Parallelizing a High Resolution Operational Ocean Model

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Abstract. The Swedish Meteorological and Hydrological Institute (SMHI) makes daily forecasts of temperature, salinity, water level, and ice conditions in the Baltic Sea. These forecasts are based on data from a High Resolution Operational Model for the Baltic (HIROMB). This application has been parallelized and ported from a CRAY C90 to a CRAY T3E.

Our parallelization strategy is based on a subdivision of the computational grid into a set of smaller rectangular grid blocks which are distributed onto the parallel processors. The model will run with three grid resolutions, where the coarser grids produce boundary values for the finer. The linear equation systems for water level and ice dynamics are solved with a distributed multi-frontal solver.

We find that the production of HIROMB forecasts can successfully be moved from C90 to T3E while increasing resolution from 3 to 1 nautical mile. Though 5 processors of the T3E are 2.2 times faster than a C90 vector processor, speedup and load balance could be further improved.

1 Introduction

The Swedish Meteorological and Hydrological Institute (SMHI) makes daily forecasts of currents, temperature, salinity, water level, and ice conditions in the Baltic Sea. These forecasts are based on data from a High Resolution Operational Model of the Baltic Sea (HIROMB) currently calculated on one processor CRAY C90 parallel shared memory vector computer. Within the HIROMB project [1], the German Federal Maritime and Hydrographic Agency (BSH) and SMHI have developed an operational ocean model, which covers the North Sea and the Baltic Sea region with a horizontal resolution from 3 to 12 nautical miles (nm). This application has to be ported to the distributed memory parallel CRAY T3E. This will save operation expenses and even more important allow a refinement of the grid resolution to 1 nm within acceptable execution times.
2 HIROMB: A High Resolution Operational Model for the Baltic Sea

The operational HIROMB code is loosely coupled via disk I/O with the atmospheric model HIRLAM [2]. Atmospheric pressure, velocity and direction of wind, humidity and temperature, all at sea level, together with cloud coverage are input, while sea level, currents, salinity, temperature, and coverage, thickness and direction of ice are output. HIROMB is run once daily and uses the latest forecast from HIRLAM as input. There are plans to couple the models more tightly together in the future.

Specifying tidal level and sea level at the open boundary between the North Sea and the North Atlantic account for the influence of the water level in the North Atlantic. The sea level is provided by a storm surge model covering the North Atlantic. Fresh water inflow is regarded at 80 major river outlets.

2.1 Grids

The 3nm grid, see Figure 1, covers the waters east of 6° E and includes the Skagerrak, Kattegat, Belt Sea and Baltic Sea. Boundary values for the open western border is provided by a coarser 12 nm grid covering the whole North Sea and Baltic Sea region, see Figure 2. In the vertical, there is a variable resolution starting at 4m for the mixed layer and gradually increasing to 60m for the deeper layers.

All interaction between the two grids is taking place at the western edge of the finer grid where values for flux, temperature, salinity, and ice properties are interpolated and exchanged.

2.2 Model Description

We can essentially identify three parts in the model, the baroclinic part, the barotropic part, and the ice dynamics.

Baroclinic Part Water temperature and salinity are calculated for the whole sea including all depth levels. Explicit two-level time-stepping is used for horizontal diffusion and advection. Vertical exchange of momentum, salinity, and temperature are computed implicitly. Temperature and salinity both obey the same physical laws and are advected using the same subroutine tflow. Assuming an average depth $\bar{k}$, the baroclinic part has a complexity of $O(surface\_points \times \bar{k})$.

Barotropic Part A semi-implicit scheme is used for the vertically integrated flow, resulting in a system of linear equations (the Helmholtz equations) over the whole surface for water level changes. This system is sparse and non-symmetric, reflecting the 9-point stencil used to discretize the differential equations over