CCPO CIRCULATION

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UNDERSTANDING THE CAUSES AND IMPACTS OF SEA LEVEL RISE

By Sönke Dangendorf

Sea level rise is one of the most serious effects of a changing climate and, here in Hampton Roads, we are already facing many of the dangerous impacts in our daily lives. The seas are surging, leading to frequent flooding of our streets and backyards, and increased saltwater intrusion and erosion. This not only disrupts our daily routines, but it also threatens lives, coastal infrastructure, and ecosystems. About 40% of the US population lives in coastal areas that may be vulnerable to sea level rise and most of the world's megacities are at or near the coast. Projections of future sea level rise point towards a further increase throughout the 21st century and beyond, thus posing a serious challenge for coastal communities. Can we stop this development, can we protect, or do we need to adapt? These are all questions that we are commonly facing these days.

Solutions to the challenges surrounding sea level change are manifold and can reach from upgrading or building coastal flood defense infrastructure to retreat. But they all have one thing in common; they require time and planning. An interesting example in this context is the Thames Barrier in London, UK. Built in 1982, the Barrier should protect London's citizens against very high flood levels with estimated return periods of one hundred years. However, its planning started after the great North Sea flood of 1953, so it took nearly 30 years of planning!

While we can relatively precisely calculate to which amount of sea level rise such a barrier or critical infrastructure can be maintained, projections of future sea level rise are deeply uncertain, hampering decision-making processes and planning. According to the latest Special Report of the Intergovernmental Panel on Climate Change in 2019, this uncertainty ranges from 17 to 40 cm in the mid-21st century and 29 to 110 cm in 2100 for global mean sea level and results from both uncertainties in greenhouse gas emission scenarios and limited understanding of the physics and feedback of individual contributing processes. Locally, where the number of processes contributing to relative sea level rise is higher than for the global mean, this uncertainty becomes even larger. In practice, stakeholders are often left alone with this uncertainty and thus struggle with finding and initiating the right response under their specific political, ethical and economic conditions.

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OLD DOMINION UNIVERSITY

Inside

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SEA LEVEL RISE | Cont.

Having my roots in coastal and civil engineering, this situation marks a key motivation for our team to increase our understanding of past sea level change with its impacts on our coasts and contribute to improved projections ideally with reduced uncertainties. Some of this work deals with the sparseness of observations that introduces a key uncertainty to our understanding of how sea levels and individual contributing processes have been developing in the past. While space agencies such as NASA and ESA have recently developed continuous observational systems that now even cover some of the most remote regions of our planet and allow for unique insights into the key physical processes affecting sea level change, information back into pre-industrial times, when modern sea level rise started, becomes increasingly sparse and is mostly based on spotty measurements taken by individuals on ships or at the coast. By coupling the information from modern remote sensing techniques with Earth System Models and the increasing computational power, we develop robust techniques that allow us to reconstruct the complex geometry of past sea level even at locations where no observations have been available before. These observation-based sea level reconstructions provide indispensable baseline data that informs impact assessments or can be used to compare observations with projections. Based on such comparisons we try to identify the most likely pathway we are currently following and ideally constrain the potpourri of future projections that informs decision-makers and planners.

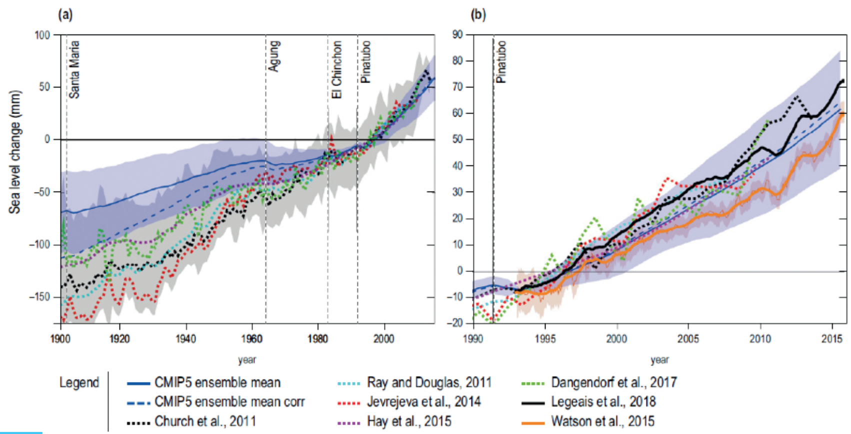


Figure 1. Comparison of global mean sea level as reconstructed from tide gauges (dotted lines) and as modelled historically with Earth System Models (CMIP5) that are also used for future projections. b) Also shown is a close-up of the modern “remote-sensing period” since the early 1990s with additional satellite altimetry measurements. The figure has been taken from the recent SROCC report (Oppenheimer et al., 2019, http://201.207.189.89/handle/11554/9280).

Our work also seeks to disentangle the different processes that affect sea level changes globally but also directly in front of our doors. For instance, recently we have become part of the prestigious NASA Sea Level Change Team that has been formed to better understand current and project future coastal sea level rise. Our sub-project focuses on the development of near-term predictions of local sea level change and nuisance flooding. We investigate the contributions of vertical land motion and non-astronomical changes in tides to relative sea level rise along the entire US coasts. While vertical land motion has been the single most important contributor to sea level changes here in the Hampton Roads area, tides are the driving force behind the reoccurring pattern of nuisance flood events that we experience so often nowadays. With our work in the NASA Sea Level Change Team, we contribute to the advancement of a new webtool, developed and maintained by our collaboration partner Phil Thompson at the University of Hawaii Sea Level Centre (https://sealevel.nasa.gov/data_tools/15), that seeks to predict the number of expected flood events over the coming years.

Overall, it is my wish to connect our work with the widespread activities that are already being done at Old Dominion University and CCPO to support the region with scientific information that is tightly linked to the needs of decision makers and affected communities. This will certainly support our common goal to become an international leader in sea level science and provide students a variety of societal relevant research options.

Travel Fellowship Honors Atkinson for Service

The *Larry P. Atkinson Travel Fellowship for Students and Early Career Scientists* was established on May 14, 2020 by The Ocean Observatories Initiative Facility Board in recognition of **Larry P. Atkinson’s** dedicated service as the Inaugural Chair of the Ocean Observatories Initiative Facility Board, May 2017 to November 2019. Throughout his career, Larry has supported and encouraged early career scientists to attend meetings, conferences, and workshops. This Fellowship will facilitate and continue Larry’s support for engagement by early career scientists in these events. More information about the Fellowship is available at: https://ooifb.org/news/ooifb-establishes-the-larry-p-atkinson-travel-fellowship-for-students-and-early-career-scientists/. Information regarding donations to this fellowship will be provided in the next issue.

CCPO Faculty Spotlight

SÖNKE DANGENDORF

Sönke Dangendorf at the University of Siegen

As the newest CCPO faculty member, I appreciate the possibility to introduce myself. I grew up in a little town near Siegen, Germany. I spent much of my childhood skateboarding, which shaped my lasting passion for all kinds of board and water sports. After finishing school in 2003, I started working as a bricklayer. I enjoyed getting my first regular salary and liked the "workman vibes", which substantially motivated me to start studying civil engineering at the University of Siegen in 2004.

Somewhat surprisingly, it was not the classical constructional engineering that attracted me most but rather the topics of water and climate change. The first time that I got in touch with our beloved ocean was a semester presentation of the topic, the physics of sea level change, in a course taught by my eventual supervisor, Jürgen Jensen. I was immediately fascinated by the interdisciplinary character of that topic, ranging from complex physics to its interaction with the coast and the far-reaching societal impacts. Jürgen offered me a position on his team, first as a student assistant and, after my graduation, as a Ph.D. student. It was a classical German engineering Ph.D.—fully paid but with the side effect of having more duties than working merely on a single research project. This included consulting projects on the flood risk of nuclear power plants, court-appointed expert reports on flood-induced construction faults, and much more. I really appreciate these experiences as they enriched me with a lot of different perspectives, including close exchange with authorities, companies, and other stakeholders. Though located far away from the coast, the nature of research at our institute was largely dominated by coastal engineering tasks linked to coastal, fluvial, and pluvial flooding. I also have very fond memories of this period because of the wonderful team. I feel very privileged to have been able to work in an environment shaped by a lively exchange of information, mutual motivation, and leisure activities outside of work. Some of those colleagues became good friends of mine such as Thomas Wahl (now at the University of Central Florida and collaborator in our new NASA project) or Arne Arns (one of the upcoming speakers for the CCPO & ICAR seminar series this fall).

In my actual Ph.D. project, I focused on the assessment of sea level variability and its role for coastal flood risk in the southeastern North Sea. One of the primary questions was how an improved understanding of natural variability can lead to an earlier detection of potential future accelerations. This question is vital for coastal planning as many safety measures require decisions years to decades in advance. An example is the famous Thames barrier in London, which took nearly 30 years of planning before it finally opened in 1982. The results of this project demonstrated that, with an improved understanding and the subsequent removal of natural variability, we might be able to detect an acceleration as much as 60 years earlier than with "raw" tide gauge records. While with obvious implications for coastal engineering, the topic brought me deeper into the field of physical oceanography and I finally graduated under the supervision of Jürgen and Hans von Storch in late summer of 2014.

After finalizing my thesis, I stayed at the University of Siegen, where I later became group leader and Akademischer Rat (the non-tenured German equivalent to the Assistant Professor position here in the US), but with the opportunity of broadening my horizon with extended stays at other international institutions (e.g. the Nansen Centre in Bergen, Norway, and IMEDEA at Mallorca, Spain). During that time, I started to work on broader spatial scales and topics related to the quantification of the human fingerprint in sea level and the reconstruction of 20th century global and regional sea level changes from the sparse tide gauge network. In 2018, my wife, Lengxi, and I spent two months at the Boston College. It was our first long-term stay in the US and we immediately fell in love with the diverse landscape and the academic richness along the US east coast. When the advertisement for the open OEAS/CCPO position came out in fall 2018, it was clear to me what a wonderful opportunity that was—working in one of the actual hotspots of sea level rise and being able to engage students with this fascinating topic. This sounded fantastic to me, and after meeting all of the nice ODU colleagues, we decided to take that next step and move to Norfolk.

It has been wonderful to be part of the OEAS/CCPO family so far, and we are very thankful for the warm welcome we got from the very beginning. Without any doubt, we moved here during challenging times, but experiencing the kind support from our OEAS/CCPO colleagues made us feel very grateful. I look forward to helping ODU with its Coastal Resilience Collaborative and other cross-disciplinary activities related to the challenges of sea level change and its impacts on the Hampton Roads area that can make a substantial difference, not only for the people in this area, but also as a role model for other regions worldwide that will sooner or later experience similar challenges.

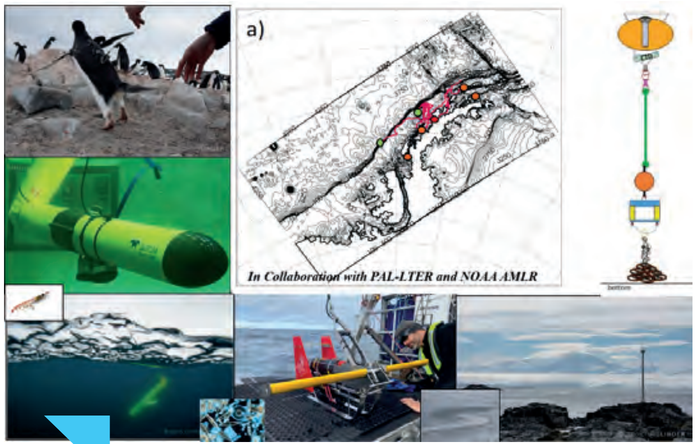
Research Update

MODELING INTERACTIONS BETWEEN ANTARCTIC CIRCULATION & ECOSYSTEMS

One of the major efforts at CCPO over the last couple of decades has been modeling the circulation of coastal regions around Antarctica and studying how the circulation interacts with different aspects of marine ecosystems. CCPO Senior Research Scientist **Mike Dinniman** is continuing this tradition with work on two new projects using different regional circulation models around the Antarctic.

The first project is studying phytoplankton growth around Antarctica. The Antarctic continental shelf has the highest phytoplankton growth rates per unit area around the entire Southern Ocean and this growth is critical to the entire Antarctic marine food web. The availability of light for photosynthesis and the supply of the micronutrient dissolved iron are the major limits of this growth. Earlier studies using satellite-based estimates suggest that phytoplankton growth is related to the melting of nearby floating portions (called ice shelves) of the Antarctic ice sheet. The mechanisms of how this works for one particular location in the Amundsen Sea were previously studied in a project led by CCPO Research Scientist **Pierre St-Laurent**. Mike, along with collaborators from CCPO (Pierre and **Eileen Hofmann**) and Stanford University (Kevin Arrigo and Gert van Dijken), used a new computer model of the circulation and ocean/ice interactions for the entire Southern Ocean to examine the different sources of dissolved iron that supply the well-lit summer surface waters around Antarctica. Dissolved iron is available in the ice of the floating ice shelves, and the direct supply of this iron to coastal waters by melting of the bottom of the ice shelf is important to phytoplankton growth. However, the melting creates less dense water at the ice shelf base that rises and brings deep waters that contain dissolved iron towards the surface in front of the ice shelf. The model shows that this mechanism provides a larger source of dissolved iron to the open surface waters than direct supply from the ice shelf meltwater in many coastal regions of the Antarctic. A paper presenting these results has just been published (Dinniman et al., 2020).

These results imply that phytoplankton growth may be vulnerable to changes in ice shelf basal melt. To explore this, Mike is running new simulations to see what happens when the model is forced with projected changes in the atmospheric forcing over the next century. The current generation of climate models does not include interactions between the ocean and floating ice shelves (although several climate centers are working on adding this capability to their models), but regional models similar to Mike's have been forced with similar atmospheric changes. Those simulations show increases in the melting of the ice shelves, but this is the first time the impact of melting on micronutrients is studied.



Different tools used to study the hotspot over Palmer Deep, including the circulation model.

The second project involves a large multi-institution (Rutgers, University of Alaska, University of Delaware, Oregon State University, Polar Oceans Research Group, and ODU) group examining the physical mechanisms that lead to areas of persistent high marine biological activity ("biological hotspot") along the west side of the Antarctic Peninsula. The field team just returned a few months ago from conducting extensive observations (Figure 1) of one particular hotspot over Palmer Deep, a submarine canyon offshore of the U.S. Antarctic Palmer Research Station on Anvers Island along the Antarctic Peninsula. The field team deployed three autonomous underwater gliders, three moorings, and a High Frequency Radar coastal surface current mapping network (similar to the one maintained along parts of the mid-Atlantic by CCPO, except there is no power grid in which to plug). They also tagged a number of Adélie and Gentoo penguins and conducted several surveys from the new Palmer Station rigid-hull inflatable boat.

The original hypothesis about why that particular location is a hotspot is that the canyon structure of the seabed leads to upwelling of nutrient rich waters that drive phytoplankton production that attracts krill and penguins to the area. However, recent observations of the surface waters contradict this idea. Mike, along with CCPO director, **John Klinck**, is using a high-resolution regional circulation model of the coastal Antarctic Peninsula ocean to tie together the previous surface observations and the newer surface and deep observations into a full 3D picture of the relevant physics. An example of this is work led by Katie Hudson, a graduate student at the University of Delaware.

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CCPO Student Profile

SHELBY HENDERSON

I am starting my second year here at Old Dominion University, working towards my master's degree in Ocean and Earth Sciences (physical oceanography concentration). My advisor is Professor **Tal Ezer**. I would like to say thank you to everyone here at CCPO who has been so welcoming and helpful during my transition back to school this past year, as it had been four years since I last stepped into a classroom.

Graduating from the U.S. Coast Guard Academy in 2015, I received a B.S. in Marine Science, with a focus on Physical Oceanography and Marine Biology. After graduation, I commissioned as an Officer in the U.S. Coast Guard and served as a Deck Watch Officer aboard the U.S. Coast Guard Cutter (USCGC) DOUGLAS MUNRO in Kodiak, AK from 2015-2017. I competed for command following this first tour and was selected to be the Commanding Officer (CO) of an 87' cutter, the USCGC BRANT, in Gulfport, MS from 2017-2019. As the CO, I was responsible for the oversight, management, and safe operation of the $4.4M cutter, executing several CG missions to include Port and Waterways Security, Search and Rescue, Maritime Law Enforcement, and Living Marine Resources. I was also in charge of the leadership, safety, training, and well-being of the 11 crewmembers and their families attached to the boat, while putting in 2,000 underway hours each year.

I have had a very fortunate career thus far with the Coast Guard, and it is how I was able to apply to graduate school and attend ODU. In comparison to the high operational tempo I am used to working in the Coast Guard, life as a graduate student has been quieter and a bit more easy-going, though of course being a student has its own challenges. Currently, I am working on my thesis with Professor Ezer, looking at the forcing and dynamics of surface currents at the mouth of the Chesapeake Bay. My research is based primarily on observed surface current data gathered by several land-based HF radar antennas known as the Coastal Ocean Dynamics Applications Radar (CODAR). Several of these radars span the East Coast, but we are fortunate to have three right near the mouth of the Chesapeake Bay. The datasets span the past 10+ years, yet little research has been done with the data. While my prospectus is still a work in progress, we are largely looking at the correlation between these surface currents and sea level rise within the Chesapeake Bay.

I have one year left before defending my thesis and graduating next summer, where I will go on to work at the International Ice Patrol (IIP). Since 1913, the IIP has monitored the iceberg danger in the North Atlantic Ocean and provided relevant iceberg warning products to the maritime community. Information on ice conditions are collected from air surveillance flights and ships in the ice area and fed into a computer model along with ocean current and wind data to predict the drift of the icebergs that becomes available to the public. My graduate education will be invaluable and bolster my career within the Coast Guard and at the IIP in the coming years.

When not at school, I am often reading or watching Netflix with my boyfriend and our two cats, Bella and Shrimp. Since we have had online classes, the cats like to walk on my laptop when I am working and make surprise appearances during Zoom meetings! I am an avid biker, hiker, camper, and skier/general outdoor enthusiast, trying whenever possible to take weekend escapes to the mountains (at least pre-COVID), and it is one of my life goals to thru-hike the Appalachian Trail. Also, pre-COVID, I had joined the ODU triathlon team with a little encouragement from a graduate student friend, Lauren, and hope to run my first race here next year. I am grateful to be here as a part of the CCPO community and look forward to the rest of my time here!

MODELING | Cont.

Observations show that particles in the surface waters over Palmer Deep do not stay over Palmer Deep for very long. However, the circulation model shows a semi-persistent eddy deeper in the water column over the canyon that would tend to trap particles at that depth for longer periods. Katie is comparing the model to the brand new observations to see how well the model simulates the deep eddy. Mike and Katie are also now running simulations of the model with passive virtual drifters at different depths, as well as drifters that swim up and down in the water column mimicking the daily feeding behavior of krill, in order to quantify the effect of the change with depth in the circulation on the retention of particles in the area. The idea is that perhaps the geology (the canyon) controls the ocean physics (circulation of the deep eddy), allowing for the location of deeper food resources (krill) for penguins to be ecologically predictable.

Reference:

Dinniman, M.S., P. St-Laurent, K.R. Arrigo, E.E. Hofmann, and G.L. van Dijken, 2020. Analysis of iron sources in Antarctic continental shelf waters. *Journal of Geophysical Research*, 125, e2019JC015736, doi:10.1029/2019JC015736.

CCPO Alumni Spotlight

ERIK CHAPMAN, PH.D., '09

I arrived at CCPO in 2004, and although I was ready to work hard, I was barely prepared for the chapter in my life that would bring deep challenges, opportunities, personal and professional growth, and incredible friendships and connections (not to mention two children, Reece and Kira!). I was comfortable as an ecologist, with six expeditions under my belt to the Antarctic studying Adélie penguins and the Western Antarctic Peninsula marine ecosystem and having received a master's degree from the University of Wisconsin-Madison in Wildlife Ecology, but I would be entering a new frontier at ODU. I landed in Norfolk, guided by the collective wisdom of Bill Fraser (Polar Oceans Research Group), Christine Ribic (UWisconsin-Madison), and **Eileen Hofmann**, who all knew that to understand marine biology and ecology, you must understand physics (and chemistry and geology). I found myself taking Ordinary Differential Equations, Partial Differential Equations, Fluid Dynamics, and learning Fortran and other computer languages. But I am eternally grateful for everyone who was so generous with their time and energy to help me along the way. Slowly, but surely, the pieces began to fit together, and I was able to learn and speak the language of a physical oceanographer and ecosystem modeler. The names are too many to provide a complete list, but Sinan Husrevoglu, Baris Salihoglu, **Mike Dinniman**, Nandita Sarkar, and more kept me on my feet, moving forward and learning. Eileen and **John Klinck** supported me and gave me incredible opportunities to share our work in Tasmania, China, Mexico, Europe, and at countless meetings where I began to develop the confidence in myself to move ahead in my career. I am eternally grateful for the challenges and support I received from the community of CCPO.

The final chapters at CCPO were marked by extreme challenges of supporting my wife, Michèle, as she faced aggressive breast cancer (she's doing great now!) while I finished my PhD. I will never forget sitting by her at weekly chemo sessions, working on my dissertation. But we made it, and afterwards, I was able to return to my home state of New Hampshire for a postdoctoral position, where I was worked with Molly Lutcavage at the University of New Hampshire (UNH). She supported a 5-week stay in Europe to develop an individual-based model for bluefin tuna in collaboration with Christian Jorgensen at the University of Bergen in Norway.

Looking down the barrel of a series of postdocs ahead of me and feeling an interest in exploring work at the intersection of university research and societal problems, my next move was a bit of a side-step from my career trajectory. I took a position at the New Hampshire Sea Grant as a Fisheries Extension Specialist. Taking that step was not easy, but I am so thankful that I did. I immediately fell in love with the "Sea Grant approach", which combines research with extension, outreach, education and communications methods, and emphasizes societal relevance and connection to societal need and stakeholders. I also loved being at the intersection of national priorities and state needs, within a ground-up organization that is firmly based in local connections. I became the leader of the NH Sea Grant Fisheries and Aquaculture Program, taught courses, and became involved in the development and emergence of the UNH School of Marine Science and Ocean Engineering.

In 2016, I became the Director of NH Sea Grant, and I could not be happier with where I have found myself, being able to work with one foot on campus and the other in 'the real world' and working to help connect the research community to the people and ecosystems in coastal and marine areas that are increasingly impacted by human use and climate effects. I love working with my team and encouraging a culture of service and dedication to the people and ecosystems of NH. As Director, I am also able to connect to the National Sea Grant Network and to National Priorities within NOAA and other Federal Organizations. For those not working with Sea Grant in some capacity, I would encourage you to reach out and introduce yourself to the Director of one of the 34 programs nationwide (https://seagrant.noaa.gov/About).

My education and experiences from CCPO prepared me for where I am today. CCPO taught me the importance of integration across disciplines or sub-disciplines in understanding complex systems and embracing the mind-set of a modeler that highlights the importance of testing and building our knowledge through scenarios developed around a complete set of important components and relationships.

Erik Chapman works with UNH students to test a barotrauma release system on a NH recreational fishing boat.

JUST THE FACTS

Presentations

Ashford, J., **M. Dinniman**, and C. Brooks. Transport pathways structuring life history distributions of Antarctic toothfish, SCAR 2020 Online Meeting, August 2020.

Dinniman, M., P. St-Laurent, K. Arrigo, **E. Hofmann**, and G. van Dijken. Direct and indirect contributions of ice shelves to micronutrient supply to the surface waters around Antarctica, SCAR 2020 Online Meeting, July 2020.

Hudson, K., M. Oliver, J. Kohut, **M. Dinniman, J. Klinck**, H. Statscewich, K. Bernard, and W. Fraser. A closed, subsurface eddy increases residence times within Palmer Deep Canyon, SCAR 2020 Online Meeting, August 2020.

Plag, H.-P., Modern Climate Change: A Symptom of a Human-Caused High-Energy Pulse, Virtual Lecture Series at the Christ and St. Luke's Episcopal Church, Norfolk, VA, Part 1: The Baseline; Part 2: The Syndrome and Diagnosis; and Part 3: The Prognosis and Therapy, May 2020.

Plag, H.-P., Can the Economy in Modern Society Work Without Polluting the Environment with our Growing Waste?, Institute for Learning in Retirement, August 2020.

St-Laurent, P., Modeling circulation and biogeochemical cycling in the GP17-ANT region. Plenary speaker at the Workshop for section GP17-ANT of US Geotraces (virtual), May 2020.

St-Laurent, P., R. Millan, E. Rignot, and **M.S. Dinniman**. Constraining an ocean model under Getz Ice Shelf, Antarctica, using a gravity-derived bathymetry (virtual poster presentation), SCAR 2020 Online Meeting, August 2020.

Publications

Buzzanga, B., D.P.S. Bekaert, B.D. Hamlington, and S.S. Sangha. 2020. Towards sustained monitoring of subsidence at the coast using InSAR and GPS: An application in Hampton Roads, Virginia, *Geophysical Research Letters*, 47, e2020GL090013, https://doi.org/10.1029/2020GL090013.

Dinniman, M.S., **P. St-Laurent**, K.R. Arrigo, **E.E. Hofmann**, and G.L. van Dijken. 2020. Analysis of iron sources in Antarctic continental shelf waters, *Journal of Geophysical Research: Oceans*, 125, e2019JC015736, doi:10.1029/2019JC015736.

Ezer, T., 2020. The long-term and far-reaching impact of hurricane Dorian (2019) on the Gulf Stream and the coast, *Journal of Marine Systems*, 208, doi:10.1016/j.jmarsys.2020.103370.

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Frederikse, T., F. Landerer, L. Caron, S. Adhikari, D. Parkes, V. Humphrey, **S. Dangendorf,** P. Hogarth, L. Zanna, L. Cheng, and H. Wu. 2020. Explaining the causes of sea-level rise since 1900, *Nature*, 584, 393-397, https://doi.org/10.1038/s41586-020-2591-3.

Han, W., D. Stammer, P. Thompson, **T. Ezer**, H. Palanisamy, X. Zhang, C. Domingues, L. Zhang, and D. Yuan. 2020. Impact of basin-scale climate modes on coastal sea level, Chap. 9. In: Ponte et al. (Eds.), *Relationships Between Coastal Sea Level and Large Scale Ocean Circulation*, Space Science Ser. ISSI Vol. 75, 978-3-030-45633-7, Springer Nature, Switzerland, pp. 247-295.

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Lawson, G., M. Sosonkina, **T. Ezer**, and Y. Shen. 2020. Applying EMD/HHT analysis to power traces of applications executed on systems with Intel Xeon Phi, *International Journal of High Performance Computing Applications*, 34(2), 187-198, doi:10.1177/1094342017731612.

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Zhang, Z., **E.E. Hofmann**, **M.S. Dinniman**, C. Reiss, W.O. Smith, Jr., and M. Zhou. 2020. Linkage of the physical environments in the northern Antarctic Peninsula region to the Southern Annular Mode and the implications for the phytoplankton production, *Progress in Oceanography*, 188, doi.org/10.1016/j.pocean.2020.102416.

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Center For Coastal Physical Oceanography (CCPO) and Institute for Coastal Adaptation & Resilience (ICAR) Virtual Seminar Series

FALL 2020 SCHEDULE

14 September	**Eugene Murphy**, *British Antarctic Survey*
21 September	**Lauren Simkins**, *University of Virginia*
28 September	**Sönke Dangendorf**, *CCPO/OEAS*
5 October	**Sarah Stafford**, *College of William & Mary*
19 October	**Arne Arns**, *University of Rostock*
26 October	**Brian Hooker**, *Bureau of Ocean Energy Management*
2 November	**Daphne Munroe**, *Haskin Shellfish Research Laboratory, Rutgers University*
9 November	**Praveen Kumar**, *CCPO*

MONDAYS at 3:30 PM

Streaming at:
www.ccpo.odu.edu/seminar.html

https://odu.zoom.us/j/96278132048