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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
SYSTEMS DEVELOPMENT OFFICE
TECHNIQUES DEVELOPMENT LABORATORY

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 $\pm$ 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.

12842 TAMPA, FLA WIND DIRECTION FORECAST--MEAN VALUE= 158.621	MEAN ABSOLUTE ERROR= 29.655	ROOT MEAN SQUARE ERROR= 43.549	NO. OF CASES= 29	
12916 NEW ORLEANS, LA WIND DIRECTION FORECAST--MEAN VALUE= 182.500	MEAN ABSOLUTE ERROR= 30.833	ROOT MEAN SQUARE ERROR= 46.458	NO. OF CASES= 24	
12921 SAN ANTONIO, TEX WIND DIRECTION FORECAST--MEAN VALUE= 172.727	MEAN ABSOLUTE ERROR= 37.273	ROOT MEAN SQUARE ERROR= 54.188	NO. OF CASES= 44	
13874 ATLANTA, GA WIND DIRECTION FORECAST--MEAN VALUE= 214.722	MEAN ABSOLUTE ERROR= 42.222	ROOT MEAN SQUARE ERROR= 58.878	NO. OF CASES= 36	
13994 ST LOUIS, MO WIND DIRECTION FORECAST--MEAN VALUE= 203.478	MEAN ABSOLUTE ERROR= 26.739	ROOT MEAN SQUARE ERROR= 39.535	NO. OF CASES= 46	
14733 BUFFALO, NY WIND DIRECTION FORECAST--MEAN VALUE= 216.486	MEAN ABSOLUTE ERROR= 27.568	ROOT MEAN SQUARE ERROR= 39.763	NO. OF CASES= 74	
14740 HARTFORD, CONN WIND DIRECTION FORECAST--MEAN VALUE= 181.190	MEAN ABSOLUTE ERROR= 31.667	ROOT MEAN SQUARE ERROR= 41.028	NO. OF CASES= 42	
14742 BURLINGTON, VT WIND DIRECTION FORECAST--MEAN VALUE= 194.545	MEAN ABSOLUTE ERROR= 30.909	ROOT MEAN SQUARE ERROR= 40.181	NO. OF CASES= 55	
14898 GREEN BAY, WIS WIND DIRECTION FORECAST--MEAN VALUE= 189.333	MEAN ABSOLUTE ERROR= 25.778	ROOT MEAN SQUARE ERROR= 39.215	NO. OF CASES= 45	
14943 SIOUX CITY, IOWA WIND DIRECTION FORECAST--MEAN VALUE= 196.825	MEAN ABSOLUTE ERROR= 26.984	ROOT MEAN SQUARE ERROR= 41.442	NO. OF CASES= 63	
23050 ALBUQUERQUE, N MEX WIND DIRECTION FORECAST--MEAN VALUE= 167.143	MEAN ABSOLUTE ERROR= 87.619	ROOT MEAN SQUARE ERROR= 100.238	NO. OF CASES= 42	
23065 GOODLAND, KANS WIND DIRECTION FORECAST--MEAN VALUE= 224.270	MEAN ABSOLUTE ERROR= 36.517	ROOT MEAN SQUARE ERROR= 51.243	NO. OF CASES= 89	
23154 ELY, NEV WIND DIRECTION FORECAST--MEAN VALUE= 184.839	MEAN ABSOLUTE ERROR= 85.000	ROOT MEAN SQUARE ERROR= 96.912	NO. OF CASES= 62	
23188 SAN DIEGO, CALIF WIND DIRECTION FORECAST--MEAN VALUE= 246.000	MEAN ABSOLUTE ERROR= 66.000	ROOT MEAN SQUARE ERROR= 82.946	NO. OF CASES= 10	
24021 LANDER, WYO WIND DIRECTION FORECAST--MEAN VALUE= 201.667	MEAN ABSOLUTE ERROR= 50.667	ROOT MEAN SQUARE ERROR= 68.215	NO. OF CASES= 30	
24157 SPOKANE, WASH WIND DIRECTION FORECAST--MEAN VALUE= 187.941	MEAN ABSOLUTE ERROR= 35.441	ROOT MEAN SQUARE ERROR= 46.826	NO. OF CASES= 68	
24229 PORTLAND, OREG WIND DIRECTION FORECAST--MEAN VALUE= 226.000	MEAN ABSOLUTE ERROR= 32.000	ROOT MEAN SQUARE ERROR= 40.866	NO. OF CASES= 10	
93193 FRESNO, CALIF WIND DIRECTION FORECAST--MEAN VALUE= 316.667	MEAN ABSOLUTE ERROR= 30.000	ROOT MEAN SQUARE ERROR= 34.156	NO. OF CASES= 3	
93721 BALTIMORE, MD WIND DIRECTION FORECAST--MEAN VALUE= 203.590	MEAN ABSOLUTE ERROR= 30.769	ROOT MEAN SQUARE ERROR= 44.836	NO. OF CASES= 39	
94847 DETROIT, MICH WIND DIRECTION FORECAST--MEAN VALUE= 217.778	MEAN ABSOLUTE ERROR= 27.619	ROOT MEAN SQUARE ERROR= 44.437	NO. OF CASES= 63	

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

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

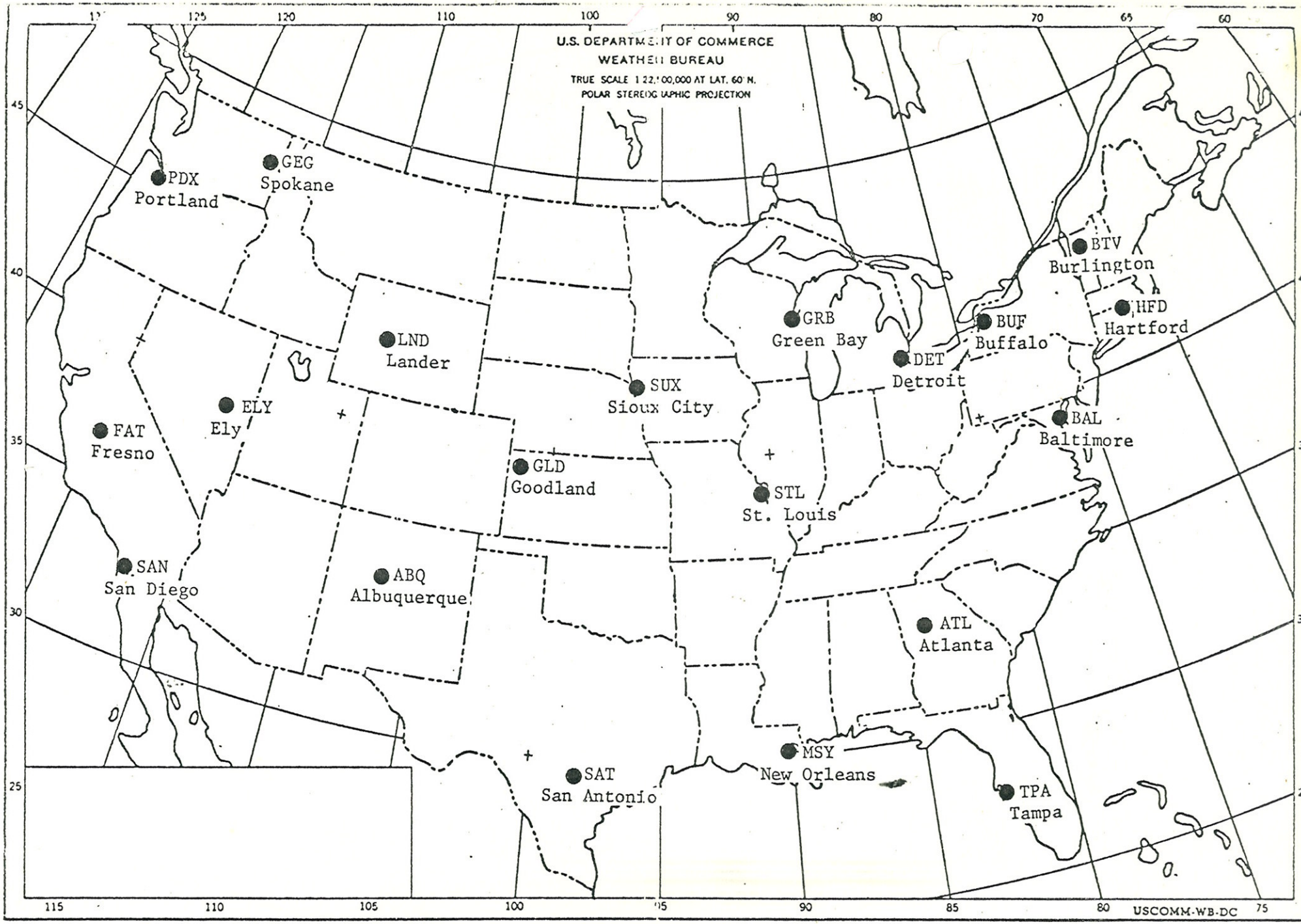

Figure 1. Twenty stations used to test the wind direction deviation scheme.