AquaModel Software Capabilities August 2020

AquaModel is designed to be useful for beginning users with simple needs or for expert users with advanced GIS and computational needs. Many users now are not computer scientists and successfully use the model for business or government needs.

The following lists many of the primary capabilities; users should refer to either the abridged or the complete Help Manual for more explanations.

Overview

AquaModel is a computational tool for planning and evaluating proposed aquaculture sites, both for single farms and multiple farms over broad geographic regions. It operates on Windows computers and provides a simple interface to enter environmental and operational information. Graphical outputs map the distribution over time of key parameters including oxygen, particulate organic and dissolved nutrient wastes, algal and plankton effects and dozens or other environmental and fish cultural/management parameters.

The model has been used by and for government agencies, consultants for industry and directly for industry in many locations worldwide. Model validation studies have been completed in some of these areas.   *AquaModel* has been adapted for seaweed (kelp) aquaculture and will include tools to assess ocean acidification mitigation of seaweed with funding from the Paul Allen Foundation's Ocean Challenge Competition.

AquaModel is a simulation program that provides for assessment of both farm operations and their environmental effects on coastal or offshore waters. It simultaneously describes nutrient transformations by fish farms of both dissolved and particulate materials in the water column and sea bottom.

A system of equations describes fish growth and physiology that integrates with flow field data to transport waste from farms, assimilate dissolved nutrients by plankton, and simulate the sinking, deposition, resuspension and mineralization of fish feces and uneaten feed. A mathematical description of fish growth and metabolism consists of a nutrient budget for carbon, oxygen, and nitrogen as determined by the size of the fish, water temperature, oxygen concentration, swimming speed, feed rate and composition. Optimal feeding rates for varying environmental conditions are provided as outputs in addition to all other simulation output data in tabular form.

AquaModel provides a dynamic 4-dimensional display (3D plus time) of aquaculture and environmental processes and resides within our *EASy* Geographic Information System. This GIS was specifically designed for marine applications and provides interfaces to import diverse

types of environmental data including satellite imagery, current meter data, modeled 3-D current data, bathymetry, and coastlines allowing site or regional-specific information to be incorporated into the simulations.

AquaModel has been used to simulate single (near field) and multiple (far field) fish farms over broad areas for 13 separate species of fish including three geographic variations of Atlantic salmon. The model has been validated by comparison to detailed measurements of the growth and physiology of target fish species using extensive laboratory and by use of fish farm field data from several locations around the world.

AquaModel Software: Conceptual Model
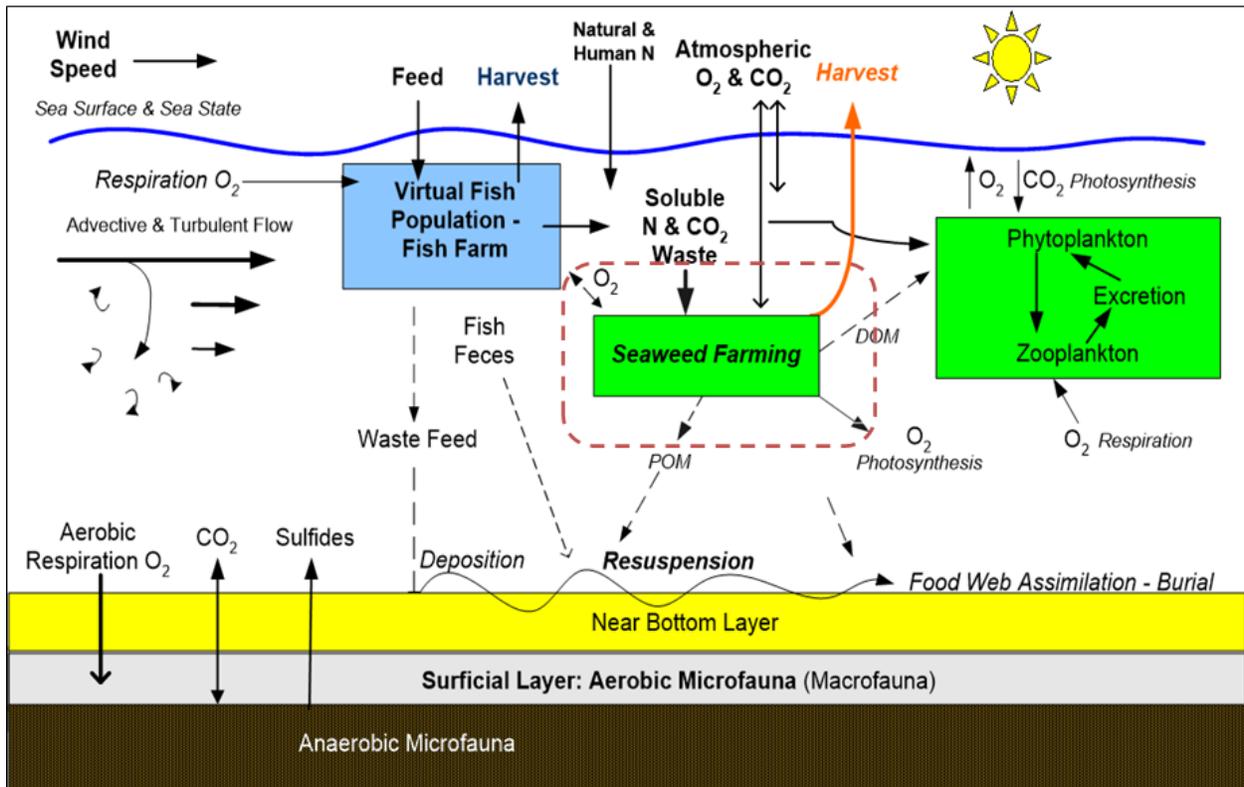
EXISTING CAPABILITIES

Operating Modes

- The AquaModel 2-D mode uses ocean current meter data to represent ocean currents. In this mode the current meter data defines ocean current vectors various depths and times at a single spatial point. AquaModel interpolates this data to match the depth of specified computational arrays for each simulated time step. For a given depth and time the ocean current is assumed to be uniform over the spatial region of interest. This assumption is generally acceptable for modeling a single farm which occupies a relatively small spatial region.

- The AquaModel 3-D mode uses modeled time/depth/spatial data to represent ocean currents. Currently, AquaModel utilizes modeled data provided in ROMS, FVCOM, ECCO2, HYCOM and other formats. The 3-D model provides for modeling of multiple spatially diverse fish farms simultaneously.

Fish Culture

- Simple set up of operations using option menu or by batch using Microsoft Notepad
- Simple creation of new farm projects by using "save as new project" menu driven option, followed by simple process to enter bathymetry from spreadsheet sources as explained in graphic form in Help Manual.
- Pen size, depth, configuration (round or rectangular/square), fish density & size entered by user
- Model calculates exact amount of feed needed for fish size, water temp. and current velocity
- User can specify different feed rates if desired and any percentage of waste feed loss
- Adjustable coefficients for waste deposition, consolidation, and resuspension with defaults
- User can enter current meter and ambient water or sediment data using simple Excel files
- Excel "Events File" used to input timing of fish stocking, harvest, mortality rate, etc.
- All critical settings are adjustable with preferred settings for the twelve different fish species, from tropical to colder temperate regions with validation studies in most cases.
- Species with AquaModel physiology templates modeled at present include:

1. Atlantic Salmon *Salmo salar,* 3 types: west coast North America, East Coast N.A. & Chile
2. Striped Bass (*Morone saxatilis*)
3. Moi (*Polydactylis sexfilis*)
4. Rainbow Trout (*Oncorhynchus mykiss*)
5. Cobia (*Rachycentron canadum*)
6. Longfin Yellowtail (*Seriola riviolani*)
7. Sea Bream (*Sparus aurata*)
8. Sea Bass (*Dicentrarchus labrax*)
9. Atlantic Cod (*Gadus morhua*)
10. Hybrid Grouper (2 species)
11. Lumpfish (*Cyclopterus lumpus* aka cleanerfish)
12. California Yellowtail (*Seriola dorsalis*)
13. Sablefish (*Anoplopoma fimbria*)
Other species added as necessary

Bathymetry

- Create gridded bathymetry arrays from sample specified sample data points.

- Add shoreline from databases or simple spreadsheet lat/long Excel files.
- Interpolates displayed bathymetry from specified contours.
- Reads GEBCO and TCARTA bathymetry data.
- Can merge two sources of bathymetry to fill in missing regions.

Ocean Currents

- Read multi-depth current meter time sequenced data.
- Read ROMS (Regional Ocean Modeling System) imagery.
- Read FVCOM imagery (Finite Volume Community Ocean Model, ungirded data).
- Read HYCOM imagery (Hybrid Community Ocean Model, ungirded data).
- Read DELFT3D output data after standard Matlab conversion to NetCDF format.
- Other 3D circulation sources also supported.
- Spatially and temporally interpolate ocean current data for each computational array cell.

Coastline

- Use coastline data to establish a boundary for dispersion, evection, and drifters
- Read and utilize WDB II coastline data
- Read and utilize WVS coastline data
- Read and utilize Google Earth selected point data
- Read and utilize Arc Info coastline shape data

Exogenous State Variables

- Read and interpolate time and depth dependent exogenous variables including:
    - Ocean Current Direction,
    - Ocean Current Velocity,
    - Deepest Nitrogen,
    - Deepest Oxygen,
    - Irradiance,
    - Mixed Layer Depth,
    - Dissolved Nitrogen,
    - Dissolved Oxygen,
    - Phytoplankton Biomass,
    - Residual Direction,
    - Residual Velocity,
    - Temperature,
    - Total Organic Carbon,
    - Wind Speed, and
    - Zooplankton Biomass.

For expert users and research purposes, many other key components of the aquatic ecosystem may be simulated as follows:

- AquaModel uses 3-D and 2-D computational arrays to model endogenous state variables.
- The program currently models four 3-D and twenty-one 2-D state variable arrays. However, AquaModel is designed to easily accommodate additional state variables and associated interactions as needed.
- The computational array is updated for each simulated time step accounting for ocean current evection, vertical, and horizontal dispersion. The computational time step size is automatically adjusted to account for water velocity.
- Four 3-D computational arrays are used to model:
    - Dissolved Oxygen,
    - Dissolved Nitrogen,
    - Plankton Biomass, and
    - Phytoplankton Biomass (as chlorophyll).
- Twenty-one 2-D computational arrays are used to model:
    - Sediment Aerobic,
    - Sediment Anaerobic,
    - Sediment Average Waste,
    - Sediment Cumulative Waste,
    - Sediment Consolidation Waste,
    - Sediment Consolidation Fractional,
    - Sediment Fecal Waste,
    - Sediment Fecal Fractional,
    - Sediment Feed type #1 Waste,
    - Sediment Feed type #2 Waste,
    - Sediment Total Waste,
    - Sediment CO_2,
    - Sediment Oxygen,
    - Sediment Sulfide,
    - Sediment TOC (Total Organic Carbon),
    - Sediment TOC Rate,
    - Suspended Fecal Waste,
    - Suspended Feed #1 Waste,
    - Suspended Feed #2 Waste,
    - Suspended Total Waste,
    - Suspended Oxygen, and
    - Drifter Spatial Concentration.
- Three transition state variables to model the transfer of feed and fecal waste from specified pens to the sediment layer.

Pen Fish Model Events Input File Components

- Five time-dependent pen event types are used to model fish operations:
    - Pen Feed Rate,
    - Fish Added,

- o Fish Harvested,
- o Fish Mortality, and
- o Fish Pen Transfer.

Current Vector Rose

- A polar vector diagram can be constructed from the current velocity and direction data
- The utility produces a single diagram for current meter driven projects and multiple location diagrams for projects driven by 3D hydrodynamic currents.
- User choice of colors, number of vector division and speed ranges are available.

Simulation Timing

- Two simulation time clocks are implemented to model computational time and display/capture time.
- The computational time clock is variable to account for variations in water velocity.
- The display/capture clock specifies the display and capture update frequency.

Sediment Total Organic Carbon to Total Volatile Solid Conversions

- Some regions use TOC, others use TVS in characterizing organic matter in the sea bed.
- This utility allows for automatic conversion between the two once the local ratio is measured.

Drifter Utility

- This existing system releases particles or dissolved matter from individual pens or farms and transports them using 3D hydrodynamic model currents and can be used for assessing probability of connectivity of individual farms or cages for fish health planning and to assist in carrying capacity estimates.

- Drifters may be deployed to evaluate the dispersion of dissolved or particulate materials including viral or bacterial particles and chemotherapeutants. Three modes are available to specify the source of deployed drifters: pen, array, and specified.
    - o Pen drifters are periodically deployed from each specified pen.
    - o Array drifters are periodically deployed from each cell of a user specified spatial array.
    - o Specified drifters are deployed by specifying drifter location and deployment in an Excel file.
- The user may control drifter characteristics including:
    - o Drifter depth,
    - o Deployment frequency,
    - o Drifter active duration, and
    - o Random dispersion factor.
- Drifter spatial concentration statistics are collected and displayed.
- Drifter motion history may be exported for off-line analysis

Operating Modes

- The AquaModel 'BROWSE' mode is used to preview images, overlays, and profile plots. It is used to explore display and analysis capabilities and to setup selections for the 'SIMULATION' mode.

- The AquaModel 'SIMULATION-CAPTURE' mode simulates state variables as they transition through simulated time. AquaModel state variables are saved to disk at each simulation display step for use in the 'SIMULATION-REPLAY' mode.

- The AquaModel 'SIMULATION-REPLAY' mode replays captured state variable data. This mode is used to review and analyze a previously simulated scenario. Selected results may also be exported in this mode for off-line analysis.

Displays

- The AquaModel plan view display contains a geo-referenced map of a user selected raster image, selected contours, and selected vector overlays (or underlays).
- AquaModel profile views display input or computed state variable data in several formats:
  - Time sequence of a selected state variable,
  - Spatial transact of a selected state variable, or
  - False color image representing a depth slice along a user selected transact.
- AquaModel image statistics includes a capability to display a 3-D perspective view of a user selected image. This perspective view is created using Excel. The plotted data array as well as the 'Chart' of the perspective view may be exported for off-line analysis.

Export and Printing Capabilities

- AquaModel provides for printing of high-resolution graphic images of the user selected plan view display. A title may also be appended to the printed image.
- AquaModel also provides for high resolution printing of selected profile plots.
- Selected graphic images may be exported to image files in various formats including: BMP, GIF, JPEG, PNG, TIFF, and NetCDF.
- Most of the computed result data may be exported to Excel including:
  - Fish pen state variables,
  - State variables at multiple user defined points,
  - Image statistics,
  - Plotted profile data, and
  - Deployed drifter history

  See later section on this for more details.

Critical Factor Analysis

- AquaModel includes a statistical analysis of user selected 2-D sediment, suspended, and drifter computational arrays. For each selected variable the program computes

average, standard deviation, and variance of the computed array values. It also computes the geographic area where the computed value exceeds a user specified critical value. The simulated time series of requested statistics are written to an Excel file for off-line analysis.

Internet Capabilities

- AquaModel projects can be viewed over the internet using the EASy NetViewer capability. The NetViewer allows clients to display and simulate specified EASy projects using standard browsers such as Internet Explorer, Chrome, and Firefox. The latest version of the NetViewer also allows users to view projects using iPads and iPhones. We are currently working on expanding the capability to support Android phones.
- AquaModel also provides for automated downloading and integration of satellite imagery from various web sources.

Contouring Capability

- As described above, AquaModel state variables are calculated in regular 2-D or 3-D spatial/depth arrays. The result values in these arrays can be displayed directly as a color raster image. Optionally, the raster array may be displayed as contours. The current contouring algorithm implemented in AquaModel is relatively simple but can be configured to produce useful and eye-pleasing results.
- Some countries such as Canada require benthic data be represented in contouring mode and the existing utility has been repeatedly used to fulfill the requirements of regulations.

Documentation

- An on-line, interactive, 270-page user manual fully documents the operation of AquaModel.
- A more abbreviated 100-page version is also available for non-modeler users. These documents include:
    - A quick start guide
    - Instructions on building 2-D projects
    - Instructions on building 3-D projects
    - Means to copy projects to a new location
    - Importing coastline data
    - Importing bathymetry data
    - Project file management
    - International computer settings
    - Using multiple scenarios
    - Importing and exporting imagery
    - Settings and output files
    - Data graphic display options
    - Contouring options

- o   Current vector rose utility
- o   Special tools
- o   GIS setup

Seaweed AquaModel

We have completed coding and development of a sugar kelp growth model to allow kelp aquaculturists to plan density of grow out without exceeding availability of dissolved inorganic nitrogen and sunlight availability. The model has been tested and validated using an actual kelp farm in Puget Sound. We may seek to add new kelp species and red algae species like *Gracilaria* spp. The program also calculates the degree that seawater is sweetened in terms of increasing pH to help mitigate the adverse effects of ocean acidification.   Seaweed AquaModel is actively being calibrated and validated over the next 1.5 years in cooperation with NOAA, Puget Sound Restoration Fund with funds from the Paul Allen Foundation and the U.S. Navy.

AquaModel Export Capabilities

AquaModel can export simulated properties in Excel, NetCDF, or picture formats. Simulated properties of farms, pens, and capture points can be exported to Excel. User configured summary array statistics can also be exported to Excel. Finally, user selected spatial images of simulated properties can be exported to NetCDF formatted files.

Farm properties that can be selected for export to Excel include:
- Surface Current Velocity
- Surface Current Heading
- Bottom Current Velocity
- Bottom Current Heading
- Total Biomass
- Drifter Concentration

Pen properties that can be selected for export to Excel include:
- Surface Current Velocity
- Surface Current Heading
- Pen Center Current Velocity
- Pen Center Current Heading
- Bottom Current Velocity
- Bottom Current Heading
- FCR
- Feed-1 Used
- Feed-2 Used
- Fish Biomass
- Fish Harvested
- Fish Mortality

- Fish Nitrogen
- Fish Weight
- Growth Rate
- Oxygen Concentration
- Nitrogen Concentration

Simulated ocean properties for user defined capture points (latitude, longitude, and depth) that can be selected for export to Excel include:
- Surface Current Velocity
- Surface Current Heading
- Cell Current Velocity
- Grid Cell Current Heading
- Bottom Current Velocity
- Bottom Current Heading
- Oxygen
- Nitrogen
- Phytoplankton
- Zooplankton
- Cell State
- Average Drifters
- Suspended Fecal
- Suspended Feed-1
- Suspended Feed-2
- Suspended Oxygen
- Suspended Total
- Sediment Fecal
- Sediment Feed-1
- Sediment Feed-2
- Sediment Consolidated
- Sediment Total
- Sediment Toc
- Sediment Toc Rate
- Sediment Aerobic
- Sediment Anaerobic
- Sediment Oxygen
- Sediment CO2
- Sediment Sulfide

Summary statistics can be selected by the user and exported to Excel. These statistics identify the area or ocean volume where calculated properties exceed user specified limits (e.g. sediment region where CO_2 exceeds a user specified value). Statistics can be configured for the following properties:

- Nitrogen Concentration
- Oxygen Concentration
- Phytoplankton Concentration
- Sediment Aerobic Organisms Biomass
- Sediment Anaerobic Organisms Biomass
- Sediment CO2 Concentration
- Sediment Consolidated CO2
- Sediment Fecal Concentration
- Sediment Feed-1 Concentration
- Sediment Feed-2 Concentration
- Sediment Total CO2
- Sediment Oxygen Concentration
- Sediment Total Sulfide Concentration
- Sediment TOC Concentration considering resuspension, transport and oxidation
- Sediment TOC Delivery Rate to the Bottom (without resuspension, required in Canada)
- Suspended (Near Bottom) Fish Fecal Concentration
- Suspended Feed-1 Concentration
- Suspended Feed-2 Concentration
- Suspended Oxygen Concentration
- Suspended Total CO2
- Zooplankton Concentration
- Drifter Average Concentration

Selected AquaModel spatial images can be exported to NetCDF file format[1]. The user first configures AquaModel to export selected spatial images. Individual images or the series of all simulated images may be selected.

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[1] 3D circulation data is also imported into AquaModel as a succession of high-resolution imagery data (vectors) in a spatial domain that is converted to numerical data.
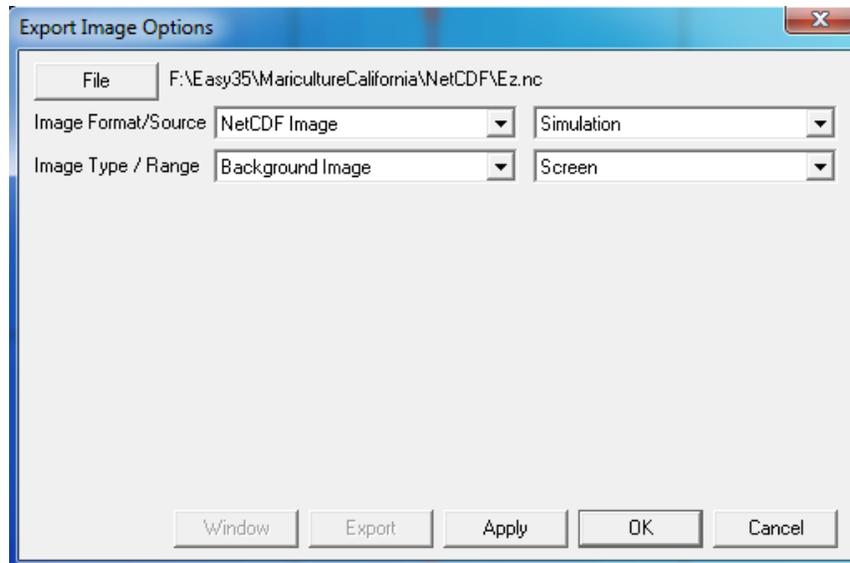
The user selects the type and depth of the AquaModel image to be displayed during a simulation run (e.g. array nitrogen at 5-meter depth overlaid by ocean current vectors shown below).
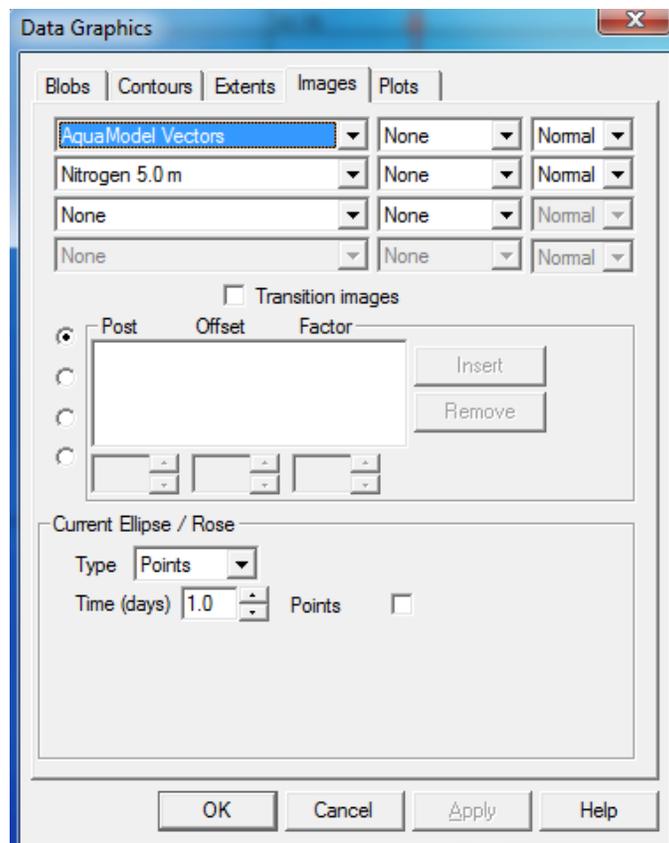
The user then runs the AquaModel simulation.
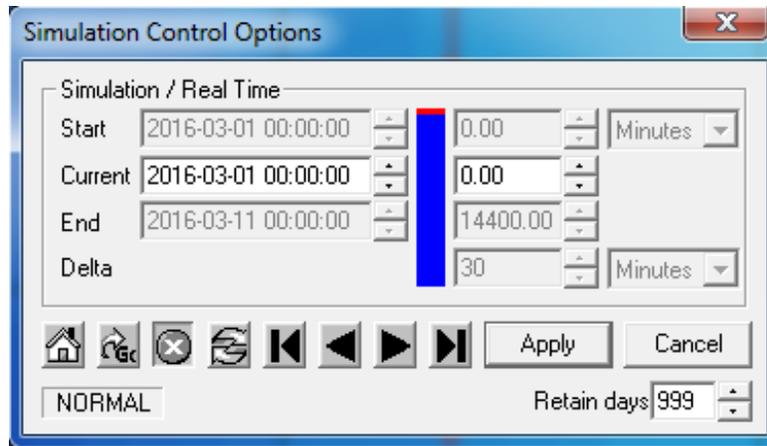
Simulated images are automatically written to a series of NetCDF files (one for each simulated time step).

For example, the two screen prints below show a time step of the RCF (Hubbs-SeaWorld) project and secondly the resulting NetCDF files beginning to accumulate.
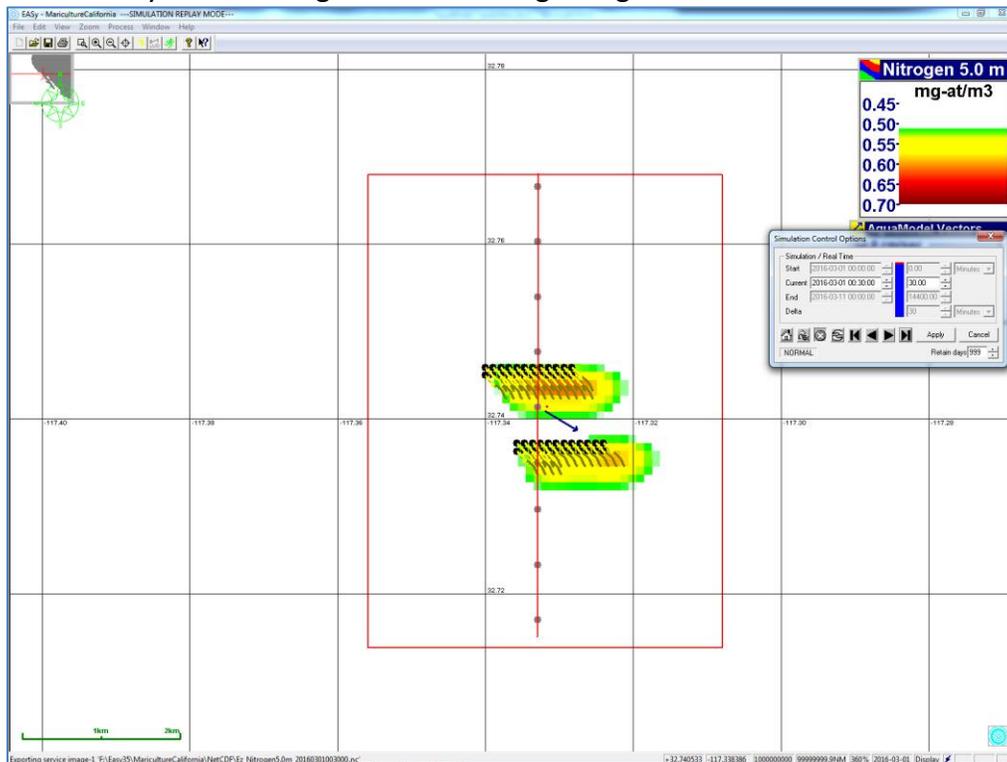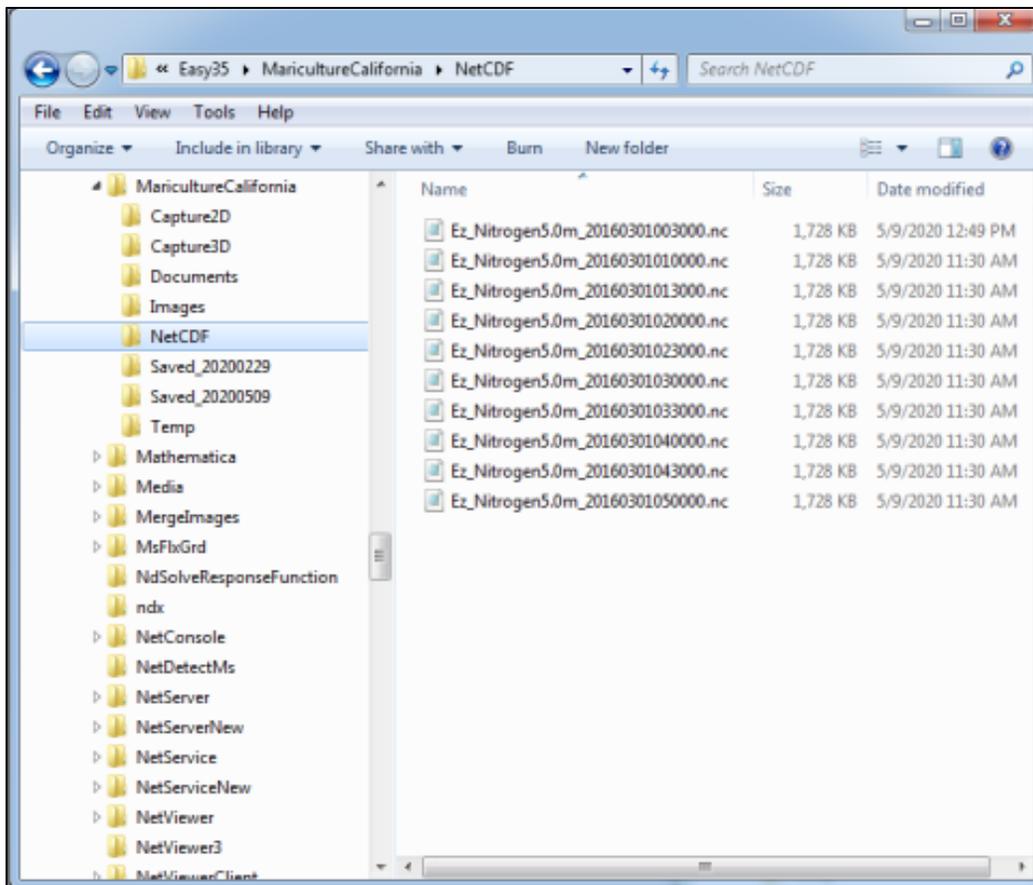
Drifter Capabilities: Tracking of pathogens and dissolved substances

AquaModel can deploy virtual objects that drift with simulated ocean currents to represent distribution of particulate matter of any kind such as pathogens or non-sinking or un-dispersed pollutants. Soluble matter can be represented by adding additional factors needed that mimic existing nitrogen distribution algorithms, with or without attenuation forcing factors. See the separate 2018 report on ammonia discharge and model validation completed at Blue Ocean Aquaculture in Hawaii for extensive details on the effectiveness of this system (Rensel 2018).

These drifters can be deployed from
1) farm pen sites (pen drifters),
2) from a specified array of cells (array drifters),
3) or from a list of user specified points (user drifters).

AquaModel drifter algorithm ensures that drifters DO NOT cross onto or over land. When currents are directed toward land, drifters stop at the oceans edge. If the currents direction changes away from land, then the drifters proceed back into the ocean.

AquaModel drifter properties include:
- Drifter type (pen, array, or user described above)

- Release frequency
- Position update increment
- Drifter duration (e.g. half-life or other temporal requirements)
- Random dispersion velocity (diffusivity)
- Array resolution (i.e., grid size)

The location of each deployed drifter is displayed as an overlay during an AquaModel simulation run. A false color image representing the spatial concentration can also be displayed. Drifter locations can also be exported to an Excel file if requested by the user. Additionally, multiple types and colors of drifters may be defined to simultaneously represent concentrations of different soluble pollutants or components.

AquaModel pen and array drifters are defined with the AquaModel drifter options dialog box shown in the first screen print below.
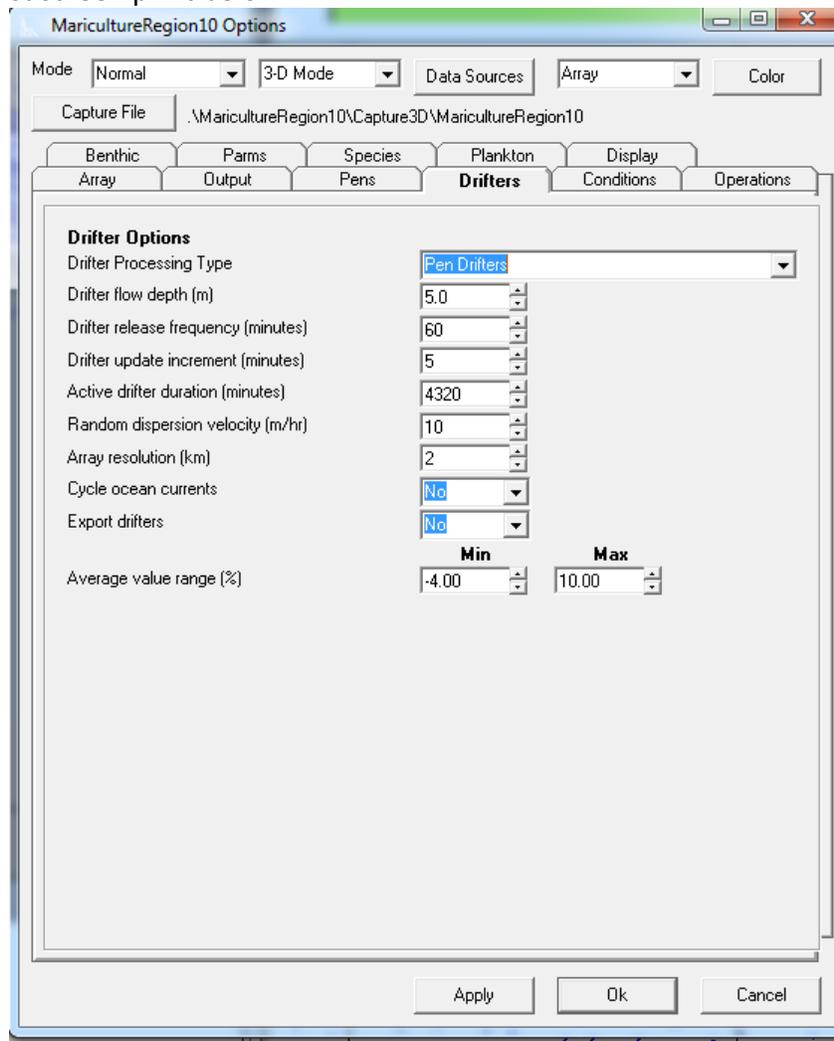
Currently AquaModel user drifters are defined in an ASCII text file as shown in the example below although we plan to add user drifter data to the drifter options dialog box in future versions of AquaModel.


```
DISCODrifters.txt - Notepad
File  Edit  Format  View  Help
* Type        Latitude   Longitude Depth Size Color       Freqency Duration Date       Time
Simulation 24.479792 56.683957 10    5    DkRed       60       129600
Simulation 23.779894 57.985607 20    5    DkGreen     60       129600
Simulation 23.641692 58.410581 30    5    DkBlue      60       129600
Simulation 23.250602 58.973981 40    5    DkCyan      60       129600
Simulation 19.661442 57.759650 50    5    DkMagenta   60       129600
AtTime     19.661442 60.010000 60    5    Black       60       129600   2017-09-12 07:08:09
```

AquaModel drifters have been used for two different purposes: 1) to represent **sea lice distribution** that may emanate from fish pens and 2) to represent pollutants that may emanate from industrial outflows such as desalination plants.

For one study with sea lice, the study area was in the near the Strait of Ancud in the Chilean Inland Sea. There are fish farms virtually everywhere in this region and two of these large farms were selected for study with collaborating Chilean Government scientists. The first image below shows oxygen, nitrogen and phytoplankton simulated effects with current vectors on the flood tide (Pacific Ocean offscreen to the left).

Example AquaModel 3D Application: Chiloé Inland Sea
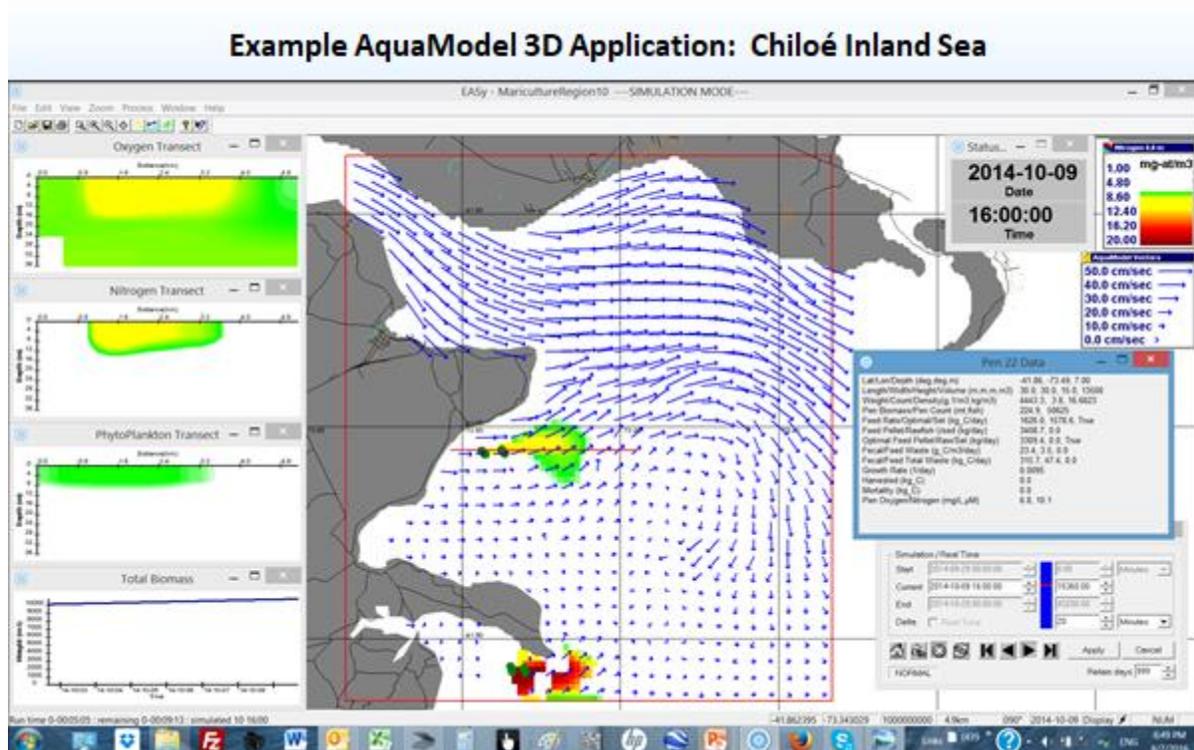
In the first two images below, the red dots are drifters that are released periodically from each of two large salmon net pen sites with 48 large cages each, but shown only as two of many time

steps, one early on, the other midway through the simulation. Inclusion of other non-related inset plots demonstrates that such analyses can be run concurrently with regular water and benthic column modeling.
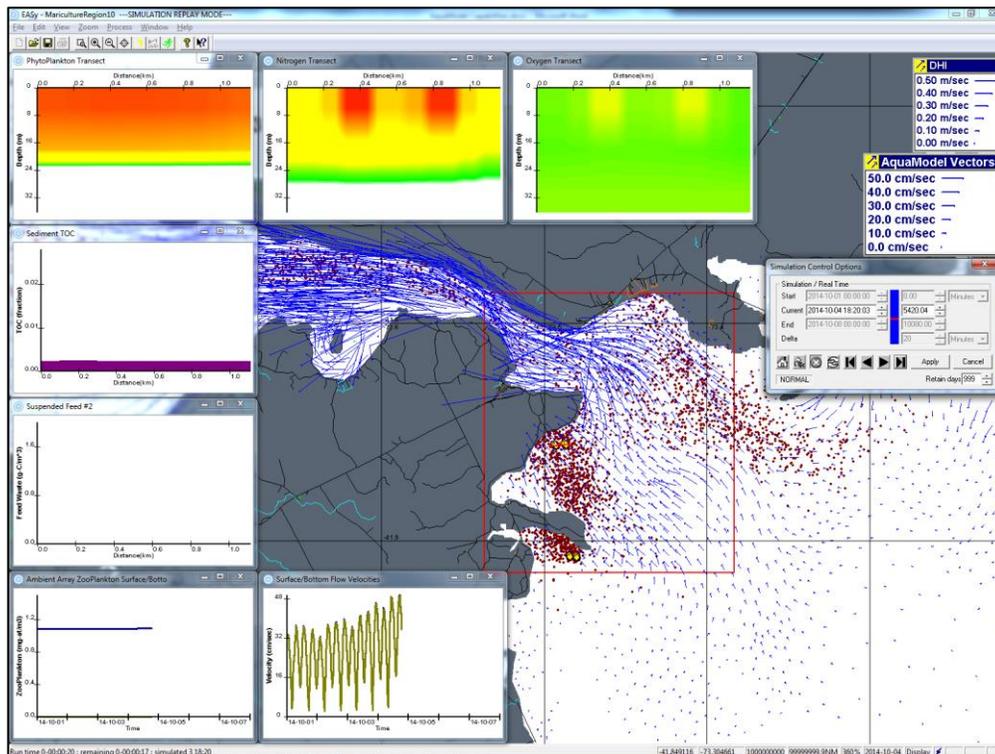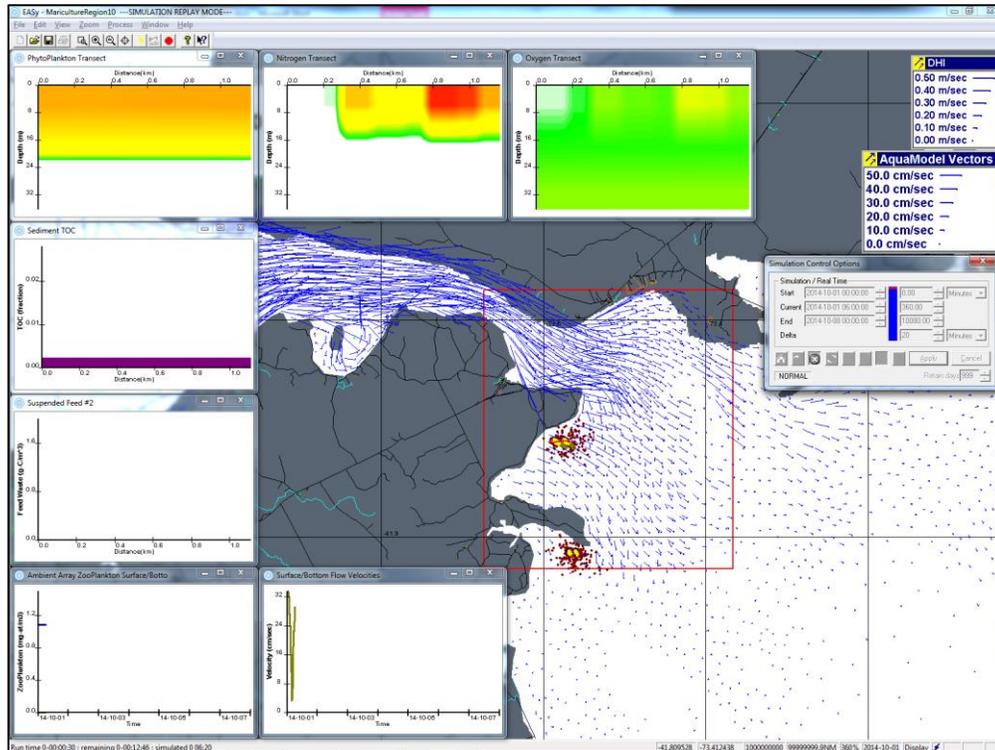
After this work in the Chilean Inland Sea, we coded to allow for color-code the tracers from separate sources. But even without separate colors, a casual inspection of the model replay shows that the southern cages' tracers mostly flow through the northern cages that can be seen in the second image above. Further quantitative analysis of the distribution and frequency of occurrence can be estimated using existing image interrogation and statistical tools already present in AquaModel (i.e., image statistics tool). The results showed that the exceptionally large farms presently used often had serious interactions due to the proximity of fish (and mussel) farms to each other. Government and industry knew this was occurring, but we quantified it to allow for re-design of net pen farm siting if the political processes would allow it. To handle therapeutants, some additional minor changes will be necessary, but this will be simple to do. Additionally, the Brits have had standalone models for this that are open source in the past that illustrate approaches that can be used.

A second example project shows drifters emanating from outfalls of five different desalination plants in Oman from a study presently underway. Oman is bisected by the UAE, hence the northern and southern locations in the Arabian Sea. Like the prior two screen shots, the first is early on in a time series, the second is later in the simulation. In this case, several different pollutants are represented in different colors and demonstrated quite different spatial distribution.
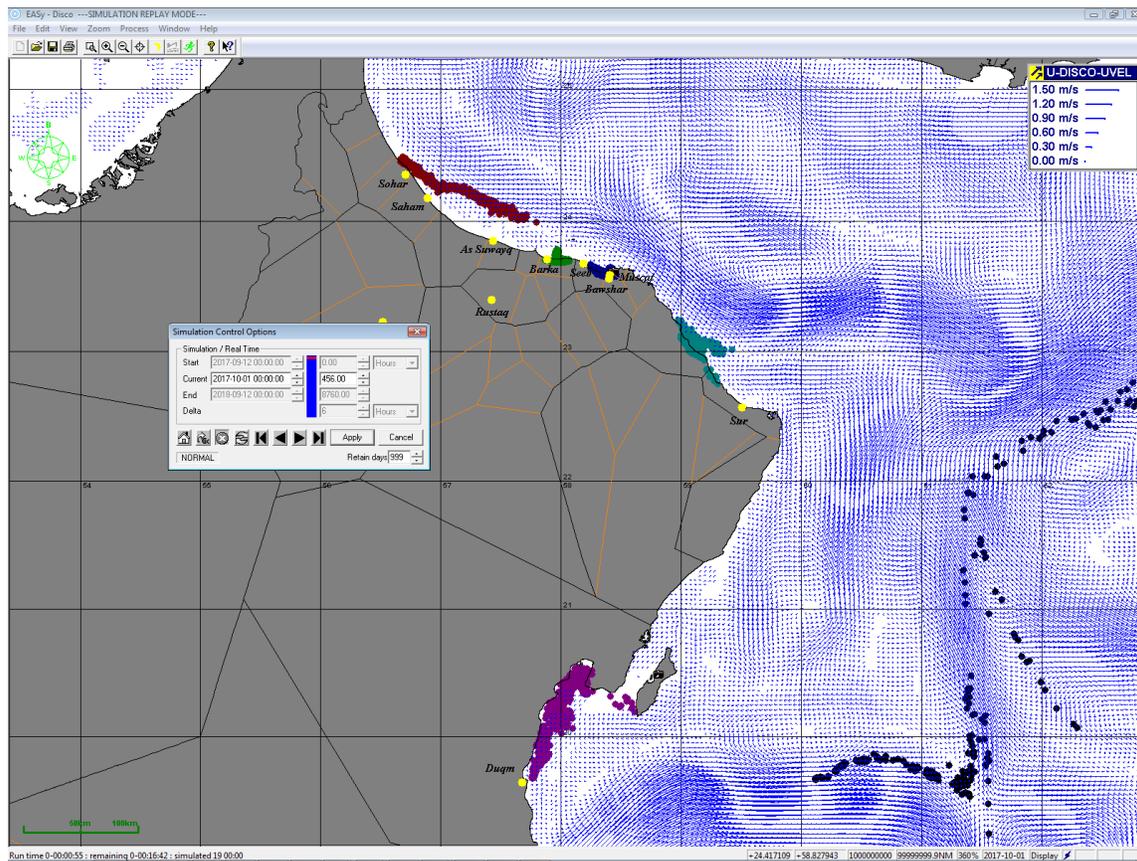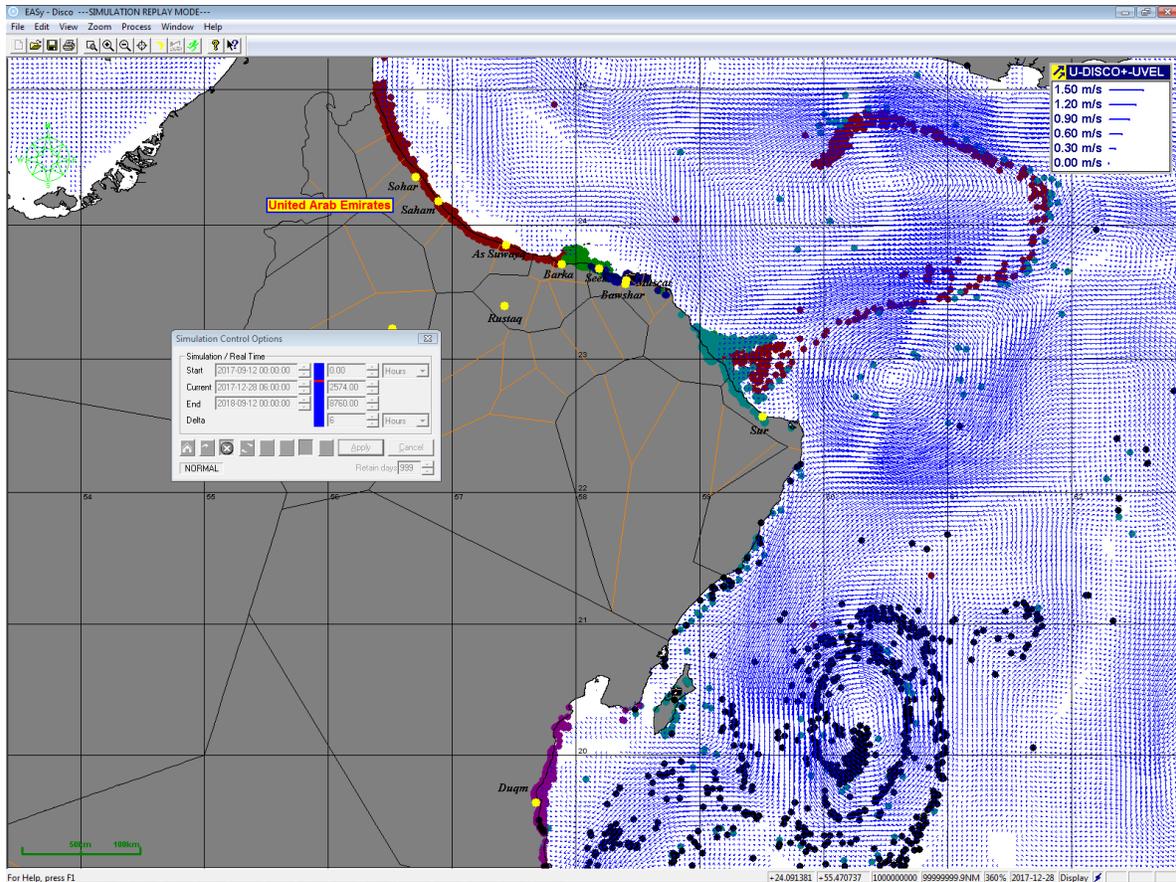
The above is just a brief overview of drifters used in AquaModel and related projects in recent years. In other EASy software projects, we have conducted we extensively use drifters for a variety of reasons with a suite of analyses tools that could be brought into AquaModel if needed.

For example, the plot below is of the equatorial Eastern Pacific Ocean showing virtual drifters along the upwelling equatorial zone and where tuna fishers congregate in El nino and La nina periods. The need was to understand the physical and biological factors controlling the fish populations and recruitment as well as patterns of catch to avoid overfishing. We used ocean circulation models, logbook data from fishers, satellite imagery for water temperature and chlorophyll and other data in this regard.

The first image shows the el nino period with strong upwelling that occurs north and more so south of the equator along the North and South American coasts, respectively. Note the differences in the equatorial countercurrent on both sides of the equator and resulting dispersion of the fleet and fish further north and south. In La nina, the opposite occurs with the upwelling more centralized with the fish, fleet and upwelling along the equator and using time series analysis and a number of statistical tools (third image below), the patterns were identified and quantified for use by InterAmerican Tropical Tuna commission for their

management and stock recruitment purposes. This project relied on our software that is within the same EASy structure.
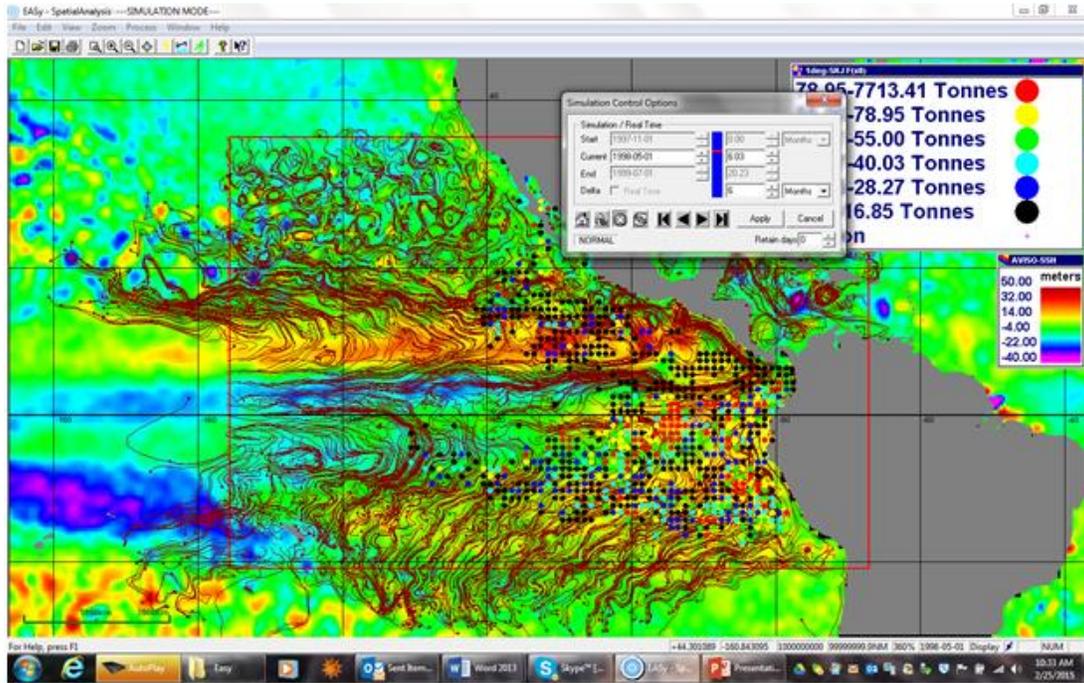
El Nino 11/1/97-5/1/98 SKJ PS Catch, ECCO-2 Drifts, AVISO SSH (5/1/98)
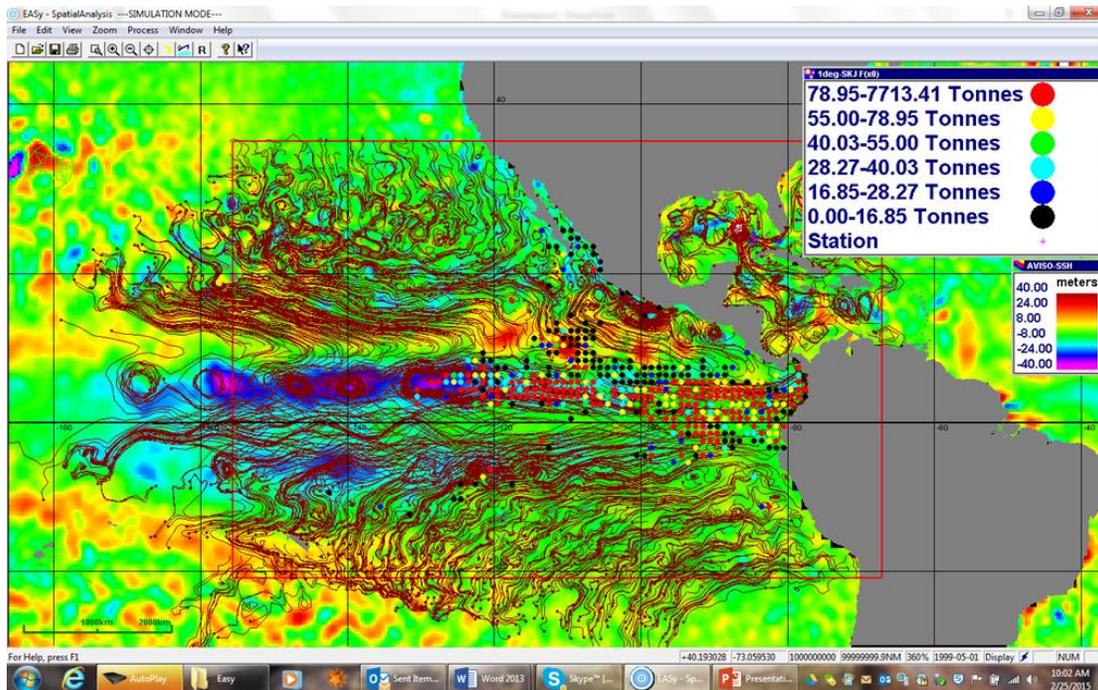
La Nina11/1/98-5/1/99 SKJ PS Catch, ECCO-2 Drifts, AVISO SSH (5/1/99)
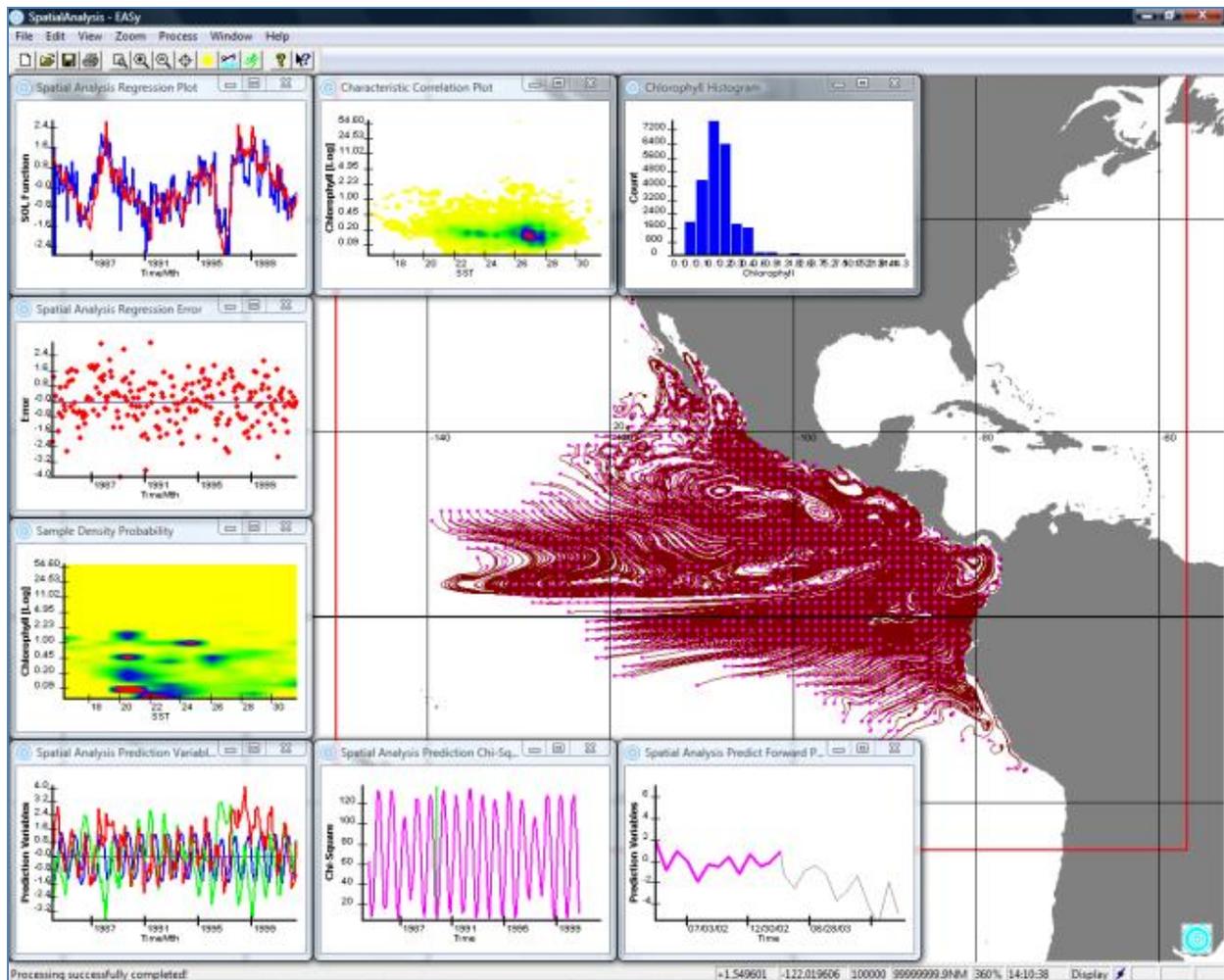
Above: some of the tools used in drifter tracking analysis of ocean currents accessible with EASy companion software to AquaModel.

Ongoing Development

NVDIA Multiprocessing

As described above, AquaModel uses 2-D and 3-D arrays to model the transition and interaction of state variables. Generally, the program applies the same algorithm to each cell in a specified array for each simulated time step. Using high-end NVIDIA display cards is should be possible to significantly improve model runtime by using separate card processors (cores) to apply the algorithm for each cell. NVIDIA display cards include as many as 5760 separate cores.

In early 2017, we developed a partially working prototype that used this multiprocessing approach. This prototype would need to be upgraded to include recently added AquaModel algorithms. The completed prototype would then need to be tested and a timing analysis conducted to estimate the cost/benefit of this approach using NVIDIA cards with various speeds, number of cores, available memory, and price.

Sediment Sulfide Concentration Estimates: Presently a beta sulfides system correctly shows that the current regime rapidly affects surficial concentrations of total sulfide in the sediments. To increase accuracy, we have planned a relatively simple modification of the sediment diagenesis system based on the latest doctoral dissertation work. We have the information and the means to alter the existing algorithms and allow for validation using either total sulfide or free sulfide estimates.

Exogenous Point Sources

AquaModel exogenous variables are used to define ambient water conditions. For example, a time sequence of values may be used to describe ambient oxygen concentration for various depths. AquaModel uses this data to define oxygen concentration that enters a computational array from upstream, as well as to calculate dispersion from array boundary cells. It is currently assumed that the same ambient water conditions apply to all computational array boundary cells.

The addition of point sources would allow modeling of conditions where ambient variable were non-uniform for all computational boundary cells. This capability would be especially useful if for aquaculture farms near or in rivers or industrial plants where water conditions might be significantly affected by run-off.

Use of Data from Multiple Current Meters

As described above, AquaModel currently provides two operating modes: 2-D and 3-D. The 2-D mode currently uses a single current meter to represent ocean current flow. As a result the current flow is assumed to be uniform over the spatial region of interest. This is generally acceptable for modeling a single farm which occupies a relatively small spatial region. Where the current is not uniform (such as for multiple farm analysis), AquaModel provides a 3-D operating mode. This mode uses modeled 3-D ocean current data (such as ROMS, FVCOM, ECCO2, DELFT3D or HYCOM). This data provides a full time/ depth/spatial representation of modeled ocean currents. The source of 3-D modeled ocean current data is not always readily available. An alternative approach would be to provide a third mode that would interpolate data from multiple current meters when 3-D model ocean current data is not available.

Embellishment of Drifter Utility

We have planned embellishments of the system to automatically record "hits" of particles on separate farms and to port all the data out in ascii form for use in other programs including GIS and contouring programs like Golden Software's Surfer or within the ESRI Arc-GIS system.

Porting of Output Data

AquaModel generates a huge amount of information for every time step that can be displayed and with some additional effort, we can provide a system for users to port selected types of data for useful output and separate analysis.

Point Source Nitrogen Input Utility:

To allow users to add major riverine, wastewater treatment outfall or similar sources of nitrogen to account for these major sources in the multiple farm model being used for carrying capacity estimates.

Modify "Image Statistics" Utility for Other Parameters other than bathymetry

The existing utility allows the user to view a 3D "surface" map of the sea bottom with several filters such as parsing of depth minimum and maximum.   The charts are then export and further analysis of 3D bathymetry images in Excel.   This utility could be applied to any of the 50+ other parameters utilized in the model. Examples would be sediment TOC and sulfides and water column oxygen and nitrogen around cages at a given depth.

New Fish Species

We have information to validate sablefish respiration and nitrogen excretion and the means to obtain current growth rate estimates that would allow us to construct a physiology submodel for this species. Other species could be added too, such as red drum.