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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
SYSTEMS DEVELOPMENT OFFICE
TECHNIQUES DEVELOPMENT LABORATORY

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TDL Office Note 75-5

FORECASTING SURFACE WIND DIRECTION USING DEVIATIONS FROM THE PE BOUNDARY LAYER WIND

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The Techniques Development Laboratory (TDL) has been providing surface wind guidance to NWS forecasters since May 1973. We compute wind direction from individual estimates of the u and v components (Carter, 1973). While this procedure does minimize the mean square vector error, it does not minimize the mean square error of the direction itself (Glahn, 1970). Therefore, we decided to test a method of forecasting instead the deviation of the observed wind direction from the concurrent PE boundary layer forecast wind direction.

Figure 1 shows the 20 widely distributed stations we selected to test the direction deviation scheme. Forecasting equations were derived by both the u and v component scheme and the direction deviation scheme. Developmental data came from the warm seasons (April-September) of 1970, 1971, and 1972, and we used our standard set of predictors from the PE model (Carter, 1974).

Simple regression estimation of wind direction poses a special problem because of the circular nature of this variable. Hence, in order to apply our linear regression technique properly, we used only direction deviations between PE boundary layer wind and the observed wind which were within ± 90 degrees of the mean deviation for the individual station. The station mean deviations are listed in Table 1. They were determined subjectively by examining the frequency distributions of the difference between the boundary layer forecast valid at 1200 GMT and the observed wind at 1200 GMT during warm seasons of 1970, 1971, and 1972. Cases were eliminated from the development sample when the observed wind was less than 5 knots or the boundary speed forecast from the numerical model was less than 5 knots. This insured that the equations were developed on meaningful deviations while allowing enough cases for stability. The numbers of cases (out of 482 possible) used in developing the deviation equations are shown in Table 1. The u and v component equations were developed on all 482 cases.

We tested these equations on the warm season of 1973. Here, analogous to our standard operational verification system, we eliminated cases where the observed wind speed was less than 8 knots.

Table 2 shows the mean absolute and root-mean-square errors for all 20 stations combined for our standard method based on u and v, the forecast deviation scheme, and the PE boundary layer direction alone. All forecasts were made from 0000 GMT data and were valid 12 hours later. As you can see, our normal procedure is far superior to the deviation technique. In fact, the method involving deviations is little better than using the raw boundary layer forecasts.

Tables 3, 4, and 5 show these scores on a station by station basis. The deviation forecasts, as well as the PE boundary layer forecasts are particularly poor for the western plateau stations of Ely, Nevada and Albuquerque, New Mexico.

These results indicate that in general the PE boundary layer forecasts of wind direction were not well enough related to observed wind directions to favor using the deviation technique. Also, the predictors we screened may not have been well-suited to the direct prediction of wind direction. However, the difference between our present scheme based on u and v and the experimental deviation method is so great, it is doubtful that any efforts to change either the predictors or the regression technique would be worthwhile.

REFERENCES

Carter, G. M., 1973: Use of model output statistics in automated prediction of surface winds. TDL Office Note 73-4, 9 pp.

_____, 1974: Use of model output statistics in automated prediction of surface winds--No. 2. TDL Office Note 74-3, 9 pp.

Glahn, H. R., 1970: A method for predicting surface winds. ESSA Technical Memorandum WBTM TDL 29, 18 pp.

Table 1. Mean values of the difference between the PE forecast boundary layer wind direction and the observed wind direction at 20 selected cities for April through September of 1970, 1971, and 1972. All data were valid at 1200 GMT. Also the number of cases used in developing the direction deviation forecasting equations is given for each city.

Station	Mean Deviation	Number of Cases
Tampa, FL	10°	275
New Orleans, LA	10°	157
San Antonio, TX	30°	261
Atlanta, GA	10°	302
St. Louis, MO	20°	302
Buffalo, NY	0°	361
Hartford, CT	10°	244
Burlington, VT	10°	247
Green Bay, WI	10°	297
Sioux City, IA	20°	315
Albuquerque, NM	20°	179
Goodland, KS	-10°	354
Ely, NV	-10°	153
San Diego, CA	20°	155
Lander, WY	0°	173
Spokane, WA	50°	298
Portland, OR	40°	157
Fresno, CA	10°	138
Baltimore, MD	10°	266
Detroit, MI	20°	319

Table 2. Errors associated with objective forecasts of wind direction for 20 stations combined (see Fig. 1) during April through September 1973. All scores apply to forecasts valid at 1200 GMT. The initial data were from the 0000 GMT runs of the PE model and 0600 GMT surface observations.

Forecast Method	Mean Absolute Error (degrees)	Root Mean Square Error (degrees)	Number of Cases
u, v Direction	24.7	37.1	874
Deviations	39.0	55.6	874
Boundary Layer Forecast	46.1	63.9	874

Table 3. Errors associated with objective forecasts of wind direction (based on u and v) during April through September 1973.

12842 TAMPA, FLA WIND DIRECTION	FORECAST--MEAN VALUE= 148.621	MEAN ABSOLUTE ERROR= 21.034	ROOT MEAN SQUARE ERROR= 33.270	NO. OF CASES= 29
12916 NEW ORLEANS, LA WIND DIRECTION	FORECAST--MEAN VALUE= 171.667	MEAN ABSOLUTE ERROR= 24.167	ROOT MEAN SQUARE ERROR= 41.833	NO. OF CASES= 24
12921 SAN ANTONIO, TEX WIND DIRECTION	FORECAST--MEAN VALUE= 188.182	MEAN ABSOLUTE ERROR= 28.636	ROOT MEAN SQUARE ERROR= 43.170	NO. OF CASES= 44
13874 ATLANTA, GA WIND DIRECTION	FORECAST--MEAN VALUE= 231.667	MEAN ABSOLUTE ERROR= 28.611	ROOT MEAN SQUARE ERROR= 40.311	NO. OF CASES= 36
13994 ST LOUIS, MO WIND DIRECTION	FORECAST--MEAN VALUE= 212.826	MEAN ABSOLUTE ERROR= 22.609	ROOT MEAN SQUARE ERROR= 32.704	NO. OF CASES= 46
14733 BUFFALO, NY WIND DIRECTION	FORECAST--MEAN VALUE= 220.405	MEAN ABSOLUTE ERROR= 21.757	ROOT MEAN SQUARE ERROR= 31.473	NO. OF CASES= 74
14740 HARTFORD, CONN WIND DIRECTION	FORECAST--MEAN VALUE= 202.143	MEAN ABSOLUTE ERROR= 25.000	ROOT MEAN SQUARE ERROR= 36.677	NO. OF CASES= 42
14742 BURLINGTON, VT WIND DIRECTION	FORECAST--MEAN VALUE= 208.727	MEAN ABSOLUTE ERROR= 21.091	ROOT MEAN SQUARE ERROR= 36.081	NO. OF CASES= 55
14898 GREEN BAY, WIS WIND DIRECTION	FORECAST--MEAN VALUE= 180.222	MEAN ABSOLUTE ERROR= 16.667	ROOT MEAN SQUARE ERROR= 19.944	NO. OF CASES= 45
14943 SIOUX CITY, IOWA WIND DIRECTION	FORECAST--MEAN VALUE= 206.667	MEAN ABSOLUTE ERROR= 29.206	ROOT MEAN SQUARE ERROR= 45.004	NO. OF CASES= 63
23050 ALBUQUERQUE, N MEX WIND DIRECTION	FORECAST--MEAN VALUE= 93.571	MEAN ABSOLUTE ERROR= 39.762	ROOT MEAN SQUARE ERROR= 50.733	NO. OF CASES= 42
23065 GOODLAND, KANS WIND DIRECTION	FORECAST--MEAN VALUE= 239.101	MEAN ABSOLUTE ERROR= 22.809	ROOT MEAN SQUARE ERROR= 33.098	NO. OF CASES= 89
23154 ELY, NEV WIND DIRECTION	FORECAST--MEAN VALUE= 200.806	MEAN ABSOLUTE ERROR= 17.419	ROOT MEAN SQUARE ERROR= 27.179	NO. OF CASES= 62
23188 SAN DIEGO, CALIF WIND DIRECTION	FORECAST--MEAN VALUE= 179.000	MEAN ABSOLUTE ERROR= 55.000	ROOT MEAN SQUARE ERROR= 72.457	NO. OF CASES= 10
24021 LANDER, WYO WIND DIRECTION	FORECAST--MEAN VALUE= 243.000	MEAN ABSOLUTE ERROR= 36.000	ROOT MEAN SQUARE ERROR= 53.728	NO. OF CASES= 30
24157 SPOKANE, WASH WIND DIRECTION	FORECAST--MEAN VALUE= 173.382	MEAN ABSOLUTE ERROR= 22.941	ROOT MEAN SQUARE ERROR= 31.012	NO. OF CASES= 68
24229 PORTLAND, OREG WIND DIRECTION	FORECAST--MEAN VALUE= 272.000	MEAN ABSOLUTE ERROR= 17.000	ROOT MEAN SQUARE ERROR= 18.708	NO. OF CASES= 10
93193 FRESNO, CALIF WIND DIRECTION	FORECAST--MEAN VALUE= 313.333	MEAN ABSOLUTE ERROR= 13.333	ROOT MEAN SQUARE ERROR= 14.142	NO. OF CASES= 3
93721 BALTIMORE, MD WIND DIRECTION	FORECAST--MEAN VALUE= 204.103	MEAN ABSOLUTE ERROR= 21.538	ROOT MEAN SQUARE ERROR= 27.456	NO. OF CASES= 39
94847 DETROIT, MICH WIND DIRECTION	FORECAST--MEAN VALUE= 194.127	MEAN ABSOLUTE ERROR= 25.556	ROOT MEAN SQUARE ERROR= 39.781	NO. OF CASES= 63

Table 4. Errors as iated with objective forecasts of wind direction sed on deviations from the PE boundary layer wind) during April through September 1973.

Station	Wind direction forecast—mean value	Mean absolute error	Root mean square error	No. of cases
12842 TAMPA, FLA	158.621	29.655	43.549	29
12916 NEW ORLEANS, LA	182.500	30.833	46.458	24
12921 SAN ANTONIO, TEX	172.727	37.273	54.188	44
13874 ATLANTA, GA	214.722	42.222	58.878	36
13994 ST LOUIS, MO	203.478	26.739	39.535	46
14733 BUFFALO, NY	216.486	27.568	39.763	74
14740 HARTFORD, CONN	181.190	31.667	41.028	42
14742 BURLINGTON, VT	194.545	30.909	40.181	55
14898 GREEN BAY, WIS	189.333	25.778	39.215	45
14943 SIOUX CITY, IOWA	196.825	26.984	41.442	63
23050 ALBUQUERQUE, N MEX	167.143	87.619	100.238	42
23065 GOODLAND, KANS	224.270	36.517	51.243	89
23154 ELY, NEV	184.839	85.000	96.912	62
23188 SAN DIEGO, CALIF	246.000	66.000	82.946	10
24021 LANDER, WYO	201.667	50.667	68.215	30
24157 SPOKANE, WASH	187.941	35.441	46.826	68
24229 PORTLAND, OREG	226.000	32.000	40.866	10
93193 FRESNO, CALIF	316.667	30.000	34.156	3
93721 BALTIMORE, MD	203.590	30.769	44.836	39
94847 DETROIT, MICH	217.778	27.519	44.437	63

Table 5. Errors associate ith PE boundary layer wind direction forecasts du g April through September 1973.

Station	Wind direction forecast—mean value	Mean absolute error	Root mean square error	No. of cases
12842 TAMPA, FLA	157.931	29.655	43.470	29
12916 NEW ORLEANS, LA	177.083	27.917	44.675	24
12921 SAN ANTONIO, TEX	172.273	37.727	55.062	44
13874 ATLANTA, GA	216.389	39.444	54.975	36
13994 ST LOUIS, MO	203.913	33.696	44.502	46
14733 BUFFALO, NY	220.946	28.784	42.283	74
14740 HARTFORD, CONN	202.857	43.333	56.484	42
14742 BURLINGTON, VT	220.909	36.909	45.984	55
14898 GREEN BAY, WIS	173.556	30.444	43.333	45
14943 SIOUX CITY, IOWA	188.095	34.444	44.597	63
23050 ALBUQUERQUE, N MEX	225.952	87.857	101.266	42
23065 GOODLAND, KANS	210.899	39.326	54.422	89
23154 ELY, NEV	180.968	99.194	114.124	62
23188 SAN DIEGO, CALIF	268.000	84.000	98.285	10
24021 LANDER, WYO	226.000	64.333	83.845	30
24157 SPOKANE, WASH	245.147	73.824	86.636	68
24229 PORTLAND, OREG	278.000	25.000	28.810	10
93193 FRESNO, CALIF	326.667	20.000	34.641	3
93721 BALTIMORE, MD	213.077	34.103	49.381	39
94847 DETROIT, MICH	204.286	29.683	42.145	63

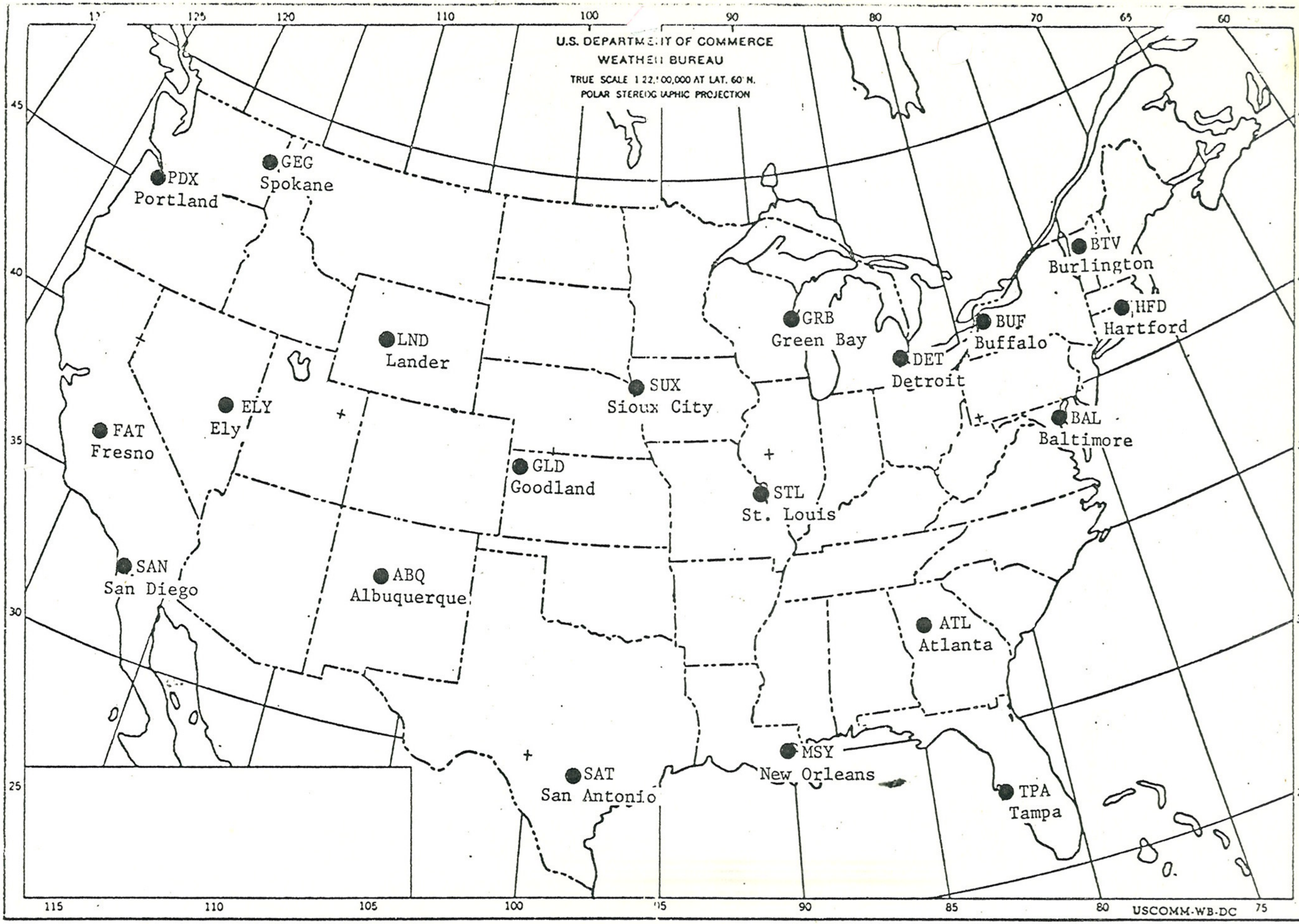

Figure 1. Twenty stations used to test the wind direction deviation scheme.