May 12th, 2020
Summary of Planning for the SCOPE 2021 Research Cruise
Meetings are at two-week intervals and will be open to all PIs in the future

Cruise planning committee:
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Cruise Planning Committee Meeting May 12th, 2020 (4:30PM-6:30PM Eastern)

The SCOPE cruise planning committee met mid-May 2020 to continue the process of outlining the objectives and logistics of the planned 2021 SCOPE expedition. The primary objectives of this second meeting were to further hone the proposed cruise foci, inclusive of ideas contributed at the NYC annual meeting, and identify common threads connecting these foci. At our first meeting, the committee felt that focusing a field campaign on the ecology of detritus and organic matter remineralization were topics where SCOPE would be best poised to make substantial progress and these topics complemented existing program expertise (*See Appendix A: Research Justification and Appendix B: Summary of Research Foci Origins*). The planning committee agreed that a cruise focusing on ocean particles, with specific focus on the ecology and biogeochemistry of particles sinking out of the euphotic zone into the upper mesopelagic waters, would complement on-going SCOPE research. In this second meeting, we considerably focused and re-aligned our guiding research questions, identified a tentative plan for ship-time as well as collaborative team leaders that will engage the broader SCOPE community in 2021 objectives and help coordinate pre-cruise activities on extended 2020 HOT cruises in the run-up to this expedition.

SCOPE 2021 cruise planning
Given the intended focus of the 2021 cruise on detritus, remineralization, and particles, the planning committee discussed several items specific to how to optimize the requested 30 days of SCOPE shiptime. Given the extensive focus of previous SCOPE research cruises on time-varying dynamics (with particular emphasis on hourly to daily scales), the committee felt the 2021 cruise provided an opportunity to improve our understanding of vertical variability in this region. Given the interest in particle dynamics and mineralization, the committee felt shipboard sampling of the upper 500 m of the water column, with more extensive focus on the upper 250 m, including high-resolution sampling across key vertical horizons along the transition from the well-lit euphotic zone into the dimly-lit upper mesopelagic waters, would be most beneficial as this is where bulk of remineralization and particle production occurs. In addition, sediment trap deployment horizons, snow catcher deployments, net trap deployments, and imaging technologies would all be used to interrogate the upper 500 m in order to characterize a broader range of particle types including those with faster sinking velocities.

The planning committee felt the cruise foci provided numerous opportunities for engaging modeling efforts. This would include mathematical descriptions of particle-microbiome ecological networks, as well as providing key parameters essential to the Darwin model's simulation of material exchange between the upper ocean and the mesopelagic waters. In addition, this cruise provides an opportunity for testing ECLIPSS model predictions on the role of viral lysis and grazing in the fate of newly produced carbon. Over the coming months, the committee will specifically engage the SCOPE modeling community to gather input on the specific types of models and model currencies, and discuss sampling and experiments most useful for developing and informing models and recursively experiments and sampling protocols.

Previous planning discussions about the 2021 cruise had suggested that including a detailed assessment of mesozooplankton could be beneficial to evaluating the role of diel vertical migration in material and energy export. The committee agreed including such studies would be informative and that using oblique zooplankton tows (both day and night) through the upper 250 m of the water column would enable collection of viable samples for zooplankton-focused experiments. Such net tows would substitute for a more personnel-, labor-, and time-intensive MOCNESS sampling approach.

The committee also agreed that a Lagrangian sampling approach would be optimal for a study focused on particle dynamics and remineralization. Past SCOPE cruises have successfully utilized in situ drifters, often deployed in mesoscale eddies, to examine ecological and biogeochemical time-varying dynamics in a discrete parcel of water. Such an approach would be optimal for the SCOPE 2021 cruise. Based on results from the summertime MESO-SCOPE cruise where the magnitude of organic matter export did not appear to vary strongly among the two eddy dipoles (cyclone vs anticyclone), but that the cyclone exported a larger fraction of biomineralized material (specifically carbonates and silica), the committee supported a plan to try and base the 2021 cruise in an anticyclone. Doing so also provides additional opportunities to pursue linkages between upper ocean nitrogen fixation and positive sea surface height anomalies which continues to be a focus of SCOPE research. Lastly, it was left undecided how best to partition the ship days; at present two 15-day legs separated by a HOT cruise would best accommodate the largest science party and is the tentative working model for the expedition.

Driving research questions and organizers for each focal area are as follows:

1) Characterization of sinking particles over the upper 500 m
   a) Depth-dependent attenuation of energy content, elemental (C, N, P, H, O, Fe, etc.), and molecular composition of particles and DOM
   b) Vertical changes in particle size structure (suspended and sinking) and the role of predation/viruses as modifiers of particle size
   c) Source-tracking of export (e.g., where vertically in the water column does the material originate)
   d) Quantify absolute and relative contributions of living (e.g., *Prochlorococcus*, diazotrophs), dead, and dormant microbes to particle concentrations and export

   Organizers: Karl, VanMooy, White, Beatty

2) Characterization of microbial assemblages (prokaryotic, eukaryotic, viruses) associated with sinking and suspended particles:
   a) Time-varying succession of microorganisms (prokaryotes, eukaryotes, viruses) on sinking particles between upper ocean and mesopelagic waters
   b) Abundance, diversity, and metabolism of particle-associated microbes
   c) Quantify viral abundance, viral diversity, % infected cells on suspended and sinking particles; evaluate the role of viruses and predation as controls on particle microbiome populations
   d) Identify microbial networks and interactions (e.g., metabolic cross feeding) associated with particles

Organizers: Caron, Demory, Delong

3) Experimentally quantify rates, stoichiometry, and controls on organic matter remineralization
   a) Remineralization stoichiometry (C, N, P, O, H, Fe, etc.) at differing depths
   b) Adsorption/desorption of specific elements onto particles
   c) Experimentally examine nutrient/energy limitation of microbial decomposition and remineralization

Organizers: Church, Granzow, Karl

Appendix A: Research Justification

Despite the importance of particles as key sites of biological activity in an otherwise dilute seawater medium, there remain major gaps in our understanding of the specific processes and organisms controlling particle transformations. We currently have poor understanding of processes and rates of biological particulate matter transformations (e.g., production, decomposition) and only sparse information on ecological interactions (e.g., predation, parasitism) that occur in association with particles. On-going and past SCOPE research focused on sinking particles and organic matter remineralization as well as information gleaned from the HOT program provide excellent starting points for framing the science of the 2021 cruise. Moreover, targeted studies on particle dynamics at Station ALOHA enable collaborative opportunities within and outside of SCOPE, including leveraging of ecological and biogeochemical models (for example via interactions with PRIME investigators).

Ocean particles are a heterogeneous collection of organic and inorganic materials, including living and dead cells, feces, mucus-rich aggregates, and mineral shells and frustules. Particles cycle rapidly through the oceans, with turnover catalyzed in large part by biology. In the well-lit upper ocean, phototrophic processes fuel cellular production of particulate matter; however, only a relatively small fraction (<10%) of this material (likely mostly detrital) escapes the recycling intensive upper ocean, transiting downward by gravitational settling into the interior waters of the sea. In the subtropical North Pacific, sinking particles are considered the major pathway supporting the vertical export of material to the deep sea. As these particles sink they are rapidly colonized by microorganisms, with resulting particle-microbiomes blurring the distinction between detritus and life. These microbially-colonized sinking particles could serve as a mechanism for vertical dispersal and transport of organisms across the physically stable main thermocline that separates the sunlit upper ocean from the dimly-lit interior waters. The colonizing microorganisms extract energy from sinking particles, catalyzing the oxidation of both organic and inorganic substrates and solubilizing particulate matter to the dissolved phase. This intense microbiological activity results in decomposition of the vast majority of sinking organic matter within the upper 500 m of the water column.

On-going and past SCOPE research specific to these topics provide information on elemental/energetic content of sinking and suspended particles, assessment of particle-microbiome genomic signatures, rates of particle-associated microbial metabolism and remineralization, and optical characterization of suspended and sinking particle size and abundance. However, there remain numerous unanswered questions regarding the fate of particles as they transit through the water column. A few of many unanswered questions include:

- Are there relationships between the energetic content of particulate material and elemental (C, N, P, O, H, Fe) and molecular stoichiometry of particle mineralization?
- How do predation and viral lysis influence sinking particle fluxes, particle-microbiome population sizes, and mineralization of sinking particles?
- Are there predictable, time-dependent patterns in the succession of microorganisms associated with particles as they sink?

- How does particle sinking rate relate to suspended and sinking particle size? Are there relationships between particle size and sinking flux attenuation and production:export ratios as a function of depth?
- Does the close spatial interaction of microorganisms associated with sinking particles promote coupled metabolic networks?

Appendix B: Summary of Research Foci Origins

Initial planning for the SCOPE 2021 cruise began in November 2018 when SCOPE investigators were asked to present ideas on how a SCOPE research cruise could be used to improve understanding of major gaps in our current understanding of microbial ecology and biogeochemistry at Station ALOHA. Three closely connected themes emerged from these presentations:

1. Export and upper ocean/mesopelagic coupling
2. The role of detritus in plankton food webs and biogeochemistry
3. Remineralization: stoichiometry, rates, and controls

Additional presentations and discussion specific to these three topics were presented at the SCOPE annual meeting 2018. Similarly, during a session at the 2019 SCOPE annual meeting specifically devoted to planning for the 2021 cruise, meeting participants were asked to provide input on types of activities or research topics they would pursue relevant to these three topics. The resulting input is summarized below:

1. Quantify molecular composition of sinking particles and how microorganisms shape depth-dependent changes in export
    a. depth-dependent attenuation of energy content, elemental (C, N, P, H, O, Fe, etc.), and molecular composition of particles and DOM
    b. vertical changes in particle size structure
2. Role of predators and viruses in controlling the magnitude, variability, and efficiency of export:
    a. % infected cells sinking
    b. Viral abundance and diversity on sinking particles
    c. Quantify the relative importance of the viruses as shunts (forming small particles and DOM) vs particle shuttles (producing larger, exportable organic aggregates)
    d. Quantify viral elemental quotas
3. Characterization of microbial assemblages (prokaryotic, eukaryotic, viruses) associated with sinking and suspended particles:
    a. Track succession of microorganism communities on sinking particles between upper ocean and mesopelagic waters;
    b. Description of diversity and metabolism of particle-associated microbes (coupling use of metagenomics, metatranscriptomics, metabolomics, rate measurements)
    c. Assess how different species (e.g., *Prochlorococcus*, diazotrophs) impact export
    d. Source-tracking of export (e.g., where in the water column does the material originate)
    e. Identify microbial networks and interactions (e.g., metabolic cross feeding) associated with particles
4. Diurnal scale processes linking variability in net community production and export:

    a. Remineralization stoichiometry (C, N, P, O, H, Fe, etc.) at differing depths
    b. Elemental adsorption to particles
    c. Characterize depth-dependent nutrient limitation of microbial decomposition and remineralization
5. Quantify absolute and relative contributions of living, dead, and dormant microbes to particle concentrations and export.

In addition to identifying specific research topics of interest to the SCOPE community, this cruise planning session also introduced the proposed shiptime request for the 2021 cruise. Although still tentative, the request was designed to maximize flexibility in use of the shiptime, including two 15-day SCOPE cruises (totaling 30 days), with HOT program cruises tentatively scheduled prior to each 15-day sampling leg. Such a schedule would allow sampling and deployment/recovery of *in situ* equipment (gliders, floats, drifting arrays, etc.) to potentially occur as part of the HOT cruises and importantly maximize the number of participants if there were personnel exchanges between the various legs

In March 2020, a cruise planning committee was formed, inclusive of five SCOPE investigators and three early career SCOPE scientists.