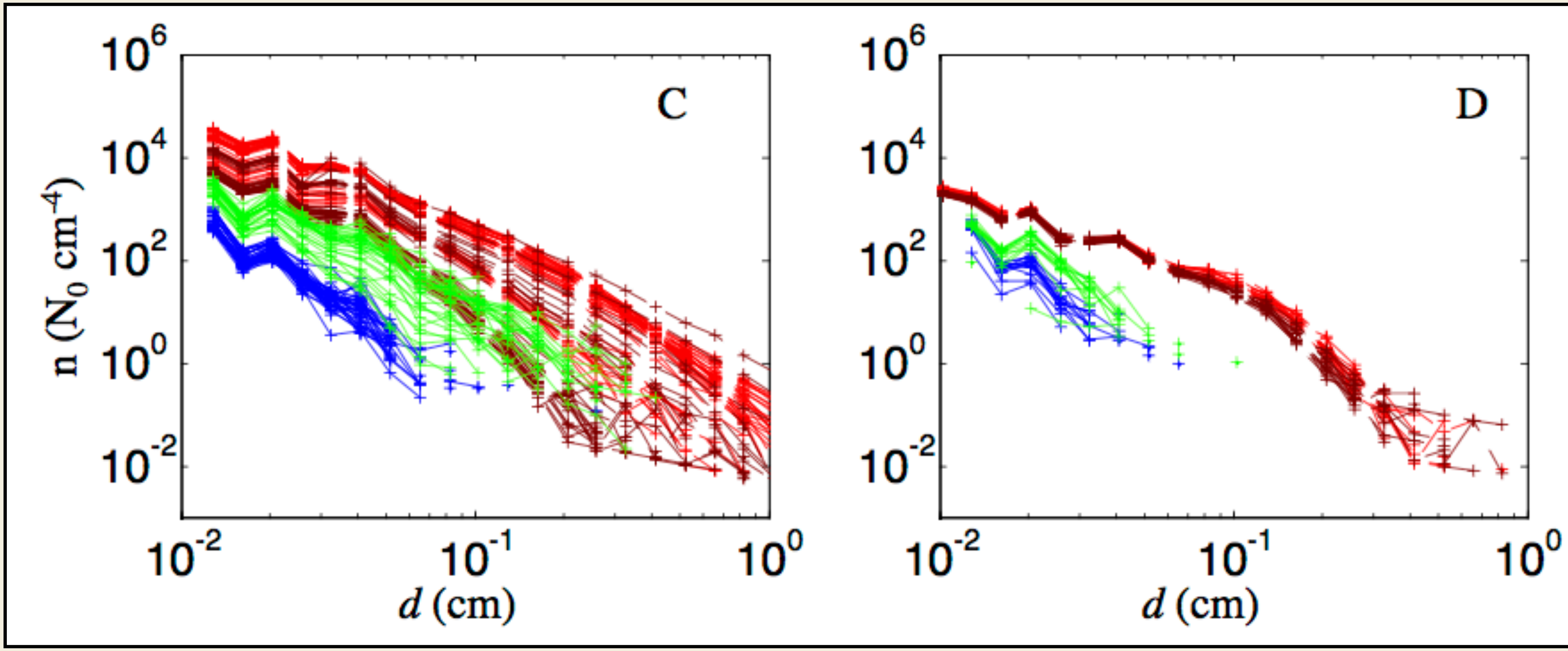
Disaggregation: Theory



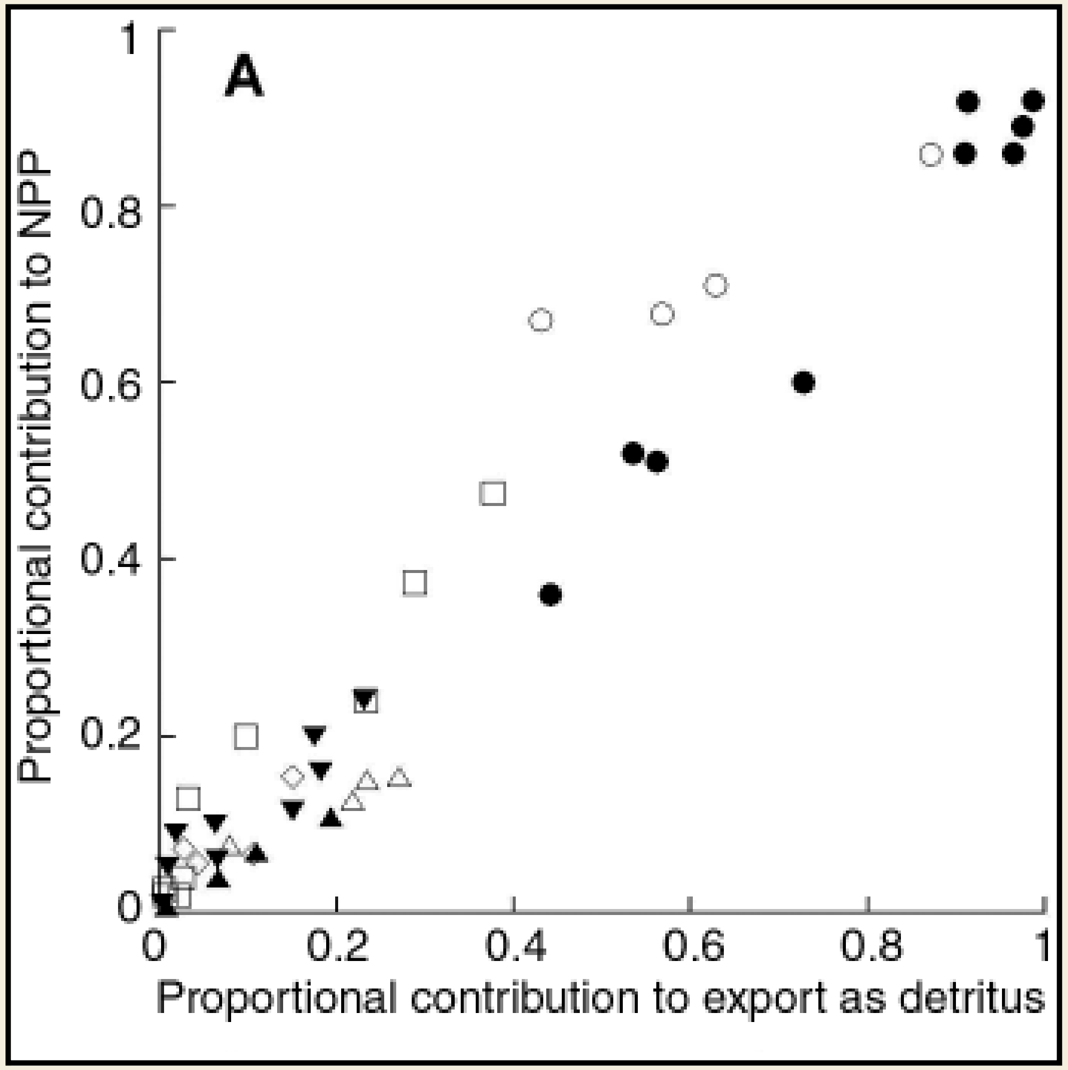
Burd & Jackson,
Env. Sci. Technol.,
36, 323–327
(2002)

Disaggregation?

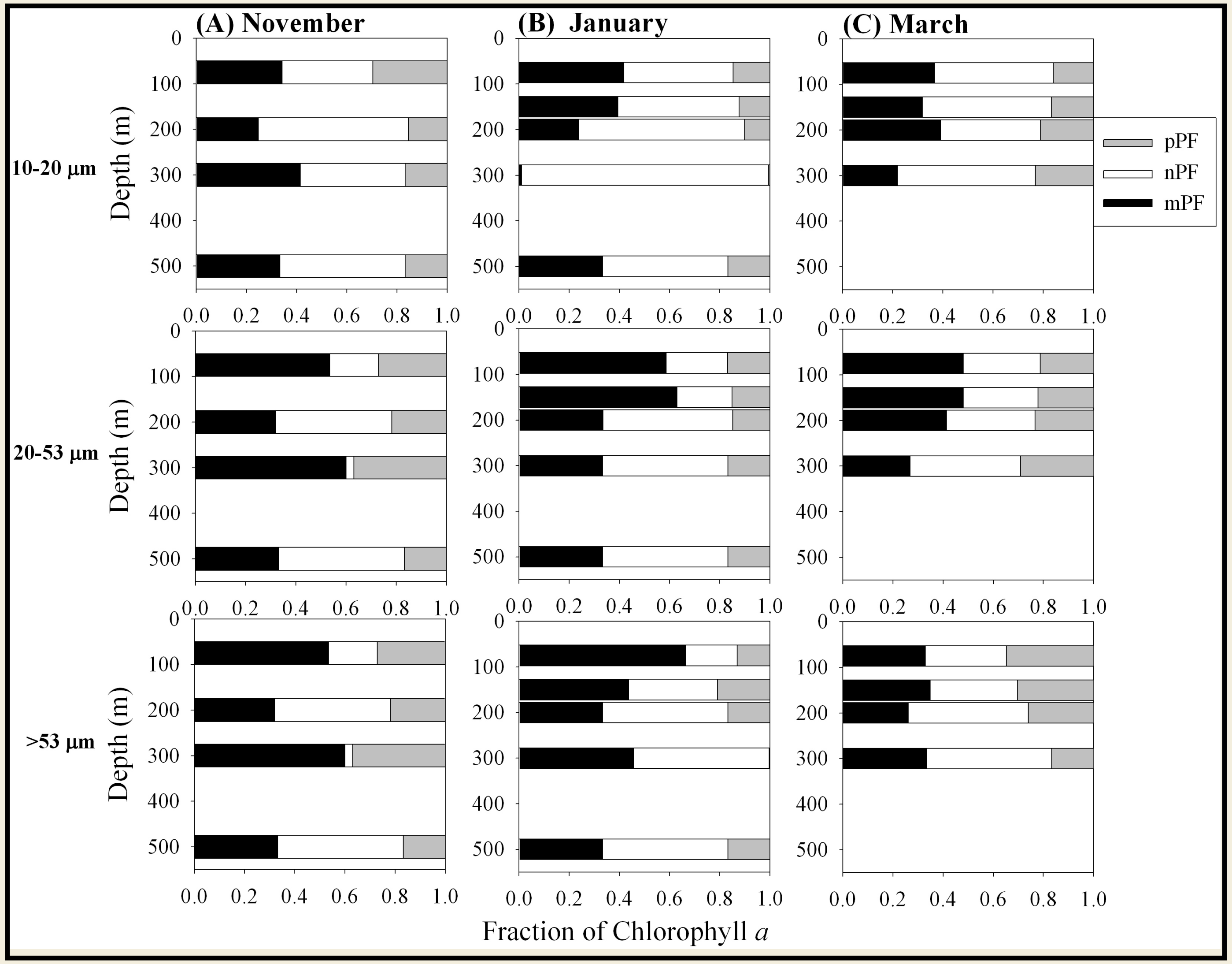
Jouandet et al. (2014, accepted)



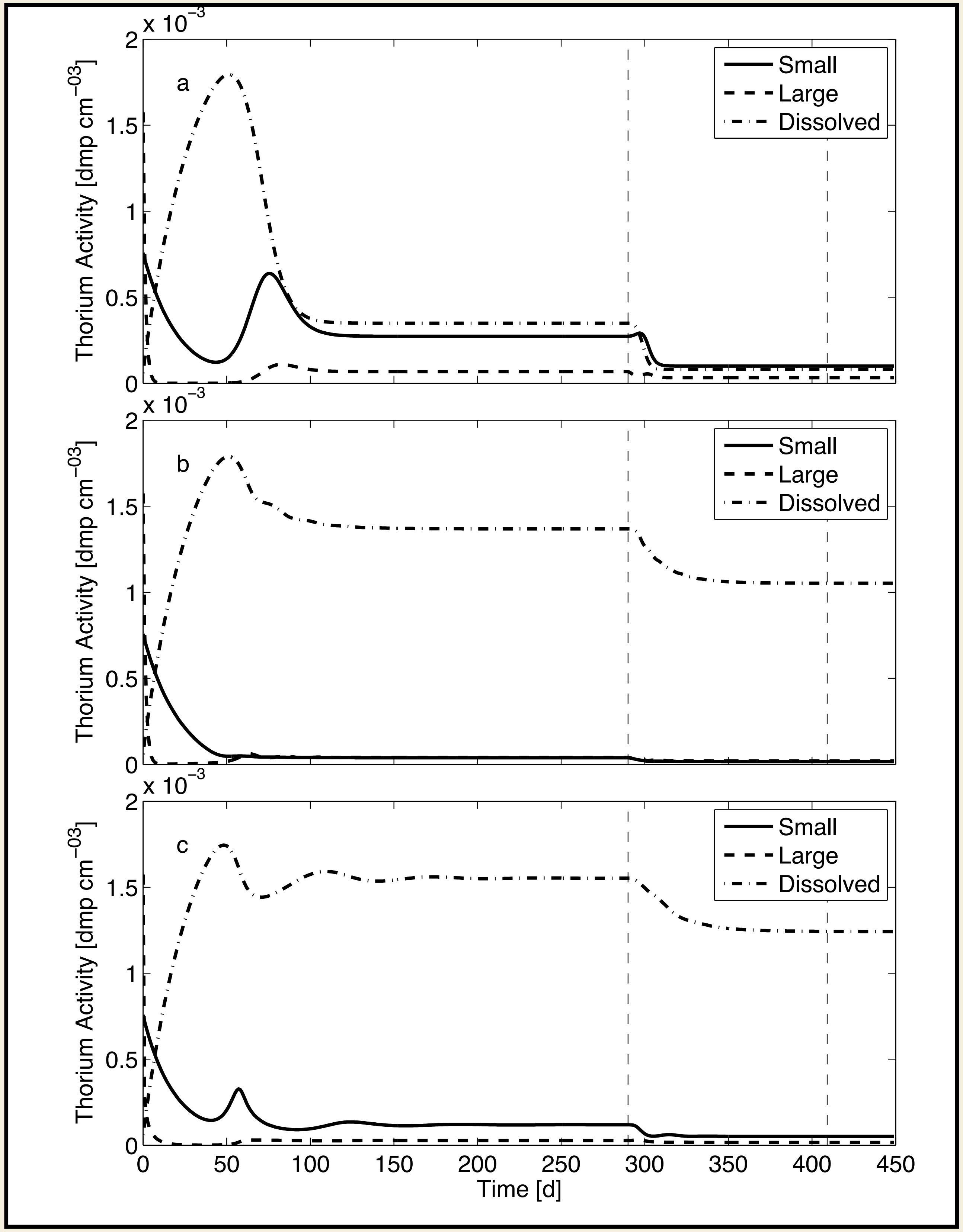
Flux of Small Cells



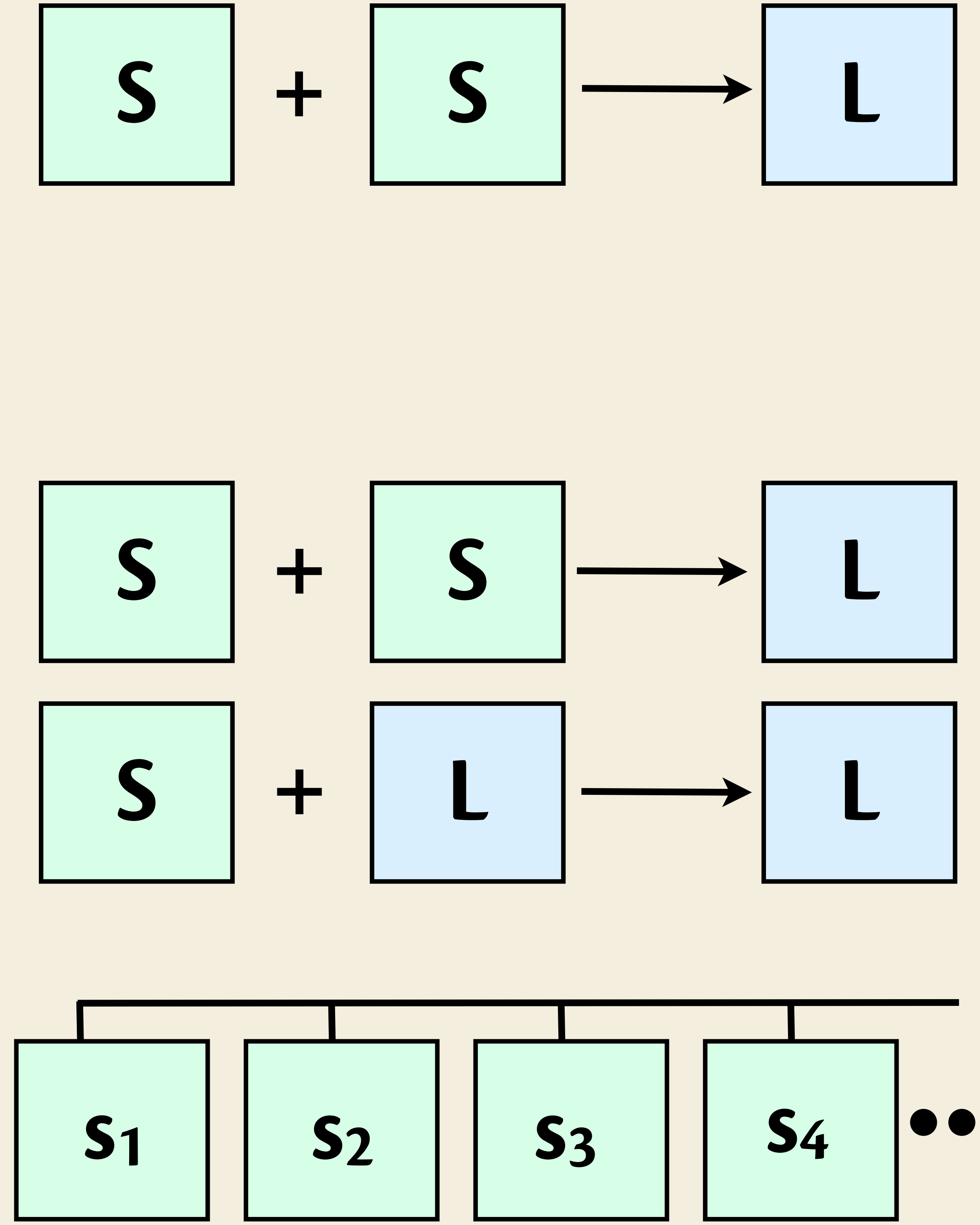
Richardson & Jackson., *Science*, 315, 838–840 (2007)



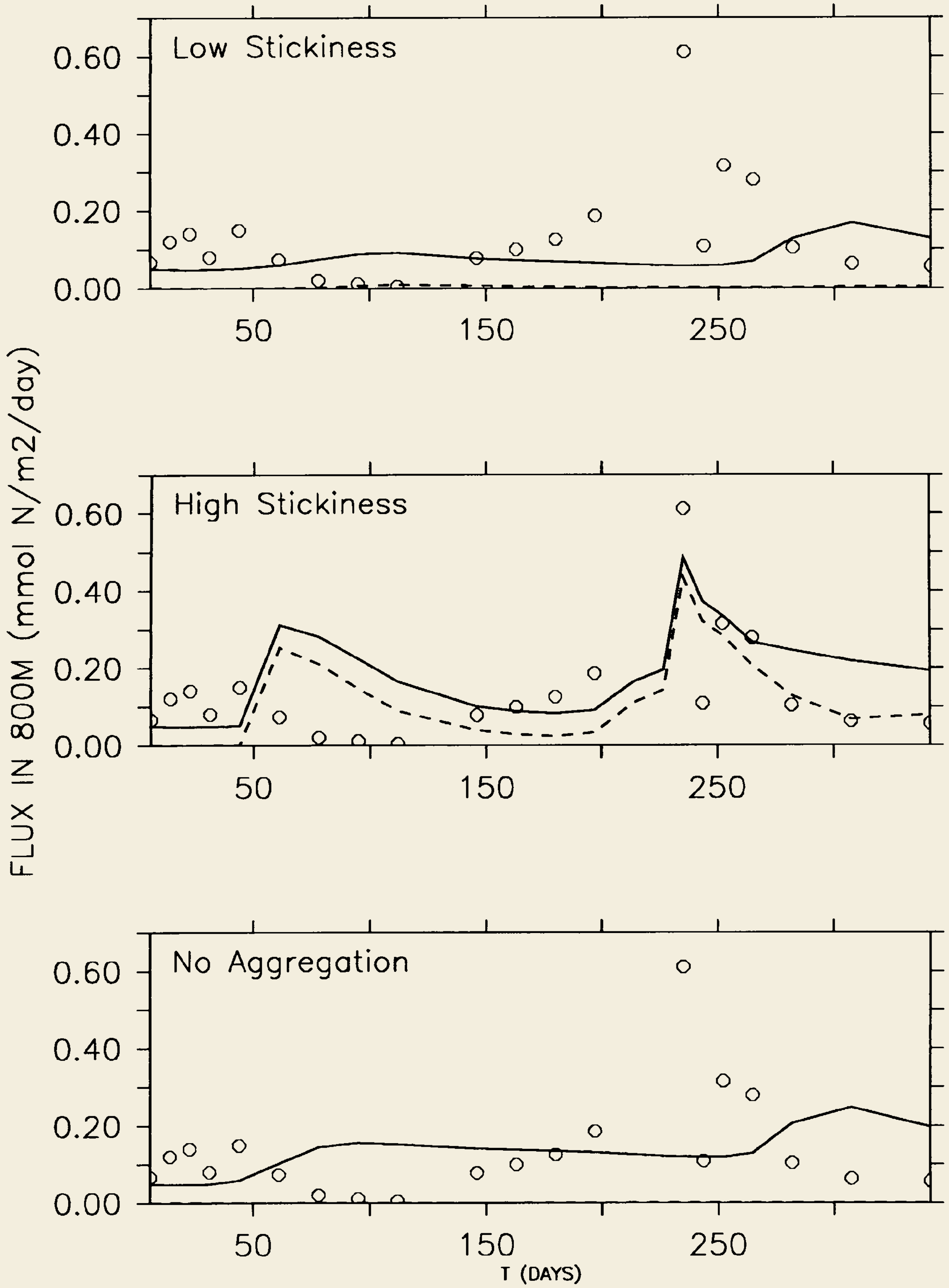
Lomas & Moran, *Biogeosciences*, 8, 203–216 (2011)



Jackson & Burd, 2014



Integrated Approaches



Kriest & Evans, *Earth Planet. Sci., 109, 453–469 (2000)*

What do we still need to know?

- **A lot more about disaggregation**
  - *Rates, daughter particle size distributions, particle strengths, preferred modes of breakup...*
- **The relative contributions to physical and biological aggregation.**
  - *Particle type & properties, concentration, settling speed, biology*
- **Representing remineralization in models**
  - *How do particles degrade? How does particle structure affect degradation rates?*

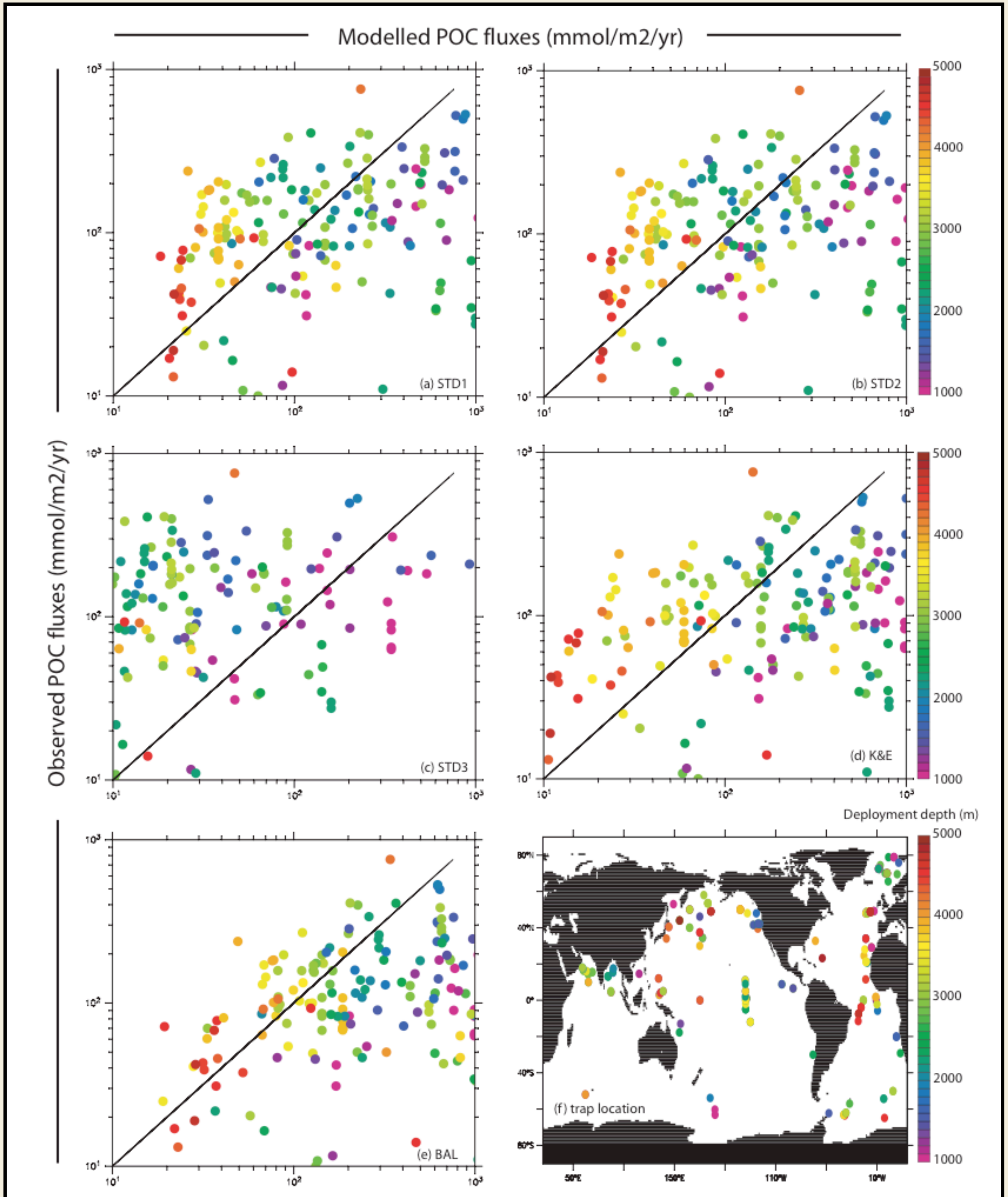
What do we still need to know?

- **Representing remineralization in models**
  - *How do particles degrade? How does particle structure affect degradation rates?*

2 size classes, prescribed settling.

2 size classes, prescribed settling, high grazing

Ballast Model



2 size classes, no aggregation, prescribed settling

Simple Spectral Model

Gehlen et al., *Biogeosciences, 3, 521–537* (2006)