课程大纲
COURSE SYLLABUS

1.	**课程代码/名称** **Course Code/Title**	海洋环流数值模拟 Numerical Simulation of Ocean Circulation
2.	**课程性质** **Compulsory/Elective**	专业选修课 Major Elective Course
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)**	刘志强 LIU Zhi-Qiang
6.	**是否面向本科生开放** **Open to undergraduates or not**	是 Open
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.） 无

8. 教学目标
Course Objectives

本课程较全面、系统地介绍海洋环流数值模拟的基本理论、研究方法和应用实例，重点讲解编程语言(Fortran)程序设计基础，海洋环流控制方程各项的数值解，真实、理想地形下三维海洋过程的空间划分，时空插值方法等，海洋环流数值模式的分析方法和可视化，海洋环流过程和物质输运特征的动力学讨论。通过本课程学习，要求学生较全面掌握海洋环流数值模拟的基本理论，可以依托数值模式和关注的科学问题自主开发、调试高性能并行计算“虚拟海洋系统”，展开敏感性分析和动力过程诊断，解析海洋环流动力机制，将课堂理论学习和数值模式实践紧密结合，解决海洋科学研究中遇到的海洋环流相关问题。

This course introduces the fundamentals of numerical simulation of ocean circulation, including basics of programming language (Fortran), the differential format of terms in governing equations of Physical Oceanography, horizontal curvilinear grid and vertical s-coordinate, initial and boundary conditions, explicit and implicit methods, high-performance parallel computation, visualization of simulation and analysis methods. Students are required to develop, tune and validate the Virtual Ocean System by themselves, analyze and visualize the model results from this system, investigate the simulated multiscale oceanic processes, conduct sensitivity experiments and project the understandings to study the real ocean circulations.

9. 教学方法
Teaching Methods

讲授
Teaching

10. 教学内容
Course Contents

Section 1	1. 绪论 （3 学时） Introduction (3 credit hours)

	海洋环流数值模拟历史和应用，虚拟海洋系统概论。 History of ocean circulation simulation, basic theories and recent advances, as well as introduction to Virtual Ocean System.
Section 2	2. Fortran 编程语言基础（6 学时） Basics of Fortran Programming Language (6 credit hours) Linux 平台下的 Fortran 语言，Fortran 数学表达式，流程控制与逻辑运算，循环，数组和函数 Fortran programming language on Linux platform, mathematical expression in Fortran, Computational Flow Control and Logic, Loop, Array and Subroutine
Section 3	3. 区域海洋环流数值模拟系统（3 学时） Application of Regional Ocean Modelling System (3 credit hours) 海洋环流数值模拟系统的基本架构和各模块设计、运行逻辑 Structure of Regional Ocean Modelling System, kernel, logic and operation.
Section 4	4. 控制方程在海洋环流数值模式中的表达（9 学时） Numerical treatment of governing equations for ocean motion (9 credit hours) 连续性方程的数值解，数值模式的时间步进，内插和外插，对流项的高阶数值解，地球自转的数值实现，密度和压强梯度力，环流过程的湍封闭方程。 Numerical solutions for continuity equation, time-stepping of momentum equation, implicit and explicit methods, and mode-split. High-order numerical solution for advection processes, numerical treatment of earth rotation, density and pressure gradient force, fundamental of turbulence closure method.
Section 5	5. 海洋环流数值模拟中的边界条件问题（3 学时） Boundary conditions for regional ocean modelling system (3 credit hours) 周期边界、固定边界、梯度边界、单波辐射边界、多波辐射边界的应用和误差分析。 Errors of Periodic Boundary Condition, Clamp Boundary Condition,

	Gradient Boundary Condition and Radiation Boundary Condition.
Section 6	6. 陆架、陆坡海洋环流过程重构（5 学时） Numerical reconstruction of coastal processes (2 credit hours) 陆架流、陆坡流对风场的响应，上升流和下降流的数值模拟和敏感性分析 The wind-driven shelf and slope processes, upwelling and downwelling circulation, their numerical reproducing and sensitivity experiments.
Section 7	7. 潮汐和河口环流（3 学时） Tides and Estuary circulation (3 credit hours) 理想河口环流的重构和交换流计算，潮汐在调整河口环流中的作用 Estuarine circulation of an idealized estuary, (un)importance of Coriolis process. Tidal elevation and currents, as well as their impacts on the exchanging flow in an idealized estuary.
Section 8	8. 虚拟海洋系统搭建（6 学时） Development of Virtual Ocean System (6 credit hours) 数值模拟水体网格划分和正交性分析，垂向水体分层，模块设置和参数化。 Horizontal and vertical discretization of ocean waters, solutions for terms in the governing equations and parameterization.
Section 9	9. 虚拟海洋系统可视化和过程分析（4 学时） Visualization of Virtual Ocean System (4 credit hours) 基于 Matlab 语言的模型可视化基础，netcdf 自解释数据处理，动力过程分析 Basics of Matlab Visualization for Oceanic Processes, netcdf data processing and ocean dynamics analyses.
Section 10	10. 虚拟海洋系统验证和调优（6 学时） Validation and optimization of Virtual Ocean System (6 credit hours)

		海洋调查数据获取和 Matlab 数据处理，模式-观测数据比对和模式调优，敏感性分析 Acquiring and reanalyses of ocean observations, Matlab-based data processing, cross validation of observation and simulation, optimization of Virtual Ocean System and sensitivity experiment.
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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.）

出勤 Attendance 10%
平时作业 Assignments 30%
期末报告 Final Presentation 60%

12. 教材及其它参考资料
Textbook and Supplementary Readings

1. 王东晓、宏波、蔡树群，海洋环流数值模拟. 气象出版社. 2005
2. Dale Haidvogel and Aike Beckmann, Numerical Ocean Circulation Modeling, Imperial College Press,1999.