

# Technical description of the LarvaMap package

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## LarvaMap Work Flow and Design

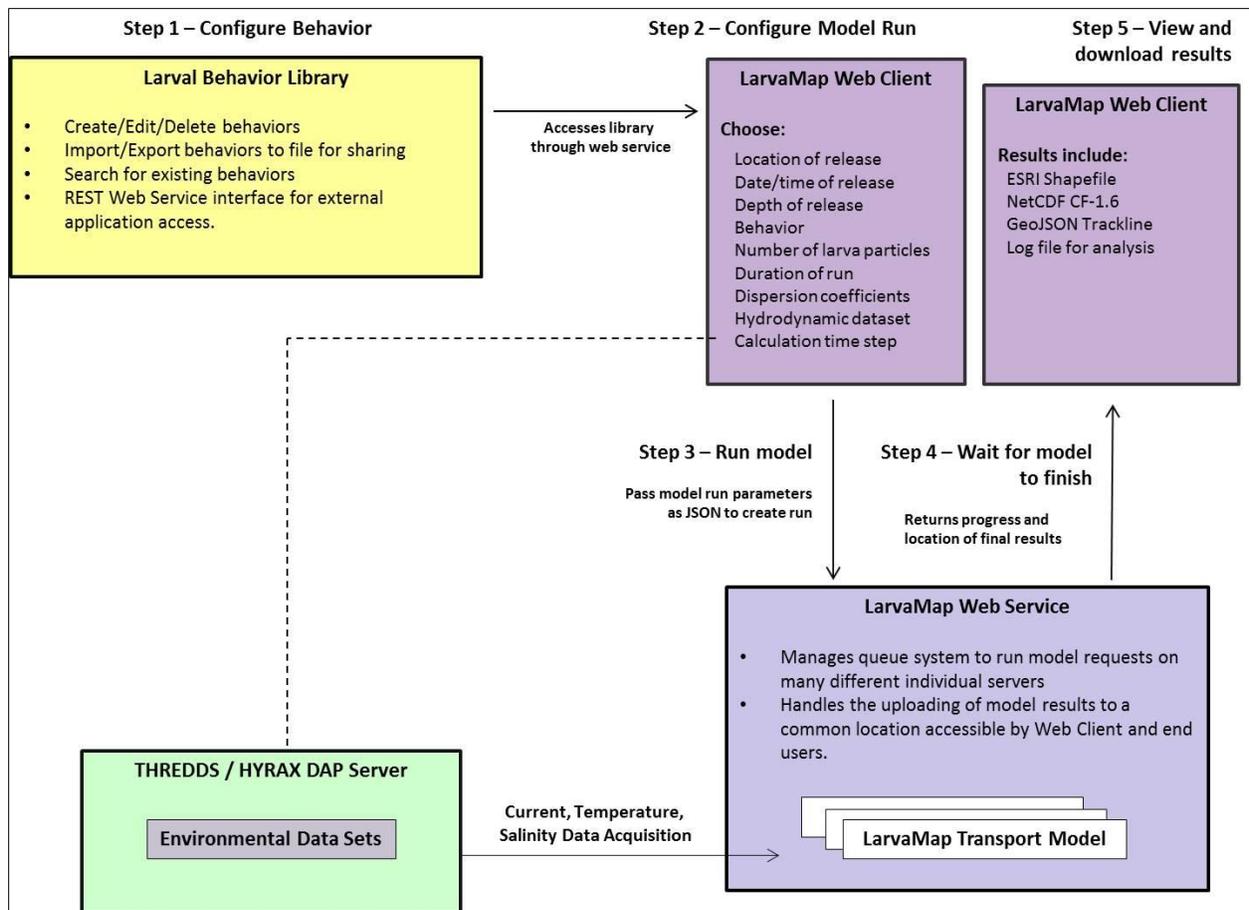
LarvaMap is a web-based modeling system that simulates long-term and large-scale larval fish and invertebrate transport. The Lagrangian particle-based larval transport model is driven by physical ocean conditions. LarvaMap can make use of many hydrodynamic data sources to drive the transport model. The system leverages the capabilities of the Paegan Common Access Library<sup>1</sup>, making it possible to use both local files that are supported by the library and remote datasets via the OPeNDAP protocol. LarvaMap is composed of four system components:

- **Larval Behavior Library** to create, catalog, and share larval behaviors
- **LarvaMap Transport Model** written as a python library<sup>2</sup>
- **LarvaMap Web Service** implementing the transport model in a cloud architecture
- **LarvaMap Web Client** for interacting with Web Service through a REST API

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<sup>1</sup> <https://github.com/asascience-open/paegan>

<sup>2</sup> <https://github.com/asascience-open/paegan-transport>



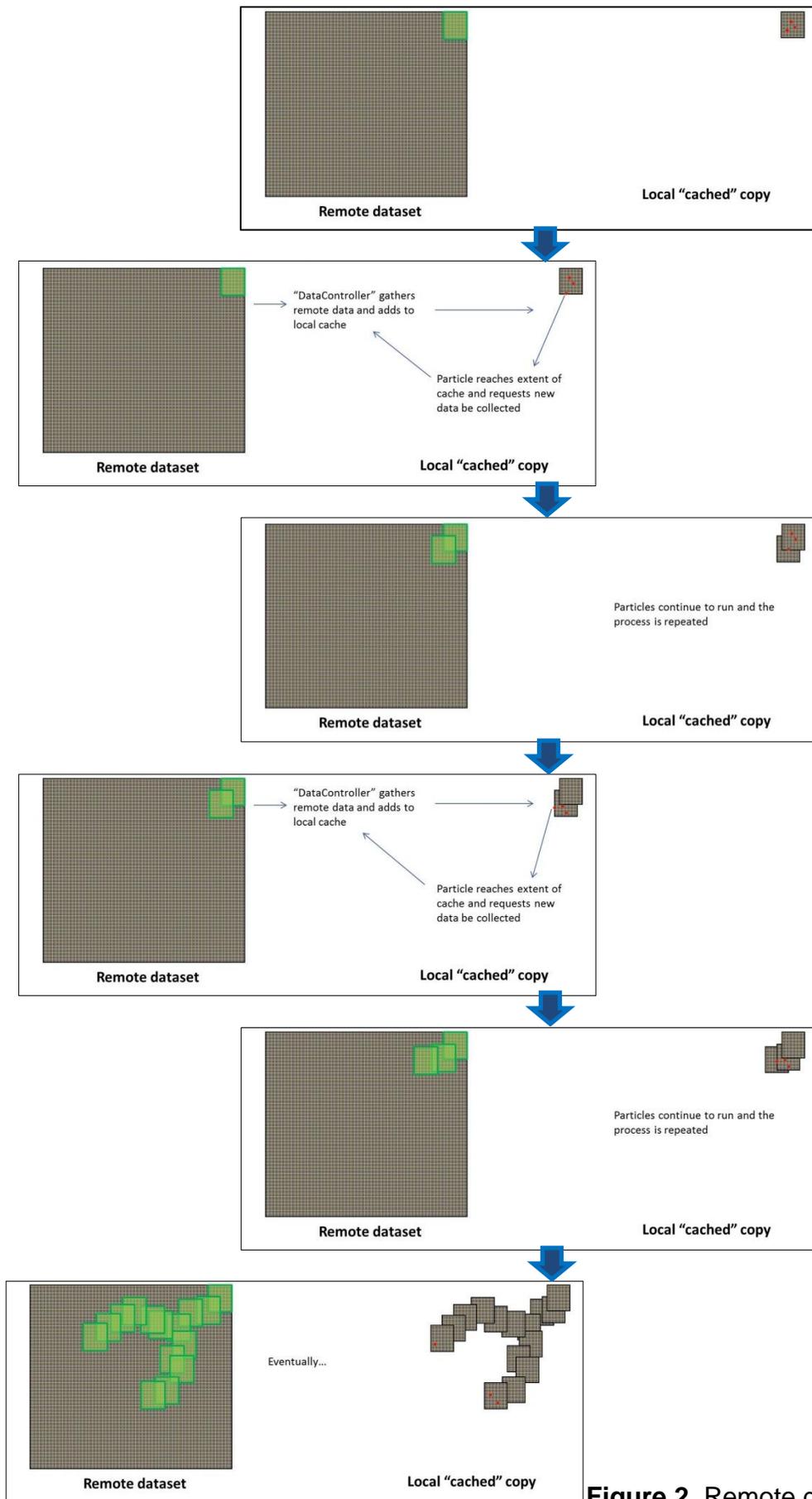
**Figure 1.** LarvaMap system component structure and work flow.

In a standalone web service the Larval Behavior Library, users can first search, create, and catalog behavior files (specific to a species) that can be shared and edited. These behavior files can be imported into (or accessed via) the LarvaMap Web Client. The front-end of the LarvaMap Web Client, built with using Adobe Flex technology and using the ERSI Flex API, provides the user with an exploratory GIS mapping interface. In the LarvaMap Web Client users first select a behavior file and hydrodynamic data set, and then define larval release parameters including release location, depth of release, timing and duration of release, duration of simulation, horizontal and vertical dispersion, number of particles released, and model time step. These values are passed via JSON to a Python based REST web service (LarvaMap Web Service) running on external servers (**Amazon cloud**) that process the parameters, generate a unique run ID (which can be used to share model runs between users), and adds the parameters onto the end of a queuing system. When the Python-based backend model runner sees a message waiting on the queue, it processes the message and initiates the larval transport model. NetCDF/DAP environmental data (e.g. currents) siting on a remote **Thematic Realtime Environmental Distributed Data Services (THREDDS) data**

**server (TDS)**, needed to run the larval transport model, is then requested and acquired. While the model is running, the service returns progress messages to the client, so that the user can monitor model progress. After the model run completes, the service returns a GeoJSON representation of the computed central trackline of the particle trajectory to the client, which is displayed on the mapping interface. Users are also able to download model results as particle output files in NetCDF and ESRI ArcGIS ShapeFile format.

### **Request and Acquisition of Hydrodynamic Data**

As the data volumes of the hydrodynamic simulations are generally huge, an “on demand” or “as needed” data retrieval system was built in LarvaMap. Data is acquired on a "per particle" basis and cached for use by any particles that are within the same grid-cell of the currents forcing dataset. An R-Tree spatial-indexing implementation allows very rapid positional lookups against both structured and unstructured datasets. The data-cache persists until the model-time step advances past the current data-time step, which allows the transport model to be run at higher temporal fidelity than the forcing data without impacting model performance.



**Figure 2.** Remote data request process.

## LarvaMap Transport Model

Net transport of a particle in LarvaMap is estimated by accounting for movement associated with three factors: current velocity ( $u,v$ ) from the hydrodynamic data, vertical and horizontal dispersion (controlled by user defined dispersion coefficients), and mobility associated with larval behavior (e.g. vertical migration, swimming speed). For every time step, the transport model calculates net movement in the sequence shown below in Figure 3.

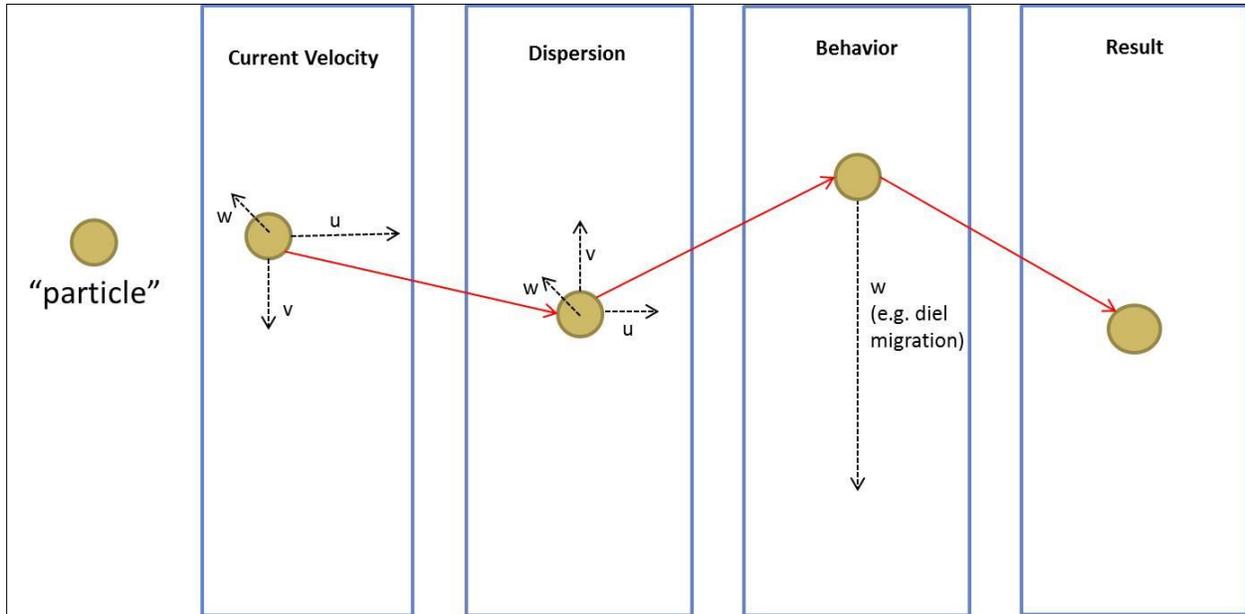


Figure 3. Transport model in Larva Map.

Interactions of a particle with the shoreline and with the bottom were frequent in the PWS herring model trajectories due to the complexity of the shoreline, and because herring are beach spawners start points were all near shore. These were dealt with according to the following rules.

When a particle hit the shore, it was reversed a configurable number of meters ( $N$ ) back in the direction it came from. The direction is randomized by  $\pm 5$  degrees. If reversing  $N$  meters landed the particle on shore,  $N$  was halved, and the process was recursively attempted until the particle was in the water. If after ten attempts the particle was still on land, it was then assumed that the particle did not move for that timestep and it was set back to its original location enabling it to be picked up by different currents in future timesteps. For the final PWS herring model runs,  $N$  was 1000, but the typical value for  $N$  in the web client is 1500. Currently  $N$  is not a configurable input option in the interface.

A rule was also set that if the particle gets stuck near the shore where the bathymetry of the hydrodynamic grid might be shallower than the bathymetry data the transport model reads, the particle was then relocated to its previous position. This promoted more longshore and nearshore movement and no “shore sticking”.

When a particle hits the bottom it resets to hover 1m above the bottom, to where it can subsequently move due to behavior or current.

## **Prince William Sound ROMS Hydrodynamic Data**

For this project, LarvaMap accessed hydrodynamic data from the Prince William Sound Regional Ocean Modeling System (PWS ROMS) (Wang et al., 2012). The three dimensional ROMS model structure uses a generalized vertical coordinate system following the bottom topography (Song and Haidvogel, 1994). PWS ROMS is a three-domain, one-way nested circulation model. The outermost North Pacific domain (L0) has a resolution of 10 km; while the other two nested model domains, L1 (Gulf of Alaska) and L2 (Prince William Sound), have resolutions of 3 km and 1 km respectively. This model is operational and forecast data is readily available for each domain. Various hindcast data sets exist, but are less accessible and vary by time span.

PWS ROMS provides current, temperature, salinity and sea surface height time series data. All the factors that influence the circulation around PWS (heat flux, wind stress, freshwater discharge, and tides) are included in model forcing. The tidal forcing for the model is obtained from a global inverse barotropic tidal model (TPXO.6) (Egbert and Erofeeva, 2002; Egbert et al., 1994). Eight major tide constituents (M2, K1, O1, S2, N2, P1, K2, Q1, ordered by their amplitudes in the region) are used for the tidal boundary condition on the L0 model domain.

PWS ROMS historical model output files were made available for this project on the Alaska Ocean Observing System's AOOS THREDDs data server. These data sets were post-processed onto an averaged grid. LarvaMap does not have the capability of reading the typical ROMS generalized vertical coordinate format. Table 1 summarizes the data sets utilized for LarvaMap modeling.

Table 1: PWS ROMS data sets.

Domain	Name	Time Step Increment (hrs)	Time Span	Link
L0 Forecast	North Pacific	6	02/01/2011 (01:00) – 06/08/2013 (02:00)	<a href="http://thredds.axiomalaska.com/thredds/dodsC/PWS_DAS.nc">http://thredds.axiomalaska.com/thredds/dodsC/PWS_DAS.nc</a>
L1 Forecast	Gulf of Alaska	3	02/01/2011 (01:00) – 5/29/2013 (02:00)	<a href="http://thredds.axiomalaska.com/thredds/dodsC/PWS_DAS.nc">http://thredds.axiomalaska.com/thredds/dodsC/PWS_DAS.nc</a>
L2 Forecast	Prince William Sound	1	02/01/2011 (01:00) – 5/29/2013 (02:00)	<a href="http://thredds.axiomalaska.com/thredds/dodsC/PWS_DAS.nc">http://thredds.axiomalaska.com/thredds/dodsC/PWS_DAS.nc</a>
L2 Hindcast	Prince William Sound	6	03/31/2009 (14:00) - 5/29/2013 (02:00)	<a href="http://thredds.axiomalaska.com/thredds/dodsC/PWS_DAS.nc">http://thredds.axiomalaska.com/thredds/dodsC/PWS_DAS.nc</a>

## References

Egbert, G.D., Bennett, A.F., Foreman, M.G.G. 1994. TOPEX/POSEIDON tides estimated using a global inverse model. *Journal of Geophysical Research* 99, 24821–24852.

Egbert, G.D., Erofeeva, S.Y. 2002. Efficient inverse modeling of barotropic ocean tides. *Journal of Atmospheric and Oceanic Technology* 19, 183–204.

Song, Y.T., Haidvogel, D. 1994. A semi-implicit ocean circulation model using a generalized topography-following coordinate system. *Journal of Computational Physics* 115, 228–244.

Wang, X., Chao, Y., Zhang, H., Farrara, J., Li, Z., Jin, Z., Park, K., Colas, F., McWilliams, J.C., Paternostro, C., Shum, C.K., Yi, Y., Schoch, C., Olsson, P. 2012. Modeling tides and their influence on the circulation in Prince William Sound, Alaska. *Continental Shelf Research*. In Press.