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AUTOMATED PREDICTION OF SURFACE WINDS IN ALASKA--NO. 3

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by

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1. INTRODUCTION

As part of TDL's on-going effort to develop an automated guidance forecast package for the Alaskan Region of the National Weather Service (NWS), we have derived another set of surface wind prediction equations. These equations, based on Model Output Statistics (MOS), are for the summer season of June, July, and August. They are quite similar to the ones for the spring season (March, April, and May) described by Carter (1977).

2. PREDICTORS AND DEVELOPMENT OF FORECASTING EQUATIONS

We generated, using the MOS approach (see Glahn and Lowry, 1972), one set of prediction equations for the 0000 GMT cycle and another for the 1200 GMT cycle of the Primitive Equation (PE) model (Shuman and Hovermale, 1968). Each set includes equations to predict the U and V components and the wind speed, S, valid 12, 18, 24, 30, 36, 42, and 48 hr after PE model's input data times of 0000 GMT and 1200 GMT. Separate equations were developed for each of the 14 stations shown in Table 1.

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

Table 2 shows the potential predictors we screened from the summer seasons of 1970 through 1976. These include 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-hr projections, we also screened surface observations of wind, sky cover, and temperature available 6 hr after the PE model data input times. Backup equations which do not contain any observed predictors were also derived for these four projections.

We allowed for the selection of 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 five predictors.

Table 3 shows the Alaskan wind equations valid 24 hr after 0000 GMT at King Salmon. Here, 11 PE forecasts and the cosine of the day of the year reduced the variance of U, V, and S by 50, 37, and 25%, 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 ranking of predictors on the basis of frequency and order of selection in all the equations valid 12, 24, 36, and 48 hr from 0000 GMT. The predictors that are selected first and most often are ranked highest in Table 4. Observed weather elements are very important for the 12-hr projection, while PE boundary layer and geostrophic wind forecasts are dominant in the equations for the other three projections.

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. Only four stations were used in this test. In particular, we verified objective forecasts based on MOS and subjective NWS local forecasts for Annette, Juneau, Fairbanks, and Anchorage during the summer seasons of 1975 and 1976. The objective predictions were produced from regression equations developed on the five summer seasons of 1970 through 1974. 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 conterminous 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.

Tables 5 and 6 show the overall verification scores and contingency tables for three forecast periods. Tables 7-10 give the verification scores for each station. The verification times are 0000 GMT (today), 1200 GMT (tonight), and 0000 GMT (tomorrow). Considering both the latest observed and forecast input data that were available to each forecast system, these valid times correspond to projections of 18, 36, and 48 hr for the objective predictions, and 9, 36, and 48 hr for the subjective forecasts. These differences

occur because the local forecasts were not transmitted until 1600 GMT, and 1500 GMT surface observations were probably used to prepare the forecasts for at least the first projection. 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.

Most of the combined and individual station scores for the initial projection indicate that the subjective wind forecasts were superior to those from our PE-based system. This may be due to the substantial influence of terrain on surface winds in Alaska, plus the 9-hr length of projection advantage for the local forecasts. However, the objective forecasts are a little better than the subjective predictions at the latter two valid times. These results are much like those we obtained with our spring season test equations (Carter, 1977).

4. FUTURE WORK

We will continue to use this same basic approach to develop Alaskan wind prediction equations for the fall season. In April of 1977 we began transmitting (via teletypewriter) objective guidance wind forecasts based on the spring season equations.

ACKNOWLEDGMENTS

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Table 2. Potential predictors available to the screening regression program for the summer 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)	12, 18, 24*, 36*, 48*
Geostrophic U, V, S (850 mb, 500 mb)	12, 18, 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**
Vertical Velocity (850 mb, 650 mb)	24**
Temperature (1000 mb, 850 mb)	12, 24*, 36**, 48**
Temperature (700 mb, 500 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 hr after 0000 GMT at King Salmon. The PE forecast data sample consisted of 570 days from the summer seasons of 1970 through 1976.

Predictor	Forecast Projection (hr)	Cumulative reduction of variance			Coefficients			Units
		U	V	S	U	V	S	
Regression Constant	--	----	-----	----	-0.595	-30.08	7.483	kt
1. Boundary layer U	24	0.402	0.006	0.035	0.474	0.319	-0.231	$m\ s^{-1}$
2. 1000 mb geostrophic V	24	0.402	0.299	0.088	-0.616	0.215	-0.197	$m\ s^{-1}$
3. 1000 mb geostrophic S	24	0.422	0.303	0.203	-0.083	0.141	0.418	$m\ s^{-1}$
4. 850 mb relative vorticity x 10^5	24	0.453	0.309	0.203	-0.619	-1.069	-1.093	s^{-1}
5. Boundary layer U	36	0.471	0.311	0.210	0.985	0.152	0.293	$m\ s^{-1}$
6. Boundary layer V	36	0.473	0.328	0.211	-0.554	0.674	0.026	$m\ s^{-1}$
7. Cosine of day of year	--	0.475	0.346	0.218	-2.005	-6.666	-3.234	None
8. 850 mb relative vorticity x 10^5	36	0.480	0.354	0.232	-1.238	1.495	0.961	s^{-1}
9. 850 mb geostrophic S	36	0.481	0.356	0.243	-0.344	0.249	0.326	$m\ s^{-1}$
10. 850 mb geostrophic V	36	0.492	0.356	0.243	0.847	0.101	0.083	$m\ s^{-1}$
11. 850 mb height	24	0.492	0.366	0.244	0.003	0.016	-0.003	m
12. Boundary layer V	24	0.499	0.367	0.247	0.568	0.072	0.138	$m\ s^{-1}$
Total standard error of estimate (kt)		5.82	5.58	4.22				

Table 4. Importance of PE forecast and 0600 GMT observed predictors on the basis of frequency and order of selection in the Alaskan summer season surface wind equations for the 0000 GMT forecast cycle. Predictors appearing first in the equations were assigned 12 points, while the second term variables were given 11 points, and so on. Points were summed for all the equations. The predictors were then ranked according to the total number of points accumulated. (Note: geo. = geostrophic, rel. vort. = relative vorticity, vert. vel. = vertical velocity, divg. - divergence, DOY = day of year.)

Rank	Forecast Projection (in hr from 0000 GMT) 12	24	36	48
1	Observed S	Bound. layer U	Bound. layer V	Bound. layer U
2	Observed V	Bound. layer V	Bound. layer U	Bound. layer V
3	Observed U	Observed S	1000 mb geo. S	850 mb geo. S
4	Bound. layer V	1000 mb geo. S	Bound. layer S	850 mb geo. U
5	Bound. layer U	1000 mb geo. V	1000 mb geo. U	850 mb geo. V
6	Bound. layer S	850 mb rel. vort.	1000 mb geo. V	1000 mb geo. S
7	1000 mb geo. U	1000 mb geo. U	850 mb geo. U	1000 mb geo. V
8	1000 mb geo. S	Observed U	Bound. layer divg.	Mean rel. humidity
9	1000 mb geo. V	850 mb vert. vel.	850 mb rel. vort.	850 mb rel. vort.
10	Mean rel. humidity	Bound. layer S	500 mb rel. vort.	Sine DOY x 2
11	850 mb geo. V	850 mb geo. S	850 mb geo. S	500 mb height
12	Observed temp.	Observed V	Sine DOY	Bound. layer S

Table 5. Verification scores for TDL objective (OBJ) and NWS subjective (SUBJ) surface wind forecasts for 4 stations in Alaska during June through August of 1975 and 1976.

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.	39	166	3.4	11.0	10.1	167	0.16	50	0.95	1.09	0.97	0.33	*	*	*	617
	SUBJ.	43		3.4	11.7			0.21	54	1.27	0.72	0.85	0.67	***	*	*	
										(296)	(246)	(66)	(9)	(0)	(0)	(0)	
1200 TONITE	OBJ.	38	78	4.1	10.6	7.8	82	0.19	67	1.00	1.01	0.78	2.00	**	*	*	611
	SUBJ.	40		4.8	11.3			0.12	62	0.96	1.11	1.00	3.00	*	*	**	
										(448)	(135)	(27)	(1)	(0)	(0)	(0)	
0000 TOMRW	OBJ.	52	166	4.1	11.3	9.0	171	0.12	45	0.76	1.25	1.25	0.67	*	*	*	609
	SUBJ.	61		4.1	11.0			0.06	47	1.31	0.79	0.46	0.22	**	*	*	
										(298)	(233)	(69)	(9)	(0)	(0)	(0)	

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

Table 6. Contingency tables for TDL objective (OBJ) and NWS subjective (SUBJ) surface wind forecasts for four stations in Alaska during June through August of 1975 and 1976.

0000 GMT Today

GUIDANCE FCST

OBS	1	2	3	4	5	6	7	T
1	168	117	11	0	0	0	0	296
2	99	118	28	1	0	0	0	246
3	14	30	20	2	0	0	0	66
4	0	4	5	0	0	0	0	9
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
T	281	269	64	3	0	0	0	617

LOCAL FCST

OBS	1	2	3	4	5	6	7	T
1	223	65	7	1	0	0	0	296
2	128	90	25	3	0	0	0	246
3	24	18	20	2	2	0	0	66
4	1	4	4	0	0	0	0	9
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
T	376	177	56	6	2	0	0	617

1200 GMT Tonight

GUIDANCE FCST

OBS	1	2	3	4	5	6	7	T
1	360	80	7	0	1	0	0	448
2	80	45	10	0	0	0	0	135
3	9	12	4	2	0	0	0	27
4	1	0	0	0	0	0	0	1
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
T	450	137	21	2	1	0	0	611

LOCAL FCST

OBS	1	2	3	4	5	6	7	T
1	333	98	16	1	0	0	0	448
2	84	43	6	2	0	0	0	135
3	12	9	5	0	0	0	1	27
4	1	0	0	0	0	0	0	1
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
T	430	150	27	3	0	0	1	611

0000 GMT Tomorrow

GUIDANCE FCST

OBS	1	2	3	4	5	6	7	T
1	134	126	35	3	0	0	0	298
2	77	125	30	1	0	0	0	233
3	14	36	17	2	0	0	0	69
4	0	5	4	0	0	0	0	9
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
T	225	292	86	6	0	0	0	609

LOCAL FCST

OBS	1	2	3	4	5	6	7	T
1	206	81	10	1	0	0	0	298
2	147	71	14	1	0	0	0	233
3	31	29	8	0	1	0	0	69
4	5	4	0	0	0	0	0	9
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
T	389	185	32	2	1	0	0	609

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

VALID TIME (GMT)	TYPE OF FCST.	DIRECTION		SPEED												
		MEAN ABS. ERROR (DEG)	NO. OF CASES	MEAN ABS. ERROR (KTS)	MEAN FCST (KTS)	MEAN OBS. (KTS)	NO. OF CASES	CONTINGENCY TABLE								
								SKILL SCORE	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	OBJ.	29	63	3.2	10.9	9.6	63	0.05	43	0.71	1.19	1.24	0.0	*	*	*	142
TODAY	SUBJ.	28		3.0	11.5			0.22	52	1.14 (56)	0.87 (68)	0.94 (17)	3.00 (1)	* (0)	* (0)	* (0)	
1200	OBJ.	34	34	3.9	10.1	7.5	36	0.17	57	0.82	1.56	0.70	**	*	*	*	144
TONITE	SUBJ.	32		4.9	11.3			0.05	51	0.86 (98)	1.42 (36)	0.70 (10)	*** (0)	* (0)	* (0)	* (0)	
0000	OBJ.	36	57	3.8	11.1	9.2	59	0.04	39	0.51	1.29	1.71	1.00	*	*	*	142
TOMRW	SUBJ.	54		3.9	11.0			0.09	47	1.21 (61)	0.92 (63)	0.59 (17)	0.0 (1)	* (0)	* (0)	* (0)	

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

Table 8. 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.	43	52	3.7	11.6	10.2	53	0.04	42	0.90	1.03	1.60	0.25	*	*	*	164
TODAY	SUBJ.	39		3.3	11.5			0.30	58	0.97	1.00	1.33	0.25	*	*	*	
										(80)	(65)	(15)	(4)	(0)	(0)	(0)	
1200	OBJ.	37	21	4.0	10.8	8.1	22	0.16	67	1.05	0.85	1.25	0.0	*	*	*	165
TONITE	SUBJ.	45			10.6			0.30	70	0.96	1.05	1.75	1.00	*	*	*	
										(121)	(39)	(4)	(1)	(0)	(0)	(0)	
0000	OBJ.	58	64	4.5	11.5	8.9	66	0.14	44	0.54	1.43	1.67	0.75	*	*	*	163
TOMRW	SUBJ.	55			11.1			-0.01	41	1.04	1.13	0.56	0.25	*	*	*	
										(80)	(61)	(18)	(4)	(0)	(0)	(0)	

*This category was neither forecast nor observed.

Table 9. 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	OBJ.	35	19	3.0	9.4	9.4	19	0.35	64	0.96	1.25	0.47	0.0	*	*	*	148
TODAY	SUBJ.	56		4.2	11.8			0.08	55	1.45	0.42	0.27	1.00	**	*	*	
										(84)	(48)	(15)	(1)	(0)	(0)	(0)	
1200	OBJ	50	3	4.0	9.3	6.8	4	0.13	81	1.11	0.48	0.0	*	*	*	*	140
TONITE	SUBJ.	40		9.8	16.0			0.16	76	1.00	0.95	1.00	*	*	*	**	
										(117)	(21)	(2)	(0)	(0)	(0)	(0)	
0000	OBJ	59	14	4.9	11.0	7.4	14	0.10	45	0.68	1.68	0.82	0.0	*	*	*	143
TOMRW	SUBJ.	71		4.3	10.4			-0.01	52	1.51	0.41	0.12	0.0	**	*	*	
										(81)	(44)	(17)	(1)	(0)	(0)	(0)	

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

Table 10. Same as Table 5 except for Anchorage, Alaska only.

VALID TIME (GMT)	TYPE OF FCST.	DIRECTION		SPEED												
		MEAN ABS. ERROR (DEG)	NO. OF CASES	MEAN ABS. ERROR (KTS)	MEAN FCST (KTS)	MEAN OBS. (KTS)	NO. OF CASES	CONTINGENCY TABLE								
								SKILL SCORE	PERCENT FCST. CORRECT	BIAS-NO. FCST./NO. OBS.						NO. OF CASES
										CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)
0000	OBJ.	57	32	3.7	11.1	11.1	32	0.16	50	1.16	0.94	0.63	0.67	*	*	*	163
TODAY	SUBJ.	68		3.8	12.3			0.15		1.47	0.51	0.84	0.33	**	*	*	
										(76)	(65)	(19)	(3)	(0)	(0)	(0)	
1200	OBJ.	43	20	4.8	11.4	8.0	20	0.19	63	1.01	0.97	0.82	**	**	*	*	162
TONITE	SUBJ.	47		4.4	11.1			-0.05	52	1.01	0.97	1.00	*	*	*	*	
										(112)	(39)	(11)	(0)	(0)	(0)	(0)	
0000	OBJ.	69	31	3.4	11.6	9.7	32	0.18	52	1.26	0.77	0.76	0.67	*	*	*	161
TOMRW	SUBJ.	83		3.7	10.8			0.10	48	1.45	0.62	0.59	0.33	*	*	*	
										(76)	(65)	(17)	(3)	(0)	(0)	(0)	

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