P4.17 # NOGAPS Tendencies in Forecasting Central Surface Pressure of Mid-Latitude Cyclones

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1. INTRODUCTION

This paper investigates Navy Operational Global Atmospheric Prediction System (NOGAPS) tendencies and biases in the central sea-level pressure forecasts of extratropical cyclones. Temporal and regional forecast biases will be addressed for the total data set and for ocean and land regions for varying categories of development including deepening, rapidly deepening, and filling cyclones, and all cyclones. The criteria for those categories will be discussed in more detail in the next section. The regions of investigation include the total dataset, North America (NOAM), North Atlantic (NATL), Eurasia (EA), and North Pacific (NPAC).

The NOGAPS (Rosmond, Peng, Hogan, Pauley, 2002) model was developed by the Naval Research Lab (NRL-MRY) and is implemented at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) as a global numerical model to provide analyses and forecasts of synoptic and macro-scale phenomena such as extratropical waves of the Polar Front, including long and short-wave troughs, surface frontal systems, and tropical cyclones. NOGAPS was upgraded from T159L24 to T239L30 on 18-September, 2002. The corresponding Gaussian grid resolution went from 0.75° to 0.50°, or about 55 km in between grid points. Forecasts are made 4 times daily and extend to 144 hrs, using a 6-hr update cycle for data assimilation.

2. METHODOLOGY

Surface central pressure data used for this study was output from an operational post-processing job known as Systematic Error Identification System (SEISRAW) that sends daily 00Z and 12Z data to monthly files in three geographical regions: (1) the eastern two-thirds of NOAM and the NATL Basin; (2) EA including the Mediterranean, North, and Baltic Seas, and east Asia; and (3) NPAC, including very western NOAM (Harr, Brody, Tsui, 1983). The latitude and longitude boundaries used for this study will be discussed in greater detail later in this section. Data used for this study are from September 1999 to May 2003, with the exception of June, July, and August periods, which are omitted as extraneous to the sample. Mid-latitude lows are generally weak and the presence of thermal lows is frequent during summer months. Cyclones greater than 1010 mb are generally too weak to be operationally important and are omitted from the dataset by SEISRAW. Further screening of the data involves eliminating lows determined to be thermal in nature or those lacking at least two consecutive verifying analyses.

Criteria established for lows as deepening, rapidly deepening, filling, and all cyclones is as follows: deepening means deepening at a rate of greater than 1 mb/12 hours but less than 7.5 mb/12 hours, rapidly deepening means deepening at 7.5 mb/12 hours or greater, filling means filling at 1 mb/12 hours or greater, and all refers to any cyclone in a defined region for the dataset.

Geographical boundaries for categorizing land and ocean lows are determined as follows. Land lows include eastern NOAM (between 30°N and 75°N latitudes and 110°W and 60°W longitudes) and EA (between 25°N and 70°N latitudes and 30°E and 130°E longitudes). Results are determined for both the combined regions and for the independent landmasses. Ocean lows include those in the combined NATL and NPAC basins (between 70°N and 15°N latitudes and 75°W and 10°W longitudes; and between 20°N and 60°N latitudes, and 135°E, and 125°W longitudes). The individual NATL and NPAC regions, including adjacent landmasses, are defined by the following areas (between 15°N and 75°N latitudes and 10°E and 110°W longitudes) and (between 15°N and 80°N latitudes, and 110°E, and 110°W longitudes), respectively.

Mean error (Bias), Root Mean Square Error (RMSE), Standard Deviation (SD), frequency of error occurrence, and storm count (SC) are calculated for the data set and regions discussed in the previous paragraph for forecast

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times from 12 to 120 hrs. Calculations are based on matching forecast and verifying analysis times.

3. RESULTS

Starting with the entire dataset of 3064 cyclones that maintained a central mslp under 1010 mb, NOGAPS has a slight deep bias for all forecast times, though most pronounced after 48 hrs. The mean error for the dataset, at all forecast times, showed NOGAPS to have bias of -0.47 mb. The bias for specific times is -0.38 mb, -0.79 mb, and -0.69mb for 24, 72, and 120 hours, respectively. The RMSE for the corresponding forecast times is 5.10 mb 7.91 mb, and 9.64 mb. Calculations are based on 13149, 5231, and 2713 occurrences of matched forecast and verifying analyses, respectively. For the deepening cyclones, NOGAPS was weak (showing a weak bias) at all forecast times, with the smallest error (0.35 mb) at 12 hours and the largest (2.09 mb) at 96 hrs. Rapidly deepening cyclones, accounting for about 6.6 percent of the total dataset, are forecast with a large weak central mslp bias, greatest at 96 hours (5.49 mb). Filling cyclones, accounting for about 47 percent of occurrences, have a deep central mslp bias, for all forecast times. Largest deep bias values (-2.5 to -3.0 mb) are found in the latest forecast times.

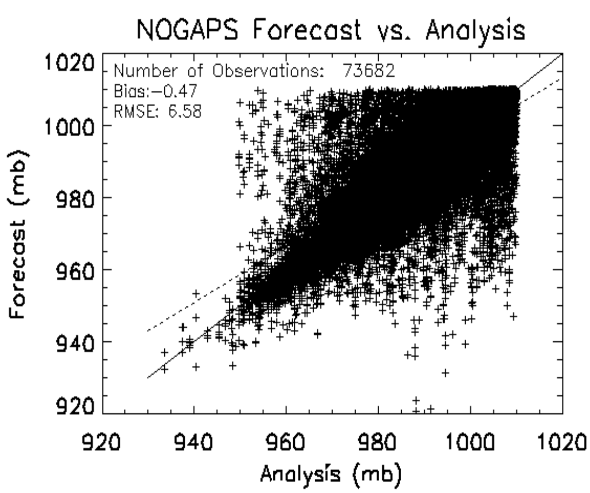

Figure 1: Data distribution for total dataset. Sharp delineation at 1010 mb indicates where SEISRAW omitted weaker storms from sample. Dashed line indicates best fit approximation and solid line bins forecast.

Figure 1 depicts the scatter of forecast versus analysis pressures (mb), for the more than 73,000 observations comprising the dataset. Figure 2 depicts pressure error (mb) from the verified rapidly deepening lows of the total dataset versus forecast time (hrs). A substantial weak bias is evident for all forecast times.

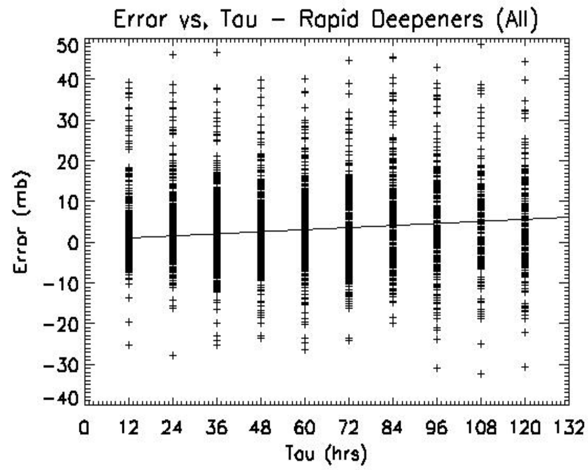

Figure 2: Forecast error (mb) vs. Time (hrs) for rapid deepening cyclones of the dataset. The best fit line indicates a large weak bias, particularly in the later forecast times.

The ocean region as described in the methodology section contained over 1000 verified lows at 12 and 24-hour forecasts, decreasing to near 350 at 120 hours. Similar to the total dataset, NOGAPS forecast ocean lows too deep at all forecast times, with the three largest deep central mslp biases at 72, 108, and 120 hours, calculated as -1.11 mb, -1.09 mb, and -1.33 mb, respectively. Forecasts of deepening ocean lows are weak, with the +1.0 mb error exceeded at 72 hours from 1062 occurrences, and the largest error 1.75 mb at 96 hours, calculated from 721 occurrences. Rapidly deepening lows are forecast with a large weak bias that exceeded 4.0 mb at 84, 96, and 108 hours, based on 174, 134, and 145 occurrences, respectively. For filling ocean lows, NOGAPS has a deep central mslp forecast bias at all forecast times. This bias exceeded -2.2 mb at all forecast times beyond 48 hours, reaching the largest bias of -2.83 mb at 120 hrs, with a respective RMSE of 10.28. The latter are calculated from 788 occurrences. Results of the ocean region are summarized in Figure 3 and Table 1. Tendencies in the NATL and NPAC regions are fairly similar to the ocean region though both have adjacent land area. Results of the NATL and NPAC regions are summarized in Figure 4 and Table 1.

NOGAPS forecast central mslp bias results for the roughly two-thirds of eastern NOAM, are contrary to those for all cases of the entire dataset and ocean region. Results from continental cyclones of NOAM showed NOGAPS to have weak forecast central mslp biases for all categories of storms except filling cases. For the all NOAM storms category the largest weak bias is 1.21 mb, with an RMSE of 7.19 mb at 84 hours, calculated from 88 identified storms. Calculated from 286 storms and 1009 occurrences, the 12-hour forecast bias was smallest at

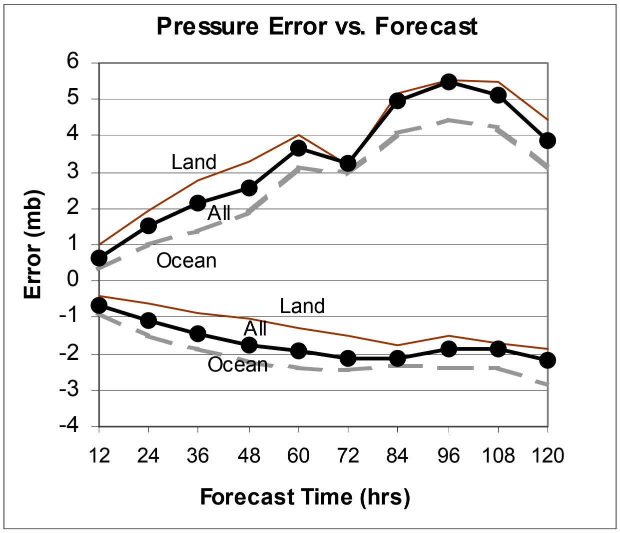

Figure 3: Mean pressure bias (mb) versus forecast time (hrs) for Land, All, and Ocean cyclones. Rapid deepeners (above) the x axis, filling cyclones (below).

0.26 mb with an RMSE of 1.79 mb. NOGAPS forecasts central mslp of Deepening NOAM cyclones with a substantial weak bias that exceeds 3.0 mb at all forecast times beyond 48 hours, except for 96 hrs. Corresponding RMSE values range from a minimum 7.2 mb at 60 hours to a maximum 10.58 mb at 120 hours. NOGAPS is deep with Filling NOAM lows to about the same magnitude that its deep with the "all" categories of ocean lows or those calculated from the total dataset. The deep bias ranged from a minimum of -0.13 mb at 48 hours, calculated from 115 storms and 196 occurrences to a maximum of -1.47 mb at 108 hours, calculated from 51 storms and 63 occurrences, respectively. Respective RMSE values are 4.05 mb and 7.28 mb. The rapid deepening lows in NOAM experienced the largest central mslp forecast bias of this study. The relative infrequence of storms whose forecasts are verified in the late forecast times makes the calculations for forecasts beyond 48 hours most questionable. The largest bias of the entire study was +8.33 mb with an RMSE of 14.67 mb, calculated from only 10 verified storms at the 84-hour forecast time. The 36-hour forecast bias, calculated from 35 storms, has a relatively high 4.31 mb.

The EA land lows due to the larger area/landmass, had substantially more verified storms (720 and 284 at 12 and 120 hours, respectively) than NOAM, and this

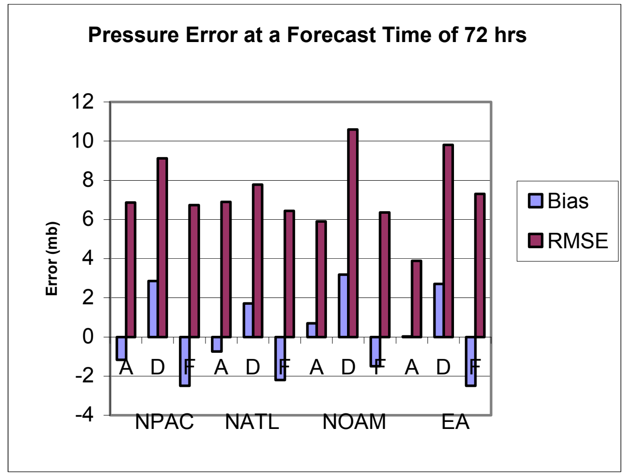

Figure 4: Mean pressure bias (mb) and RMSE (mb) for all (A), deepening (D), and filling (F) Ocean and Land regions, starting on the left with North Pacific, North Atlantic, North America, and Eurasia.

probably explains in part why forecast errors are smaller for this region. The central mslp bias was near zero (0.02, 0.00, and -0.04 mb, at 60, 72, and 84 hours, respectively) for all cases at most forecast times. Corresponding RMSE are relatively low. The 72-hour bias and RMSE for deepening, rapidly deepening, and filling lows are 0.95 mb and 4.31 mb, 2.70 mb and 6.67 mb, and -0.69 mb and 3.92 mb, respectively. Calculations are from 388, 22, and 518 occurrences from 188, 21, and 256 verified storms, respectively. Results of the combined EA and NOAM regions comprising land lows are summarized in Figure 4 and Table 1.

Ocean	48 hrs			72 hrs			96 hrs		
All	-1.0	6.9	5408	-1.1	8.2	3379	-0.9	9.6	2234
Deep	0.8	7.1	1826	1.1	8.6	1062	1.7	10.6	721
RD	1.8	8.6	408	3.0	10.3	268	4.4	12.9	174
Fill	-2.2	6.8	2704	-2.5	8.1	1778	-2.4	9.0	1165
NATL	48 hrs			72 hrs			96 hrs		
All	-.4	5.2	2286	-0.7	6.9	1367	-0.7	8.7	926
Deep	1.2	5.6	1060	1.7	7.8	439	1.9	9.5	303
RD	1.2	5.6	798	1.7	7.8	439	1.9	9.5	303
Fill	-1.6	5.1	1110	-2.2	6.4	693	-2.6	8.4	478
NPAC	48 hrs			72 hrs			96 hrs		
All	-1.3	5.5	3027	-1.2	6.9	1907	-1.1	8.3	1211
Deep	0.2	6.0	1004	1.0	7.5	578	1.0	9.5	388
RD	1.1	6.7	233	2.8	9.1	157	3.2	11.5	102
Fill	-2.4	5.3	1542	-2.5	6.7	1044	-2.4	7.9	641

Land	48 hrs			72 hrs			96 hrs		
All	-0.04	5.4	4961	-0.3	6.5	3138	-0.02	7.7	2214
Deep	1.4	5.9	1630	1.6	7.3	988	2.1	8.7	734
RD	3.3	8.42	254	3.2	10.6	172	5.5	12.9	120
Fill	-1.0	5.2	2314	-1.5	6.3	1460	-1.5	7.5	1009
NOAM	48 hrs			72 hrs			96 hrs		
All	0.9	4.6	434	0.7	5.9	201	0.7	7.6	148
Deep	2.4	5.3	153	3.7	8.2	56	2.1	9.0	52
RD	3.2	6.3	25	5.5	6.4	6	7.7	12.1	7
Fill	-0.1	4.0	196	-0.7	5.0	103	-0.5	6.9	70
EA	48 hrs			72 hrs			96 hrs		
All	0.3	3.4	1059	0.2	4.2	723	0.3	4.6	495
Deep	0.8	3.6	484	0.9	4.1	339	0.9	4.5	229
RD	4.6	6.9	30	2.7	6.7	22	3.4	6.3	14
Fill	-0.9	3.2	440	-0.6	4.4	280	-0.5	5.1	190

Table 1: Summarized regional results. The four cyclone categories listed under each region in the left column. Moving from left to right under 48, 72, and 96 hours, respectively, is bias (mb), RMSE (mb), and number of occurrences from which calculations are made.

4. CONCLUSIONS

Calculations made with this three-year data sample of over three thousand cyclones show NOGAPS to have a clearly weak forecast central mslp bias with deepening lows, which becomes even more pronounced with rapid deepeners. Conversely, weakening/filling lows have a statistically deep bias through the majority of the forecast cycle. These tendencies don't seem to be specific to lows of continental or oceanic origin, with the exception of eastern NOAM, where the largest weak biases are observed. A previous study on NOGAPS performance with NPAC cyclone central mslp forecasts (Harr, Elsberry, Hogan, Clune 1992) produced similar results. When all cases (deepening, rapidly deepening, filling, and those not meeting any criteria), at all times, and regions, oceanic and continental, are included in the calculation, NOGAPS exhibits a slightly deep bias of nearly –0.5 mb. To the forecaster using NOGAPS for guidance, this information would be best interpreted as, NOGAPS tends to be slow to deepen the central mslp of deepening and rapidly deepening lows resulting in a net weak pressure error. And conversely, NOGAPS tends to be slow at filling the central mslp of weakening lows. These tendencies don't appear to be particularly region specific, as defined by the regions of this study. If statistics are calculated specifically for regions of high cyclone activity and concentration where rapid deepeners are most frequent, it would be reasonable to expect the magnitude of the tendencies documented in this paper to increase.

Statistical validity is most questionable for later forecast times when the frequency of matching forecasts with verifying analyses is lowest. Though statistics on latest forecast times are not out-of-line with those observed at earlier times, there are a few examples where errors at 108 or 120 hours are smaller than errors at earlier forecast times, and this may have been a function of number of occurrences in the sample.

Future studies should address the question of whether recent parameterization improvements in NOGAPS have changed the tendencies documented in this report.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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