# EFDC_DSI_OMP White Paper

## Introduction

Dynamic Solutions-International (DSI) is continually upgrading the multi-threading capabilities for EFDC_DSI to provide remarkable improvement in model run times. Depending on the computer software and hardware used to run the model, multi-threading can have a dramatic effect on the application speed. DSI’s EFDC_DSI_OMP now consistently produces **run times up to 4 times faster** on a six core processor than the conventional single-threaded EFDC model (EFDC_DSI_SGL). Multi-threading is an optional extra with any purchase of EFDC_Explorer FULL Version.

## What is OMP?

Open Multi-Processing (OMP) is an API designed to facilitate the use of multithreaded programming. It does this by creating and synchronizing threads automatically at your command. OMP is an unofficial standard for FORTRAN, and is supported by IBM and Intel amongst others. Both Microsoft and Intel's most recent compilers provide excellent support.

With OMP the compiler is informed that a section of code may be parallelized through use of certain directives. The compiler is then able to generate an application that consists of a single thread, which forks into several threads for a parallel region; these threads are then synchronized and all but one terminate at the end of the parallel region as the program execution reverts to a single master thread.

## OMP Testing

It is DSI's commitment that the EFDC_DSI_OMP models produce exactly the same results no matter how many threads are used. To test this DSI, routinely runs a range of EFDC example problems with different sub-models activated. We then run these models with a range of threads from 1 (referred to as "OMP1") to 16 threads (OMP16). As described in detail at the end of this paper, model comparisons demonstrate model differences are equal to zero i.e. model results are exactly the same, within model precision.

## How fast is OMP?

The Intel® runtime library binds OMP threads to physical processing units. Depending on the machine topology, application, and operating system, thread affinity can have a substantial impact on the application speed. DSI typically produces **run times up to 4 times faster** on a six core processor than the conventional single-threaded EFDC model. The figure below shows the speed gains from one processor (OMP1) to six processors (OMP6) for various computational groups in an EFDC model setup for the Sacramento-San Joaquin Delta. As can be seen in the first column, "Elapsed Total", overall run times are now up to 4 times faster with 6 threads than what they were running a single thread. See below for a detailed description of each computational group.

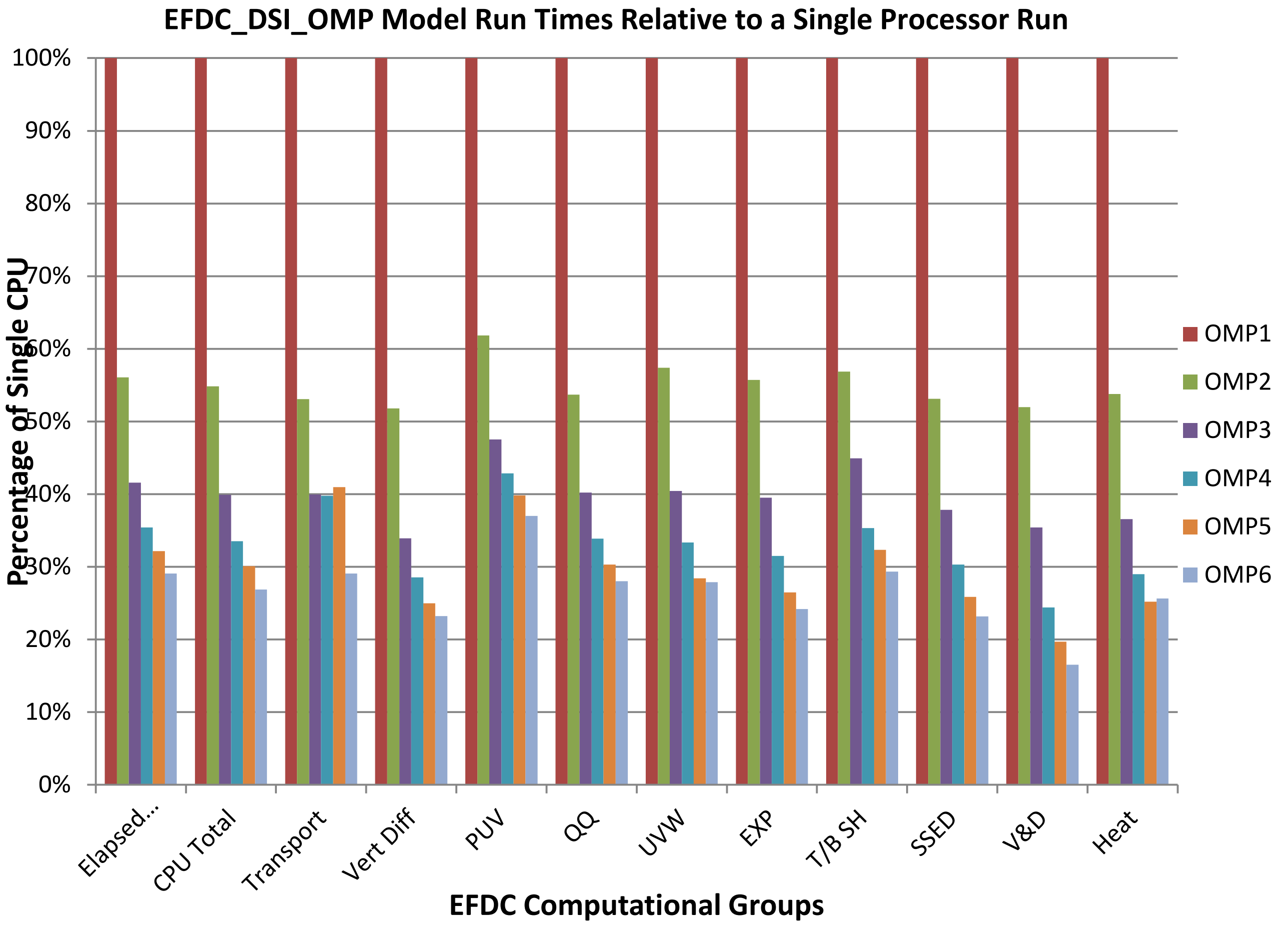


**Figure 1 EFDC_DSI_OMP Model Run Times Relative to a Single Processor Run.**

Note that the **computational groups**, or sub-models, within EFDC have been individually timed in order to track the internal process that uses the majority of the run times. The sub models shown here are:

- **Elapsed Total** = total elapsed time;
- **CPU Total** = total CPU time;
- **Transport** = advective transport calculations;
- **Vert Diff** = vertical diffusivity calculations;
- **PUV** = pressure fields for 2D solution of water surface elevation;
- **QQ** = turbulence intensity;
- **UVW** = internal mode momentum calculations;
- **EXP** = explicit terms in momentum calculations;
- **T/B SH** = top and bottom shear calculations;
- **SSED** = sediment transport calculations;
- **V&D** = horizontal and vertical diffusivity calculations;
- **Heat** = heat transfer calculations.

### OMP testing with the 3-D Hydrodynamic Model of the San Joaquin Delta

The graphic in Figure 2 came from the EFDC model of DSI's 3-Dimensional hydrodynamics and sediment transport model developed for a study of the Sacramento-San Joaquin Delta. The model was calibrated with measured flow, salinity, water temperature and total suspended solid data from more than ten stations in the Delta.

With 11,708 horizontal cells and four vertical layers it is a sophisticated structured grid representation of this highly complex waterbody. Simulated parameters included five river bed layers with morphology changes during calculation. The results provide information on the nature and location of deposition or erosion in the system. The model serves as a basis for advanced watershed management, ecosystem restoration, water storage, water quality planning and management supply.

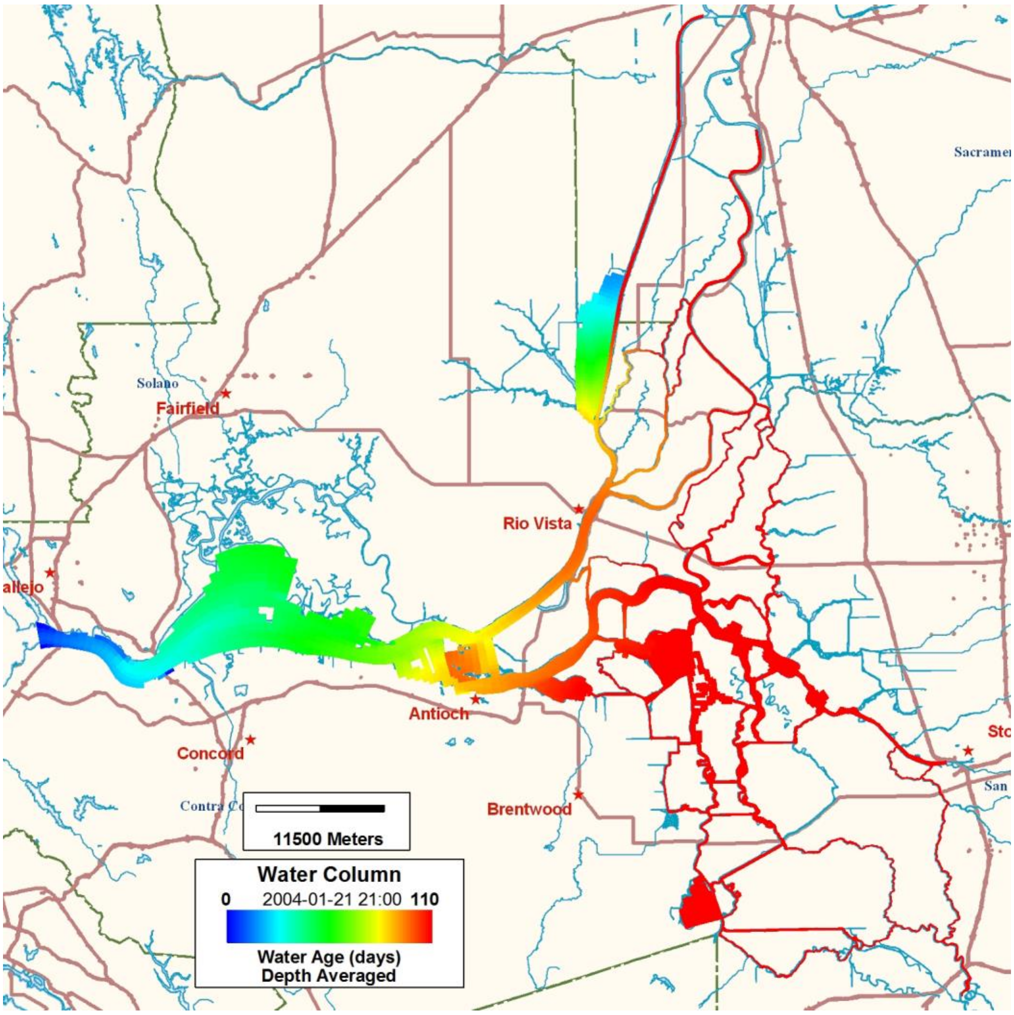


**Figure 2 Sacramento-San Joaquin Delta Model for which EFDC_DSI_OMP was implemented.**

## OMP testing for varying numbers of threads

As discussed earlier, DSI commits to the EFDC_DSI_OMP models producing exactly the same results no matter how many threads are used. To test this DSI ran an EFDC example problem with different sub-models activated. We run these models with a range of threads from 1 (referred to as "OMP1") to 16 threads (OMP16). To compare these models, we use the EE feature of "Model Comparison" where the model initial conditions and/or model results can be compared. The main method we use for model comparison is subtracting the 2D results from one model from some base model for the same time snapshot. This approach produces a 2D view of the differences between models. For the OMP comparisons, the differences should be equal to 0.0.

Plots from an example that has full 3D hydrodynamics, sediments and water quality activated are shown in Figure 3. DSI ran the model for five days for OMP1 and OMP2. The two models were then compared and plots below generated. A plot is shown of the model results (left) and the comparison for each of the main parameters (right). As can be seen, all of the model comparisons produce plots showing the model differences equal to zero. The model results are exactly the same, within model precision.

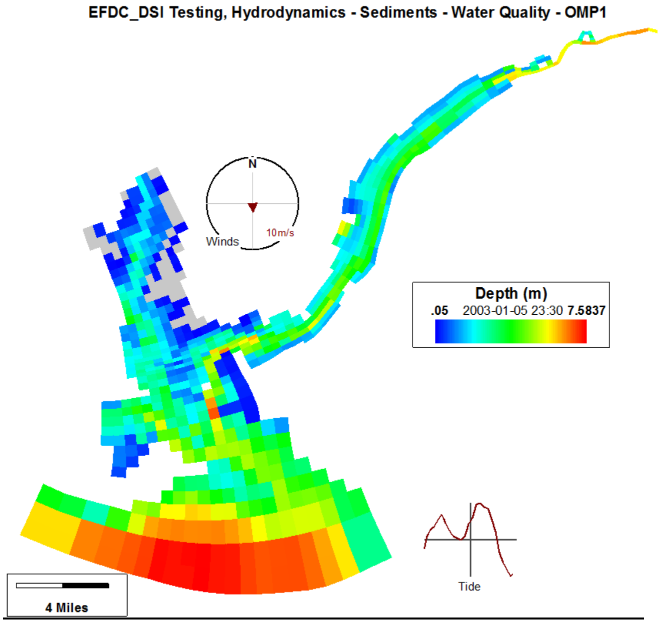


Fig 3a Depth on OMP1.

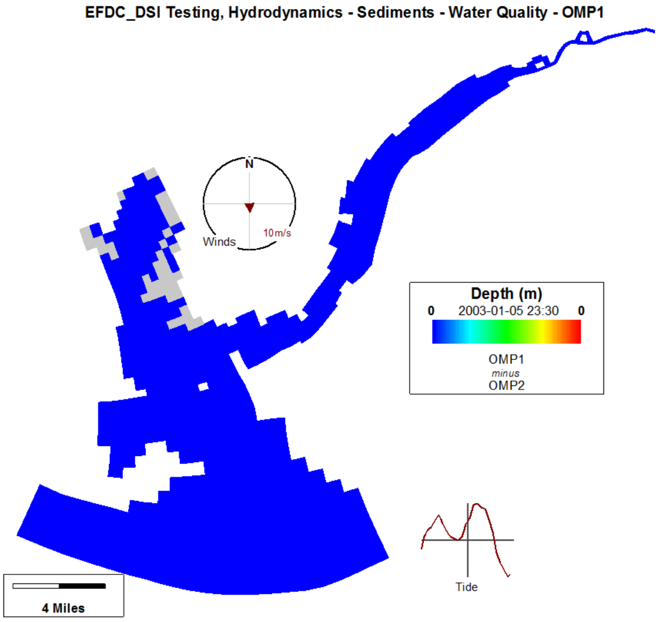


Fig 3b Depth Comparison: OMP1 minus OMP2.

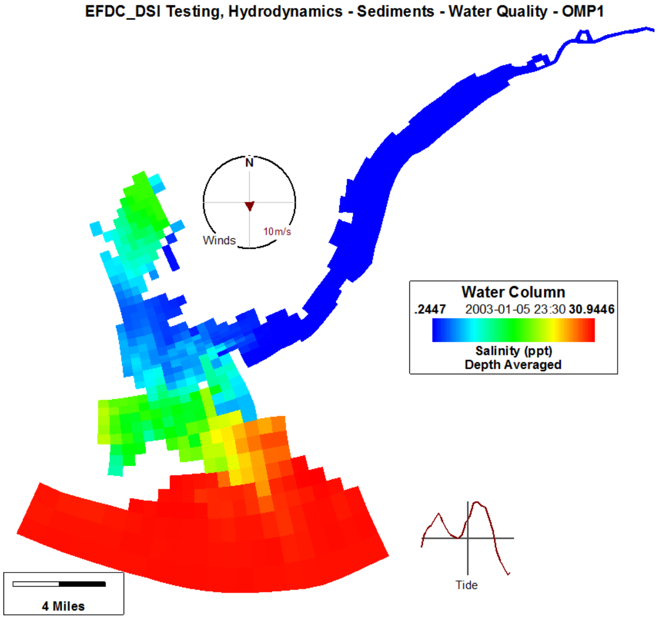


Fig 3c Salinity on OMP1.

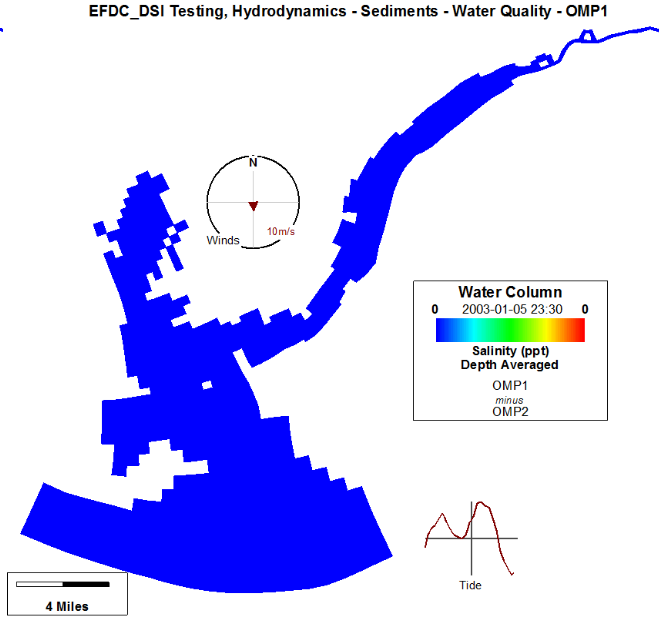


Fig 3d Salinity Comparison: OMP1 minus OMP2.

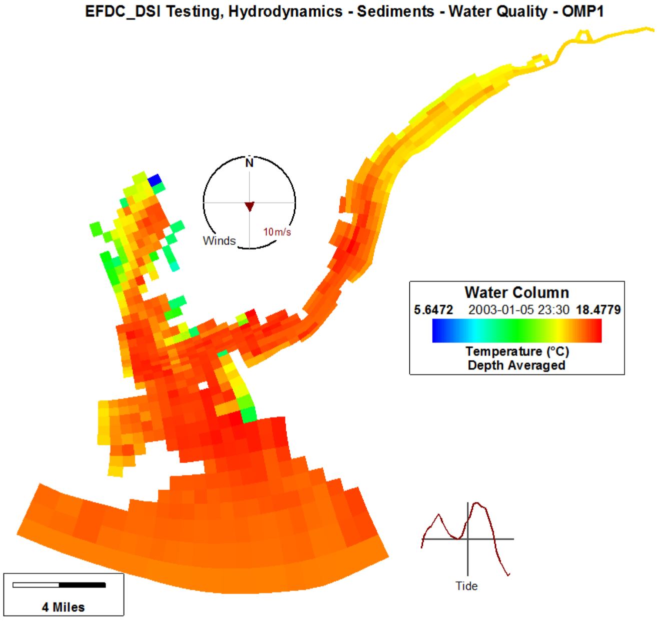


Fig 3e Depth OMP1.

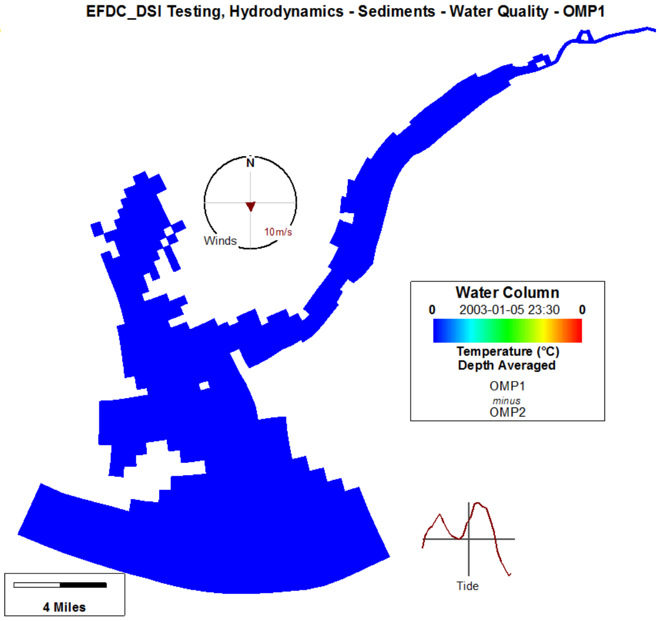


Fig 3f Depth Comparison OMP1 minus OMP2.

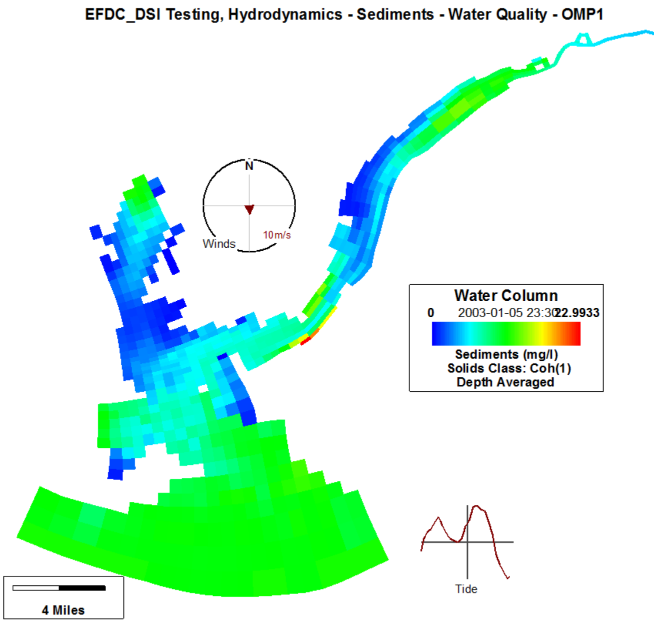


Fig 3g  Sediments for OMP1.

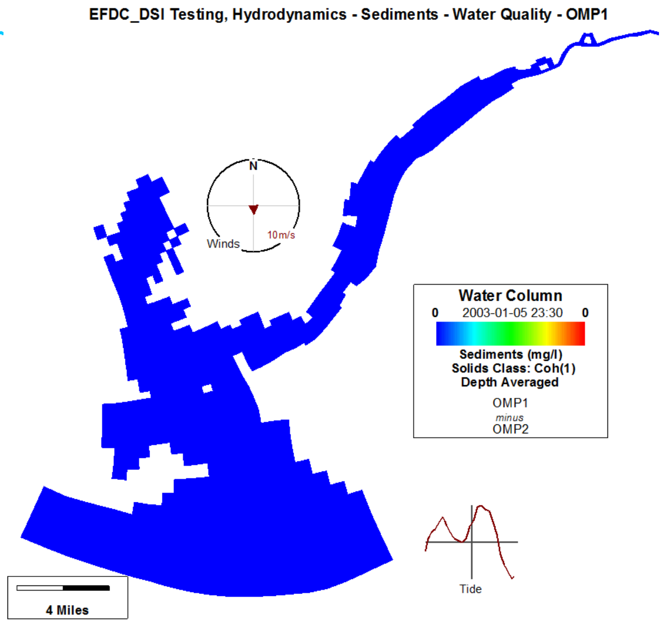


Fig 3h  Sed Comparison: OMP1 minus OMP2.

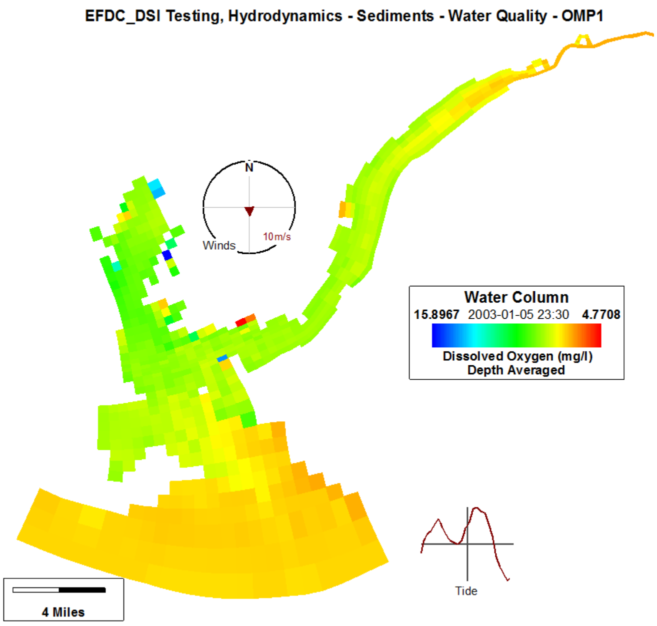


Fig 3i  DO for OMP1.

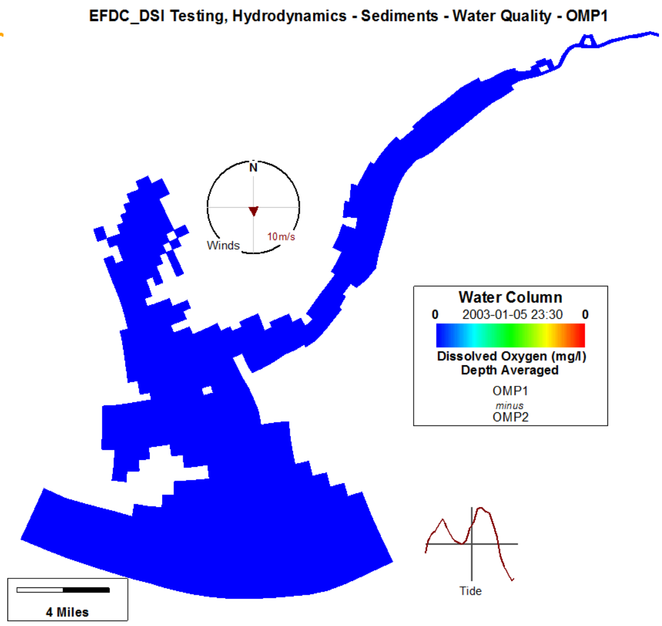


Fig 3j  DO Comparison: OMP1 minus OMP2.