# Scientific Documentation of Seatrack Web; physical processes, algorithms and references

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## 1 Purpose

The purpose of this appendix is to present a scientific description of Seatrack Web HELCOM. It is intended to give an overview of the processes, algorithms and methods which Seatrack Web is based on. The documentation focuses on the oil drift model PADM (PArticle Dispersion Model), the program that performs the drift simulations requested by the user.

## 2 Fundamentals

### 2.1 System overview

The Seatrack Web system consists of three main parts: forcing in the form of forecasted flow and wind fields, an oil drift model and a graphical user interface. The oil drift model PADM has been jointly developed by the Swedish Meteorological and Hydrological Institute (SMHI) and the Danish Maritime Safety Administration (DAMSA). It is executed whenever a Seatrack Web user requests a simulation. The graphical user interface has been developed at SMHI and is based on open source GIS-server technology, i.e. the user interacts with georeferenced data in a map.

The area covered by the Seatrack Web HELCOM system is the Baltic Sea, the sounds between Sweden and Denmark, the Kattegat and the Skagerrak, and the North Sea to about longitude 3° east.

The forcing fields for Seatrack Web HELCOM are presently provided by the weather model HIRLAM and the ocean model HIROMB. These are run operationally and form the basis for weather and ocean forecasts at SMHI. For longer forecasts forcing fields from the European Centre for Medium-Range Weather Forecasts[1] replace those from HIRLAM.

[1] See ECMWF homepage

## 2.2 Conceptual model

The oil drift model PADM is a Lagrangian particle spreading model. This means that the substance or object being simulated is represented as a cloud of particles. The trajectory of each particle is calculated based on time- and space-varying flow fields.

At present it is assumed that the particles do not influence the flow field, i.e. a particle does not have any effect on the flow in which it is located.

Particles are affected by boundaries such as the coastline, the bottom or the surface. Particles cannot pass through a solid boundary but may either stick to a boundary or slip along it.

Each particle has a set of properties. Most important of these is of course its position. However, a particle can have a variety of additional properties depending on what substance or object it represents, e.g. mass, volume, size, chemical properties, density, etc. These can be constants or vary with time, location, temperature, etc.

In the current version of Seatrack Web HELCOM, algorithms have been implemented for the following substances:

- oils,
- tar balls,
- floating objects or algae, and
- passive tracers.

Tar balls are currently treated as passive floating objects.

The processes that as of today have been included in PADM can be divided into two main sections: spreading, which includes all processes related to the movement of the particles, and weathering of oil.

## 2.3 Time and space discretization

Before continuing we must describe how the real world is represented in the model. To begin, it is assumed that the flow field is defined in a discrete, structured grid of six-sided cells at discrete times (see Figure 1). The grid discretization is assumed to be staggered, i.e. the flow velocities are located on the faces of each grid cell. Within a given grid cell the flow field is determined by the velocities on the six faces, with the assumption that $u$, the velocity component in the x-direction, only varies in the x-direction, $v$, the velocity in the y-direction, only varies in the y-direction, and $w$, the velocity component in the z-direction, only varies in the z-direction. In other words, the perpendicular velocity component on a particular face is constant over that face.

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Figure 1: A schematic 2-D view of the internal grid, showing the space and time discretization. For clarity only a few flow vectors are shown.

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Figure 2: A 2-D schematic showing how internal positions are defined in the grid. The point indicated is located in cell (i, j) and its local position within that cell is (0.62, 0.69), where the local origin is located in the corner node designated (i, j) and the extent of the cell is unity in all directions.

As time progresses beyond the current interval, the flow field changes abruptly and is then constant in time for the following time interval, and so on.

The model representation implies that for a given time interval the flow parameters at each location in the grid are constant in time, but may vary spatially. The spatial variation is of course limited by the grid resolution and the temporal variation by the time step. This means that we have two fundamental time scales: the time it takes a particle to reach the next grid cell $T_u$ and the time step between successive flow fields $T_t$.

Note that the grid described above is a strictly internal representation. Thus, when talking about $x$, $y$ and $z$ it is the internal coordinate directions that are referred to. All positions and velocities are referenced in a system based on the indices of the grid cells and the local position within a given cell (see Figure 2)[2]. So-called transformation functions, which handle the conversions between real world coordinates and the internal representation in PADM, need to be specified.

In Seatrack Web HELCOM the internal PADM grid is mapped onto the HIROMB grid, an orthogonal, structured grid in spherical coordinates. In HIROMB the x-direction runs from west to east (longitude), the y-direction from south to north (latitude) and the z-direction points upwards (inverted depth).

The bottom boundary in PADM is defined by the bottom in the HIROMB computational grid. Thus, the bottom at a particular location is represented by the horizontal face of the lowermost grid cell at that location, which in turn is defined by the HIROMB bathymetry. Because HIROMB uses a grid with constant levels in the vertical (z-level) a sloping bottom will be represented by a stairway shape. Hence a particle reaching the bottom may interact with a horizontal or a vertical face of a grid cell (see Figure 3).

The surface boundary is simply the upper face of the uppermost grid cells. Varying sea levels are not taken into account in the particle spreading calculations.

[2]The cell indexing begins in the bottom lower left cell (1,1,1) and increases to the right (x-index), upwards (y-index) and towards the surface (z-index).

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Figure 3: A 2-D vertical section through the HIROMB grid showing the staircase approximation of the bottom (thick line).

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Figure 4: A schematic showing how a detailed coastline consisting of three line segments intersects a grid cell (the shaded area is considered to be up on land). Note also how the line segments extend down into the water column all the way to the local bottom, forming vertical surfaces that are treated as bottom areas.

The lateral boundaries at the surface, i.e. the coastline, are not defined by the PADM grid. Instead, a coastline digitised from available charts is used. Thus the coastline is described in greater detail than that allowed by the horizontal resolution of the grid. The coastline consists of a large number of line segments. Each line segment actually constitutes the upper edge of a vertical face which stretches down to the bottom at the grid location where the coastline segment is located (see figure 4).

Because PADM is not restricted to the resolution and boundaries set by the HIROMB grid, there may be grid cells which are considered dry in HIROMB but part of which are considered wet by PADM, i.e. if the coastline runs through a HIROMB cell which has been defined as dry. In these cells, HIROMB obviously cannot provide any current velocities or scalar properties such as salinity or temperature. To provide a better approximation of the advective current field in these cells a velocity directly proportional to the wind velocity is inserted into the forcing fields. Presently the constant of proportionality is 0.01, i.e. 1 %, based on comparisons between the surface current in HIROMB and wind speeds. Scalar fields such as salinity and temperature are extrapolated from the nearest wet HIROMB cells.