

Curriculum Vitae

Z. A. Wang

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Zhaohui Aleck Wang, PhD

Associate Scientist with Tenure

Department of Marine Chemistry & Geochemistry

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Education

1998-2003 Ph.D., Marine Science, University of Georgia, Athens, GA.

Advisor, Professor Weijun Cai.

1996-1998 M.Sc., Oceanography, University of New Hampshire, Durham, NH.

Advisor, Professor Theodore Loder.

1990-1994 Marine Chemistry, Xiamen University, Xiamen, China.

Professional Experience

2018-Present	Associate Scientist with Tenure	Woods Hole Oceanographic Institution
2013-2018	Associate Scientist	Woods Hole Oceanographic Institution
2009-2013	Assistant Scientist	Woods Hole Oceanographic Institution
2003-2009	Postdoc Research Associate	University of South Florida (Mentor, Professor Robert Byrne)
1994-1996	Project Manager	State Oceanic Administration of China

Selected Awards

2003: Dissertations Symposium on Chemical Oceanography (DISCO XVIII) Invited Participant

2003: Dissertation Completion Assistantships, University of Georgia

2002: Student Travel Grant Award, American Geophysical Union

1996-1998: Departmental Tuition Scholarship, Department of Earth Science, University of New Hampshire.

Professional Affiliations

Member, American Geophysical Union

Member, Association for the Sciences of Limnology and Oceanography

Member, American Chemical Society

Member, Geochemical Society

Research Interests

Marine/aquatic biogeochemistry: CO₂ system (carbonate chemistry); Ocean acidification and its impacts; Carbon Dioxide Removal (CDR) and its monitoring, reporting, and verification (MRV); Blue carbon and carbon exports from coastal wetlands; Coastal carbon cycling

Sensing technology development: CO₂ system parameters (dissolved inorganic carbon, pH, pCO₂, and total alkalinity), dissolved oxygen, and other chemical species

Professional Activities and Service

(a) At WHOI

Chair, WHOI International Committee 2022 – present

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JCCO 2nd year student advisor, MIT-WHOI Joint PhD Program 2023 – 2024
JCCO 1st year student advisor, MIT-WHOI Joint PhD Program 2022 – 2023
Member, WHOI Scientific Staff Executive Committee (SciSEC) 2021 – 2023
Member, MC&G scientific staff search committee 2020, 2021
WHOI Summer Student Fellowship Selection Committee, 2016-2018
Chair, WHOI Sensor Workshop. 2017.

(b) Elsewhere

Associate Editor, Marine Chemistry (Journal), 2023 – present
Board Member, Board of Directors, NERACOOS, 2022 – present
Lead organizer, OCB Scoping Workshop “*Building a Cost-effective Coastal Biogeochemical Observing Network in Collaboration with the Commercial Fishing Community*”. Jan 18 – 20, 2023. Woods Hole, MA.
Chair, Plenary Session: *Tidal Carbon Exports from Coastal Wetlands as a Significant Component of Blue Carbon Sequestration*. OCB 2022 Summer Workshop. Jun 20 – 23, 2022. Woods Hole, MA.
NSF Coastlines and People (CoPe) Workshop (invited). September 26-28, 2018. San Diego, CA.
Committee member of OCB Workshop ‘Lateral Carbon Fluxes in Tidal Wetlands.’ Aug 21-23, 2018. Woods Hole, MA.
Chair or co-chair of 9 program sessions in professional conferences and workshops (last 5 years)
Organizing Committee Member of the 4th Ocean Acidification PI Workshop (NSF), 2017-2018.
Co-chair, Plenary Session: *Carbon fluxes in coastal wetlands: What is state-of-the-art?* Ocean Carbon Biogeochemistry program Summer Workshop. June 26-29, 2017. Woods Hole, MA.
2nd State of the Carbon Cycle Report (SOCCR-2) contributing writer, 2016-2019
NSF Graduate Research Fellowship Program review panelist, 2016
Member of Editorial Committee, Acta Oceanologica Sinica (Journal), China, 2016-present
Northeast Coastal Acidification Network (NECAN) Scientific Committee member. 2015-present
Panelist for the Northeast Coastal Acidification Network (NECAN), 2013-2014
Group leader for East Coast CO₂ flux synthesis, U.S. East Coast Carbon Cycle Synthesis Workshop, Ocean Carbon Biogeochemistry (OCB) and North America Carbon Program (NACP). January 19-20, 2012.
Member for Ocean Observatories Initiative instrument selection board, Consortium for Ocean Leadership, 2011
Invited instructor, Ocean Acidification Short Course (Ocean Carbon Biogeochemistry program sponsored), Woods Hole, MA. November 2009.
Journal reviewer: *Nature Reviews Earth & Environment*; *Nature Communication*; *Environmental Science and Technology*; *The ISME Journal*; *Marine Chemistry*; *Limnology and Oceanography*; *Limnology and Oceanography: Methods*; *Deep Sea Research*; *Proceedings of the Royal Society B (Biological Sciences)*; *Continental Shelf Research*; *Biogeosciences*; *Aquatic Geochemistry*; *Journal of Marine Systems*; *Nature Scientific Reports*; *Journal of Geophysical Research*; *Methods in Oceanography*
Proposal reviewer: NSF, DOE, NOAA

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Teaching

- MIT-WHOI Joint Program: Geodynamics Seminar, Marine Climate Solutions (12.752), Spring 2022. Co-taught with Adam Subhas, Heather Kim, Tom Bell, Scott Lindell, Ken Buesseler, and Ken Kostel.
- MIT-WHOI Joint Program: Geochemistry of Marine Sediments (12.743), Spring 2019. Co-taught with D. McCorkle and M. Long.
- Invited lecturer, Seawater chemistry and ocean acidification, Sixth Intergovernmental Oceanographic Commission (IOC) Sub-Commission for the Western Pacific (WESTPAC) Summer School on Monsoon Onset Monitoring and its Social & Ecosystem Impacts (MOMSEI), Oct 2015. Phuket, Thailand.
- Invited lecturer, Carbonate chemistry in natural waters (lecture for graduate students), College of Chemistry and Chemical Engineering Ocean University of China, Qingdao, China. 2011-2019
- Invited lecturer, Training course on Basic Oceanography organized by IOC Sub-Commission for the Western Pacific (WESTPAC), Phuket Marine Biological Center (PMBC), Phuket, Thailand. May 2015.
- Instructor, Ocean Acidification Short Course (Ocean Carbon Biogeochemistry program sponsored), Woods Hole, MA. November 2009.

Supervision and Advising

Visiting Scholars:

- Mr. Xiaobo Ni, the Second Institute of Oceanography, State Oceanic Administration, China. 2018-2020
- Dr. Boaz Lazar, the Fredy and Nadine Hermann Institute of Earth Sciences, the Hebrew University, Israel. 2017.
- Dr. Xuewei Xu, The Second Institute of Oceanography, State Oceanic Administration of China. 2017.
- Mr. Yabin Men, Chief Senior Engineer, National Ocean Technology Center, State Oceanic Administration of China. 2016-2017.
- Dr. Enrique García Luque, Department of Physical Chemistry, University of Cadiz, Spain. 2016.
- Dr. Chunlin Ning, The First Institute of Oceanography, State Oceanic Administration of China. 2014 – 2015.
- Dr. Peisong Yu, The Second Institute of Oceanography, State Oceanic Administration of China. 2014 – 2015 and 2016 – 2017
- Dr. Minhan Dai, Xiamen University, China, 2014, 2015
- Dr. Quanlong Li, Xiamen University, China. 2011-2012

WHOI Postdoctoral Scholar:

- Dr. Qipei Shangguan (co-advise with K. Kroeger at USGS), 2023 – present
- Dr. Maggie Johnson (co-advise with A. Tarrant), 2020-2022
- Dr. Adam Subhas (co-advise with D. McCorkle and M. Long), 2017-2019
- Dr. Kristina Brown (co-advise with B. Peucker-Ehrenbrink and V. Galy), 2014-2017

Postdoctoral Investigators:

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Dr. Mona Norbistrath, 2024 – present
Dr. Louise Cameron, 2020 – 2021
Dr. Eyal Wurgaft, 2017-2019

Technical Staff:

Even Lechner, Research Associate II, 2024 – present
Steve Learner, Senior Engineer, 2022 – present
Fritz Sonnichsen, Senior Engineer, 2021 – present
Kate Morkeski, Research Assistant III, 2016 – present
Dylan Titmuss, Research Assistant II, 2021 – 2023
Zoe Sandwith, Research Assistant III, 2015 – 2018
Katherine Hoering, Research Assistant II/III, 2010 – 2016

MIT-WHOI Joint Program Student:

Sophie Kuhl, MIT-WHOI Joint Program student, 2023-present
Jonathan Pfeifer, MIT-WHOI Joint Program student, 2022-present
Mallory Ringham, MIT-WHOI Joint Program student, 2016-present
Beckett Colson, MIT-WHOI Joint Program student, 2016-present (dissertation committee)
Sophie Chu, MIT-WHOI Joint Program student, 2011-2017

Visiting PhD Student:

Shuzhen Song, East China Normal University, 2016-2018
Haorui Liang, Ocean University of China, 2017-2019

WHOI Summer Student Fellow:

Casper Pratt, California Polytechnic State University, San Luis Obispo, 2023
Jonathan Pfeifer, Flathead Valley Community College, 2020
Maxwell Furigay, Trinity College, 2018
Stacey Felgate, University of the Highlands and Islands, 2016
Lloyd Anderson, Bowdoin College, 2015
Alterra Sanchez, San Diego State University, 2013
Jacinta Edebeli, University of Massachusetts Amherst, 2011

Undergraduate and Master Student Interns:

Sarvesh Tandel, Co-op M.S. student, Northeastern University, 2023
Kaleb Riggle, Blue Economy Internship Program, Cape Cod Community College, 2023
Jonathan Pfeifer, Cornell University, 2020 – 2022
Mackenzie Fiss, North Carolina State University, 2018
Katie Carter, Bowdoin College, 2015
Dmitro Martynowych, Scranton University, 2014
Lenna Quackenbush, Worcester Polytechnic Institute, 2013
Yue Qiu, Oberlin College, 2013
Yujuan Zhou, Ocean University of China, 2012-2013
Robert "Nick" Tuttle, Drexel University, 2012
Kelly Knorr, University of Rhode Island, 2012
Mohammad M. Uddin, University of New Hampshire, 2011
Cris Luttazi, Kingston University, 2010, 2011
Charles Zhu, Yale University, 2010

High School Intern Student:

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Juliette Parmenter, Meridian Academy, 2014

Expeditions and Cruises

- April, July - August 2023. Multiple field sampling trips for tidal sampling and sensor development at 3 Marsh sites, Cape Cod, MA. R/V Carson. NSF Carbon–Northeast Wetlands Time-series Study (C-NEWTS) project. Co-PI.
- Sept 01 – 04, 2023. South of Martha Vineyard, R/V Connecticut. Tracer release study, LOC-NESS (Locking away Ocean Carbon in the Northeast Shelf and Slope) Project. Co-chief Scientist, Co-PI.
- Apr 24 – 26, 2023. Potomac River, Chesapeake Bay. R/V Carson. NSF Chesapeake Bay Alkalinity Study (CHALK). Co-PI.
- Oct 24 – Nov 6, 2022. In situ mesocosm experiments on particle-triggered CaCO_3 precipitation (2nd trip), Inter-university Institute of Marine Sciences. Eilat, Israel.
- May 10-13, 2022. LUMCOM, LA. R/V Acadiana. Ocean Alkalinity Enhancement (OAE) analog project ‘*Assessing Ocean Alkalinity Enhancement through the Seasonality of the Mississippi River Alkalinity Flux*’. Co-PI.
- Oct 11-18, 2019. St. Petersburg, FL. R/V Point Sur. Exploration and Characterization of Fine-scale Physical-biogeochemical Environment over Deep Coral Reefs on the West Florida Slope using Integrated ROV-lander-sensor Systems. Co-chief Scientist and lead PI.
- Jun 15 – July 4, 2019. In situ mesocosm experiments on particle-triggered CaCO_3 precipitation, Inter-university Institute of Marine Sciences. Eilat, Israel.
- Sept 9 – 16, 2017. LUMCON, Chauvin, LA. R/V Pelican. The Role and Mechanisms of Nuclei-induced Calcium Carbonate Precipitation (NICP) in the Coastal Carbon Cycle: A First In-depth Study. Chief Scientist and PI.
- Jun 17 – 23, 2016. Woods Hole, MA. R/V Armstrong Science Verification Cruise, South New England Shelf Break. Shelf break processes. Co-PI.
- Apr 18 – May 07, 2015. Phuket, Thailand. R/V Chakratong Tongyai, Andaman Sea. Effects of internal waves on water column physics, chemistry and coral reef biology in Andaman Sea. Co-PI.
- Jan, 2014 – Jul, 2015. Woods Hole, MA. R/V Tioga. Five seasonal cruises in the Gulf of Maine. Ocean Acidification Susceptibility of New Hampshire Coastal Waters. Co-PI.
- May – Oct, 2013. Woods Hole, MA. R/V Tioga. Three seasonal cruises in the Gulf of Maine. Ocean acidification: Are Deep Waters of the Gulf of Maine Already Corrosive to Pteropods? PI and Chief Scientist.
- Aug 09 – Sept 18, 2012. Newport, OR – Los Angeles, CA. R/V New Horizon, North Pacific. Ocean acidification: Horizontal and Vertical Distribution of Thecosome Pteropods in Relation to Carbonate Chemistry in the Northwest Atlantic and Northeast Pacific. Co-PI, Chemistry team leader.
- Aug 07 – Sept 01, 2011. Woods Hole, MA – Woods Hole, MA; R/V Oceanus, North Atlantic. Ocean acidification: Horizontal and Vertical Distribution of Thecosome Pteropods in Relation to Carbonate Chemistry in the Northwest Atlantic and Northeast Pacific. Co-PI,

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Chemistry team leader.

Sept 2011. Sampling in the Mackenzie River Delta. Arctic Research Initiative: Towards Long-term Monitoring of the CO₂ System in Arctic Rivers. PI.

Jun 2010. Sampling in the Mackenzie River Delta. Arctic Research Initiative: Towards Long-term Monitoring of the CO₂ System in Arctic Rivers. PI.

July 10 – August 04, 2007. Galveston, TX – Boston, MA. R/V Ronald H. Brown. Gulf of Mexico and East Coast Carbon (GOMECC) cruise.

March 10 – 30, 2006. Honolulu, HI – Kodiak, AK, USA. R/V Thomas G. Thompson. NOAA CLIVAR/CO₂ Repeat Hydrography P16N Cruise in the North Pacific Ocean.

January 11 – February 24, 2005. Punta Arenas, Chile - Fortaleza, Brazil. R/V Ronald H. Brown. NOAA CLIVAR/CO₂ Repeat Hydrography A16S Cruise in the South Atlantic Ocean.

Patents

Wang, Z. A. and F. N. Sonnichsen. System and Method to Measure Dissolved Gases in Liquid. 2015. US Patent No: 10,067,111.

Peer-reviewed Papers and Book Chapters

(* Advised students, postdocs, and visiting scholars; # Corresponding author)

In review, revision, and production:

58. Titmuss*, F.D., J.E. Rheuban¹, J.H. Grabowski, L.P. Cameron¹, Z.A. Wang. Seasonal dynamics of the carbonate system on Georges Bank. *Limnol. Oceanogr.* *In revision.*

Published:

57. Carter, B. R., J. D. Sharp, M. I. García-Ibáñez, R. J. Woosley, M. B. Fong, M. Álvarez, L. Barbero, S. L. Clegg, R. Easley, A. J. Fassbender, X. Li, K. M. Schockman, and **Z. A. Wang**. 2024. Random and systematic uncertainty in ship-based seawater carbonate chemistry observations. *Limnol. Oceanogr.* doi: <https://doi.org/10.1002/lno.12674>

56. Maas, A. E., G. L. Lawson, A. J. Bergan, **Z. A. Wang**, and A. M. Tarrant. 2024. Sea butterflies in a pickle: reliable biomarkers and seasonal sensitivity of *Limacina retroversa* to ocean acidification in the Gulf of Maine. *Conservation Physiology* 12. doi: 10.1093/conphys/coae040.

55. Ringham, M.*, **Z. A. Wang**[#], F. Sonnichsen, S. Lerner, G. McDonald, and J. Pfeifer. 2024. Development of the Channelized Optical System II for In Situ, High-Frequency Measurements of Dissolved Inorganic Carbon in Seawater. *ACS ES&T Water*. doi: 10.1021/acsestwater.3c00787.

54. **Wang, Z. A.** and W.-J. Cai. The Inorganic Carbon System across the Land-to-Ocean Continuum. 2024. Elsevier. Reference Module in Earth Systems and Environmental Sciences. Published at <https://doi.org/10.1016/B978-0-323-99762-1.00032-2>. *This article is a chapter in Treatise on Geochemistry, 3rd Edition, which will be released in Aug. 2024.*

53. Na, R., Z. Rong, **Z. A. Wang**, S. Liang, C. Liu, M. Ringham, and H. Liang. 2024. Air-sea

- CO₂ fluxes and cross-shelf exchange of inorganic carbon in the East China Sea from a coupled physical-biogeochemical model. *Sci. Total Environ.* 906: 167572. doi: 10.1016/j.scitotenv.2023.167572
52. Carter, B. R., J. D. Sharp, A. G. Dickson, M. Álvarez, M. B. Fong, M. I. García-Ibáñez, R. J. Woosley, Y. Takeshita, L. Barbero, R. H. Byrne, W.-J. Cai, M. Chierici, S. L. Clegg, R. A. Easley, A. J. Fassbender, K. L. Fleger, X. Li, M. Martín-Mayor, K. M. Schockman, and **Z. A. Wang**. 2024. Uncertainty sources for measurable ocean carbonate chemistry variables. *Limnol. Oceanogr.* 69: 1-21. doi: 10.1002/lno.12477
 51. Reithmaier, G. M. S., A. Cabral, A. Akhand, M. J. Bogard, A. V. Borges, S. Bouillon, D. J. Burdige, M. Call, N. Chen, X. Chen, L. C. Cotovicz, M. J. Eagle, E. Kristensen, K. D. Kroeger, Z. Lu, D. T. Maher, J. L. Pérez-Lloréns, R. Ray, P. Taillardat, J. J. Tamborski, R. C. Upstill-Goddard, F. Wang, **Z. A. Wang**, K. Xiao, Y. Y. Y. Yau, and I. R. Santos. 2023. Carbonate chemistry and carbon sequestration driven by inorganic carbon outwelling from mangroves and saltmarshes. *Nat. Commun.* 14: 8196. doi: 10.1038/s41467-023-44037-w
 50. Bansal, S., I. F. Creed, B. A. Tangen, S. D. Bridgham, A. R. Desai, K. W. Krauss, S. C. Neubauer, G. B. Noe, D. O. Rosenberry, C. Trettin, K. P. Wickland, S. T. Allen, A. Arias-Ortiz, A. R. Armitage, D. Baldocchi, K. Banerjee, D. Bastviken, P. Berg, M. J. Bogard, A. T. Chow, W. H. Conner, C. Craft, C. Creamer, T. Delsontro, J. A. Duberstein, M. Eagle, M. S. Fennessy, S. A. Finkelstein, M. Göckede, S. Grunwald, M. Halabisky, E. Herbert, M. M. R. Jahangir, O. F. Johnson, M. C. Jones, J. J. Kelleway, S. Knox, K. D. Kroeger, K. A. Kuehn, D. Lobb, A. L. Loder, S. Ma, D. T. Maher, G. McNicol, J. Meier, B. A. Middleton, C. Mills, P. Mistry, A. Mitra, C. Mobilian, A. M. Nahlik, S. Newman, J. L. O'connell, P. Oikawa, M. P. Van Der Burg, C. A. Schutte, C. Song, C. L. Stagg, J. Turner, R. Vargas, M. P. Waldrop, M. B. Wallin, **Z. A. Wang**, E. J. Ward, D. A. Willard, S. Yarwood, and X. Zhu. 2023. Practical guide to measuring wetland carbon pools and fluxes. *Wetlands* 43: 105. doi: 10.1007/s13157-023-01722-2
 49. Song, S.*, **Z. A. Wang**[#], K. D. Kroeger, M. Eagle, S. N. Chu, and J. Ge. 2023. High Frequency Variability of Carbon Dioxide Fluxes in Tidal Water Over a Temperate Salt Marsh. *Limnol. Oceanogr.* 68: 2108-2125. doi: 10.1002/lno.12409
 48. Song, S., R. G. Bellerby, **Z. A. Wang**, E. Wurgaft, and D. Li. 2023. Organic alkalinity as an important constituent of total alkalinity and the buffer system in river-to-coast transition zones. *J. Geophys. Res. – Oceans* 128: e2022JC019270. doi: 10.1029/2022JC019270
 47. Lima, I. D., **Z. A. Wang**, L. P. Cameron, J. H. Grabowski, and J. E. Rheuban. 2023. Predicting carbonate chemistry on the northwest Atlantic shelf using neural networks. *J. Geophys. Res. – Biogeosci.* 128: e2023JG007536. doi: 10.1029/2023JG007536
 46. Wurgaft, E.*, **Z. A. Wang**, N. Shalevd, N. Moragc, R. Golane, I. Gavrielic. 2023. Precise determination of dolomite content in marine sediments. *Limnol. Oceanogr. – Meth.* 21: 13-23. doi: 10.1002/lom3.10518
 45. Voss, B. M., T. I. Eglinton, B. Peucker-Ehrenbrink, V. Galy, S. Q. Lang, C. McIntyre, R. G.M. Spencer, E. Bulygina, **Z. A. Wang**, and K. A. Guay. 2023. Isotopic evidence for sources of dissolved carbon and the role of organic matter respiration in the Fraser River basin, Canada. *Biogeochem.* 164: 207-228. doi: 10.1007/s10533-022-00945-5
 44. Xiao, K., N. Chen, Z. A. Wang, J. J. Tamborski, D. T. Maher, and X. Yu. 2022. Editorial:

- Advances in understanding lateral blue carbon export from coastal ecosystems. *Front. in Mar. Sci.* **9**. doi: 10.3389/fmars.2022.1060958.
43. Zhang, Y., C. Zou, **Z. A. Wang**, X. Wang, Z. Zeng, K. Xiao, H. Guo, X. Jiang, Z. Li, and H. Li. 2022. Submarine groundwater discharge in the northern Bohai Sea, China: Implications for coastal carbon budgets and buffering capacity. *J. Geophys. Res. – Biogeosci.* **127**: e2022JG006810. doi: 10.1029/2022JG006810
 42. Pousse, É., D. Munroe, D. Hart, D. Hennen, L. P. Cameron, J. E. Rheuban, **Z. A. Wang**, G. H. Wikfors, and S. L. Meseck. 2022. Dynamic energy budget modeling of Atlantic surfclam, *Spisula solidissima*, under future ocean acidification and warming. *Mar. Environ. Res.* **177**: 105602. doi: 10.1016/j.marenvres.2022.105602
 41. Jiang, L.-Q., D. Pierrot, R. Wanninkhof, R. A. Feely, B. Tilbrook, S. Alin, L. Barbero, R. H. Byrne, B. R. Carter, A. G. Dickson, J.-P. Gattuso, D. Greeley, M. Hoppema, M. P. Humphreys, J. Karstensen, N. Lange, S. K. Lauvset, E. R. Lewis, A. Olsen, F. F. Pérez, C. Sabine, J. D. Sharp, T. Tanhua, T. W. Trull, A. Velo, A. J. Allegra, P. Barker, E. Burger, W.-J. Cai, C.-T. A. Chen, J. Cross, H. Garcia, J. M. Hernandez-Ayon, X. Hu, A. Kozyr, C. Langdon, K. Lee, J. Salisbury, **Z. A. Wang**, and L. Xue. 2022. Best practice data standards for discrete chemical oceanographic observations. *Front. In Mar. Sci.* **8**. doi: 10.3389/fmars.2021.705638
 40. Siedlecki, S., J. Salisbury, D. Gledhill, C. Bastidas, S. Meseck, K. McGarry, C. Hunt, M. Alexander, D. Lavoie, **Z. A. Wang**, J. Scott, D. Brady, I. Mlsna, K. Azetsu-Scott, C. Liberti, D. Melrose, M. White, A. Pershing, D. Vandemark, D. Townsend, C. Chen, W. Mook, and R. Morrison. 2021. Projecting ocean acidification impacts for the Gulf of Maine to 2050: New tools and expectations. *Elementa: Sci. Anthro.* **9**. doi: 10.1525/elementa.2020.00062.
 39. Wurgaft, E. *, **Z. A. Wang**, J. H. Churchill, T. Dellapenna, S. Song, J. Du, M. C. Ringham, T. Rivlin, and B. Lazar. 2021. Particle triggered reactions as an important mechanism of alkalinity and inorganic carbon removal in river plumes. *Geophys. Res. Lett.* **48**: e2021GL093178. doi: 10.1029/2021GL093178.
 38. Tamborski, J. J., M. Eagle, B. L. Kurylyk, K. D. Kroeger, **Z. A. Wang**, P. Henderson, and M. A. Charette. 2021. Pore water exchange-driven inorganic carbon export from intertidal salt marshes. *Limnol. Oceanogr.* **66**: 1774-1792. doi: <https://doi.org/10.1002/lno.11721>.
 37. Yu, P. *, **Z. A. Wang**#, J. Churchill, M. Zheng, J. Pan, Y. Bai, and C. Liang. 2020. Effects of Typhoons on surface seawater $p\text{CO}_2$ and air-sea CO_2 fluxes in the northern South China Sea. *J. Geophys. Res. – Oceans* **125**: e2020JC016258. doi: 10.1029/2020jc016258.
 36. Kipp, L. E., P. B. Henderson, **Z. A. Wang**, and M. A. Charette. 2020. Deltaic and estuarine controls on Mackenzie River solute fluxes to the Arctic Ocean. *Estuaries Coasts* **43**: 1992-2014. doi: 10.1007/s12237-020-00739-8
 35. Maas, A. E., G. L. Lawson, A. J. Bergan, **Z. A. Wang**, and A. M. Tarrant. 2020. Seasonal variation in physiology and shell condition of the pteropod *Limacina retroversa* in the Gulf of Maine relative to life cycle and carbonate chemistry. *Prog. Oceanogr.* **186**: 102371. doi: 10.1016/j.pcean.2020.102371
 34. Song, S. *, **Z. A. Wang**#, M. E. Gonneea, K. D. Kroeger, S. N. Chu, D. Li, and H. Liang. 2020. An important biogeochemical link between organic and inorganic carbon cycling:

- Effects of organic alkalinity on carbonate chemistry in coastal waters influenced by intertidal salt marshes. *Geochim. Cosmochim. Acta* 275: 123-139. doi: 10.1016/j.gca.2020.02.013
33. Turk, D., H. Wang, X. Hu, D. K. Gledhill, **Z. A. Wang**, L. Jiang, and W.-J. Cai. 2019. Time of Emergence of Surface Ocean Carbon Dioxide Trends in the North American Coastal Margins in Support of Ocean Acidification Observing System Design. *Front. in Mar. Sci.* 6. doi: 10.3389/fmars.2019.00091.
 32. **Wang, Z. A.**, H. Moustahfid, A. V. Mueller, A. P. M. Michel, M. Mowlem, B. T. Glazer, T. A. Mooney, W. Michaels, J. S. McQuillan, J. C. Robidart, J. Churchill, M. Sourisseau, A. Daniel, A. Schaap, S. Monk, K. Friedman, and P. Brehmer. 2019. Advancing observation of ocean biogeochemistry, biology, and ecosystems with cost-effective in situ sensing technologies. *Front. Mar. Sci.* 6: 519. doi: 10.3389/fmars.2019.00519
 31. Fennel, K., S. Alin, L. Barbero, W. Evans, T. Bourgeois, S. Cooley, J. Dunne, R. A. Feely, J. M. Hernandez-Ayon, X. Hu, S. Lohrenz, F. Muller-Karger, R. Najjar, L. Robbins, E. Shadwick, S. Siedlecki, N. Steiner, A. Sutton, D. Turk, P. Vlahos, and **Z. A. Wang**. 2019. Carbon cycling in the North American coastal ocean: a synthesis. *Biogeosci.* 16: 1281- 1304.
 30. Chu, S. N.*, **Z. A. Wang**[#], K. D. Kroeger, M. E. Gonneea, and N. K. Ganju. 2018. Deciphering the dynamics of inorganic carbon export from intertidal salt marshes using high- frequency measurements. *Mar. Chem.* 206: 7-18. doi: 10.1016/j.marchem.2018.08.005
 29. Liu, Q., Y.-H. Wu, L. Liao, D.-S. Zhang, Y. Yuan, **Z. A. Wang**, C.-S. Wang, and X.-W. Xu. 2018. Shift of bacterial community structures in sediments from the Changjiang (Yangtze River) Estuary to the East China Sea linked to environmental gradients. *Geomicrobiol. J.* 35: 898-907. doi: 10.1080/01490451.2018.1489914.
 28. Najjar, R.G, M. Herrmann, R. Alexander, E. W. Boyer, D. Burdige, D. Butman, W.-J. Cai, E. A. Canuel, R. F. Chen, M. A. M. Friedrichs, R. A. Feagin, P. Griffith, A. L. Hinson, J. R. Holmquist, X. Hu, W. M. Kemp, K. D. Kroeger, A. Mannino, S. L. McCallister, W. R. McGillis, M. R. Mulholland, C. Pilskaln, J. Salisbury, S. Signorini, P. St-Laurent, H. Tian, M. Tzortziou, P. Vlahos, **Z. A. Wang**, and R. C. Zimmerman. 2018. Carbon budget of tidal wetlands, estuaries, and shelf waters of eastern North America. *Global Biogeochem. Cy.* 32: 389-416. doi: 10.1002/2017GB005790.
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6. Zhai, W. D., M. H. Dai, W. J. Cai, Y. C. Wang, and **Z. A. Wang**. 2005. High partial pressure of CO₂ and its maintaining mechanism in a subtropical estuary: the Pearl River estuary, China. *Mar. Chem.* 93: 21-32.
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2. **Wang, Z. A.**, W. J. Cai, Y. C. Wang, and B. L. Upchurch. 2003. A long pathlength liquid-core waveguide sensor for real-time pCO₂ measurements at sea. *Mar. Chem.* 84: 73-84.
1. **Wang, Z. A.**, Y. H. Wang, W. J. Cai, and S. Y. Liu. 2002. A long pathlength spectrophotometric pCO₂ sensor using a gas-permeable liquid-core waveguide. *Talanta* 57: 69-80.

Other Publications

- i. **Wang, Z. A.**, A. P. M. Michel, and T. A. Mooney. 2021. Accelerating Global Ocean Observing: Monitoring the Coastal Ocean Through Broadly Accessible, Low-Cost Sensor Networks. *Mar. Technol. Soc. J.* 55: 82-83.
- ii. Windham-Myers, L., W.-J. Cai, S. R. Alin, A. Andersson, J. Crosswell, K. H. Dunton, J. M. Hernandez-Ayon, M. Herrmann, A. L. Hinson, C. S. Hopkinson, J. Howard, X. Hu, S. H. Knox, K. Kroeger, D. Lagomasino, P. Megonigal, R. G. Najjar, M.-L. Paulsen, D. Peteet, E. Pidgeon, K. V. R. Schäfer, M. Tzortziou, **Z. A. Wang**, and E. B. Watson, 2018: Chapter 15: Tidal wetlands and estuaries. In *Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report* [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 596-648, <https://doi.org/10.7930/SOCCR2.2018.Ch15>.
- iii. Fennel, K., S. R. Alin, L. Barbero, W. Evans, T. Bourgeois, S. R. Cooley, J. Dunne, R. A. Feely, J. M. Hernandez-Ayon, C. Hu, X. Hu, S. E. Lohrenz, F. Muller-Karger, R. G. Najjar, L. Robbins, J. Russell, E. H. Shadwick, S. Siedlecki, N. Steiner, D. Turk, P. Vlahos, and **Z. A. Wang**, 2018: Chapter 16: Coastal ocean and continental shelves. In *Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report* [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 649-688, <https://doi.org/10.7930/SOCCR2.2018.Ch16>.
- iv. **Wang, Z. A.**, Cahill, B., Cai, W.-J., Fennel, K., Friedrichs, M., McGillis, W., Salisbury, J., Schaaf, C., and S. Signorini, S. 2012. Air-sea exchange. In: Najjar, R.G., Friedrichs, M., Cai, W.-J. (Editors), *Report of the U.S. East Coast Carbon Cycle Synthesis Workshop, January 19-20, 2012, Ocean Carbon and Biogeochemistry Program and North American Carbon Program*, pp. 11-12.
- v. **Wang, Z. A.** Biogeochemical changes of chemical signals in the Georgia “land-to-ocean continuum”. 2003. University of Georgia, Athens, GA. Ph.D. Thesis. doi: 10.13140/RG.2.1.1131.4809.
- vi. **Wang, Z. A.** The annual and seasonal variations of nitrogen in Massachusetts Bay. 1998. University of New Hampshire, Durham, NH. M.S. Thesis.

Invited Lectures

Inorganic carbon and alkalinity exports from tidal wetlands: uncounted blue carbon (Keynote speech). Advanced Study Institute International Workshop on Blue carbon (2.0). May 13-14, 2024. Hongkong University of Science and Technology.

Towards high-frequency, low-cost in situ sensing of the seawater carbonate system. September 2023. NECAN 2023 Webinar Series.

Lateral exports of inorganic carbon and alkalinity from tidal wetlands: uncounted blue carbon capacity. March 2023. University of Massachusetts Dartmouth.

Developing Low-cost Chemical Sensors to Enable Fishery-based Biogeochemical Ocean Observing Networks. *Invited Panelist*. OCB Scoping Workshop “*Building a Cost-effective Coastal Biogeochemical Observing Network in Collaboration with the Commercial Fishing*”

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Community". Jan 18 – 20, 2023. Woods Hole, MA.

Lateral exports of inorganic carbon and alkalinity fluxes from intertidal saltmarshes in the lens of Blue Carbon capacity. Invited Talk. Session B12B - *Coastal Wetland Carbon and Nitrogen Cycles: Recent Advances in Measurements, Modeling, and Syntheses*. AGU Fall Meeting 2022. Dec 12 – 16, 2022. Chicago, IL.

Assessing lateral exports of inorganic carbon and air-water CO₂ effluxes from saltmarshes over multiple spatiotemporal scales. *Invited Panelist*. Plenary session: Tidal Carbon Exports from Coastal Wetlands as a Significant Component of Blue Carbon Sequestration. OCB Summer Workshop 2022. Jun 20-23, 2022. Woods Hole, MA.

Building a cost-effective coastal biogeochemical observing network in collaboration with the commercial fishing community. *Invited Panelist*. Plenary session: Coastal observing systems to understand and predict ecosystem changes. OCB Summer Workshop 2022. Jun 20-23, 2022. Woods Hole, MA.

Accelerating Observation of Ocean Biogeochemistry through Broadly Accessible, Community-based Low-cost Sensor Networks. *Invited Panelist*. ACS Webinar Series: Taking Earth's Pulse with Low-Cost Sensors: A Discussion of Opportunities and Obstacles. Talk. Virtual. May 05, 2022.

The Role of Inorganic Carbon Exports from Intertidal Salt Marshes in the Coastal Carbon Cycle: New Insights from Recent Measurements (virtual). April 2021. University of Georgia.

Advancing ocean carbon biogeochemistry research using in-situ sensing technologies. Inter-university Institute of Marine Sciences. June 2019. Eilat, Israel.

Shipboard Underway Measurements of Partial Pressure of CO₂. INMARTECH 2018 Symposium. October 16-18, 2018. North Falmouth, MA.

Advancing coastal carbon science with in-situ sensors: the role of lateral exports by tidal marshes in the coastal carbon cycle. September 2018. Texas A&M University, Galveston, TX.

Biogeochemistry and fluxes of lateral inorganic carbon exports by tidal salt marshes. Nov. 2018. Xiamen University, Xiamen, China.

Advancing coastal carbon science with in-situ sensors: the role of tidal marshes in the coastal carbon cycle. June 2018. Second Institute of Oceanography, State Oceanic Administration of China, Hangzhou, China.

The role of tidal salt marshes in the coastal carbon cycle. June 2018. Ocean University of China, Qingdao, China.

Advancing ocean carbon and acidification research with in-situ sensing technologies. June 2018. First Institute of Oceanography, State Oceanic Administration of China, Qingdao, China.

Carbonate Chemistry in Northeastern U.S. Shelf Waters: Sensitivity, Control and Linkage to Pteropods. Workshop: Coastal ocean acidification in the North Atlantic region, from science to outreach, A Sea Grant - NART regional integration project. UConn Avery Point, Groton, CT. April 10-12, 2018.

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Resolving the Intricacies of Lateral Exports of Inorganic Carbon and Alkalinity from Coastal Salt Marshes (Invited). February 2018. Scripps Institute of Oceanography, La Jolla, CA.

Carbonate Chemistry in Northeastern U.S. Shelf Waters: Sensitivity, Control and Linkage to Pteropods. Workshop: Coastal ocean acidification in the North Atlantic region, from science to outreach, A Sea Grant - NART regional integration project. UConn Avery Point, Groton, CT. April 10-12, 2018.

How much did we miss? – Intertidal Salt Marshes as an Important Source of Inorganic Carbon to the Coastal Ocean. August 2016. College of Environmental Science & Engineering, Ocean University of China. Qingdao, China.

The Marine CO₂ system and Ocean Acidification. Sixth IOC Sub-Commission for the Western Pacific (WESTPAC) Summer School on Monsoon Onset Monitoring and its Social & Ecosystem Impacts (MOMSEI). October 26-30, 2015. Phuket, Thailand.

Simultaneous, in-situ measurements of seawater carbon dioxide system parameters – The development and potential application. The 3rd Ocean Acidification PI Workshop. June 2015. Woods Hole, MA.

Carbonate Chemistry in Seawater and Its Role in Climate Change. May 2015. Phuket Marine Biological Center (PMBC), Thailand.

The U.S. Northeast Coast: A Coastal Ocean Acidification Sensitive Region. Workshop “Latitude 41 under Siege: Impact of Nutrient Pollution & OA on Coastal Waters, Estuaries and Marine Life”. February 12, 2015. University of Connecticut Avery Point, CT.

The Paradox of Salt Marshes as a Source of Alkalinity and Low pH, High Carbon Dioxide Water to the Ocean. The 2nd Xiamen Symposium on Marine Environmental Sciences. January 07 – 09, 2015. Xiamen, China.

High-frequency spectrophotometric measurements of seawater CO₂ system parameters – The need, development, and potential application. The 2nd Seafloor Observation Symposium of China. November 08 – 10, 2014. Xiamen, China.

Thousands of Miles of Carbonate Chemistry. September 2014. Ocean University of China, Qingdao, China.

The marine CO₂ system in the Northeast Coast of the United States: Ocean Acidification and Controlling Processes. April 2014. University of Massachusetts Boston. Boston, MA.

Ocean Acidification of the Shelf Waters of NECAN: The marine inorganic carbon system along the Atlantic and Gulf of Mexico coasts of the United States. November 2013. Northeastern Regional Association of Coastal and Ocean Observing Systems (NARACOOS) Webinar Series.

Towards a Better Understanding of Changes and Drivers of the CO₂ System in Aquatic Environments. June 2013. College of Chemistry and Chemical Engineering, Ocean University of China. Qingdao, China.

Real-time Measurements of the Marine CO₂ System. June 2013. Shandong Institute of Marine Instruments. Qingdao, China.

The Marine Inorganic Carbon System along the Gulf of Mexico and Atlantic Coasts of the United States. December 2011. School of Marine Science, University of Maine. Orono, ME.

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Coastal CO₂ System: From Sensor Development to Observational Studies. December 2010. The Second Institute of Oceanography, State Oceanic Administration of China. Hangzhou, China.

Distributions of the CO₂ System along the US Atlantic and Gulf of Mexico Coast. December, 2010. State Key Laboratory of Estuarine and Coastal Research, East China Normal University. Shanghai, China.

Inorganic carbon fluxes in rivers and coastal oceans. December, 2010. College of Chemistry and Chemical Engineering, Ocean University of China. Qingdao, China.

Coastal CO₂ System: From Sensor Development to Observational Studies. April 2010. Department of Oceanography, Dalhousie University, Canada.

Coastal CO₂ System: From Instrumentation to Observation. March 2010. Department of Earth, Atmospheric and Planetary Sciences, MIT. Boston, MA.

Conference Papers and Abstracts (last 10 years)

(* Supervised students, postdocs, visiting scholars)

Wang, Z.A and W-J. Cai. The Inorganic Carbon System across the Land-to-Ocean Continuum: Impacts of Organic Alkalinity. Goldschmidt Conference 2024. Talk. Chicago, IL. August 18 – 23, 2024.

Wang, Z. A., S. Kuhl, K. Morkeski, E. Rivest, A. Hardison, and R. Najjar. Impacts of organic alkalinity on carbonate chemistry and carbon fluxes in the two tidal tributaries of the Chesapeake Bay. Chesapeake Community Research Symposium 2024. Talk. Annapolis, Maryland. Jun. 10 – 12, 2024.

R. Najjar, M. Herrmann, Matthew Fantle, J. Arriola, S. Ajayi, E. Rivest, M. Friedrichs, P. St-Laurent, A. Hardison, H. Walker, Q. Roberts, B. Thomas, A. Putney, A. Labossiere, J. Pujols, N. Mann, R. Woodland, L. Harris, L. Lapham, T. Murphy, C. Ross, **Z. A. Wang**, S. Kuhl, C. Gurbisz, E. Stets, and R. Westman. The Chesapeake Carbon and Alkalinity Study (CHALK). Chesapeake Community Research Symposium 2024. Talk. Annapolis, Maryland. Jun. 10 – 12, 2024.

Mann, N., Q. Roberts, E. Rivest, A. Hardison, R. Najjar, and **Z. A. Wang**. Seasonal and Spatial Variability of Dissolved Inorganic Carbon (DIC) in the York River and Potomac River. Chesapeake Community Research Symposium 2024. Talk. Annapolis, Maryland. Jun. 10 – 12, 2024.

Arriola, J. M., R. G. Najjar, M. Herrmann, S. Ajayi, A. Hardison, Q. Roberts, H. Walker, E. Rivest, A. Putney, and **Z. A. Wang**. Seasonality of carbon and alkalinity export from a well-constrained brackish tidal creek along the York River, Virginia. Chesapeake Community Research Symposium 2024. Talk. Annapolis, Maryland. Jun. 10 – 12, 2024.

Kuhl, S. *, **Z.A. Wang**, K. Morkeski, E. B. Rivest, A. Hardison, and R. Najjar. Contrasting influence of organic alkalinity on carbonate chemistry between the York and Potomac River Estuaries in Chesapeake Bay. 2024 Ocean Sciences Meeting. Talk. New Orleans. Feb. 18-23, 2024.

Rheuban, J. E., H. H. Kim, K. Chen, **Z. A. Wang**, I. D. Lima, A. V. Subhas. Site selection

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characteristics for Ocean Alkalinity Enhancement determined through machine learning. 2024 Ocean Sciences Meeting. Talk. New Orleans. Feb. 18-23, 2024.

Pratt, C.*, Z. A. Wang, S. Kuhl, K. Morkeski, K. D. Kroeger, G. Andrews, T. P. Smith, E. Eitel and E. Jankowska. Enhanced coastal weathering as marine CO₂ removal – Biogeochemical effects of ultrabasic olivine deployment in low-pH tidal saltmarshes. 2024 Ocean Sciences Meeting. Talk. New Orleans. Feb. 18-23, 2024.

Wang, Z. A., K.D. Kroeger, G. Andrews, N. G. Walworth, T. P. Smith, S. Khul, C. Pratt, K. Morkeski, S. Fox, E. Jankowska, E. Eitel, O. van Loenen, M. McCormick, P. Zuniga, R. A. Sohn, M. A. Briggs, F. Montserrat and S. Meseck. Novel mCDR Approach: Coupling Blue Carbon capture with Olivine Weathering and Ocean Alkalinity Enhancement in Tidal Wetlands. 2024 Ocean Sciences Meeting. eLightning talk. New Orleans. Feb. 18-23, 2024.

Eitel, E. M., E. Jankowska, J. Cebrian, S. Kuhl, P. Zuniga, C. Pratt, O. van Loenen, H. van de Mortel, K. Morkeski, M. McCormick, F. Montserrat, N. Walworth, S. Fox, **Z. A. Wang**, T. P. Smith, G. Andrews and K. D. Kroeger. Assessing ecosystem response to olivine placement within a salt marsh environment and implications for mCDR. 2024 Ocean Sciences Meeting. eLightning talk. New Orleans. Feb. 18-23, 2024.

Subhas, A., A. Michel, **Z. A. Wang**, J. E. Rheuban, H. H. Kim, K. Chen, D. C. McCorkle, J. Kapit, C. Dean, L. Marx, M. G. Hayden, K. Morkeski, M. Burkitt-Gray and F. Elder. Introducing the LOC-NESS Project and results from LOC-01, our first tracer release experiment. 2024 Ocean Sciences Meeting. Talk. New Orleans. Feb. 18-23, 2024.

Pfeifer, J.*, **Z. A. Wang**, J. E. Rheuban, M. Ringham, S. Lerner, F. N. Sonnichsen, S. Tandel, and G. McDonald. Development of high-frequency carbonate parameter sensors: from Channelized Optical System (CHANOS) to low-cost pH sensors. 2024 Ocean Sciences Meeting. Talk. New Orleans. Feb. 18-23, 2024.

Kroeger, K.D., **Z. A. Wang**, G. Andrews, N. G. Walworth, T. P. Smith, S. Khul, S. Fox, E. Jankowska, E. Eitel, O. van Loenen, M. McCormick, P. Zuniga, R. A. Sohn, M. A. Briggs, F. Montserrat and S. Meseck. Tidal wetlands as a low pH environment for accelerated and scalable olivine dissolution, driving carbon dioxide removal and ocean alkalinity enhancement. 2023 AGU Fall Meeting. Talk. San Francisco, CA. Dec. 11-15, 2023.

Jankowska, E. Eitel, S. Khul, P. Zuniga, M. J. McCormick, S. Fox, **Z. A. Wang**, T. Smith, G. Andrews and K. D. Kroeger. Response of a salt marsh ecosystem to coastal enhanced weathering (CEW) with olivine. 2023 AGU Fall Meeting. Poster. San Francisco, CA. Dec. 11-15, 2023.

Kroeger, K.D., **Z. A. Wang**, Z. Zhu, J. R. Holmquist, S. Crooks, L. Windham-Myers, P. Y. Oikawa, E. Ward, M. Tzortziou. Crediting blue carbon lateral fluxes from tidal wetlands to ocean retention. 2023 AGU Fall Meeting. Talk. San Francisco, CA. Dec. 11-15, 2023.

Wang, Z.A., A. V. Subhas, K. Morkeski, M. G. Hayden, and D. Titmuss. The Mississippi River as an Analog for Large-Scale Ocean Alkalinity Enhancement. Gordon Research Conference Chemical Oceanography. Poster. Manchester, NH. July 16 - 21, 2023.

Wang, Z.A., J. Rheuban, G. Gawarkiewicz, G. Maynard, J. Manning, D. Bethoney, A. Ellertson, C. Van Vranken, E. Pelletier, H. Xu, H. Benway and M. Maheigan. Building a Fishery-based Biogeochemical Observing Network in U.S. Coastal Waters: Major Findings from a Scoping Workshop. 2023 ASLO Aquatic Sciences Meeting. Talk. Palma de Mallorca, 16

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Spain. Jun 4 – 9, 2023.

Subhas, A. V., **Z. A. Wang**, M. G. Hayden, K. Morkeski, and D. Titmuss. The Mississippi River as an Analog for Large-Scale Ocean Alkalinity Enhancement. AGU Fall Meeting 2022. Poster. Chicago, IL. Dec 12 – 16, 2022.

Wang, Z.A. Beyond CO₂ Calculation Uncertainties: Contributions of Organic Alkalinity to the Carbonate System from River to Coastal Sea. 2022 Ocean Sciences Meeting. Talk. Virtual. Feb. 28 – Mar. 4, 2022.

Song, S. *, **Z.A. Wang**, K.D. Kroeger, M.E. Gonneea, J. Ge., and S.N. Chu. Developing High-resolution Carbon Dioxide Effluxes in Tidal Water Over a Temperate Salt Marsh using High-frequency Measurements. 2022 Ocean Sciences Meeting. Talk. Virtual. Feb. 28 – Mar. 4, 2022.

Ringham, M.C. *, **Z.A. Wang**, F.N. Sonnichsen, and S. Lerner. High-frequency time series and spatial mapping of Dissolved Inorganic Carbon using CHANnelized Optical System II in-situ carbonate chemistry sensor. Talk. Ocean Sciences Meeting. Talk. Virtual. Feb 24-March 4, 2022.

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