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AUTOMATED PREDICTION OF SURFACE WINDS IN ALASKA--NO. 1

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1. INTRODUCTION

Objective surface wind forecasts for 233 stations in the counterminous United States are available on teletypewriter as guidance to National Weather Service (NWS) forecasters. This automated system, based on the Model Output Statistics (MOS) technique (Klein and Glahn, 1974), is described in detail by Carter (1975). Forecasts of wind direction and speed are provided for projections of 12 to 48 h in advance of 0000 GMT and 1200 GMT. The definition of our forecast wind is the same as that of the observed wind: namely, the one-minute average direction and speed for a specific time.

We are now in the process of developing a similar automated system to predict surface winds in Alaska. Table 1 shows the 14 stations for which we have derived regression equations for the winter season of December, January, and February. As part of this project, we also conducted a verification study involving four of these stations.

Table 1. Fourteen stations used to develop an automated surface wind forecasting system for Alaska.

Anchorage	Juneau
Annette	King Salmon
Barrow	Kotzebue
Barter Island	McGrath
Bethel	Nome
Cold Bay	St. Paul Island
Fairbanks	Yakutat

2. PREDICTORS AND DEVELOPMENT OF FORECASTING EQUATIONS

We generated, using the MOS approach, one set of prediction equations for the 0000 GMT runs and another for the 1200 GMT runs of the Primitive Equation (PE) model (Shuman and Hovermale, 1968). Each set includes equations to predict U, V, and S for projections of 12, 18, 24, 30, 36, 42, and 48 h. Separate equations were developed for each station.

Table 2 shows the potential predictors we screened from December through February of 1969-70, 1970-71, 1971-72, 1972-73, 1973-74, 1974-75, and 1975-76. These included several wind related forecast fields from the PE model, plus the first and second harmonics of the day of the year. For the 12, 18, 24, and 30 h projections, we also screened surface observations of wind, sky cover, and temperature available six hours after the PE model input times. Backup equations free of observed predictors were also derived for these four projections.

We allowed the screening procedure to select up to 12 predictors, but only as long as each one reduced the variance of any one of the three predictands (U, V, or S) by an additional three-fourths of one percent. Thus, many of the equations contain less than the full 12 terms. However, all of the equations contain at least six predictors.

Table 3 shows the Alaskan wind equations valid 24 h after 0000 GMT at King Salmon. Here, nine PE forecasts, two 0600 GMT observed weather elements, and the cosine of the day of the year reduced the variance of U, V, and S by 43, 51, and 38%, respectively. The three equations for U, V, and S all use the same 12 predictors, but of course, each equation has its own unique set of regression coefficients.

Table 4 is a summary of the predictors selected most frequently by all the equations for projections of 12, 24, 36, and 48 h from 0000 GMT. Observed weather elements are very important for the 12 h projection, while PE boundary layer forecasts of U, V, and S heavily influence the equations for the other three periods.

3. TESTING

We carried out a verification experiment in order to determine how our automated forecasts compare with those prepared at Weather Service Forecast Offices (WSFO's) in Alaska. In particular, we verified objective forecasts based on MOS and subjective NWS local forecasts for Annette, Juneau, Fairbanks, and Anchorage during December, January, and February of 1974-75 and 1975-76. The objective predictions were produced from regression equations developed on the five winters of 1969-70, 1970-71, 1971-72, 1972-73, and 1973-74. These forecasts were generated solely for verification purposes, so they were not available as guidance to the field forecasters. We adjusted each automated forecast of wind speed using an "inflation" technique in the same manner as we enhance our operational forecasts for the counterminous United States (see Carter, 1975).

Since the local forecasts were recorded as calm if the wind speed was expected to be less than 8 knots, we verified these forecasts in two ways. First, for all those cases where both the objective and subjective wind speed forecasts were at least 8 knots, the mean absolute error (MAE) of speed was computed. Cases where the observed wind was calm were then eliminated from this sample and the MAE of direction was computed. Secondly, for all cases where both objective and subjective forecasts were available, skill score, percent correct, and bias by category (i.e., the number of forecasts in a particular category divided by the number of observations in that category) were computed from contingency tables of wind speed. The seven categories were: less than 8, 8-12, 13-17, 18-22, 23-27, 28-32, and greater than 32 knots.

Table 5 shows the overall verification scores for three forecast periods. The verification times are 0000 GMT (today), 1200 GMT (tonight), and 0000 GMT (tomorrow). Considering both the latest observed and forecast input data that was available to each forecast system, these valid times correspond to projections of 18, 36, and 48 h for the objective predictions, and 9, 21, and

33 h for the subjective forecasts. These differences are present because the local forecasts were not transmitted until 1600 GMT, and 1500 GMT surface observations were most likely used in their preparation. In contrast, the objective predictions were based mainly on 0000 GMT cycle forecasts from the PE model; except for the initial projection where 0600 GMT observed data were also used.

Table 5 shows the comparative scores for all four stations combined, and Tables 6-9 give the verification scores for each individual station. Most of these scores indicate that the subjective wind forecasts were superior to those from our PE-based system during the test period. This may be due to the substantial influence of terrain on surface winds in Alaska, plus the 9 to 15 h length of projection advantage for the local forecasts. Considering the latter factor, and the overall merits of an objective guidance scheme, the comparative verification scores are encouraging.

4. FUTURE WORK

We will continue to use this same basic approach to develop Alaskan wind prediction equations for the spring, summer, and fall seasons. In 1977 we plan to begin transmitting (via teletypewriter and/or facsimile) objective guidance wind forecasts based on these equations.

ACKNOWLEDGMENTS

Special thanks are extended to George Hollenbaugh of TDL for assistance in verifying the objective and subjective surface wind forecasts. We also are grateful to the Technical Procedures Branch of the Office of Meteorology and Oceanography for providing us with the local forecasts.

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Table 2. Potential predictors available to the screening regression program for the winter season. The stars indicate that the field is smoothed over 5 (*) or 9 (**) grid points.

Predictors	Projection (hours from model run time)
a) PE Model Output	
U, V, S (Boundary Layer)	6, 12, 18, 24*, 36**, 48**
U, V, S (850 mb, 700 mb, 500 mb)	24
Geostrophic U, V, S (1000 mb, 850 mb, 700 mb)	12, 18, 24*, 36*, 48*
Geostrophic Relative Vorticity (1000 mb, 850 mb, 500 mb	12, 18*, 24*, 36**, 48**
Boundary Layer Wind Divergence	12, 18*, 24*, 36**, 48**
Constant Pressure Height (1000 mb, 850 mb, 500 mb	12, 18, 24, 36*, 48*
Thickness (500 mb Hgt-1000 mb Hgt)	12, 18, 24, 36*, 48*
Surface Pressure (P)	12, 24*, 36*, 48**
Surface Pressure Change	$P_{24} - P_{12}$, $(P_{36} - P_{24})$*, $(P_{48} - P_{36})$**
Mean Relative Humidity (1000 mb to 400 mb)	12, 18*, 24*, 30**, 36**, 42**, 48**
Temperature (1000 mb, 850 mb)	12, 24*, 36**, 48**
Temperature (700 mb)	24
Potential Temperature (Boundary Layer)	12, 18, 24, 36*, 48*
Stability (850 mb Temp - 1000 mb Temp)	12, 24, 36*, 48
Stability (700 mb Temp - 850 mb Temp)	24
b) Other Predictors	
Sine and Cosine of the Day of the Year and Twice the Day of the Year	0
Surface Observations (Total Sky Cover, Temperature, U, V, S)	6

Table 3. Sample equations for estimating the U and V wind components and the wind speed, S, 24 h after 0000 GMT at King Salmon. The PE forecast data sample consisted of 560 days from the winter seasons of 1969–70 through 1975–76.

Predictor	Forecast Projection (h)	Cumulative reduction of variance			Coefficients			Units
		U	V	S	U	V	S	
Regression Constant	----	----	----	----	0.374	-5.465	0.514	kt
1. Boundary layer V	24	0.096	0.413	0.007	0.076	0.150	0.056	$m\ s^{-1}$
2. 1000 mb geostrophic S	24	0.161	0.415	0.254	0.286	0.155	0.417	$m\ s^{-1}$
3. Boundary layer U	24	0.309	0.444	0.256	0.275	0.130	0.014	$m\ s^{-1}$
4. Observed S	6	0.312	0.444	0.310	0.045	-0.034	0.192	kt
5. 850 mb geostrophic S	18	0.359	0.451	0.314	-0.495	0.026	0.057	$m\ s^{-1}$
6. 1000 mb geostrophic U	24	0.368	0.480	0.319	0.311	0.628	-0.237	$m\ s^{-1}$
7. Mean relative humidity	24	0.387	0.480	0.345	-0.049	-0.015	0.067	%
8. 850 mb geostrophic V	36	0.406	0.493	0.345	-0.278	0.337	-0.024	$m\ s^{-1}$
9. Cosine of day of year	0	0.414	0.493	0.361	4.229	2.269	-5.731	none
10. 500 mb geostrophic S	36	0.414	0.497	0.376	0.027	0.112	0.156	$m\ s^{-1}$
11. Boundary layer U	18	0.414	0.508	0.376	-0.060	-0.284	0.083	$m\ s^{-1}$
12. Observed U	6	0.425	0.510	0.384	0.152	-0.068	-0.113	kt
Total standard error of estimate (kt)		5.45	5.85	4.92				

Table 4. PE forecast and 0600 GMT observed predictors listed according to the total number of times they are used by the winter season surface wind equations for the 0000 GMT forecast cycle. (Note: geo.-geostrophic, rel. vort.-relative vorticity, pot. temp.-potential temperature)

Rank	Forecast Projection (in hours from 0000 GMT) 12	24	36	48
1	Observed V	Bound. layer S	Bound. layer V	Bound. layer V
2	Observed S	Bound. layer U	1000 mb geo. V	Bound. layer U
3	Observed U	Bound. layer V	Bound. layer S	1000 mb geo. S
4	Bound. layer U	Observed S	Bound. layer U	Bound. layer S
5	Bound. layer S	1000 mb geo. S	Mean rel. humidity	850 mb geo. S
6	Bound. layer V	1000 mb geo. V	1000 mb geo. S	1000 mb geo. U
7	1000 mb geo. U.	850 mb geo. S	850 mb geo. S	500 mb geo. V
8	850 mb geo. S	1000 mb geo. U	850 mb geo. V	Bound. layer pot. temp.
9	1000 mb geo. S	Observed V	1000 mb geo. U	500 mb geo. S
10	850 mb geo. V	Observed U	850 mb geo. U	850 mb geo. U
11	1000 mb geo. V	Bound layer pot. temp.	1000 mb rel. vort.	500 mb height
12	Sfc. pressure change	Mean rel. humidity	500 mb geo. S	850 mb rel. vort.

Table 5. Verification scores for TDL objective (OBJ) and NWS subjective (SUBJ) surface wind forecasts for 4 stations in Alaska during December through February of 1974-75 and 1975-76.

VALID TIME (GMT)	TYPE OF FCST.	DIRECTION		SPEED													
								CONTINGENCY TABLE									
										BIAS-NO. FCST./NO. OBS.							
		MEAN ABS. ERROR (DEG)	NO. OF CASES	MEAN ABS. ERROR (KTS)	MEAN FCST (KTS)	MEAN OBS. (KTS)	NO. OF CASES	SKILL SCORE	PERCENT FCST. CORRECT	CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)	NO. OF CASES
0000 TODAY	OBJ. SUBJ.	29 23	156	5.1 3.7	14.5 14.7	13.1	159	0.28 0.40	58 65	1.03 1.01 (349)	0.84 1.00 (134)	0.90 0.93 (70)	1.70 1.17 (23)	0.86 0.64 (14)	2.00 2.00 (2)	** * (0)	592
1200 TONITE	OBJ. SUBJ.	40 36	147	5.8 5.0	15.0 14.3	11.9	150	0.26 0.33	58 62	0.90 0.93 (378)	1.21 1.29 (109)	0.94 0.98 (62)	1.43 0.96 (28)	1.71 1.14 (7)	1.67 0.33 (3)	0.0 0.0 (1)	588
0000 TOMRW	OBJ. SUBJ.	35 38	145	5.8 5.0	13.9 13.0	11.6	151	0.26 0.22	56 55	1.00 1.00 (343)	1.07 1.22 (129)	0.82 0.81 (72)	1.22 1.00 (23)	0.83 0.08 (12)	1.67 0.33 (3)	* * (0)	582

* This category was neither forecast nor observed.
** This category was forecast once but was never observed.

Table 6. Same as Table 5 except for Annette, Alaska only.

VALID TIME (GMT)	TYPE OF FCST.	DIRECTION		SPEED													
								CONTINGENCY TABLE									
										BIAS-NO. FCST./NO. OBS.							
		MEAN ABS. ERROR (DEG)	NO. OF CASES	MEAN ABS. ERROR (KTS)	MEAN FCST (KTS)	MEAN OBS. (KTS)	NO. OF CASES	SKILL SCORE	PERCENT FCST. CORRECT	CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)	NO. OF CASES
0000 TODAY	OBJ. SUBJ.	31 22	80	4.4 3.8	13.9 15.7	13.7	81	0.22 0.30	42 48	1.00 0.98 (53)	0.94 0.92 (51)	1.20 1.17 (30)	1.33 1.17 (12)	0.40 0.60 (10)	0.50 2.00 (2)	* * (0)	158
1200 TONITE	OBJ. SUBJ.	45 37	78	4.9 4.7	15.4 14.8	12.7	78	0.19 0.35	40 53	0.79 0.95 (61)	1.06 1.06 (47)	0.88 1.00 (33)	2.00 1.00 (13)	1.25 1.25 (4)	1.00 0.50 (2)	* * (0)	160
0000 TOMRW	OBJ. SUBJ.	38 43	77	5.3 4.9	13.1 13.6	12.6	78	0.17 0.04	39 31	0.85 1.00 (54)	1.25 1.28 (47)	1.17 0.83 (30)	0.85 1.08 (13)	0.50 0.13 (8)	0.0 0.33 (3)	* * (0)	155

*This category was neither forecast nor observed.

Table 7. Same as Table 5 except for Juneau, Alaska only.

VALID TIME (GMT)	TYPE OF FCST.	DIRECTION		SPEED														
								CONTINGENCY TABLE										
										BIAS-NO. FCST./NO. OBS.								
		MEAN ABS. ERROR (DEG)	NO. OF CASES	MEAN ABS. ERROR (KTS)	MEAN FCST (KTS)	MEAN OBS. (KTS)	NO. OF CASES	SKILL SCORE	PERCENT FCST. CORRECT	CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)	NO. OF CASES
0000	OBJ.	21	61	6.3	16.1	13.3	63	0.17	41	1.09	0.63	0.76	2.09	2.00	***	**	163
TODAY	SUBJ.	18		3.3	14.2			0.41	60	1.13	0.92	0.86	1.00	0.75	*	*	
										(68)	(51)	(29)	(11)	(4)	(0)	(0)	
1200	OBJ.	34	59	7.2	15.3	11.7	62	0.14	40	0.84	1.14	1.13	1.00	2.33	3.00	0.0	160
TONITE	SUBJ.	33		5.4	14.0			0.17	44	0.85	1.51	0.83	0.93	1.00	0.0	0.0	
										(80)	(37)	(24)	(14)	(3)	(1)	(1)	
0000	OBJ.	25	59	6.3	15.2	11.2	62	0.12	38	1.01	0.94	0.62	1.60	1.50	****	*	160
TOMRW	SUBJ.	28		5.2	12.4			0.16	43	0.93	1.32	0.93	0.50	0.0	*	*	
										(67)	(50)	(29)	(10)	(4)	(0)	(0)	

* This category was neither forecast nor observed.
** This category was forecast once but was never observed.
*** This category was forecast three times but but was never observed.
**** This category was forecast five times but was never observed.

Table 8. Same as Table 5 except for Fairbanks, Alaska only.

VALID TIME (GMT)	TYPE OF FCST.	DIRECTION		SPEED													
								CONTINGENCY TABLE									
										BIAS-NO. FCST./NO. OBS.							
		MEAN ABS. ERROR (DEG)	NO. OF CASES	MEAN ABS. ERROR (KTS)	MEAN FCST (KTS)	MEAN OBS. (KTS)	NO. OF CASES	SKILL SCORE	PERCENT FCST. CORRECT	CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)	NO. OF CASES
0000 TODAY	OBJ.	29	7	4.9	10.3	7.3	7	0.20	87	0.97	2.33	0.33	*	*	*	*	161
	SUBJ.	43		4.4	10.7			0.19	85	0.95	3.00	0.33	*	*	*	*	
										(149)	(6)	(6)	(0)	(0)	(0)	(0)	
1200 TONITE	OBJ.	46	5	3.6	9.6	6.0	5	0.14	86	0.94	1.90	*	*	*	*	*	160
	SUBJ.	20		5.4	11.4			0.27	89	0.97	1.40	**	*	*	*	*	
										(150)	(10)	(0)	(0)	(0)	(0)	(0)	
0000 TOMRW	OBJ.	80	3	6.8	10.0	3.3	4	0.09	86	0.97	2.80	0.33	*	*	*	*	159
	SUBJ.	80		8.8	12.0			-0.06	86	0.99	2.00	0.33	*	*	*	*	
										(148)	(5)	(6)	(0)	(0)	(0)	(0)	

* This category was neither forecast nor observed.
** This category was forecast once but was never observed.

Table 9. Same as Table 5 except for Anchorage, Alaska only.

VALID TIME (GMT)	TYPE OF FCST.	DIRECTION: MEAN ABS. ERROR (DEG)	DIRECTION: NO. OF CASES	SPEED: MEAN ABS. ERROR (KTS)	SPEED: MEAN FCST (KTS)	SPEED: MEAN OBS. (KTS)	SPEED: NO. OF CASES	CONTINGENCY TABLE: SKILL SCORE	CONTINGENCY TABLE: PERCENT FCST. CORRECT	BIAS-NO. FCST./NO. OBS.: CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)	NO. OF CASES
0000 TODAY	OBJ.	74	8	3.8	11.6	9.4	8	0.08	65	1.11	0.73	0.60	*	*	*	*	110
	SUBJ.	49		3.6	11.8			0.22	68	1.05	0.85	0.60	***	*	*	*	
										(79)	(26)	(5)	(0)	(0)	(0)	(0)	
1200 TONITE	OBJ.	32	5	5.4	10.0	7.8	5	0.07	69	0.98	1.40	0.40	0.0	*	*	*	108
	SUBJ.	66		4.2	11.6			0.05	64	0.91	1.40	1.40	1.00	*	*	*	
										(87)	(15)	(5)	(1)	(0)	(0)	(0)	
0000 TOMRW	OBJ.	58	6	6.1	13.3	9.4	7	0.16	65	1.15	0.67	0.57	**	*	*	*	108
	SUBJ.	58		3.7	12.3			0.11	60	1.07	0.78	0.57	****	*	*	*	

* This category was neither forecast nor observed.
** This category was forecast once but never was observed.
*** This category was forecast twice but never was observed.
**** This category was forecast four times but never was observed.