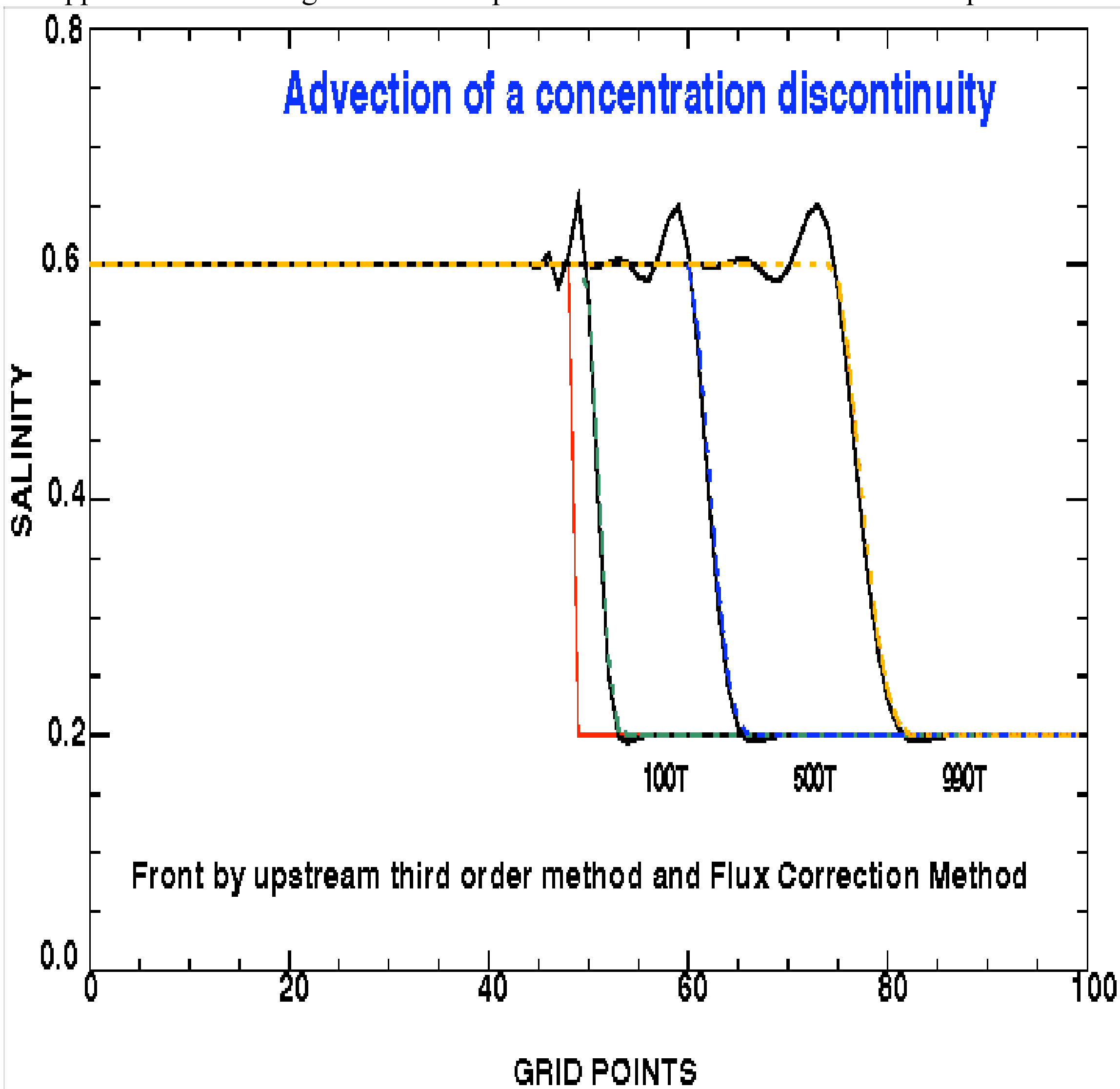
NUMERICAL MODELING OF OCEAN DYNAMIC (MSL-629)

ONE-DIMENSIONAL PROBLEMS: TRANSPORT EQUATIONS

1. Mathematical rudiments (basic numerical formulas and notation)
2. Boundary and initial conditions
3. Basic numerical properties (approximation and stability)
4. Explicit versus implicit numerical schemes
5. Computational errors: diffusion and dispersion
6. Diffusive processes
7. Application of the higher order computational schemes to the advective equation



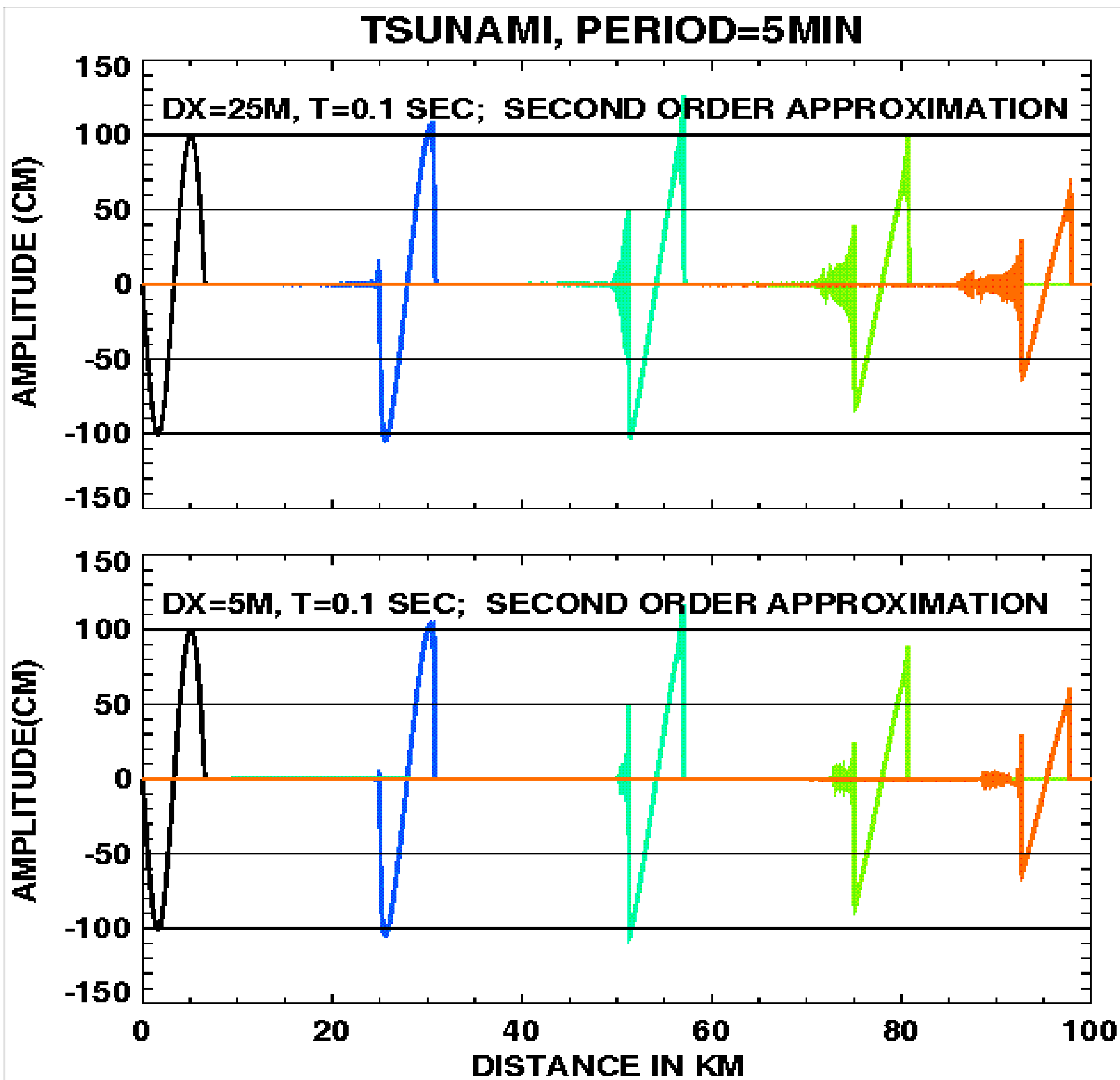
TWO--DIMENSIONAL NUMERICAL MODELS

1. Basic problems (type of equation, open boundary and initial conditions)
2. Numerical solution and stability of the system of equations
3. Step by step approach to the construction and analysis of simple numerical schemes
4. Two-dimensional models (tides, storm surges and ice)

4.1 Errors in the two-dimensional staggered grid

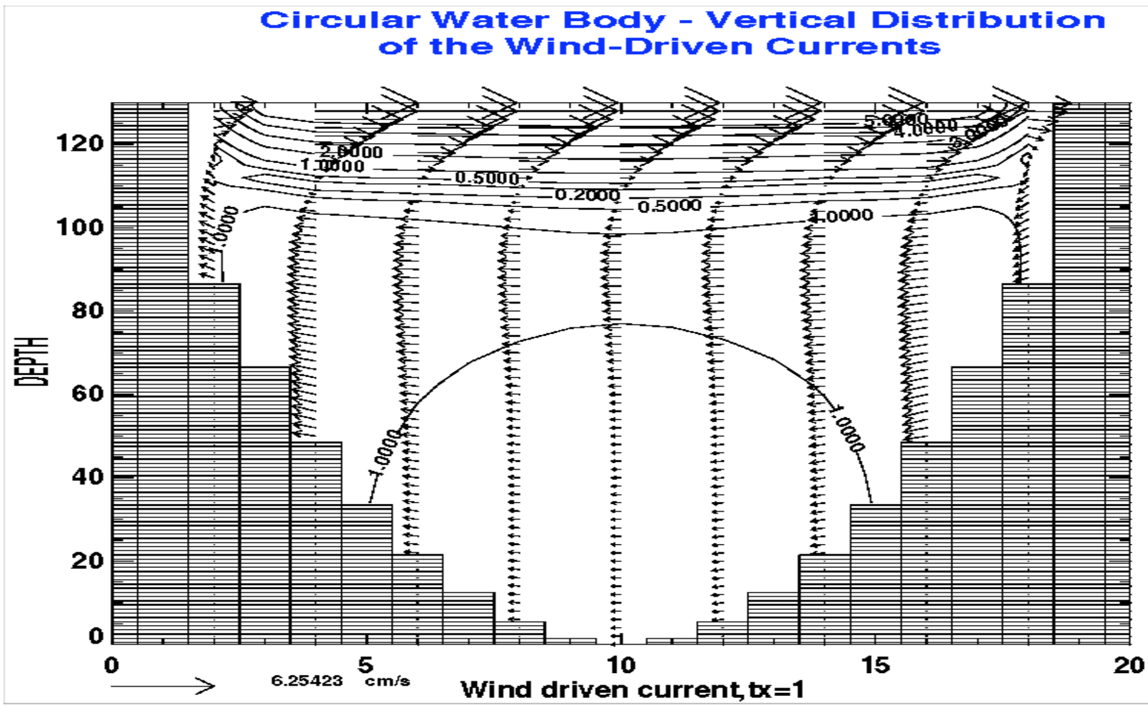
5. Numerical filtering
6. Grid refinement
7. Simulation of long wave run-up

Tsunami propagation in an upsloping channel



THREE-DIMENSIONAL TIME-DEPENDENT MOTION

1. Numerical modeling of the fjord circulation
2. Three-dimensional motion in the shallow seas
3. Three-dimensional modeling utilizing the mode splitting and sigma coordinate
4. General circulation model -- rigid lid condition



A brief description of the course

The course will be based on the book by Z. Kowalik and T.S. Murty entitled: Numerical Modeling of Ocean Dynamics, Published by: World Scientific Publishing Co., Singapore, New Jersey, London, 1993; and a Workbook on Numerical Modeling by Z. Kowalik (see pdf file).

This course will describe fundamentals of computer simulation applied to partial differential equations describing dynamical processes in the ocean and atmosphere. Numerical approximation schemes for the geophysical fluid dynamics will be analyzed through equations of motion, continuity and transport. Special consideration will be given to the description of the frictional processes in the turbulent flow and transport/diffusion phenomena. The course will include laboratory practice, therefore during the course every student will learn fundamentals and will be also involved in the practical projects for the real hands-on experience in applying numerical methods.

(Prerequisites: baccalaureate degree in physics, engineering or mathematics or equivalent; experience with FORTRAN.)

Ocean dynamics is a vast field and it will be unrealistic on our part to cover in this short course the entire field; instead we will confine ourselves to transport equations (diffusion and advection), shallow water phenomena (tides, storm surges including ice dynamics), and three-dimensional time dependent oceanic motion. The aim of this course is to give an introduction to the application of finite-difference methods to ocean dynamics.

The basic numerical methods in the finite-difference approach for one-dimensional problem will be demonstrated through the equation of transport for the advective and diffusive processes. This ``prototype'' equation has been applied in the numerous investigations to study transport of salt, heat and spreading of pollutants in the oceans. It will serve during the course for introduction of the basic notions such as: approximation, stability, computational errors and application of explicit versus implicit marching in time.

Two-dimensional and time-dependent phenomena such as storm surges and tides will be examined through the vertically averaged equation of motion and continuity. Particular emphasis will be given to space-staggered schemes, problems with open boundaries, nonlinear advective terms and grid refinement.

The problems encountered in modeling three-dimensional and time dependent motion in the oceans, i.e., economy of computation, approximation and stability are especially demanding. One additional space coordinate (along the vertical direction) introduce severe requirements on computer memory and computation time.
Starting from a simple algorithms, a few approaches to the time integration will be delineated: explicit method, split mode method and semi-implicit method. The first approach serves for the shallow water problems, the two latter approaches aim at saving computer time and can be used to study the open ocean dynamics.