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EXTRATROPICAL STORM SURGE GUIDANCE: THE MRPECS BULLETIN

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1. BACKGROUND

Recently, several strong extratropical storms along the East Coast of the United States have resulted in widespread damage associated with coastal flooding and beach erosion. In particular, the "Halloween Storm" of October 28 through November 1, 1991, caused destruction from the Maine coast southward to the east coast of Florida and the north shore of Puerto Rico (National Oceanic and Atmospheric Administration (NOAA), 1992). These events have brought a renewed focus on techniques to forecast storm surge and erosion associated with extratropical storms.

Recent developmental efforts have produced the Sea, Lake, and Overland Surge for Hurricanes (SLOSH) model (Jelesnianski et al. 1984), which has been quite successful in predicting storm surges associated with landfalling hurricanes such as Hugo (NOAA 1990; Townsend 1990). Currently, the only source of objective storm surge guidance for extratropical storms is the AFOS product MRPECS (WMO header FZUS3; Figure 1). This guidance was implemented by the Techniques Development Laboratory (TDL) during the late-1970s. One finding of the NOAA Disaster Survey team that investigated the Halloween Storm was that many forecasters were unfamiliar with the techniques used by, and the characteristics of, the MRPECS guidance (NOAA 1992). This document is intended to provide an overview of the MRPECS bulletin by reviewing its development, assessing strengths and weaknesses of the product, and discussing forthcoming changes, as well as new developmental efforts.

2. DEVELOPMENTAL APPROACH

2.1. The Storm Surge Guidance

The storm surge forecasts in the MRPECS bulletin are produced by single station regression equations (i.e., separate equations for each station) derived by using a multiple regression screening technique (National Weather Service 1978). The equations are based on the perfect prog approach (Klein and Lewis 1970). The regression program correlated observed storm surges at 0000, 0600, 1200, and 1800 UTC from a historical database (predictand) with observed sea-level pressures at grid points defined in the old Primitive Equation (PE) model (predictor). The equations were later applied to the Limited Fine Mesh (LFM) model. (As of March, 1992, the MRPECS is still based on output from the LFM.)

It is important to note that the **only predictor** for the storm surge forecasts is LFM sea level forecasts at PE model grid points (National Weather Service 1978). There are three major impacts of this fact. First, the storm surge forecasts can only be as good as the model's pressure forecasts. Second, the LFM pressure forecasts are interpolated to the coarser PE model grid, further degrading the quality of the pressure forecasts.

Finally, wind forecasts are not explicitly used as predictors. This is important because the specific wind direction (and length of fetch) is usually crucial to storm surge and any resultant flooding and erosion. Surface winds were not used because at the time the equations were developed, model forecast winds were not as stable a forecast field as pressure, and observed wind data at the PE grid points were not available for equation development. In addition, the observed pressure data were derived from archived analyses. Retrieving pressure values in this manner is much more reliable than retrieving wind data (W. Richardson, personal communication).

This is not to imply that wind information is not indirectly incorporated into the equations. The multiple regression screening technique utilized in the development resulted in the inclusion of specific grid points in the equations for each station. The selection of those grid points whose pressure values correlate highest with observed storm surges implicitly incorporates the effects of the geostrophic wind. However, the accuracy of the guidance is still linked to the quality of the pressure forecasts, and how the pressure fields compare to those in the event database used to derive the equations.

This brings up another important point. As with all statistical guidance, the performance of these equations is affected, in part, by the event database that was used in the development. Assuming accurate model pressure forecasts, the equations will perform best during events that are similar to events in the developmental database. Events that are substantially different from the developmental sample may not be handled well by the regression equations. As was the case in the Halloween Storm, events that have a very unusual evolution and/or structure, may result in unreliable guidance despite very good base model forecasts. For more information regarding the derivation of this guidance, consult Pore et al. (1974).

2.2 The Beach Erosion Guidance

The beach erosion guidance is based on statistical regression equations derived by using the perfect prog approach. A multiple regression screening program was used to correlate observed, qualitative estimates of erosion (predictand) with observed meteorologic and oceanographic variables (predictors); (National Weather Service 1980).

The qualitative estimates of erosion were extracted from **Storm Data** for events occurring during the winter (November-

April) between March 1962 and April 1977. The **Storm Data** descriptions were subjectively converted to numerical values as follows: 0 (no erosion); 1 (minor erosion); 2 (moderate erosion); 3 (major erosion); and 4 (severe erosion). The predictors used were: observed storm duration (the number of consecutive high tides that water levels reach or exceed critical threshold values); maximum storm surge height; and maximum tide height above mean sea level for these events.

Based on tidal ranges, the states of Maine and Massachusetts (ME-MA) were grouped together for equation development, while the second group consisted of the remaining states (Rhode Island south to South Carolina; RI-SC). Equations were developed for each group to forecast erosion intensities based on a linear scale. In addition, for the RI-SC group, an equation using a "power-of-two" intensity scale was developed, which was used whenever the erosion intensity of moderate or greater was forecast. For more details, see National Weather Service (1980). Another difference between the groups is that the storm duration predictor was not used for the ME-MA group equation. Richardson (1980) found that the inclusion of this predictor in this area resulted in substantial overforecasts of erosion, especially during high astronomical spring tide events. The existence of, and differences between, the groups are important to keep in mind when evaluating the quality of erosion forecasts that are generated by the different equations (e.g., the Massachusetts forecast compared to the Rhode Island or New York forecast).

The forecasts for each state in each of the groups are generated from the same basic regression equation(s). The difference is that the surge and astronomical tide forecasts are from the tide gauge location within the state. For example, the Massachusetts erosion forecasts are generated using the Boston tide gauge surge and tide forecasts as input, while the Virginia forecasts use data from the Norfolk (Hampton Roads (ORF) in Figures 1 and 2) tide gauge.

3. PRODUCT OVERVIEW

The MRPECS bulletin (Figure 1) consists of three parts (National Weather Service 1979). Part 1 contains extratropical storm surge forecasts (in feet) at 6-hour intervals out to 48 hours, for 12 points along the East Coast. These storm surge height forecasts are meteorologically generated water fluctuations, which do not incorporate astronomical tide heights (National Weather Service 1978). The astronomical tides must be added to these surge forecasts to yield a tide forecast. It is also important to note, the surge forecasts are valid only at the specific points where the equations were derived (Figure 2).

Part 2 of the message gives qualitative forecasts for beach erosion at 12-hour intervals out to 48 hours (National Weather Service 1980). Terms used to describe the forecast erosion are: none, minor, moderate, major, and severe. Note, this guidance gives only a qualitative "regional" forecast of erosion along the oceanic coastline of an entire state. Coastal erosion can have substantial spatial and temporal variations due to the complex bathymetry of the nearshore regions. A dynamical model, such as SLOSH, is necessary to fully resolve much of the localized nature of coastal erosion. Finally, the forecasts in parts 1 and 2 are not valid for tropical systems.

Part 3 contains LFM boundary layer wind and temperature forecasts at 12-hour projections out to 48 hours for the 35 LFM grid points in the northwestern Atlantic depicted in Figure 3 (National Weather Service 1979). The first four digits in each forecast group comprise the wind forecasts in a conventional "ddff" format, with wind speed in knots. The last two numbers are the boundary layer temperature forecast (°K), with the first digit (2 or 3) removed. Note, these are actual LFM grid point forecasts, not the output of statistical guidance like Parts 1 and 2.

4. FUTURE PLANS

It is expected that by late spring, 1992, the MRPECS will be converted to run off the Nested Grid Model (NGM; W. Shaffer, personal communication). An advantage of using the perfect prog technique is that the predictors are not model specific (i.e., the equations can be applied to different models without a complete re-derivation of the equations). However, while the new MRPECS storm surge guidance will use NGM pressure forecasts as input, these data will still be extrapolated onto the old PE model grid because these equations require data at these specific points. Hence, the primary impact of the change from LFM to NGM, with respect to the storm surge and beach erosion forecasts, will be to make use of the NGM's superior pressure forecasts for the surge guidance.

Part 3 of the bulletin will experience some minor modifications. The current LFM grid point boundary layer forecasts will be replaced by NGM 10-meter wind forecasts, and temperature forecasts from the NGM's lowest sigma level (e.g., analogous to the T1 forecasts in the FRHT, or FOUE bulletin). These forecasts will be interpolated to the LFM grid points currently used (Figure 2). Note, a proposal is pending to remove this section of the bulletin, since it is similar to other available guidance. However, at the time of this writing, a final determination has not been made. Finally, an updated **NWS Technical Procedures Bulletin** is being prepared that will further describe the updated guidance.

While the conversion of the MRPECS to the NGM may result in some improvements to the surge and erosion forecasts due to the input of better pressure forecasts, most of the concerns associated with the MRPECS as discussed in Section 2.1 will still exist. As documented by the NOAA disaster survey team that investigated the Halloween Storm, there is a need for a new, higher resolution, extratropical storm surge model, possibly patterned after SLOSH (NOAA 1992). The Marine Techniques Branch of TDL has initiated a effort to develop such guidance. On-going developmental efforts include the use of wind forecast information from the Aviation (AVN) model. It is hoped an initial version of this model will be ready for testing and evaluation at TDL in time for the 1992-1993 winter season (W. Shaffer, personal communication).

5. ACKNOWLEDGEMENTS

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NMCMRPECS
FZUS3 KWBC 290000
STORM SURGE FCST FT (INVALID FOR TROPICAL STORMS)

	00Z	06Z	12Z	18Z	00Z	06Z	12Z	18Z	00Z
PWM	0.6	0.6	0.7	0.7	0.5	0.7	1.0	1.1	1.2
BOS	0.9	0.7	0.9	0.7	0.5	0.8	1.0	1.2	1.3
NWP	1.4	1.3	1.5	1.4	1.2	1.6	1.5	1.8	1.6
SFD	1.8	1.3	1.3	1.2	0.7	0.5	1.1	0.6	1.1
LGA	1.9	2.0	2.6	2.3	2.1	1.7	1.7	2.3	1.6
NYC	2.0	2.3	2.2	2.5	2.3	2.2	2.2	2.6	1.9
ACY	1.9	2.1	2.3	2.0	1.9	1.8	1.9	2.3	2.2
BWH	2.0	2.2	2.4	2.1	2.0	1.7	1.0	2.2	1.9
BAL	0.4	0.8	1.3	2.3	2.6	3.3	2.7	2.6	2.0
ORF	1.7	1.9	2.7	2.2	2.6	2.7	2.4	2.0	1.9
AVN	1.8	1.8	2.0	1.7	2.0	2.0	2.2	2.3	2.0
CHS	1.8	2.1	2.1	1.9	1.8	1.3	1.1	0.9	0.6

BEACH EROSION GUIDANCE FOR EAST COAST STATES
INVALID FOR TROPICAL STORMS

	00Z	12Z	00Z	12Z	00Z
ME.	NONE	NONE	NONE	NONE	NONE
MASS.	NONE	MINOR	NONE	MINOR	NONE
R.I.	NONE	NONE	NONE	NONE	NONE
N.Y.	NONE	MODERATE	NONE	MODERATE	NONE
N.J.	NONE	MODERATE	NONE	MODERATE	NONE
DELMAR.	NONE	MODERATE	NONE	MODERATE	NONE.
VA.	MINOR	MODERATE	MODERATE	MAJOR	NONE
N.C.	NONE	MODERATE	NONE	MODERATE	MODERATE
S.C.	NONE	MODERATE	NONE	NONE	NONE

EAST COAST OFFSHORE BOUNDRY LAYER WIND AND TEMPERATURE FORECAST

	01	02	03	04	05	06	07	08	09
00Z	066479	054485	046381	021790	035878	034987	044470	035683	044982
12Z	014570	025379	365370	024283	364577	365281	363477	355180	364379
00Z	023579	025181	014880	035683	013880	015882	012879	365481	364380
12Z	043482	045284	034983	055886	024382	036184	013481	015883	365082
00Z	053384	054885	044885	074489	034685	054887	023986	035085	015085

	10	11	12	13	14	15	16	17	18
00Z	045289	043783	045687	054293	052684	044787	045992	072996	043487
12Z	354984	013580	354582	354489	022583	014184	354287	354892	013486
00Z	365884	013280	365483	354588	042382	364682	354887	333590	023683
12Z	025783	013782	365983	023387	022483	354984	355185	341491	363584
00Z	044088	364485	024685	051492	353286	355085	032888	251293	344486

	19	20	21	22	23	24	25	26	27
00Z	045891	045396	051987	034691	036495	032990	043190	035694	025390
12Z	363988	354891	022587	013590	363691	354894	023890	013393	363694
00Z	364385	343988	032486	363886	353787	333290	013188	363489	353390
12Z	345285	333588	012385	354185	334387	312890	363186	354087	333489
00Z	354487	341191	352687	334987	333590	291892	353587	324689	313291

	28	29	30	31	32	33	34	35
00Z	071791	044193	025497	052893	023996	061594	032896	070795
12Z	032689	023194	013295	032994	012997	042694	022697	052295
00Z	032489	013191	363191	022992	012892	042893	022994	062895
12Z	022286	353788	343489	013489	363491	022790	363392	032392
00Z	352189	343888	323790	352890	343490	362892	353892	021492

Figure 1. The MRPECS bulletin from the 0000 UTC cycle LFM, October 29, 1991.

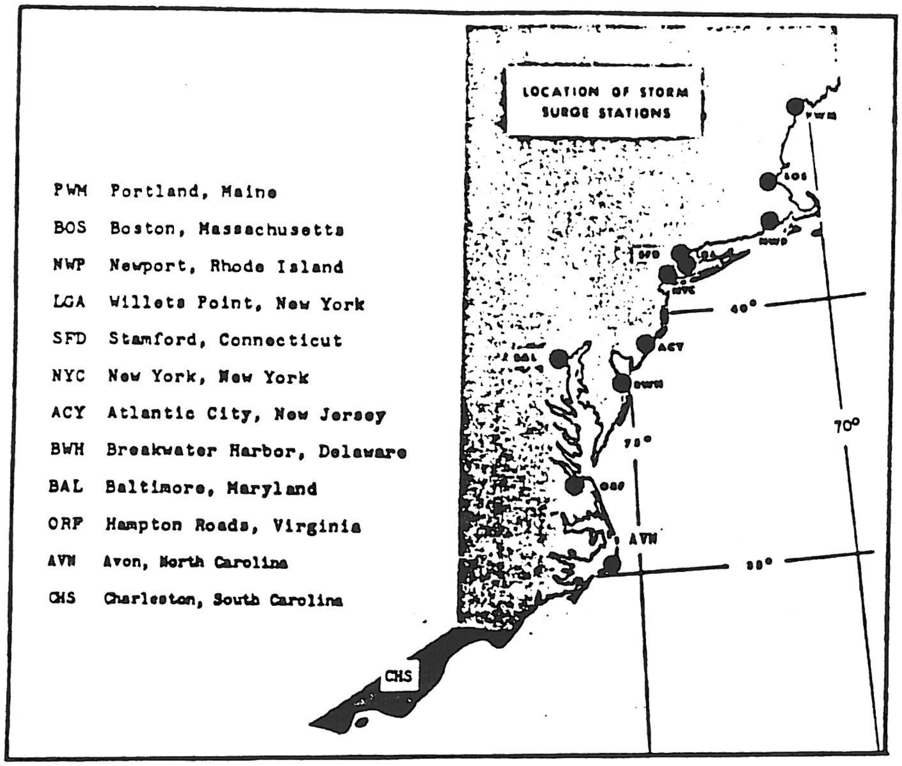

Figure 2. The twelve east coast locations for which extratropical storm surge forecasts are generated (from National Weather Service 1978).

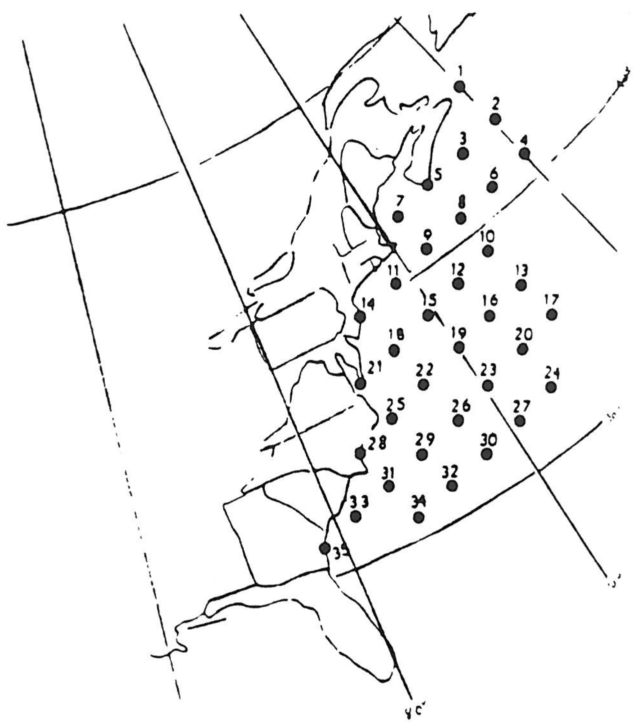

Figure 3. The LFM grid points for which the wind and temperature forecasts in Part 3 of the MRPECS bulletin are valid (from National Weather Service 1979).