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Inside

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COMBINING FORCES TO UNDERSTAND HARMFUL ALGAL BLOOM DYNAMICS

By Eileen Hofmann, Brynn Pecher, and Margie Mulholland

Over the last 20 years the lower Chesapeake Bay and its tributaries have experienced massive blooms of the harmful dinoflagellate, *Margalefidinium polykrikoides* (recently renamed from *Cochlodinium polykrikoides*). Observations made by Dr. Margie Mulholland's research group in Old Dominion University's Department of Ocean, Earth and Atmospheric Sciences (OEAS) identified the Lafayette and Elizabeth Rivers, local subtributaries of the lower Chesapeake Bay, as hot spots for bloom initiation of this algal species (Figure 1). These blooms, which can last throughout the summer, cause local hypoxia and affect shellfish and larval fish.

The increasing frequency of the harmful algal blooms over the past twenty years (Figure 1) and consequences for water quality and ecosystem services pointed to the need to understand environmental controls on bloom initiation, magnitude, and persistence. The extensive lab measurements and observations of the bloom process made by the Mulholland research group extend over several years and multiple blooms. The collection and analysis of these data sets have been supported by local organizations, such as the Hampton Roads Sanitation District.

Combining these data with a numerical model is a natural next step for identifying and understanding bloom dynamics. CCPO scientists, **Eileen Hofmann** and **John Klinck**,

Photo at top by Wolfgang K. Vogelbein, Virginia Institute of Marine Science.

Article continued on page 2

COMBINING FORCES | Cont.

participated in a proposal, led by Margie, that was submitted to the NOAA Harmful Algal Bloom program. This proposal was funded in late summer 2018 and model development and associated data analyses were underway.

Brynn Pecher, CCPO research associate, joined the modeling group and is implementing a staged approach for model development. The first model avoids variations in space to simulate the time evolution of a bloom which includes *M. polykrikoides* growth, and cyst germination and formation. The cyst and growth dynamics included in the model are based on field and experimental data obtained by the Mulholland research program and data in the published literature.

The simulations done to date highlight the importance of temperature in regulating cyst germination and bloom initiation and the role of nutrients in maintaining the bloom. These simulations have identified specific cyst and algal growth processes that require experimental studies. Experiments designed to better define these processes and their role in bloom initiation and maintenance are planned for this summer. They are being implemented by Eduardo Perez Vega, Michael Echevarria, and Iliana Flefel, graduate students in the Mulholland research group, and additional students associated with the OEAS Research Experiences for Undergraduate summer program.

While these experiments are underway, the modeling group is extending the time-dependent model to include a vertical dimension so that the effects of both depth variations in environmental conditions and vertical migration by *M. polykrikoides* on bloom initiation and duration can be assessed. Eventually, the *M. polykrikoides* model will be embedded in a three-dimensional model structure which will include water movement as well as diffusion of various properties.

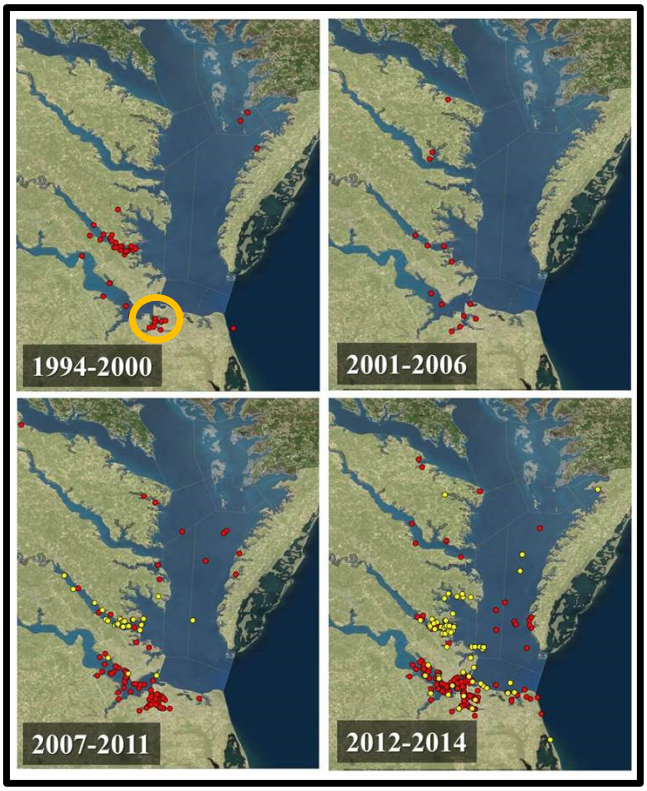

Figure 1. Maps of observed occurrence of blooms of the harmful algae, *Margalefidinium polykrikoides* (red circles) and *Alexandrium monilatum* (yellow circles), in the lower Chesapeake Bay and subtributaries from 1994 to 2014. The Lafayette River study site is indicated (orange circle).

This sequence of models provides the group a tool that can assess the conditions that support harmful algal blooms in the lower Chesapeake Bay. This model analysis is a step towards the development of policies and management procedures that can forecast and mitigate the impacts of these harmful algal blooms.

Letter from the Director

Much of the effort of the folks at CCPO involves exotic locales and travel to far-away places. It is nice, sometimes, to look at questions closer to home. Several of us have recently worked on water quality and phytoplankton dynamics in the Lafayette River. While this is a small, local, tidal tributary, it provides interesting questions to think about with important consequences. As Eileen and Brynn tell the story, we are interested in the processes causing blooms of potentially harmful dinoflagellates. These organisms have an important effect on the people that live near the water and are an indicator of nutrient fluxes from the surrounding population, nearby rivers and subsurface aquifers.

A similar local interest is developing with wind turbines being placed on the continental shelf off the Virginia coast. Some of us are directly involved in helping to plan the permitting, placement and support of these large machines in the marine environment. Others of us are thinking of how we can generally support this activity by evaluating conditions in the atmosphere and ocean near these turbines, by considering their effects on marine activities, and by providing educational opportunities for the people who will maintain and expand these electricity generating facilities.

I seem to mention outreach in most newsletters, but I think that it is an important activity for people employed by universities. We (all of us) know many details about how the environment works; it is important that we pass on that understanding to the local community and, perhaps, encourage a few of the younger listeners to be interested enough to pursue science training and contribute to the further understanding of the earth and its processes.

— Dr. John Klinck, Director of CCPO & Professor of Oceanography

Environmental Stewardship, Girl Scouts, and Chesapeake Bay

TOP From left to right: Brynn Pecher, Teresa Updyke, Eileen Hofmann, Julie Morgan, and Emily Anderson.

MIDDLE The Girl Scouts enjoyed holding the periwinkle snails from the touch tanks.

BOTTOM Brynn Pecher assists a Cadette with observing zooplankton under the microscope.

A team consisting of **Eileen Hofmann**, **Teresa Updyke**, **Brynn Pecher**, **Julie Morgan**, and Emily Anderson (graduate student, Department of Biological Sciences, ODU) visited *A Place for Girls* in Chesapeake, VA on 18 April to provide a program that allowed the Girl Scouts to earn an Environmental Stewardship badge as part of a spring break camp. The fifty Girl Scouts who participated in the event included Daisies (grades K–1), Brownies (grades 2–3), Juniors (grades 4–5), and Cadettes (grades 6–8).

The morning program included three stations in the outdoor nature venue located onsite. At station 1, Brynn and Teresa led an activity about the impacts of trash on marine life and how waste can be reduced with environmentally friendly alternatives. The Scouts went on a "trash treasure hunt" to find pictures of trash, i.e., plastic bags, plastic straws and cutlery, and then talked with Brynn and Teresa about how the trash is harmful to marine life. The "How Can We Fix This?" part of the activity showed environmentally friendly alternatives that reduce waste. The Scouts then placed the pictures of harmful trash on a poster board under the "Instead of This" column and identified its environmentally friendly counterpart under the "Choose This" column.

At station 2, Emily and Julie provided markers and reusable tote bags for the Scouts to decorate and they discussed why single-use plastic bags are not a good choice for the environment. The girls also learned about the important role of the oyster in keeping estuarine waters clean and were given an oyster shell to decorate and take home as a reminder to help prevent pollution.

The third station was a nature walk and leaf treasure hunt led by Eileen. The Scouts looked for different leaves and discussed the different trees and their habitat. The leaf treasure hunt showed the diversity of trees that occur along a gradient from a wet swampy habitat to a drier sandy habitat.

For the afternoon indoor program, Julie used a coastal model table to do hands-on demonstrations of the effects of pollution and run-off in waterfront areas. The Scouts offered suggestions for solutions to keep pollutants out of the water and to improve coastal environments.

Teresa kept the girls on their feet as they learned how fast Chesapeake Bay waters move by walking at speeds that are typical of maximum flood and ebb currents. They considered how surface waters could transport floating objects or pollutants by learning a dance called the Chesapeake Shuffle. The basic moves of the shuffle are a steady movement toward the ocean and steps in clockwise circles to represent the influence of the tide. However, the girls also had to watch out for winds blowing them in different directions!

Touch tanks that included periwinkle snails, oysters, mussels, mud crabs, worms and barnacles provided hands-on experiences with animals that live in the Chesapeake Bay. The sponges, anemones, barnacles, oysters, and other filtering organisms in an aquarium showed their importance to the ecology of Chesapeake Bay by making the water clearer as it was filtered.

Emily and Brynn set up video microscopes to show phytoplankton, zooplankton, fish eggs, and barnacle, blue crab, fish and polycheate larvae that live in local waters. They talked with the girls about plankton, its importance to the Chesapeake Bay food web, and the difference between zooplankton and phytoplankton.

A short presentation by Eileen that showed life on an Antarctic cruise was the final activity. The videos of crabeater seals on the ice and underwater kept the Scouts' attention at the end of a busy day.

Afterward, the Scouts formed smaller groups to talk with individual ODU team members and discuss what they had learned. Their enthusiasm and positive energy made the experience enjoyable and worthwhile.

THE LAND OF A MILLION PLASTIC BITS

Clean the Bay Day 2019

By Brynn Pecher

As oceanographers, we are well versed in the anthropogenic effects on our oceans, including the global marine debris crisis. When the registration for Clean the Bay Day (CTBD) opened, it only made sense for us to participate. CTBD is an annual event hosted by the Chesapeake Bay Foundation where several thousand volunteers pick up trash along the Chesapeake Bay watershed for three hours on the first Saturday in June.

This is our second year participating in CTBD. Last year, we collected 550 pounds of trash from a "jungle-like" inlet behind the Talbot Apartments in Norfolk. This year, our CTBD efforts were split between two weekends because thunderstorms cut our time short on the originally scheduled date. Still, our team bravely managed to clean up 180 pounds of litter in the rain in just one hour before the cancellation of the event. Our team set out again on June 9 to tackle another day of litter removal to finish the site.

Our 2019 location was at a kayak launch at the end of La Valette Avenue behind the Virginia Zoo. This site was challenging in a different kind of way. Instead of trekking through the swampy marsh collecting water bottles and plastic bags, our efforts this year were spent picking up an overwhelming amount of small plastic bits that were densely mixed with the leaf debris along a restored living shoreline. Not only were the pieces small, but the challenge was to avoid the thick, barbed vines that grew from the ground. Plastic cups that had been there for so long would instantly crumble as we attempted to pick them up with our litter grabbers, forcing us to go back and pick them up piece by piece.

In combination with the trash that was picked up on the first weekend, within the 0.75 miles of shoreline and park area, we collected 580 pounds of trash! Among this was 355 pounds of litter including: cigarette butts, cigar mouthpiece tips, bottle caps, small plastic pieces, Styrofoam, pens, one recreational needle, food wrappers, plastic utensils, straws, plastic bottles and plastic bags, one 25-pound car tire, and 200 pounds of chemically treated construction wood. Four hours of work split between two weekends and one ground wasp sting was all worth it knowing that 580 pounds of debris are no longer a potential threat to the marine life.

Clean the Bay Day is so impactful, not just for the amount of litter removed, but because it encourages our neighbors to get outside, care for the Bay, and change our habits! Thanks so much to our adventurous volunteers and please consider helping at next year's Clean the Bay Day on June 6, 2020! Check out the CCPO Facebook page to see more photos of our cleaning efforts!

The clean-up crew from June 9 event (l to r): Praveen Kumar, Andrew Foor, Desiray Wines, Mike Dinniman, Eileen Hofmann, John Klinck, Brynn Pecher, Nate Pecher, and Rachel McMahon (not pictured: Teresa Updyke).

A TRIP TO THE PAST

...to help figure out the future.

One of the major activities at CCPO is modeling past interactions between the ocean and the floating portions of the Antarctic ice sheet to try and help figure out what may happen to both the ocean and ice sheet in the future. For various reasons, ranging from how far back reliable atmospheric forcing data is available to how long it takes to run simulations, the earliest time period simulated at CCPO had been the 1990s. However, current (**Mike Dinniman**) and former (Stefanie Mack) CCPO researchers recently went to visit a city famous for its history over the last 1500 years to help out on a project involving interactions between the ocean and the Antarctic ice sheet during the Miocene epoch (a high-CO2 warm period 25 to 5 million years ago that could be an analogue for future warming).

Mike, and, more recently, Stefanie had been modeling interactions between the Ross Ice Shelf, an enormous (about the size of Spain) floating extension of the Antarctic Ice Sheet and the coastal Antarctic ocean for over ten years now. Much of the melting of ice shelves in Antarctica is controlled by the flow of (relatively) warm water from the open ocean onto the continental shelf and into the cavity underneath the ice shelf. A critical factor in accurately simulating this circulation is the bathymetry of the area: not only the depth below mean sea level at the base of the ocean, but also the extent and thickness (which is often more than 1000 feet) of the ice shelf. The Ross Ice Shelf does not currently have much of this warm water circulating underneath it, but that could change in the future and may have been different in the past.

Meanwhile, an international team of scientists, including Laura De Santis and Florence Colleoni, from the Italian National Institute of Oceanography and Applied Geophysics (OGS) in Trieste and Andrea Bergamasco from the Institute of Marine Sciences (ISMAR) in Venice had returned from a cruise to the Ross Sea (https://eos.org/project-updates/exploring-the-unknown-of-the-ross-sea-in-sea-ice-free-conditions) to study the current and past structure of the seafloor of this region. As part of their work, they were able to recreate what the seafloor looked like during the Miocene epoch and wanted to see how this would control the flow of warm water to the floating edges of the ice sheet in order to study the past vulnerability of the Ross Ice Shelf. They reached out to Mike and Stefanie about applying the current day model of the Ross Sea ice and ocean to the past.

Left to right: Andrea Bergamasco, Francesco Falcieri, Stefanie Mack, Alessandro Bergamasco, and Mike Dinniman.

Mike and Stefanie were invited to Venice to help the ISMAR group (Andrea and Francesco Falcieri) get Stefanie's latest version of the model up and running on the computers there and Stefanie and Francesco actually had a preliminary version with the Miocene bathymetry running before the trip was over. Mike and Stefanie also gave seminars in Venice and Trieste and got to do some fantastic sight-seeing (including meeting former CCPO scientist, Tosca Ballerini, in Florence). The collaborations in studying the Ross Sea between CCPO and ISMAR and OGS will continue for quite a while with further computer modeling at both ISMAR and OGS and a graduate student from OGS likely visiting CCPO later this year for a few months.

Entrance to the Arsenale di Venezia (Venice Arsenal), a complex of former shipyards and armories where the majority of Venice's trading ships were built during the glory days of the Venetian Republic. It is now primarily a naval base but includes several research offices, including the ISMAR offices where Mike and Stefanie worked.

JUST THE FACTS

Presentations

Brearley, J.A., C. Moffat, H.J. Venables, M.P. Meredith, and **M.S. Dinniman**. Meander-Driven Export of Shelf Water in the West Antarctic. AMS 15th Conference on Polar Meteorology and Oceanography, Boulder, CO, May 2019.

Bruciaferri, D., G. Shapiro, S. Stanichny, A. Zatsepin, **T. Ezer**, F. Wobus, X. Francis, and D. Hilton. New numerical model for the Black Sea circulation. Geophysical Research Abstracts, Vol. 21, EGU2019-5933, EGU General Assembly, Vienna, Austria, April 8, 2019.

Cambazoglu, M.K., J. Wiggert, S. O'Brien, T. Miles, A. Greer, **M. Dinniman**, and P. Fitzpatrick. Impact of wave forcing on sediment resuspension and transport in the Mississippi Sound and Bight. 2019 Gulf of Mexico Oil Spill and Ecosystem Science Conference, New Orleans, LA, February 2019.

Dinniman, M., Ocean Melting of Antarctic Ice Shelves: Why do we care (besides sea level rise)? Global Modeling and Assimilation Office (invited), NASA Goddard Space Flight Center, Greenbelt, MD, March 5, 2019.

Dinniman, M.S., J.D. Wiggert, and M.K. Cambazoglu. The impact of diurnal winds on exchange through barrier island passes into the Mississippi Sound. 2019 Gulf of Mexico Oil Spill and Ecosystem Science Conference, New Orleans, LA, February 2019.

Ezer, T., On the impact on coastal sea level from the combined effect of hurricanes and the Gulf Stream. US CLIVAR Workshop, Sea Level Hotspots from Florida to Maine, Norfolk, VA, April 23, 2019.

Hofmann, E.E. and the USECoS Team. Modeling Continental Shelf Nutrient and Carbon Budgets: Approaches and Challenges. Invited keynote plenary presentation, Fourth Xiamen Symposium on Marine Environmental Sciences, Xiamen, China, January 6-9, 2019.

Hofmann, E.E., Modeling Southern Ocean Food Webs: Approaches and Challenges. Marine science seminar, Shanghai Jiao Tong University, Shanghai, China, January 11, 2019.

Hofmann, E.E., Increased Dermo Disease in Chesapeake Bay Oysters Caused by Continued Warming and Nutrient Loading. Oral presentation, Aquaculture 2019, New Orleans, LA, March 7-11, 2019.

Hofmann, E.E., Southern Ocean Food Webs: Approaches and Challenges. Marine science seminar, Universidad Austral de Chile, April 9, 2019.

Hofmann, E.E., M.S. Dinniman, M.K. Cambazoglu, and J.D. Wiggert. Approaches and Challenges to Modeling Transport and Exchanges in the Northern Gulf of Mexico. 2019 Gulf of Mexico Oil Spill and Ecosystem Science Conference, New Orleans, LA, February 2019.

Howden, S.D., L. Hode, M.K. Cambazoglu, J. Wiggert, K. Martin, **M. Dinniman**, B. Dzwonkowski, and S. Parra. Connectivity of the Gulf of Mexico to the Mississippi Sound. 2019 Gulf of Mexico Oil Spill and Ecosystem Science Conference, New Orleans, LA, February 2019.

O'Brien, S.J., S.L. Dykstra, S.M. Parra, B. Dzwonkowski, J.W. Book, C. Pan, **M.S. Dinniman**, P.J. Fitzpatrick, Y.H. Lau, M.K. Cambazoglu, and **E. Hofmann**. Suspended Sediment Transport in Mississippi Bight During Two Cold Front Events in Spring 2016. 2019 Gulf of Mexico Oil Spill and Ecosystem Science Conference, New Orleans, LA, February 2019.

St-Laurent, P., Modeling the pathways of oceanic heat and glacial meltwater on the continental shelf of the Amundsen Sea, Antarctica. University of California, Irvine, Earth System Science Seminars (invited), Irvine, CA, January 15, 2019.

Tuleya, R., The evolution of numerical modeling of hurricanes. Hampton University Atmospheric and Planetary Science Seminar Series, Hampton, VA, February 6, 2019.

Updyke, T.G. and **L.P. Atkinson**. Sub-tidal Surface Current Variability in the Lower Chesapeake Bay. 2018 Fall AGU Meeting, Washington, DC, December 2018.

Publications

Ezer, T., 2019. Regional differences in sea level rise between the Mid-Atlantic Bight and the South Atlantic Bight: Is the Gulf Stream to blame?, *Earth's Future*, 7, doi:10.1029/2019EF001174.

Oliver, H., **P. St-Laurent**, R.M. Sherrell, and P.L. Yager. 2019. Modeling iron and light controls on the summer *Phaeocystis antarctica* bloom in the Amundsen Sea Polynya, *Global Biogeochemical Cycles*, doi:10.1029/2018GB006168.

Piñones, A., **E.E. Hofmann**, D.P. Costa, K. Goetz, J.M. Burns, F. Roquet, **M.S. Dinniman,** and **J.M. Klinck**. 2019. Temporal and spatial variability of hydrographic conditions along the inner shelf of the Ross Sea obtained using instrumented seals, *Progress in Oceanography*, 174, 131-142, https://doi.org/10.1016/j.pocean.2019.01.003.

St-Laurent, P., P.L. Yager, R.M. Sherrell, H. Oliver, **M.S. Dinniman**, and S.E. Stammerjohn. 2019. Modeling the seasonal cycle of iron and carbon fluxes in the Amundsen Sea Polynya, Antarctica, *Journal of Geophysical Research*: *Oceans*, 124(3), 1544-1565, https://doi.org/10.1029/2018JC014773.

Spotlight

SE-HYEON CHEON

I earned my Engineering Ph.D. from Seoul National University (SNU) in Spring 2017. During the first two years at SNU, I focused on applying the reliability design process to coastal structures that are vulnerable to risks associated with climate change. During the second half of my Ph.D., I came to CCPO as a visiting scholar to study historical reconstruction of sea level (SL) and surface waves to provide historical data for statistical analysis.

Se-Hyeon Cheon visits Washington, DC with his son, Kanghee Cheon, and wife, Jihae Min.

My research activities can be roughly divided into three periods. During my master's degree and subsequent work at the research institute of Handong University (2003–2011), I worked on numerical analysis of coastal processes and, in the process, developed new methods of gathering data for which I hold three patents. I also developed a numerical 2-D sediment transport model. For the first two years of my Ph.D. (2012–2013), I applied these skills to coastal engineering challenges. Specifically, I proposed a method for calculating the relative variation of design waves due to rising SL. I then implemented reliable design techniques to breakwater designs. During this time, I continued to hone and expand a variety of analytical skills: time series analysis, reliability analysis, and CycloStationary Empirical Orthogonal Function (CSEOF) analysis. The final three years of my Ph.D. and subsequent post-doctoral research (2014–present) have been dedicated to understanding SL changes by using satellite-based observations, such as NASA altimetry missions and GRACE. I have reconstructed SL around the Korean Peninsula and estimated the interannual and decadal variabilities of global SL using the CSEOF analysis. Most recently I proposed a combined CSEOF analysis to evaluate the contributions of each source of SL change (steric SL and terrestrial water storage changes) to the total SL change.

In the near future, I will move to the Jet Propulsion Laboratory in Pasadena, California, where I will continue to work on understanding sea level variability and its causes at regional scales. These efforts are consistent with what I have accomplished so far at CCPO.

When I first came to CCPO, I was very worried about how I could adapt here. But I was able to settle down here without any difficulty because of the excellent support and friendly CCPO members. What's disappointing now is that my lack of English and social skills has prevented me from interacting with you more actively. I really appreciate all CCPO members for helping me out so far.

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MEMO OF UNDERSTANDING IN SUPPORT OF VIRGINIA OFFSHORE WIND GENERATION

Old Dominion University (ODU) has joined the Virginia Department of Mines, Minerals and Energy (DMME) through a Memo of Understanding (MOU) to provide offshore wind research and support activities. The signing was part of a Town Hall meeting (May 28, 2019) supported by ODU and the Sierra Club Virginia Chapter. ODU President John Broderick delivered the keynote address, followed by an address from Thomas Brøstrom, President of Ørsted North America, which holds more than a third of the offshore wind lease area on the Mid-Atlantic outer continental shelf. There were four panel presentations along with an extended question and answer session. The panel included representatives from Dominion Energy, owner and operator of the Coastal Virginia Offshore Wind (CVOW) project, whose two turbines will be installed in the summer of 2020, Tidewater Community College, the Port of Virginia, Ørsted, and Avangrid (who holds the commercial lease off Kitty Hawk, NC).

George Hagerman, Senior Project Scientist at CCPO, was instrumental in supporting the development of offshore wind generation and has played a leading role in connecting ODU to this activity. Our role will be to evaluate meteorological and oceanographic design and operating conditions, as well as the effects of these turbines on the atmosphere and marine environment as well as on maritime and military operations over the continental shelf. We look forward to advancing several new CCPO-sponsored research initiatives to support ODU's collaboration with the development of offshore wind energy generation.