

GCOOS Pilot Project
Proof of Concept for a 3-D Operational Ocean Current Forecast
Model of the Gulf of Mexico
9 January 2007

GOALS OF THE PILOT

The primary goal of the pilot is to determine whether a 3-D current model that can supply forecasts, nowcasts, and hindcasts of currents and hydrography with sufficient accuracy to be useful to a sizeable constituency around the Gulf of Mexico. Secondary goals include better identifying and meeting the needs of the various beneficiaries of such a model, increasing our understanding of Gulf of Mexico oceanography, advancing modeling technology, and laying the foundation for a permanent operational forecast model in the Gulf.

GCOOS is in an excellent position to achieve these goals because its members are intimately aware of the needs of the local users. We know how to access local data that will be important for assimilation and validation. We have experience with previous and ongoing attempts to establish operational models in the Gulf.

INTRODUCTION

Operational weather forecast models have been in use for more than four decades and it is hard to imagine a modern world without the forecasts made possible by those models. As of today, there are few analogous operational ocean current forecast models in US coastal waters. The dearth of such models is not because of a lack of potential benefits. Obvious applications for a forecast model include:

1. predicting the trajectory of hazardous spills and harmful algal blooms,
2. optimizing ship routing,
3. assisting in rescue operations, e.g. man-over-board,
4. improving meteorological (weather) forecasts for weather systems which are strongly affected by the local ocean
5. optimizing fish catch,
6. predicting strong and potentially hazardous current conditions for the oil industry,
7. predicting the intensity and aerial extent of hypoxic zones, and
8. as a key input into the prediction of the fate and ecological effects of hazardous spills and pollutants.

Of course the necessary forecast horizon would vary according to the application. The first five items would tend to require an accurate forecast for relatively short periods, i.e. 10 days or less, while the last items could encompass those short periods but could also benefit from much longer forecast horizons, e.g. a month or more.

In the Gulf, two recent GCOOS workshops with potential users have identified a strong need for more accurate current forecasts.

The GCOOS-RA will continue to identify needs of various stakeholder groups for currents in the Gulf. During the first year of this pilot moves forward, we will determine for a very broad range of potential stakeholders:

- Requirements for accurate current forecasts (where, what features, lead times, etc);
- What models are currently being used to meet, at least partially, these requirements;
- What requirements are not being met by the present models; and
- What are the estimated economic benefits that might be achieved by fully meeting the requirements?

A successful forecast model also will provide a base for building a climatology of currents and hydrography. Potential benefits of such a climatological database include improvements in the management of fisheries and other biological resources, understanding and managing the impacts of pollution, optimizing the design of offshore facilities, and investigating the effects of climate change. To achieve these benefits a successful model is required because we can never afford to measure the ocean with the temporal and spatial resolution needed by many potential users.

In the Gulf, there have been, and continue to be, attempts to run operational ocean current forecast models. Kantha et al. (in Sturges and Lugo-Fernandez, 2006, AGU Monograph Series) report an early attempt at forecasting the Loop Current (LC) and associated eddies (LCEs), but this was discontinued because the model error exceeded the needs of its sponsors. NOAA's National Centers for Environmental Prediction post forecasts¹ for the N. Atlantic including the Gulf but their effort covers a large area and is clearly not focused on the Gulf. They do not appear to be assimilating Gulf real-time measurements nor do they appear to be assessing forecast errors in the Gulf. The Navy² provides an operational product with free public access. However, in an extensive comparative study by DeepStar (an oil industry consortium), no ocean forecast models have been found by the oil industry to achieve needed predictive accuracy of the LC and LCEs (personal communication, D. Driver, BP & chairman of DeepStar metocean committee). Further, it is beyond the mandate of the Navy to provide forecasts for the public so it is doubtful they could satisfy most of the needs identified above. The only available options are specialized commercial efforts (e.g., those by Horizon Marine³ and Ocean Numerics⁴). The Horizon Marine model has been running for roughly one year while the Ocean Numerics model is still in a beta mode. These models are focused primarily on predicting the LC and LCEs in deep water. While such commercial models may satisfy the needs of some stakeholders, such as the oil industry, their present products will not satisfy the needs of many potential users, such as for search and rescue operations on the shelf, tracking harmful algal blooms along the coast for coastal and fisheries managers

¹ <http://polar.ncep.noaa.gov/ofs/>

² http://www7300.nrlssc.navy.mil/altimetry/regions/reg_gom.html

³ <http://www.horizonmarine.com/>

⁴ <http://www.oceannumerics.com/services/forecasting.htm>

and beach users, forecasting changes in currents and salinity conditions from unusual river discharges, and allowing assessment of associated impacts to living marine resources needed for management.

There are many good reasons to carry out this pilot in the Gulf of Mexico. First, the Gulf is a semi-enclosed sea with reasonably well-defined boundary conditions, and its limited size ensures that a high resolution model can be run on an operational basis at a reasonable cost. Second, the Gulf is well studied with a relatively large database, thus ideally suited for validating model performance. Third, the Gulf is heavily exploited from a commercial standpoint so there are many possible beneficiaries and substantial potential economic benefits. Fourth, the oceanography in the Gulf is one of the most energetic and complex in the world so it represent a rigorous testing ground. Finally, there are roughly 50 active current measurement sites in the Gulf, as well as several satellites collecting Gulf-wide surface fields, that can provide measurements for real-time data assimilation and model validation.

It is clear that there are many potential stakeholders that would receive numerous benefits derived from having an operational ocean current model for the Gulf. However, it is doubtful that these multiple benefits could be delivered by a commercial enterprise largely because it would be difficult for many if not most the diverse customers to afford the high commercial fees. Indeed, the present state of forecast modeling in the Gulf illustrates this all too well. Today, only a few major corporations can afford access to available forecast model results.

In the long run, it seems clear that the government or quasi-government groups such as GCOOS will have to step in and provide forecast models just as they did in meteorology decades ago. With this in mind, it makes sense to develop this capability for the Gulf for the reasons stated above. GCOOS is in an excellent position to guide this pilot study because of its close links with Gulf modelers and beneficiaries; many such modelers and beneficiaries are signatories to the GCOOS agreement.

It can be argued that a modeling forecast pilot project such as this might represent an unfair encroachment on existing commercial businesses. However, this argument is problematic for several reasons. First, although the forecast system sought through the pilot will address the needs of a diverse customer base, there still will be a need for highly specialized and focused products such as are currently available to some degree for the oceans. Second, it is envisioned that the existing commercial forecast modeling companies will compete to perform the pilot; hence, this pilot actually will be creating business opportunities. Finally, if this GCOOS pilot project results in a proven and accurate forecast model AND becomes operational, the output from this model will be available to companies to create added-value products that address the specific needs of their target clients. In other words, the end result will probably look much like what exists today in the meteorological world with many successful commercial businesses adding value to the core government analyses and forecasts.

TECHNICAL PLAN

The underlying principle of this Technical Plan is to rely on a “contractor” selected to carry out the pilot study through a competitive Request for Proposals. The contractor could be either a single company or a consortium. This approach uses the economy and efficiency of the private sector. It builds on existing efforts, such as those of the four existing organizations that have recently run or are presently running operational deepwater Gulf forecasts⁵. We think it likely that other consortia may form and respond to our Request for Proposal. With these underlying principles in mind, the major tasks in setting up pilot project will be those to follow.

1. Governance Setup. a technical advisory committee (TAC) of roughly ten will be formed to monitor the pilot and advise the GCOOS Board. Several of the members will come from NOAA since it will be the most likely agency to implement an operational model if the pilot proves successful. Several TAC members will come from the pilot funding agencies, and several more will have strong technical experience with circulation and/or operational modeling. The TAC will write the detailed workscope for the pilot, select the contractor in conjunction with the GCOOS Board, assist in finalizing the commercial agreements, and frequently review the contractor’s progress. It will be a responsibility of the TAC, together with the selected contractor to maintain close awareness of developments of operational models of large areas including the Gulf as a sub region, particularly those of the US Navy, NOAA, and Mercator. The GCOOS Board will ultimately be responsible for all decisions.

2. Pilot Model Selection. The first goal of the TAC will be to review stakeholder input and identify the key space and time-scales and products required. The next major goal will be to identify several existing 3-D models of the Gulf and hire the modelers to forecast two periods: a recent one-year historical period and a forthcoming 3-month time period. The length of the forecast periods will depend on the water depth. For the 1-yr historical period *in deep water*, a forecast will be started at the beginning of each month and run for a three-month period, i.e. 36 forecasts out to 3-months⁶. For the 3-month future period *in deep water*, the forecasts will be restarted every 2 weeks and run out to the end of the initial 3-mo deadline. Error statistics will be calculated based on the difference between the modeled and observed distance from a set of deepwater sites to the nearest edge of the LC & LCEs as described in Oey et al. (2005, Geophys. Res. Letters).⁷ Figure 1 gives an example of one of the primary products. Additional comparisons will be made between measurements (e.g. currents) and model output along the same lines as comparisons to be made on the shelf (see next paragraph).

⁵Ocean Numerics, Horizon Marine/AcuFore, Danish Hydraulics, and NRL-Stennis.

⁶This is based on results from a recent DeepStar proprietary Project, results of which will probably be made available to the TAC.

⁷Oey et al. describes the work they did for the DeepStar consortium in 2005. Three other models were also included in the DeepStar study and the results proved quite revealing. Unfortunately the effort is proprietary although it is believed that DeepStar would give the TAC access to the final report prior to the TAC’s initial model selection.

The forecasts *on the shelf* will extend out to 2-weeks only, since the shelf currents are dominated by winds and the practical upper limit of wind forecasts is about 2 weeks. Statistical and direct comparisons will be made of the model output to measured current, temperature, salinity, and sea level, with special emphasis on data from shelf sites and profiles. The TAC will follow closely the model testbed, referred to as Model Evaluation Environment, that has been developed by NOAA's National Ocean Service. [Reference needed] They began by assembling for Delaware Bay for the 1984-85 period rather complete forcing and boundary conditions for numerical circulation models along with evaluation data sets for winds, surface fluxes, river inputs, T, S, currents, and water levels. Using this information they are testing models for tides, fresh water events, water levels, currents, T, and S. Preliminary results for some of the more commonly used models (e.g., ADCIRC, ROMS, POM, FVCOM, and ELCIRC/SELFE) should be available by the end of the summer of 2006 according to Frank Aikman.

Each modeler will document their results in a written report. Part of that report will include a proposal to set up, enhance, and operate their model for a two-year pilot. Each proposal also will include an offer to “license” the model to a third-party for use in a long-term “operational” mode. Fixed prices will be quoted. Based on the above information and other factors, the TAC will recommend a model to proceed with into the pilot.

As indicated above, the forecasts will be done on a one-year historical period and on a three-month future period. Some might argue that all attention should be placed on forecasting the future period. However, there are several reasons to include the historical period. For example, we can include a much longer time period (and hence improve the uncertainty on our comparison statistics) without lengthening the pilot project schedule. In other words if we wanted to forecast one year of a future period, we would obviously have to wait one year to see if the forecast is correct. Another advantage of using an historical period is that we can pick an especially interesting period during which there were lots of measurements, e.g. a period when eddy separation occurs or when an eddy impacts the shelf. If we only used a future period, we might not get such a period without waiting a long time.

3. Pilot Model Setup. The first three months of the pilot will focus on setting up the model. Links to key measurement sources (satellite infrared and altimetry, current measurements, etc.) will be established so that routine data assimilation will occur. A public web portal will be set up to provide access to raw model output and simple graphical summary products, i.e., surface velocity vector snapshots at browser specified time intervals. A critical part of the web site will entail monitoring who is using the site and encouraging user feed-back. In addition, routine archival of model nowcasts will be established, and tests (see Task 2) will be updated weekly to benchmark model improvements. Model results will not be posted in real-time on the web site in this stage; potential users should not be discouraged by potentially poor results or delays.

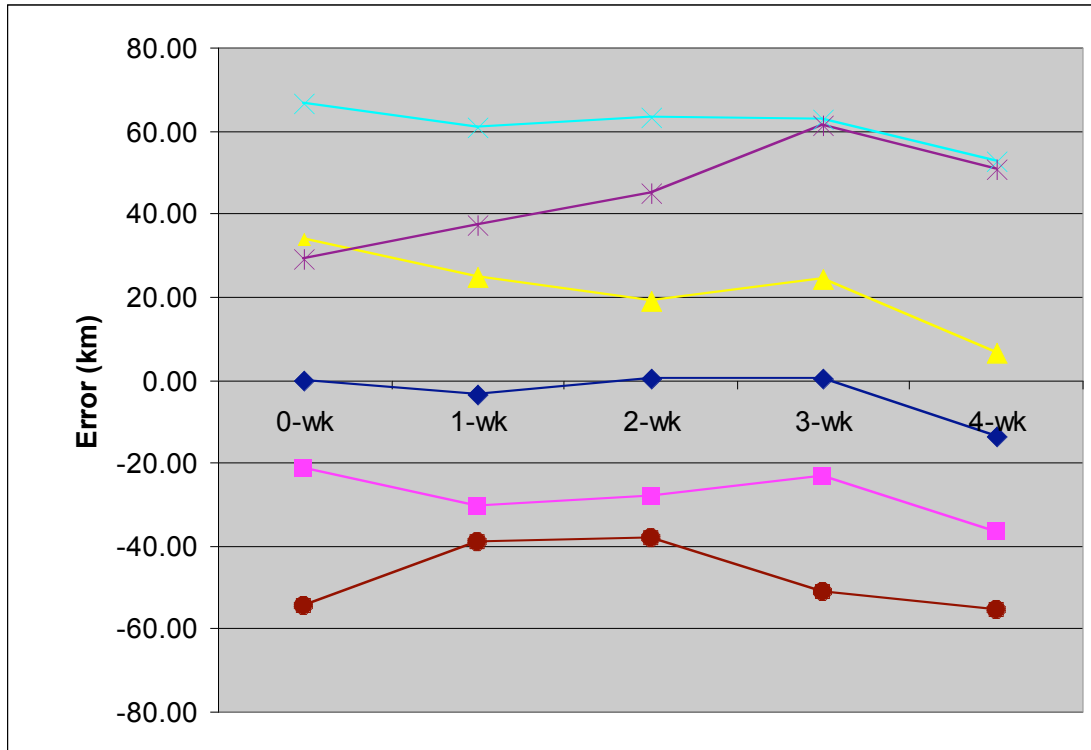


Fig 1: Comparison of forecast error for 5 different models and “persistence” (blue diamonds). The “error” is the sum of the differences between the modeled and observed distance from the nearest LC or LCE front to 7 deepwater sites in the Gulf. Statistics were accumulated for twelve 1-month forecasts.

4. Pilot Model Improvements. Over the next 12 months the contractor will continue to issue forecasts updated twice weekly. Model forecasts will be posted on the web site in near real-time, results of tests posted, and hindcast results archived. The contractor will investigate ways of improving the model forecasts with better initial conditions, ensemble averaging, and better boundary conditions. Results will be summarized in semi-annual reports which will include comparisons with measurements and error statistics. Key sections of that report will include user feed-back and proposed model improvements. At least four papers will be presented at AGU or Oceans conferences to publicize progress.

5. Model Finalization. The last 6 months will focus on setting up a final operational **system** (*with emphasis on the word “system” because it would include model source code, data access software, data filtering software, web posting software, and rigorous documentation*) that could be handed over to a third party such as NOAA to operate and modify as needed. One of the important subtasks will be to use the model to suggest a network of new observation sites that would greatly enhance forecasts. We must consider what data sets will be needed to evaluate and improve the Gulf model that will meet the requirements determined by the foregoing assessment, as well as requirements for delivery of such data. It is clear that an enhanced integrated system of observations within the Gulf will be required as we move from a pilot to a fully operational current model. It will be the responsibility of the GCOOS Board of Directors

to recommend this system based on suggestions made from experience in using the pilot model and from the GCOOS committees.

A final report will be issued which will follow the format of the semi-annual reports. A detailed user survey will be conducted by a separate contractor (to avoid the obvious conflict of interest that the modeling subcontractor would have) and results summarized. At least two papers will be presented, and at least one journal article submitted. It is expected that if the decision is made to proceed with a full-time operational model in the Gulf that one option will be to fund the contractor to continue that effort.

SCHEDULE AND BUDGET

Task 1 (Governance setup) could be accomplished in one month. Task 2 (Pilot Model Selection) will take slightly less than 2 years, including: two months for the TAC to develop a RFP, one month for potential contractors to respond, three months to finalize the decision and get contracts in place, 12 months for the modeling, and two months for review and selection of the winning model. The cost will depend heavily on the number of models selected. For preliminary budgetary purposes we suggest four models at \$125 K each (based on experience by the DeepStar projects), or \$500 K plus another \$100 K to support travel by TAC members who need it.

Tasks 3-5 (set up and running of the Pilot Model) will take about 3 years including the upfront time to set up the commercial agreement. Costs for these tasks are difficult to estimate but for now we suggest \$900 K, a value that has been vetted with one commercial vendor of an operational model.

The total estimated time for the Pilot is 5 years with a budget of \$1,500 K.