课程大纲
COURSE SYLLABUS

1.	**课程代码/名称** **Course Code/Title**	**海洋生物地球化学循环 Marine Biogeochemical Cycles**
2.	**课程性质** **Compulsory/Elective**	专业选修 Major Elective
3.	**课程学分/学时** **Course Credit/Hours**	3 / 48
4.	**授课语言** **Teaching Language**	英语 English
5.	**授课教师** **Instructor(s)**	Mark James Hopwood
6.	**是否面向本科生开放** **Open to undergraduates or not**	否 No
7.	**先修要求** **Pre-requisites**	（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.） Undergraduate modules in biology, chemistry or physics. 无，但是建议有本科生物、化学或者物理背景 None, but some undergraduate background in biology, chemistry or physics is suggested.

8. 教学目标
Course Objectives

（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.）

The ocean is a sink for anthropogenic carbon and a protein source for a significant fraction of the world's population. Despite its vast volume, the ocean is not immune to the effects of anthropogenic climate change. Ocean acidification, ocean deoxygenation and ocean warming all affect the biogeochemical functioning of marine environments and may have feedbacks on the associated ecosystem services that benefit humanity. In this module we will study the cycling of nutrients and elements within the ocean, assess how these cycles are affected by ongoing climate change, and evaluate whether or not there is potential for these cycles to be artificially manipulated to help humanity address the challenges of climate change. A key skill developed in this module will be the ability to find, read and review scientific papers at the cutting-edge of marine science research.

海洋是人类活动产生的碳元素的调节池，也是全球相当一部分人口的一个重要的蛋白质来源。尽管体量巨大，海洋并不是完全不受人类活动造成的气候变化的影响。海洋的酸化、脱氧和升温都会影响海洋环境的生物地球化学功能，并且可能影响和人类息息相关的和海洋相关联的生态系统。在此背景下，本课程将主要着眼于海洋中营养和元素的循环，这些循环会如何被当下的气候变化影响，以及评估这些循环是否有被人为控制的可能。这将帮助人类应对气候变化带来的挑战。技能方面，学生将学习在海洋科研领域如何查找、阅读以及评论科研论文。

9. 教学方法
Teaching Methods

（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.）

Following the chapters of the textbook, lectures will be given to students. Self-written lecture notes and multimedia teaching methods will be integrated into the course.

主要为理论讲授，遵循教材编排循序渐进，结合自编讲义和多媒体教学优势进行实际教学。

10.	教学内容 **Course Contents** （如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.）

	Section 1	Introduction to Marine Biogeochemical Cycles 海洋生物地球化学循环简介
	Section 2	Why do marine biogeochemical cycles matter? 为什么海洋生物地球化学循环很重要？
	Section 3	Playing with data, how to look at the ocean in 4 dimensions 数据分析，如何从四维的角度去认识海洋
	Section 4	Bottom-up controls on primary production in the ocean Part A Nutrients. 自下而上的海洋初级生产机制控制 － 第一部分：营养物质
	Section 5	Bottom-up controls on primary production in the ocean Part B Micro-Nutrients. 自下而上的海洋初级生产机制控制 － 第二部分：微营养物质
	Section 6	Chemical warfare, suicide and starvation: The Haber-Bosch Process and its far-reaching implications for Earth. 化学战争、自我了结以及忍饥挨饿：哈伯-博世过程及其对地球的深远影响
	Section 7	Top-down controls on primary production in the ocean 自上而下的海洋生产机制控制
	Section 8	Inorganic carbon in the ocean 海洋中的无机碳
	Section 9	Basic math for biogeochemical oceanographers 生物地球化学海洋学中的数学应用
	Section 10	The biological carbon pump 生物碳泵
	Section 11	Carbon export efficiency 碳输出效率
	Section 12	“Give me a tanker of iron and I will produce an ice age” Iron, carbon and climate change “给我一箱铁，我可以创造一个冰河世纪”铁、碳以及气候变化
	Section 13	Oxygen, what drives ocean deoxygenation? 氧气 – 什么驱动着海洋脱氧过程？
	Section 14	Ocean freshening, changes at the cryosphere-ocean interface 海洋的更新，冰冻圈-海洋界面的变化
	Section 15	Multi-stressors, how does the ocean respond to multiple changes – a case study in the Arctic? 多重压力源，海洋如何适应多重变化 – 北冰洋的个案分析
	Section 16	Multi-stressors, how does ocean respond to multiple changes – a case

		study in the Mediterranean? 多重压力源，海洋如何适应多重变化 – 地中海的个案分析
	Section 17	A basic over-view of global biogeochemical and physical models from a policy perspective. Where are the uncertainties and how can we help reduce them? 从政策的角度对全球生物地球化学和物理模型进行基本概述。有哪些不确定性，我们能够做些什么？
	Section 18	Case study, the Anthropocene, how has industry changed global oceanic metal cycles? 个案分析，人类世，工业是如何改变海洋金属循环的？
	Section 19	Case study, the Anthropocene, how have plastics changed the marine carbon cycle? 个案分析，人类世，塑料是如何改变海洋碳循环的？
	Section 20	Case study, how will “Atlantification” of the Arctic affect future marine biogeochemistry? 个案分析，北冰洋的“大西洋化”会如何影响未来的海洋生物地球化学？
	Section 21	Case study, how will deoxygenation in Peru affect future marine biogeochemistry? 个案分析，秘鲁地区的脱氧效应会如何影响未来的海洋生物地球化学？
	Section 22	Case study, how will increasing runoff in Greenland affect future marine biogeochemistry? 个案分析，格陵兰的径流会如何影响未来的海洋生物地球化学？
	Section 23	Geoengineering case study, how do we evaluate what methods to test further? Open assignment (Power Point, 12 minute oral assessment) 地球工程个案分析，我们如何评估进一步的测试方法？开放式大作业（ppt， 12 分钟口试）
	Section 24	Geoengineering case study, how do we evaluate what methods to test further? Open assignment (Power Point, 12 minute oral assessment) 地球工程个案分析，我们如何评估进一步的测试方法？开放式大作业（ppt， 12 分钟口试）

11.	**课程考核** **Course Assessment**
	（◯,1考核形式 Form of examination； ◯,2.分数构成 grading policy； ◯,3如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.） Attendance 出勤 20%; Final assignment 期末大作业 80%.
12.	**教材及其它参考资料** **Textbook and Supplementary Readings**
	Textbook

Marine Biogeochemical Cycles, Edited by Rachael H. James

Reading (during lectures/workshops)

Bach, L. T., Paul, A. J., Boxhammer, T., von der Esch, E., Graco, M., Schulz, K. G., Achterberg, E., Aguayo, P., Arístegui, J., Ayón, P., Baños, I., Bernales, A., Boegeholz, A. S., Chavez, F., Chavez, G., Chen, S.-M., Doering, K., Filella, A., Fischer, M., Grasse, P., Haunost, M., Hennke, J., Hernández-Hernández, N., Hopwood, M., Igarza, M., Kalter, V., Kittu, L., Kohnert, P., Ledesma, J., Lieberum, C., Lischka, S., Löscher, C., Ludwig, A., Mendoza, U., Meyer, J., Meyer, J., Minutolo, F., Cortes, J. O., Piiparinen, J., Sforna, C., Spilling, K., Sanchez, S., Spisla, C., Sswat, M., Moreira, M. Z. and Riebesell, U.: Factors controlling plankton community production, export flux, and particulate matter stoichiometry in the coastal upwelling system off Peru, Biogeosciences, 17(19), doi:10.5194/bg-17-4831-2020, 2020.

Bristow, L. A., Mohr, W., Ahmerkamp, S. and Kuypers, M. M. M.: Nutrients that limit growth in the ocean, Curr. Biol., 27(11), R474–R478, doi:https://doi.org/10.1016/j.cub.2017.03.030, 2017.

Browning, T. J., Achterberg, E. P., Rapp, I., Engel, A., Bertrand, E. M., Tagliabue, A. and Moore, C. M.: Nutrient co-limitation at the boundary of an oceanic gyre, Nature, doi:10.1038/nature24063, 2017.

Erisman, J. W., Sutton, M. A., Galloway, J., Klimont, Z. and Winiwarter, W.: How a century of ammonia synthesis changed the world, Nat. Geosci., 1(10), 636–639, doi:10.1038/ngeo325, 2008.

Henson, S., Le Moigne, F. and Giering, S.: Drivers of Carbon Export Efficiency in the Global Ocean, Global Biogeochem. Cycles, 33(7), 891–903, doi:https://doi.org/10.1029/2018GB006158, 2019.

Hopwood, M. J., Carroll, D., Dunse, T., Hodson, A., Holding, J. M., Iriarte, J. L., Ribeiro, S., Achterberg, E. P., Cantoni, C., Carlson, D. F., Chierici, M., Clarke, J. S., Cozzi, S., Fransson, A., Juul-Pedersen, T., Winding, M. S. and Meire, L.: Review Article: How does glacier discharge affect marine biogeochemistry and primary production in the Arctic?, Cryosph., 14, 1347–1383, doi:10.5194/tc-2019-136, 2020.

Krisch, S., Browning, T. J., Graeve, M., Ludwichowski, K.-U., Lodeiro, P., Hopwood, M. J., Roig, S., Yong, J.-C., Kanzow, T. and Achterberg, E. P.: The influence of Arctic Fe and Atlantic fixed N on summertime primary production in Fram Strait, North Greenland Sea, Sci. Rep., 10(1), 15230, doi:10.1038/s41598-020-72100-9, 2020.

Larsen, A., Egge, J. K., Nejstgaard, J. C., Di Capua, I., Thyrhaug, R., Bratbak, G. and Thingstad, T. F.: Contrasting response to nutrient manipulation in Arctic mesocosms are reproduced by a minimum microbial food web model., Limnol. Oceanogr., 60(2), 360–374, doi:10.1002/lno.10025, 2015.

Law, K. L.: Plastics in the Marine Environment, Ann. Rev. Mar. Sci., 9(1), 205–229, doi:10.1146/annurev-marine-010816-060409, 2017.

Martin, J. H., Gordon, R. M. and Fitzwater, S. E.: Iron in Antarctic waters, Nature, 345, 156–158, doi:10.1038/345156a0, 1990.

Millero, F. J.: The Marine Inorganic Carbon Cycle, Chem. Rev., 107(2), 308–341, doi:10.1021/cr0503557, 2007.

Oschlies, A., Brandt, P., Stramma, L. and Schmidtko, S.: Drivers and mechanisms of ocean deoxygenation, Nat. Geosci., doi:10.1038/s41561-018-0152-2, 2018.

Rusiecka, D., Gledhill, M., Milne, A., Achterberg, E. P., Annett, A. L., Atkinson, S., Birchill, A., Karstensen, J., Lohan, M., Mariez, C., Middag, R., Rolison, J. M., Tanhua, T., Ussher, S. and Connelly, D.: Anthropogenic Signatures of Lead in the Northeast Atlantic, Geophys. Res. Lett., 45(6), 2734–2743, doi:https://doi.org/10.1002/2017GL076825, 2018.

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Schlitzer, R., Anderson, R. F., Dodas, E. M., Lohan, M., Geibert, W., Tagliabue, A., Bowie, A., Jeandel, C., Maldonado, M. T., Landing, W. M., Cockwell, D., Abadie, C., Abouchami, W., Achterberg, E. P., Agather, A., Aguliar-Islas, A., van Aken, H. M., Andersen, M., Archer, C., Auro, M., de Baar, H. J., Baars, O., Baker, A. R., Bakker, K., Basak, C., Baskaran, M., Bates, N. R., Bauch, D., van Beek, P., Behrens, M. K., Black, E., Bluhm, K., Bopp, L., Bouman, H., Bowman, K., Bown, J., Boyd, P., Boye, M., Boyle, E. A., Branellec, P., Bridgestock, L., Brissebrat, G., Browning, T., Bruland, K. W., Brumsack, H.-J., Brzezinski, M., Buck, C. S., Buck, K. N., Buesseler, K., Bull, A., Butler, E., Cai, P., Mor, P. C., Cardinal, D., Carlson, C., Carrasco, G., Casacuberta, N., Casciotti, K. L., Castrillejo, M., Chamizo, E., Chance, R., Charette, M. A., Chaves, J. E., Cheng, H., Chever, F., Christl, M., Church, T. M., Closset, I., Colman, A., Conway, T. M., Cossa, D., Croot, P., Cullen, J. T., Cutter, G. A., Daniels, C., Dehairs, F., Deng, F., Dieu, H. T., Duggan, B., Dulaquais, G., Dumousseaud, C., Echegoyen-Sanz, Y., Edwards, R. L., Ellwood, M., Fahrbach, E., Fitzsimmons, J. N., Russell Flegal, A., Fleisher, M. Q., van de Flierdt, T., Frank, M., Friedrich, J., Fripiat, F., Fröllje, H., Galer, S. J. G., Gamo, T., Ganeshram, R. S., Garcia-Orellana, J., Garcia-Solsona, E., Gault-Ringold, M., et al.: The GEOTRACES Intermediate Data Product 2017, Chem. Geol., doi:10.1016/j.chemgeo.2018.05.040, 2018.