Coastal Hydrodynamics

Alexandre Stegner & Yannis Cuypers
3 ECTS

This course is shared with ENSTA ParisTech engineer's program

The development of strict environmental regulations, renewable energies and climatic changes provides new challenges for coastal engineering. The increase of industrial activities along the coast demands new generation of coastal models. These high resolution models should be able to reproduce the coastal circulation at relatively small scale to quantify accurately the transport and the mixing of pollutants or biogeochemical species for instance.
The aim of this course is to give students advanced knowledge on the main dynamical processes which control the coastal circulation, especially the tidal flows, the wind induced circulation and the density driven flows such a fluvial plumes and coastal currents. The goal is to provide students with expertise in the complexity of real processes and a critical approach towards their numerical modeling.

1. Introduction, turbulent dynamics of coastal flows (A. Stegner)
New challenges for coastal hydrodynamic: scientific issues, numerical modeling and high resolution monitoring.
Scaling, Dimensionless numbers, Reynolds averaged Navier-Stokes (RANS), turbulent scheme, turbulent boundary layers.

2. Non-rotating shallow-water dynamics (A. Stegner)
Non-rotating shallow water equations, Froude number, sub-critical / super-critical transition, bottom friction.
Application: hydraulic control of internal flows in straits and narrows.

3. Rotating shallow-water dynamics (A. Stegner)
Rotating shallow water equations, Rossby and Burger numbers, vorticity and potential vorticity, baroclinic-barotropic motion, internal gravity waves, Kelvin waves.
Application: wave signature on surface drifters trajectories, coastal Kelvin waves .

4. Tidal forcing (Y. Cuypers)
Astronomical forcing, ocean response, harmonic decomposition, tidal resonance, tidal range power plant.
Application: tidal resonance of bays or estuaries.

5. Steady wind forcing (Y.Cuypers)
Ekman boundary layer and Ekman transport, two-layer idealization, upwelling, downwelling. mixed layer and Langmuir cells.
Application: upwelling and coastal current adjustment.

6. Unsteady or non-uniform wind forcing (A.Stegner / Y. Cuypers)
Ekman pumping induced by topographic winds, unsteady upwelling response
Application: oceanic eddy induced by non-uniform wind generation.

7. River plumes, bulges and coastal currents (A.Stegner)
River outflow, impact of rotation, anticyclonic bulge, coastal current and bathymetric impact.
Application: Unsteady bulge of a river outflow.

8. Case studies and practical analysis

9. Exam

Alexandre Stegner is a CNRS Researcher at the Dynamic Meteorology Lab. (LMD) and Associate Professor at Ecole Polytechnique. His research domains are: Topographic impact on coastal dynamics - Small-scale and non-hydrostatic inertial instabilities - Von-Karman street in the atmosphere and the ocean, cyclone-anticyclone asymmetry - Gravity-wave emission induced by geostrophic adjustment in the atmosphere and the oceans. Wave mean-flow interactions. - Dynamics of large-scale and long-lived vortices in the ocean and the Jovian atmosphere.
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