

Toward a 3-D Coupled Bio-Physical Model for the Ecosystem in Prince William Sound, Alaska

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Before moving to IARC, I was involved in the EVOSTC-sponsored SEA (Sound Ecosystem Assessment) Program from 1995-1997, conducting a 3-D numerical simulation of Prince William Sound (Wang et al. 1997; Mooers and Wang, 1998), working with principal investigators from PWSSC and UAF. After I moved to IARC-IMS/UAF, I was able to continue conducting project entitled “3-D seasonal PWS circulation under forcing of freshwater runoff of a line source” (Wang et al., 1999) during 1998, under the sponsorship of Oil Spill Recovery Institute (OSRI), granted by the OSRI director, Dr. Gary Thomas and the OSRI Board Committee.

Since June 1999, I, again with the sponsorship of the OSRI (Board Committee), was funded (multi-years) to further conduct the coupled bio-physical model in PWS, based on the previous 3-D physical only model. This project is underway. By the end of first fiscal year (May 2000), I

would like to take this opportunity to acknowledge support from OSRI led by Dr. Gary Thomas and its Board members and to introduce the public what I am doing.

Why do we need a numerical model of PWS (the ocean)? First, field observation is important to measure and record what is really going on in PWS (Vaughan et al. 1997), such as water temperature, salinity, density, water current, tide heights, etc. However, with limited funding, observation arrays usually cannot cover entire PWS. In other words, the resolution is not enough to reveal what we really need to explain physical and biological processes in PWS. Thus, a 3-D, time-dependent numerical model appears to be essential tool to explain dynamic processes in the time and 3-D space domain, based on the validation with the observations. Second, the 3-D numerical model can predict some phenomena that observations may miss due to the coarse resolution, and then, in return, provides the information to guide the field observation. Third, the 3-D numerical model will be used, together with the data assimilation (Wang 1999, 2000), to nowcast and forecast the physical and biological processes (such as possible oil spill event, phytoplankton and zooplankton blooms) in PWS, which is one of the most important goals of OSRI and its Board Committee. This is the goal to which I am committed and working hard together with my colleague and the OSRI director Gary Thomas and its Board members.

How will a model prediction help us in a possible future oil spill? Alaskan residents and PWS and neighboring community have suffered from the EVOS (on March 24 1989) for more than ten years now and expect such an event will never occur again. How about it really happens? If it does, can we predict the oil spill trajectories and concentration? The answer is positive. For example, suppose that an oil spill occurs at Hinchinbrook Entrance, can we know the fate of the oil spill 25 days later? The answer can be demonstrated in Fig. 1, which shows that the high concentration (ranging from 0 to 100) retention zone is in both western and central-eastern Sound after 25 days. Actually, the model is user-friendly designed to release an oil spill event at any location in PWS. This 3-D PWS circulation model with prediction capability of oil spill exists and has been running at the IARC-IMS/UAF after four-year EVOSTC support (1995-1997) and two-year OSRI sponsoring effort (1998-present). This three-dimensional model may be the first one in PWS.

Fig. 1. The fate of a hypothetical oil spill occurring at Hinchinbrook Entrance after 25 days' spill.

We are not satisfied with physical-only PWS model, as Dr. Gary Thomas, the director of OSRI, expects. EVOSTC supported Dr. Dave Eslinger to set up a 1-D ecosystem (nutrient, phytoplankton, zooplankton, and detritus) NPZD model (Eslinger et al. 1999) during the SEA (1994-1998). After the SEA, OSRI Board Committee continued to sponsor me to continue the 3-D coupled bio-physical model in PWS. The present model has the following features:

- NPZD biological model (Eslinger etc., 1999)
- Imbedded with a mixing layer model
- Grid: horizontally 1.2km; vertically 3m.
- Time step: 1 hour for biological model; 100 second for physical model.
- Using half-hourly PWS buoy data (wind, air temperature and sea surface temperature) to calculate sea surface heat flux in 1996.

The cycle and interactions among four components of the model can be shown in Fig. 2.

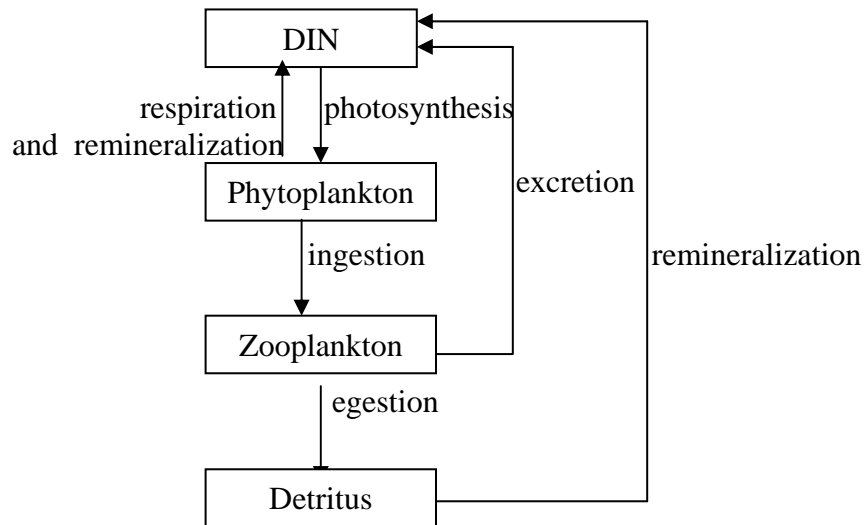


Fig 2. Biological cycle between the components in the model

We start to simulate the 1996 spring bloom as the first case that was presented at the Ocean science Meeting, San Antonio January 25-19, by Jin and Wang (AGU Abstract). Figure 3 can summarize the simulated time series of the upper 25m-averaged N, P, Z, and D, which are consistent with the SEA observations.

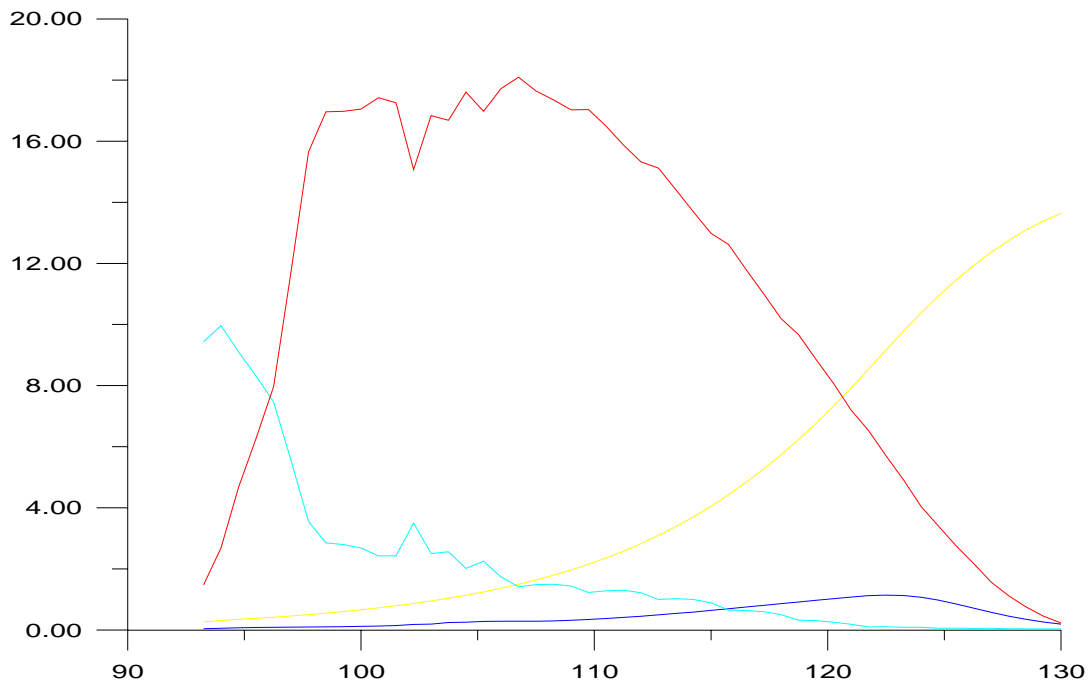


Fig 3. Time series of simulated upper 25m-averaged Chlorophyll (red), Nitrate + Nitrite (green), Zooplankton (yellow) and Detritus (blue) concentration of PWS. The x-axis denotes the day of the year 1996, while the y-axis denotes the concentration.

Figure 4 shows a south-to-north transect of nutrient from Hinchinbrook Entrance (south) to the lower Valdez Arm (north), at about 213.2 E (or 146.8W) on days April 08 (upper panel), April 12 (middle), and April 13 (lower), 1996 during s passage of a synoptic storm. We can see that the nutrient was low in the Central Sound on April 8. Excited by a passage of storm, the nutrient bloomed in the surface layer and mixed down by the wind (middle). One day later (April 13, lower panel), the upper layer nutrient returned to its pre-storm conditions. We can see the important wind forcing and the spatial structure that was missed by the 1-D model.

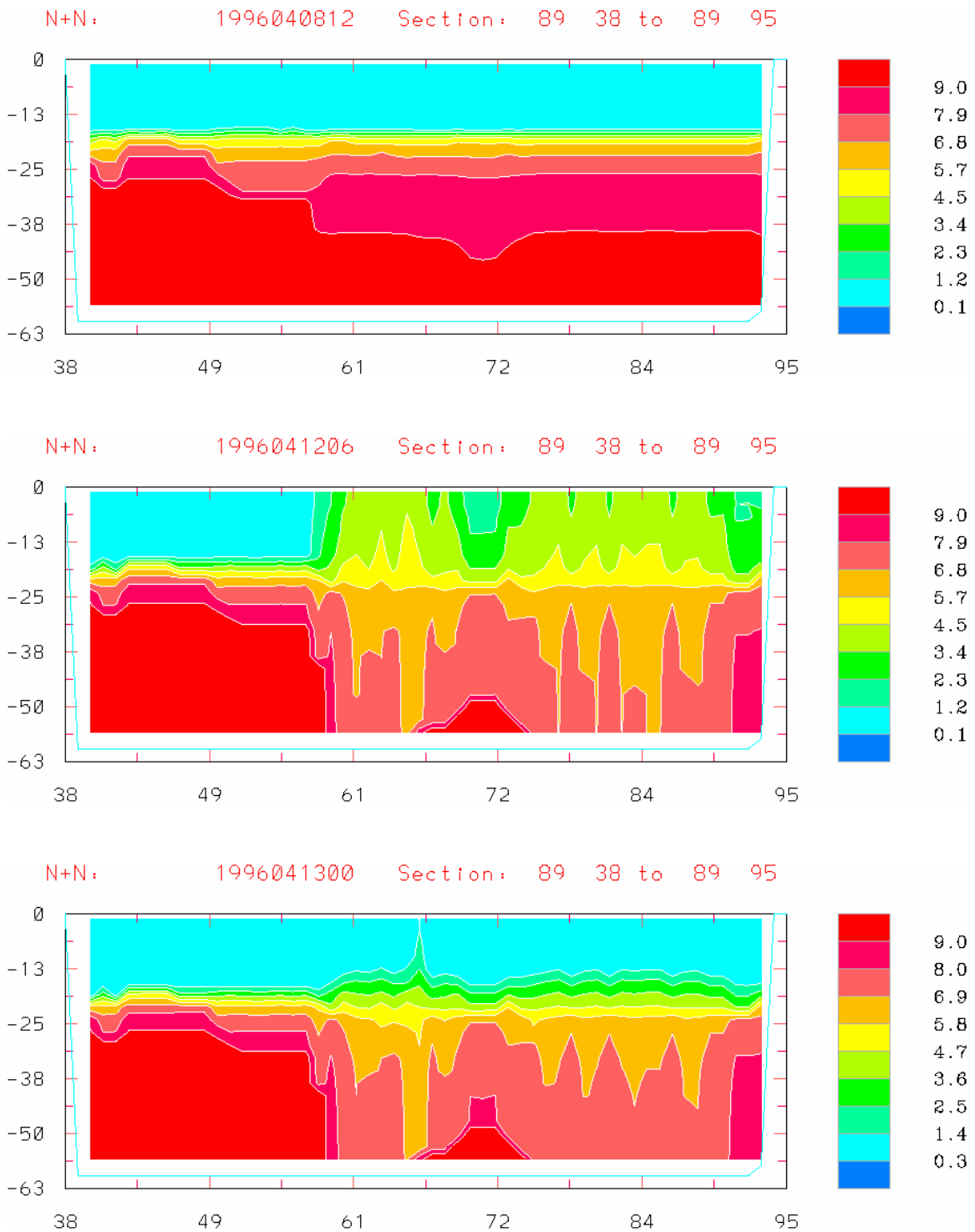


Fig. 4. A south-to-north transect of Nitrate + Nitrite concentration on April 8 upper panel, pre-storm), April 12 (during the storm passage, middle), and April 13 (after passage of the storm, lower).

From this coupled bio-physical modeling exercise, we learn the following:

- 1) The model exhibits a spring phytoplankton bloom, which is a feature of a steadily repeating annual cycle of plankton population in PWS.
- 2) The bloom starts from sea surface warming and stratification and ends from surface nutrient limitation.
- 3) The bloom starting and ending time and the intensity of the bloom fits well with observations.
- 4) The western Sound bloom starts and ends earlier than east Sound. The intensity in the east Sound is stronger. Circulation pattern affects the plankton distribution.
- 5) 3-D model will further be used to investigate the impacts of GOA water inflow/outflow, freshwater runoff etc. on the plankton population.

In summary, this coupled bio-physical model will be further developed and be validated against the observations under the sponsorship of OSRI. The 3-D ocean-only model and oil spill model will be first transferred to PWSSC to set up a nowcast/forecast system (NFS) in PWS. Then, with the bio-physical model further refined, the coupled model will be moved to PWSSC, Cordova to be incorporated in the NFS. The real-time N/F System will automatically run the model and put the prediction information in the web that the planners and oil spill responders, as well as the interested public can access in a real-time manner. The NFS will probably take about 2 years to implement in PWS, depending on the postdoctoral researcher hired and a computer system readiness in Cordova.

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