MAE 224A Environmental Fluid Dynamics

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Practical information

See http://maecourses.ucsd.edu/∼sllewell/MAE224A_2010/.

Introductions. Sign-up sheet.

What is this course about?

In MAE210A-B-C you learn(ed) the fundamentals of fluid mechanics at a graduate level.

In MAE224A-B we want to use fluid mechanics to solve environmental problems and gain insight into environmental processes governed by fluid mechanics.

We will use the tools of MAE210A-B-C. It doesn't matter if you are taking those classes concurrently, I will derive everything I need starting at a convenient point.

How would you do the following?

Terrorist threat? Predict the spread of a release of a pollutant in a large city in the Western United States. Bonus: do it in real time.

Save energy? Design buildings that don't need air conditioning in summer. This is called Natural Ventilation and works well in climates like California's.

Mystery ship sinkings? Rogue waves have been known to reach enormous heights and sink large ships.

Bumpy ride? Predict Clear Air Turbulence for aircraft travel.

Some others to consider

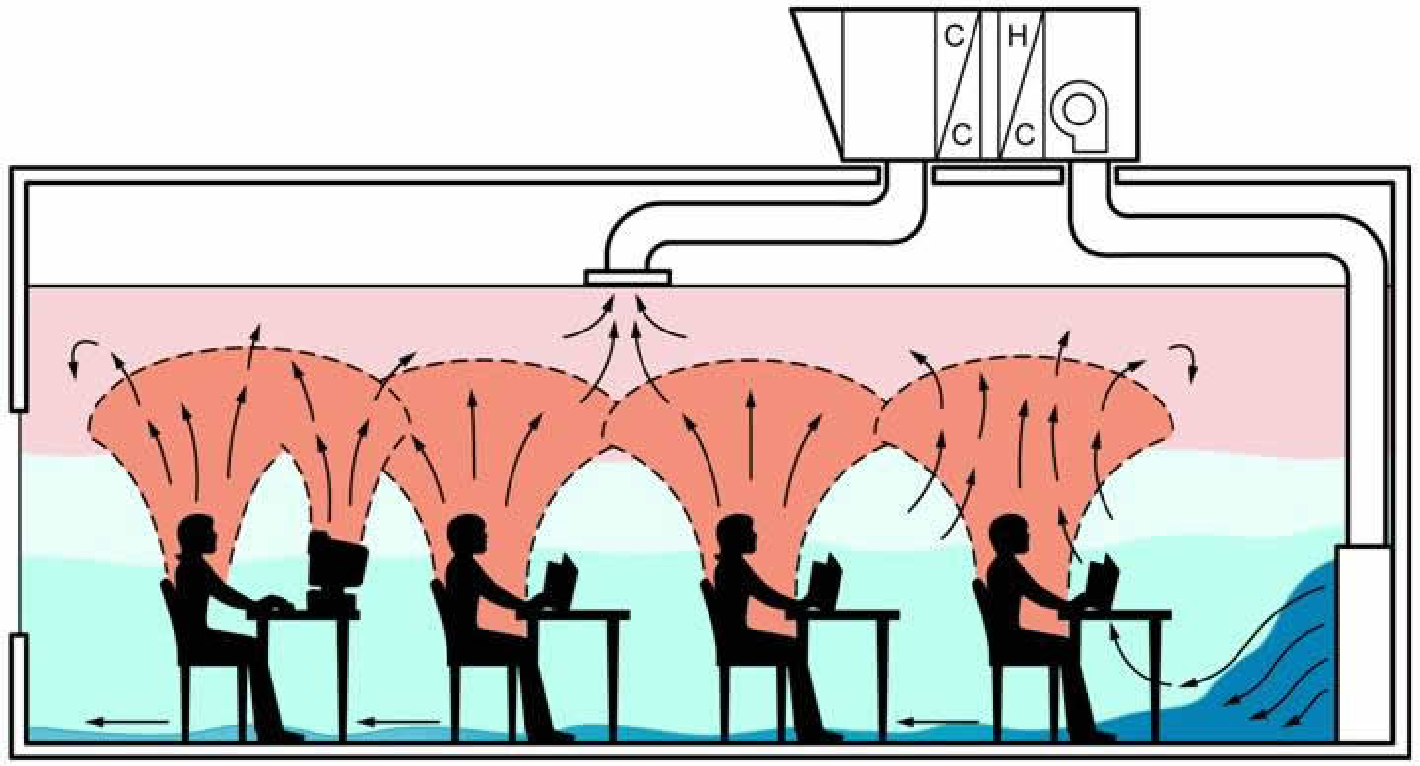
- Predict the degradation of oil in the Gulf of Mexico after an accident
- Predict the likelihood of wildfires. Predict their dynamic evolution.
- Predict the circulation of San Diego Bay. Of the Gulf California. Of the global ocean. Over hundreds of years. Coupled with the atmosphere.
- Predict the likelihood and dynamics of dust storms on Mars.
- CO_2 sequestration.
- What is the flow of water through a coral reef?

Governing equations

No appealing picture.

Graduate Applied Math Brown Bag Seminar (University of Arizona).

Plumes



Energy efficient design.

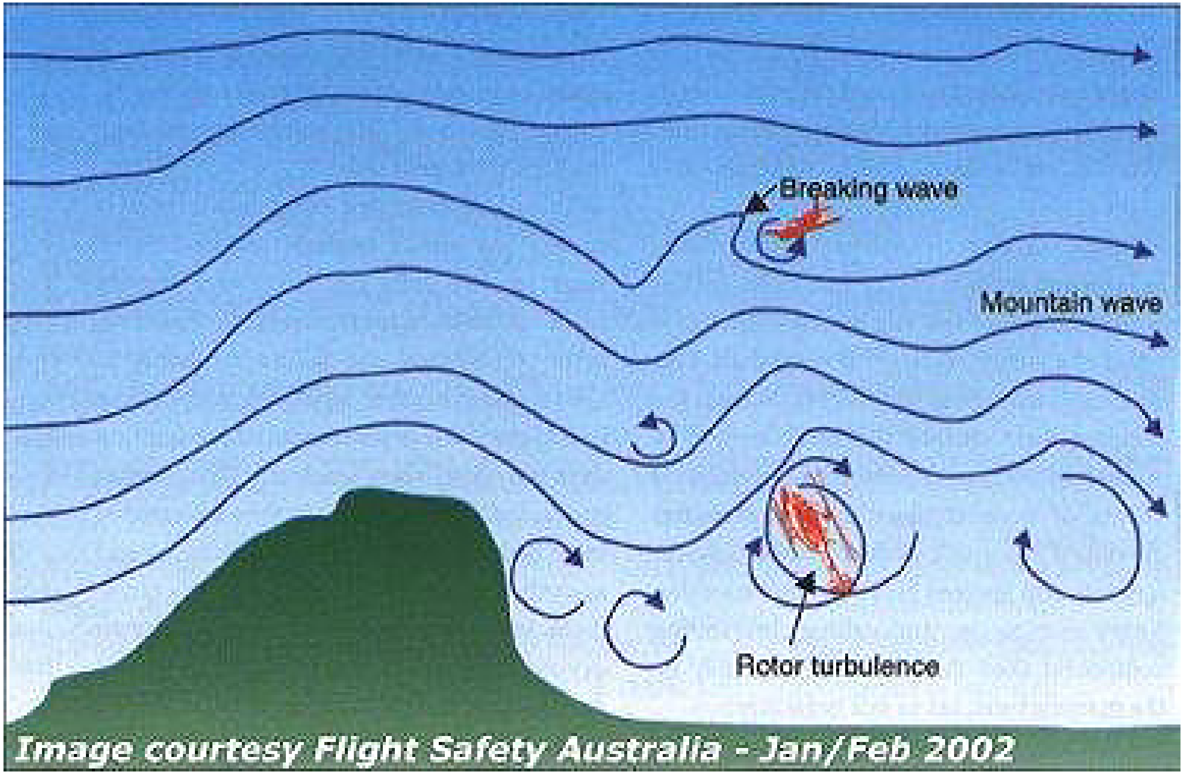
EnergyPlus page

Rogue waves

http://www.deathwaves.com.

Disturbing videos.

Clear Air Turbulence



Minnesota Public Radio article.

Popular Mechanics article.

Others

Gulf of Mexico Oil.

San Diego Official Very High Fire Hazard Severity Zone Map.

2007 fires.

GCM used to predict possible fate of Gulf Oil in Atlantic.

Sequestration of Carbon Dioxide in Appalachian Coal Deposits.

How do we do these things?

I This lecture.

II We need equations appropriate to the situation at hand. We need to be able to deal with density differences, salt, water vapor, the rotation of the Earth, its spherical shape, etc. . .

These equations will be nonlinear (remember Navier–Stokes) so we need ways of solving them. Numerically is one way: dealt with in MAE290A-B, MAE223, but not here. To extract relevant physics, need to simplify equations by understanding scalings.

III The equations are still difficult. Consider one-dimensional and similarity solutions. Are these useful?

IV Another class of solutions has a simple density structure that can be approximated by layers of homogeneous fluid. The simplest case is a single layer of fluid, i.e. Surface gravity waves.

V One can generalize this by taking the limit of many narrow layers. The resulting waves are very different. There are internal gravity waves. To understand behavior far from sources, use Ray Theory.

Syllabus

I Introduction.

II Equations for a stratified rotating fluid.

III Plumes.

IV Surface gravity waves.

V Internal gravity waves.

Themes

There are certain themes that recur in MAE224A and MAE224B that are relevant to a variety of applications and helpful in understanding them.

1. Conservation and partition of energy.
2. Asymptotics (stationary phase).
3. Dimensional analysis.
4. Similarity solutions.
5. WKB and ray theory.
6. Eigenfunction expansions (Sturm–Liouville theory) vs. propagating waves.
7. Stability vs. instability.

Some of these are mathematical techniques that we will investigate. Some are of a more physical nature.

Semantics

Often see references to GFD and AFD.

GFD: geophysical fluid dynamics, i.e. flows in oceans and atmosphere. Rarely used to describe fluid mechanics of the mantle, which is definitely geophysical.

AFD: astrophysical fluid dynamics, i.e. flows in stars. Also used in relation to flows in other planets' atmospheres and oceans (water, methane, etc. . .).

Occasionally see references to Geological Fluid Mechanics, i.e. flows in magma chambers, volcanic eruptions, and to Environmental Fluid Mechanics, i.e. flows in the natural environment on scales smaller than the whole planet.

In this course I won't really distinguish between applications.

The critical physical phenomena are density differences and rotation. MAE224A concentrates on the former. The latter is critical in GFD. The geometrical constraints are the aspect ratio and the shape of the Earth.

We will start from the following

Conservation of mass, Newton’s Second Law, the First and Second law oft Thermodynamics, conservation of a scalar (e.g. salt), the equation of state and the constitutive relation for a fluid.

No equations today!