Flocculation is the packaging of small particles into larger aggregated particles. The flocculation process is governed by a balance between particles colliding and sticking together and being torn apart by small-scale turbulence. The resulting aggregates (often called flocs or marine snow) are delicate aquatic particles composed of primary particles held together by polymers. They are often amorphous or "fluffy" and have sizes $> 100\,\mu$m. A large fraction of an aggregate is often water ($> 90\%$ by volume) and hence its physical (e.g., settling speed) and optical properties (especially scattering) can be significantly different from the constituent particles. When mechanically disturbed (e.g., due to pumping through an instrument, sampling through the spigot of a Niskin bottle, or in the wake of a rosette) fragile aggregates may break apart, which often results in large changes in the optical properties of the water column.

Aggregation converts small particles into larger particles, which gives relatively fewer small particles and more large particles and thereby decreases the overall slope of the particle size distribution (PSD). Scattering depends strongly on the PSD (Eq. 2 of the previous page or the page on Mie Theory), so aggregation can be expected to affect optical properties even though the mass remains unchanged. These changes are caused for two primary reasons. First, the packing of particles within aggregates is often dense enough that coherent interactions between scattered waves emanating from individual particles within the aggregate will cause a different scattering pattern than the simple superposition of scattering by the individual particles in suspension. Second, aggregate porosity is observed to grow with increasing aggregate size, so the cross-sectional areas of aggregates can be significantly larger than that derived by assuming that the solid mass is packed into a sphere of the same density as the component particles.

The difficulty of modeling scattering by aggregates can be understood as follows. Consider a spherical particle of diameter d. The volume of the particle is $V = (\pi/6)d^3$ and the cross-sectional area is $A = (\pi/4)d^2$. If two such particles are combined into a new spherical particle, and the density of material remains unchanged, then the new particle has twice the mass and twice the volume of an individual original particle, but the diameter increases by a factor of only $\sqrt[3]{2} = 1.26$. (This is the situation if two small raindrops coalesce into one larger drop.) The cross-sectional area thus increases by a factor of only $\sqrt[2/3]{2} = 1.58$. Combining the two particles thus decreases their cross-sectional area compared to the total cross-sectional area of the two individual particles. Forward scattering (dominated by diffraction) is roughly proportional to the cross-sectional area, so in this case the aggregate scatters less that the two individual particles. However, the situation for actual marine aggregates is more complicated. Rather than the aggregate mass being proportional to d^3, as for a homogeneous sphere, aggregate mass is found to be proportional to d^D, with D in the range of 1.5 to 2.5 (Li and Logan (1995) and references therein). In other words, aggregates are fractal particles ($D \neq 3$).

Consider an aggregate composed of a number N of component particles, and let F be the ratio of the gross volume of the aggregate to the total volume of the component particles. Then fractal theory shows that

$$F = N^{1-3/D}\,.$$

For "perfect" aggregation (e.g., the aggregation of small raindrops to make a larger one), $D = 3$ and $F = 1$. For oceanic aggregates, $D < 3$, so F decreases with increasing aggregate

size, and F is typically in the range of 0.1 to 0.5 (Latimer (1985)). This complexity in aggregate structure greatly complicates modeling scattering properties (you certainly cannot use Mie theory to model scattering as an "equivalent-sphere" aggregate particle).

The role of aggregates in determining oceanic optical properties is remains poorly understood. However, aggregates have been found to contribute significantly to backscattering with little change in the backscattering-to-mass ratio as they formed in the lab or field (Hatcher et al. (2001), Flory et al. (2004)). Boss et al. (2009b) found that aggregation helps explain the relative constancy of scattering to mass or attenuation to mass found in coastal areas. These observations are inconsistent with traditional modeling of marine particles (e.g., using Mie theory), which assumes that particles are solid and which predicts a decrease in scattering efficiency per mass with size. Almost no measurements of scattering phase functions of aggregates have been made (Hou et al. (1996)).