IMPLEMENTATION OF A NOWCAST/DATA ASSIMILATION CYCLE IN THE COASTAL OCEAN FORECAST SYSTEM

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I. Introduction

NOAA's Coastal Ocean Forecast System (COFS) is run each day at the National Centers for Environmental Prediction (NCEP) to produce experimental nowcasts and 24-h forecasts of the physical state of the coastal ocean off the U.S. East Coast. Real-time information is important to a variety of users including search and rescue missions, fish recruitment, tracking of pollutants, commercial shipping, and to provide external forcing on the open boundaries of nowcast/forecast models being developed for estuaries (ex. Chesapeake Bay and Port of NY/NJ) by the National Ocean Service (NOS). COFS is a collaborative project between the National Weather Service (NWS), NOS, Princeton University and the U.S. Navy.

II. Nowcast/Data Assimilation Cycle

A two cycle configuration of COFS, consisting of a nowcast/data assimilation cycle and a 24-h forecast cycle was implemented on April 1, 1998. The purpose of the nowcast/data assimilation cycle is to provide a 3-D nowcast for use as the initial conditions for the forecast cycle. Currently, COFS only assimilates sea surface temperature (SST) data. A description of the COFS nowcast/data assimilation cycle is given next. This includes a description of the ocean model, the SST data and quality control procedures, and the data assimilation procedure.

A. Ocean Model

COFS is based on the Princeton Ocean Model (POM) (Blumberg and Mellor, 1987) which is a three-dimensional ocean circulation model. The model employs a free surface, has a turbulent closure submodel (Mellor and Yamada, 1982) to parameterize mixing, and includes tidal forcing (Chen and Mellor, 1998). POM uses a bottom-following sigma-vertical coordinate and a coastal-following, curvilinear orthogonal horizontal grid. The horizontal grid has a resolution of 10 km near the coast to 20 km offshore. There are 19 sigma levels in the vertical with increased resolution in the mixed layer and the upper thermocline. The levels are 0.0, -0.0004, -0.0008, -0.0016, -0.0032, -0.0064, -0.0128, -0.0256, -0.005, -0.10, -0.20, -0.30, -0.40, -0.50, -0.60, -0.70, -0.80, -0.90, and -1.0. The domain extends from the Florida Straits to Newfoundland and offshore to 50 W (Fig. 1). The model bathymetry is based on the U.S. Navy DBDB-5 (Digital Bathymetric Data Base; 5 minute gridded), modified over the continental shelf with the more accurate NOS-15 (15 second gridded bathymetry). At the shoreward boundary, the model's minimum depth is 10 meters.

Since there is currently no operational daily global or basin-scale forecast model covering the Atlantic Basin, POM must be driven along its open southern and eastern boundaries by climatological estimates of temperature, salinity and transport. The temperature and salinity are based on the U.S. Navy's Generalized Digital

Environmental Model (GDEM) (Teague et al., 1990). At its coastal boundary, freshwater inflow is specified for 16 rivers, bays and estuaries along the East Coast with the monthly climatology of Blumberg and Grehl (1987) and Koutitonsky and Bugden (1991).

Surface boundary conditions, i.e. surface heat, moisture and momentum fluxes are derived from 3-hourly output from NCEP's high-resolution Eta atmospheric forecast model for the North America continent and adjacent waters (Black, 1994; Rogers et al., 1998). The Eta-32 model has a resolution of 32-km in the horizontal and 45 levels in the vertical. For its specification of SSTs, the Eta model uses NOAA's National Environmental Satellite, Data and Information

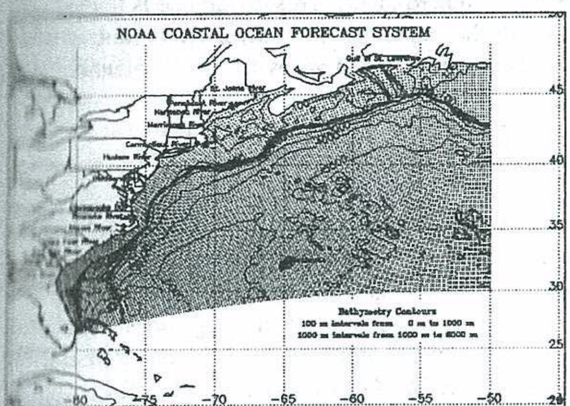

Fig. 1. COFS grid domain, bathymetry (m) and names of estuaries where monthly freshwater inflow are specified.

Service (NESDIS) 50-km resolution Multi-Channel Sea Surface Temperature (MCSST) Analysis that is updated approximately twice a week. The Eta-32 model is run four times a day at 0000, 0300, 1200 and 1800 UTC. Each run or cycle is preceded by the Eta Data Assimilation System (EDAS-32). COFS uses output from the 0000 UTC Eta-32 forecast cycle but has the backup capability to run with forecasts from previous 0000 and 1200 UTC cycles.

B. Data and Quality Control Procedures

Currently, COFS assimilates SST data including in-situ and remotely-sensed observations. The in-situ observations are obtained from a variety of platforms including fixed and drifting buoys, Coastal-Marine Automated Network (C-MAN) stations, and ships participating in the Voluntary Observing Program. Within the COFS domain there are usually 27 fixed buoys and C-MAN stations that measure SSTs and approximately 5-10 drifting buoys on any given day.

The remotely-sensed observations consists of MCSST retrievals. These retrievals are derived from multi-channel data from the Advanced Very High Resolution Radiometer (AVHRR) on board NOAA's operational polar-orbiting satellites, NOAA-12 and NOAA-14. Separate MCSST equations are used for day and night data. Each retrieval represents an approximate 8 x 8 km area. The retrieval is based on an average of four AVHRR Global Area Coverage (GAC) spots arranged as a 2 x 2 unit array. Each GAC spot in the unit array is an approximate 4 x 4 km square of 1 km horizontal resolution AVHRR data. The number of retrievals in the COFS domain on a given day ranges from 400 to 7000.

In addition to the quality control that is performed by the National Data Buoy Center prior to the in-situ fixed buoy data being received at NCEP, a gross check is done to remove data less than 1°F and greater than 33°F. These limits will be modified after quality control checks for missing data and geographic positional error are implemented in COFS.

C. Data Assimilation Procedure

The data assimilation procedure is based on two assimilation schemes, the optimal interpolation scheme of Behringer (1994) and the mixed-layer assimilation scheme of Chalikov et al. (1997). The optimal interpolation is used to determine a correction field of the model's top layer temperature. The mixed-layer assimilation technique is used to project the surface data into the model's mixed-layer. A similar approach has been used in the United Kingdom Meteorological Office's Forecasting Ocean Atmosphere Model for the Arctic and Atlantic Oceans (Forbes, 1995).

The surface correction field is calculated by an objective analysis of the MCSST and SST observation increments or observation-minus-background differences at the observation sites. In other words, the purpose of the objective analysis is to spread out the differences at the observation sites into the model grid domain. Thus, the correction field is an analysis of the observation increments. In this scheme, the objective analysis equation is solved using an equivalent variational formulation (Derber and Rosati, 1989). In this formulation, the goal is to minimize the objective function or functional which consists of two terms. The first term is a measure of the fit of corrected temperature field to the uncorrected model temperature field and the second is a measure of the fit of the corrected temperature field to the observations. The form of the functional is