University of Gdańsk

Subject card

Subject name and code	Introduction to Geophysical Fluid Mechanics - lecture, PG_00206215		
Field of study	Oceanography		
Date of commencement of studies	October 2026	Academic year of realisation of subject	2026/2027
Education level	Master's studies	Subject group	Obligatory subject group in the field of study Optional subject group Subject group related to scientific research in the field of study
Mode of study	full-time studies	Mode of delivery	at the university
Year of study	1	Language of instruction	Polish
Semester of study	2	ECTS credits	3.0
Learning profile	academic	Assessment form	exam
Conducting unit			
Name and surname of lecturer (lecturers)	Subject supervisor	dr Jordan Badur	
	Teachers		

Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	45.0	0.0	0.0	0.0	0.0	45
	E-learning hours included: 0.0						

Learning activity and number of study hours	Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
	Number of study hours	45	1.0	29.0	75

Subject objectives	Students are introduced into Fluid Mechanics, in geophysical setting, including large- and medium-scale ocean circulation and using relevant mathematical methods.

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[OCEANMU2-W02] knows and understands complex processes and phenomena occurring in the marine environment, with particular emphasis on the coastal zone, as well as complex relationships between living and non-living elements of the aquatic environment	knows and understands complex aspects of fluid mechanics and large to mesoscale flows as well as their interaction with marine life.	[SW4] test/exam - oral or written [SW1] oral statement/ conversation/discussion
	[OCEANMU2-U01] is able to formulate and solve complex and unusual problems regarding the functioning of individual components of the marine environment using knowledge from various fields and scientific disciplines and propose solutions	is able to solve complex problems regarding geophysical flows using relevant mathematical techniques.	[SU4] test/exam - oral or written
	[OCEANMU2-W01] knows and understands in-depth specialized terminology used in oceanography and related sciences (in Polish and a selected foreign language)	knows and understands in-depth specialized terminology used in Geophysical Fluid Mechanics (in Polish and English)	[SW4] test/exam - oral or written [SW1] oral statement/ conversation/discussion
	[OCEANMU2-W04] has an in-depth understanding of the latest research trends in oceanography, as well as the possibilities for practical application of related achievements; evaluates their usefulness and limitations in solving scientific research problems, and critically analyzes and assesses their applicability	knows and understands, in-depth, recent trends in fluid mechanics applications to large and mesoscale flows	[SW4] test/exam - oral or written [SW1] oral statement/ conversation/discussion
	[OCEANMU2-K04] is ready to critically evaluate his/her knowledge and received content in the field of natural sciences in in particular in the field of the studied specialty, a in problematic situations, supports oneself with knowledge experts	is ready to critically evaluate his/ her knowledge and received content in geophysical fluid mechanics and seeks expert support when necessary	[SK1] oral statement/conversation/ discussion [SK4] test/exam - oral or written

Subject contents

A. Fluid mechanics:

1. The continuum model and kinematics: Eulerian and Lagrangian descriptions, mixed formulations, material derivative, decomposition of the velocity gradient tensor.
2. Conservation equations of mass, momentum, and energy in inertial and non-inertial reference frames. Cauchy momentum equation, decomposition of the stress tensor and constitutive relations for the viscous stress tensor.
3. Energy conservation equations and the Bernoulli equation for unsteady flows.
4. Elements of vorticity kinematics: vorticity and circulation, Kelvin's circulation theorem, potential vorticity, Ertel's theorem. Elements of two-dimensional flows.
5. Turbulence in in-compressible flows: Reynolds averaging, the mean energy equation, turbulence closures, and elements of the statistical theory of turbulence.

B. Elements of large- and medium scale circulation:

1. Momentum and energy balance on the rotating earth; the Boussinesq approximation.
2. The shallow water equations: in homogeneous, multi-layer, and stratified media; geostrophic balance and the thermal wind relation. Conservation of vorticity and energy within the shallow water framework. Poincaré waves and Kelvin waves.
3. Advanced analysis of the geostrophic approximation: geostrophic adjustment: energy balance and available potential energy; asymptotic methods; the planetary and quasi-geostrophic approximations.
4. Frictional boundary layers: Ekman layer model.
5. Rossby waves and the energy transport equation. Internal waves.
6. Hydrodynamic instability of baroclinic and barotropic flows on the rotating Earth: Kelvin-Helmholtz instability, vortex sheet model, Rayleigh equation, Rayleigh-Kuo criterion, and Eady problem.
7. Depth-averaged ocean circulation: Stommel, Munk and Fofonoff models and vertically structured ocean circulation: the two-layer quasi-geostrophic (QG) model, vorticity balance, and thermocline dynamics.

Prerequisites and co-requisites

Passing grade in "Mathematical methods in Oceanography" and "Programming and data analysis" OR working knowledge of single and multi-variate calculus; ability to solve selected types of differential equations and to calculate Fourier transform of a given function.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
in-class discussions	51.0%	10.0%
final written examination	51.0%	90.0%

Recommended reading	Basic literature	• Kundu, Cohen, Dowling, 2016. Fluid Mechanics, Academic Press, London (selected chapters, part A), • Cuishman-Roisin B. & Beckers J.M, 2011. Introduction to Geophysical Fluid Mechanics, Academic Press, Amsterdam (selected chapters, part B) • Vallis G.K, 2019. Atmosphere and Ocean Dynamics , Cambridge Univ. Press, Singapore, (selected chapters, part B)
	Supplementary literature	• White F., 2017. Fluid Mechanics in Si units, McGraw Hill India (part A, selected chapters, good for developing an intuition for hydrostatics and Bernoulli eqn) • Mellor G.L., 1996. Introduction to physical oceanography, Wyd. AIP Press (part B, selected chapters) • Druet, Cz. 2010. Dynamika morza, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk. (part B, selected chapters) • Massel S.R. 2010. Procesy hydrodynamiczne w ekosystemach morskich. Wyd. Uniwersytetu Gdańskiego, Gdańsk. (part B, selected chapters) • Pedlosky, J. 2013(1987). Geophysical Fluid Dynamics. Springer, New York. (alternative for the vorticity conservation dicsussion)
	eResources addresses	
Example issues/ example questions/ tasks being completed	Derive the vorticity conservation equation for a general, viscous flow Discuss the stress tensor separation and constitutive equations for viscous flow. Describe the QG model.	
Work placement	Not applicable	

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