6 Effects of Salinity-Induced Density Variation on DSM2 Hydrodynamics

6.1 Introduction

With DSM2, the Delta is modeled assuming a one-way coupling between hydrodynamics and salinity. Flow and stage results from HYDRO are used to drive the salinity transport model QUAL, but ignore feedback that salinity-induced density gradients have on hydrodynamics. The assumption of no feedback is made for convenience, but is supported by order-of-magnitude arguments that play down the importance of baroclinic terms in the governing equations. DSM2 does not support a coupled solution of hydrodynamics and transport.

Numerical testing of the effects of variable density is a task that is revisited from time to time. Recent motivation for investigation came from the 1999-2000 IEP PWT calibration project, where certain mild systematic errors were thought to be attributable to density. This report documents a simple numerical experiment on the importance of longitudinal density variation on 1-D hydrodynamics in DSM2 (no representation is made that this captures all the nuances of baroclinic hydrodynamics).

The experiment was from September 15, 1997 to October 31, 1998. The original idea was to span two IEP calibration periods, one in April 1998 and another in September 1998, plus a warm-up period for the quality model. Salinity varied considerably over this period, as demonstrated by the tidally averaged (EC) plot of Figure 6-1. However, the most important high salinity periods occurred before the first IEP calibration periods. The April 1998 calibration period had almost zero salinity, and in the September 1998 period salinity was low to medium.

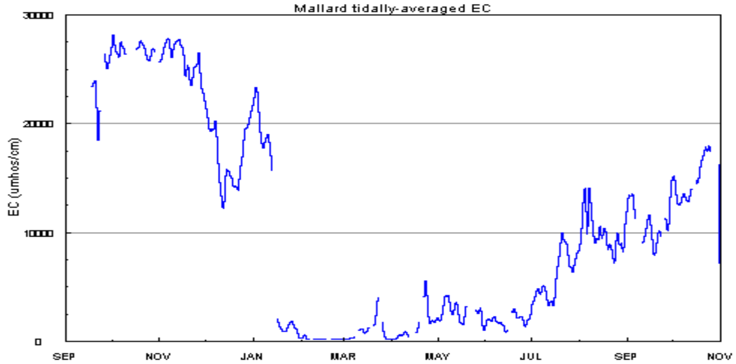

Figure 6-1: EC at Mallard (RSAC075) during the study period.

6.2 Methods

Internally, DSM2 is able to incorporate variable density into the flow equations -- this capability is a legacy of the FourPt model written by Lew de Long. However, there is no supporting input/output system for inserting density information and DSM2 does not solve the full hydrodynamic and salt transport system simultaneously.

For the present project, EC output from QUAL was used to calculate a density estimate offline, which was then reinserted into HYDRO using a crude input system designed for this experiment.

Three model runs were carried out for the experiment:

1. a preliminary HYDRO run to establish a flow field;
2. a QUAL run to estimate salinity; and
3. a follow-up HYDRO run.

The feedback cycle could, of course, be repeated *ad nauseum* with successively improved flow fields passing from HYDRO to QUAL, and improved density fields returning from QUAL to HYDRO. The scheme is not guaranteed to converge, but due to the small changes over one cycle it seems likely to do so very rapidly. Such detail was not required here, and if density effects were to be incorporated formally into DSM2, the iterative process would probably be replaced by simultaneous solution of hydrodynamics and salt transport.

Density was estimated by converting EC to total dissolved solids (TDS) and then adding the TDS concentration to the density of water to obtain the density in solution. The conversion from EC to TDS was calculated using regression results from the Suisun Marsh Reports (`http://iep.water.ca.gov/suisun/`). A single conversion formula for Mallard Island (RSAC075) was applied over the whole delta:

$$\text{TDS (mg/l)} = -60.06 + 0.614 * \text{EC (umhos/cm)}$$

The range of density over space and time was between 1.0 g/cc and 1.022 g/cc, the latter is about two-thirds of the value quoted by Fischer (1972) for seawater. The variable density results were compared to a base case with fixed density – none of the results were compared to field observations.

6.3 Results

The main difference between the “base case” (with constant density) and the “variable density case” is that stage in the variable density case is up to several tenths of a foot higher. Figure 6-2 shows stage at Mallard (RSAC075) and Figure 6-3 shows flow on the Sacramento near Sherman Lake (RSAC084) for a typical time segment during the early part of the experiment, when salinity was high. Proportionally, the difference in stage is larger than the difference in flow.

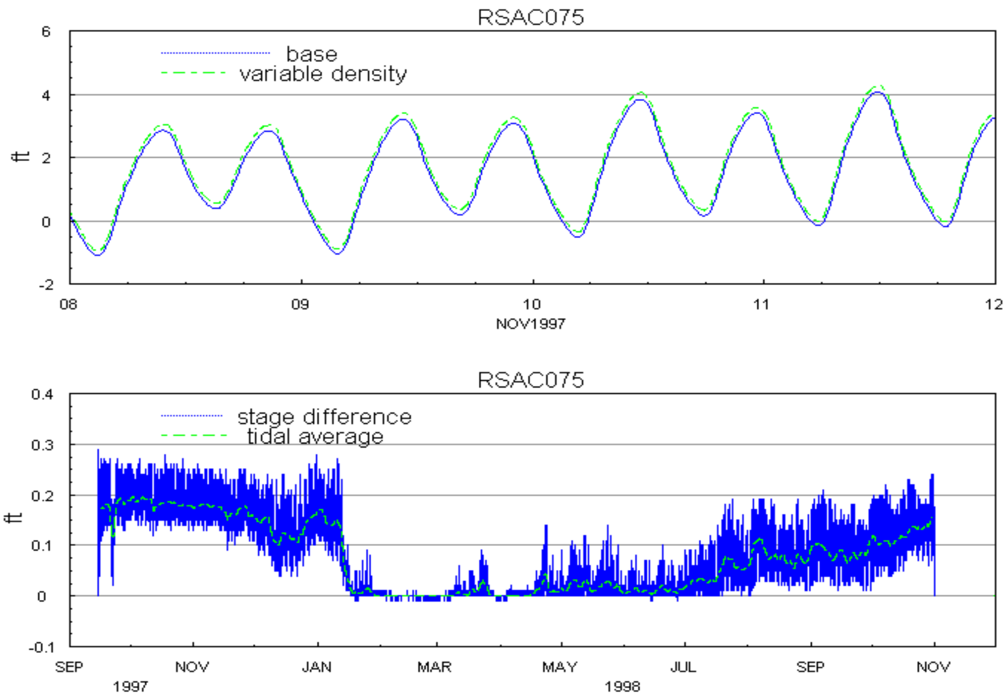

Figure 6-2: (Top) Stage results for Mallard (RSAC075). (Bottom) Difference between the two cases (variable density minus base) and its tidal average.

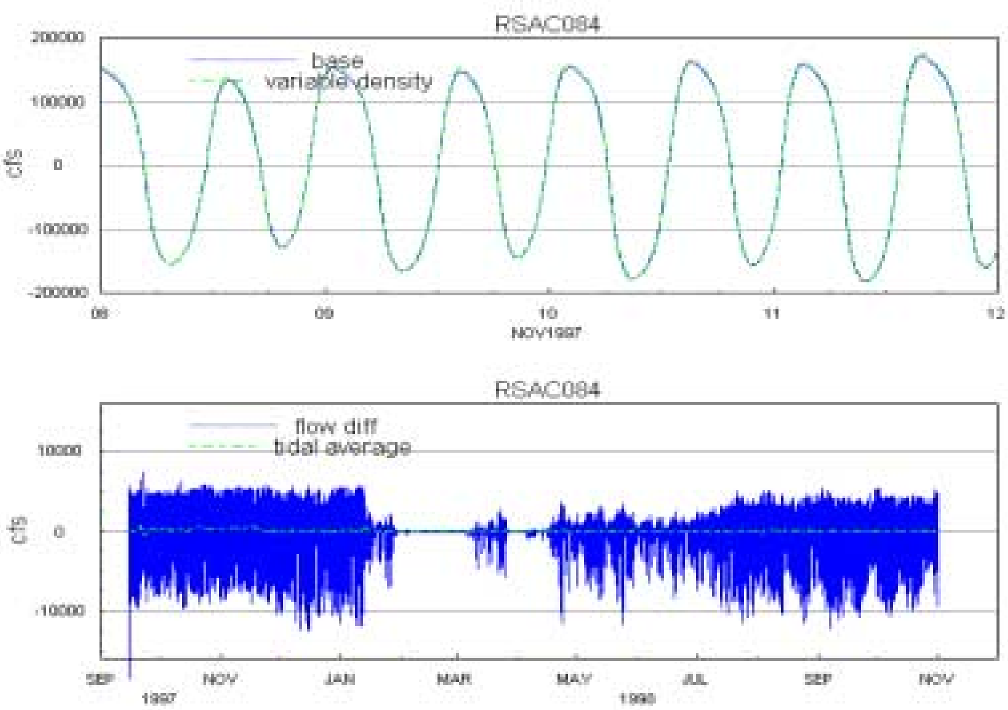

Figure 6-3: (Top) Flow near Sherman Lake. (Bottom) Difference between cases (variable density minus base) and its tidal average.

The right side of Figure 6-2 shows the evolution of stage and flow differences during the experiment (variable density minus base). This difference varies tidally, and a filtered (tidally averaged) line has been added to give some idea of the "average" difference between the two cases. Not unexpectedly, the difference between the two cases depends on how much salt is in the Delta (compare to Figure 6-1).

The stage differences between the base and variable density cases are fairly uniform over the Delta. Figure 6-4 shows stage difference on the Sacramento at Collinsville (RSAC081), Rio Vista (RSAC101), Delta Cross Channel (RSAC128), and at the head of Old River (ROLD074). The amount of tidal variation is different from location to location, but the trends are the same and have a similar magnitude.

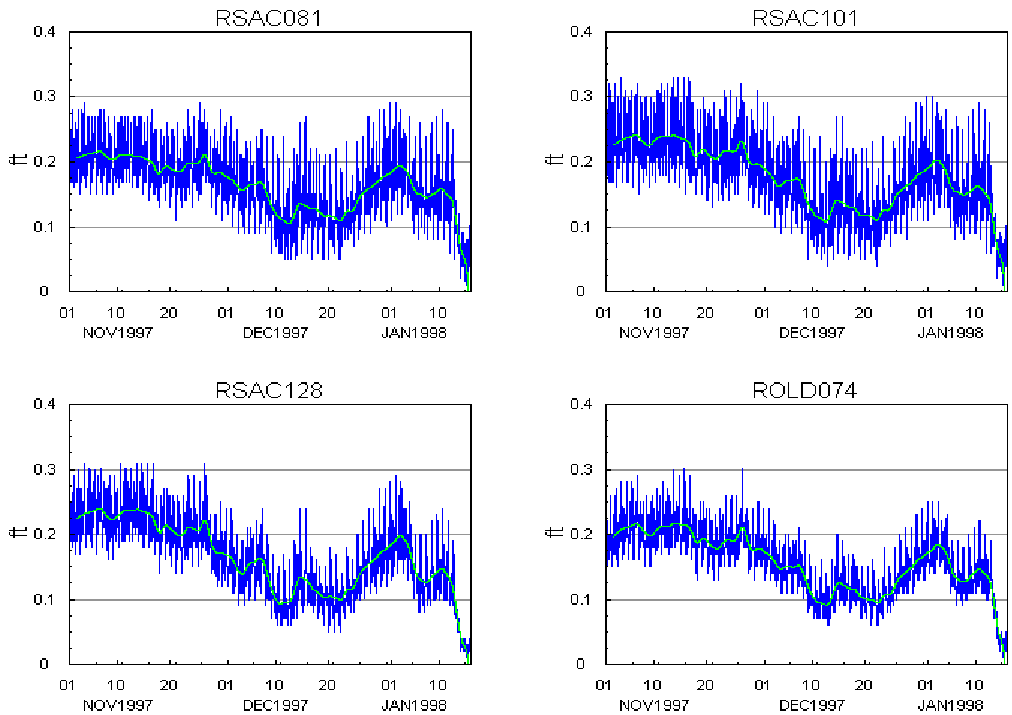

Figure 6-4: Stage difference (variable density minus base) at four locations: Collinsville (RSAC081), Rio Vista (RSAC101), Delta Cross Channel (RSAC128), and Old River at Head (ROLD074).

The lack of spatial variation is not surprising. Density is highest and the density gradient steepest near Martinez –magnitude and gradient decrease precipitously more than 20-30 km toward the east and south. West of Emmaton or Jersey Point the density gradients induced by salinity are always gentle and insufficient to produce hydrodynamic change on their own. Instead, the changes that are induced in most of the Delta are just due to the propagation inward of changes near the western boundary. It is as if the "boundary condition" had been changed.

6.4 Conclusions

The inclusion of density gradients influences model results. Whether the magnitude of the effect is important will depend on application, but it can be called “mild” compared to other sources of model error. Baroclinic effects depend strongly on the timing of hydrology (they are almost nil when salinity is low), but only weakly on location. Because the IEP calibration periods in 1998 are times of low salinity, longitudinal baroclinic effects were probably not the cause of the errors that motivated this experiment.

6.5 Reference

Fischer, H.B., E.J. List, R.C.Y. Koh, J. Imberger and N.H. Brooks. (1972). *Mixing in Inland and Coastal Waters*, Academic Press, San Diego.