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AUTOMATED PREDICTION OF SURFACE WINDS IN ALASKA--NO. 2

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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 a set of surface wind prediction equations for the spring season of March, April, and May. These equations, based on Model Output Statistics (MOS), are quite similar to the ones for the winter season (December, January, and February) described by Carter (1976).

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 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 hr. 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 March through May of the years 1970 through 1976. 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-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 free of 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 58, 52, and 34%, 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 hr from 0000 GMT. Observed weather elements are very important for the 12-hr 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 March, April and May of 1975 and 1976. The objective predictions were produced from regression equations developed on the five spring seasons of 1970, 1971, 1972, 1973, and 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.

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 hr for the objective predictions, and 9, 21, and 33 hr 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 the 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, these factors do not appear to be as significant for the latter two periods because here the objective forecasts are a little better than the subjective predictions.

4. FUTURE WORK

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

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Table 2. Potential predictors available to the screening regression program for the spring 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 - 1000 mb Temp)	24
Stability (700 mb Temp - 850 mb Temp)	24
Stability (500 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 . Sample equations for estimating the U and V w components and the wind speed, S, 24 hr after , GMT at King Salmon. The PE forecast data sample consisted of 564 days from the spring seasons of 1970 through 1976.

Predictor	Forecast Projection (hr)	Cumulative reduction of variance			Coefficients			Units
		U	V	S	U	V	S	
Regression Constant	--	----	----	----	-54.75	-46.56	12.03	kt
1. Boundary layer U	24	0.495	0.027	0.074	0.877	0.243	-0.312	m s^{-1}
2. Boundary layer V	24	0.499	0.459	0.079	0.354	0.798	-0.048	m s^{-1}
3. 850 mb S	24	0.510	0.460	0.267	-0.351	0.167	0.467	m s^{-1}
4. 650 mb vertical velocity	24	0.512	0.460	0.295	602.6	-4.931	-1072.	mb s^{-1}
5. Cosine of day of year	--	0.512	0.487	0.314	1.826	-3.340	-3.290	none
6. Boundary layer U	36	0.532	0.488	0.319	0.513	0.236	0.204	m s^{-1}
7. Boundary layer S	36	0.532	0.488	0.340	0.244	0.129	0.474	m s^{-1}
8. 850 mb geostrophic V	36	0.532	0.508	0.340	-0.011	0.457	0.036	m s^{-1}
9. 500 mb height	24	0.549	0.508	0.340	0.011	-0.003	-0.001	m
10. Mean relative humidity	30	0.557	0.513	0.341	-0.403	-0.052	-0.042	%
11. Mean relative humidity	24	0.577	0.513	0.342	0.293	-0.019	0.024	%
12. Boundary layer potential temp.	24	0.578	0.521	0.342	0.024	0.226	-0.004	K
Total standard error of estimate (kt)		6.48	5.95	5.02				

Tab . PE forecast and 0600 GMT observed predictors sted according to the total number of times they are used in the Alaskan spring season surface wind equations for the 0000 GMT forecast cycle. (Note: geo. = geostrophic, rel. vort. = relative vorticity, pot. temp. = potential temperature, div. = divergence, DOY = day of year).

Rank	Forecast Projection (in hours from 0000 GMT) 12	24	36	48
1	Observed S	Bound. layer V	Bound. layer V	Bound. layer V
2	Observed V	Bound. layer U	Bound. layer U	Bound. layer U
3	Observed U	1000 mb geo. U	1000 mb geo. S	Thickness (500 mb - 1000 mb)
4	Bound. layer V	1000 mb geo. S	1000 mb geo. U	1000 mb geo. S
5	Bound. layer U	1000 mb geo. V	Bound. layer S	1000 mb geo. U
6	Bound. layer S	Sin DOY x 2	1000 mb geo. V	850 mb geo. S
7	Bound. layer wind divg.	Bound. layer S	850 mb geo. U	500 mb geo. S
8	1000 mb geo. U	Observed S	850 mb geo. S	850 mb geo. V
9	850 mb geo. S	850 mb geo. V	500 mb geo. S	1000 mb geo. V
10	850 mb geo. U	Observed U	Bound. layer wind divg.	850 mb geo. U
11	1000 mb geo. V	Bound. layer pot. temp.	850 mb geo. V	COS DOY
12	1000 mb geo. S	850 mb geo. S	500 mb height	COS DOY x 2

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

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 CASE
										CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)
0000 TODAY	OBJ.	37	201	3.8	12.6	11.5	202	0.17	46	0.96	1.02	1.15	0.68	1.50	*	*	580
	SUBJ.	32		3.4	13.0			0.27	53	1.31	0.77	0.76	0.80	2.00	***	*	
										(239)	(226)	(88)	(25)	(2)	(0)	(0)	
1200 TONITE	OBJ.	44	94	5.0	11.5	8.8	102	0.19	63	1.02	1.05	0.71	0.88	*	*	*	574
	SUBJ.	50		6.2	13.5			0.17	57	0.86	1.24	1.43	1.63	****	**	*	
										(401)	(123)	(42)	(8)	(0)	(0)	(0)	
0000 TOMRW	OBJ.	50	167	4.2	12.4	10.6	169	0.14	45	1.08	0.96	0.96	0.74	0.0	**	*	574
	SUBJ.	54		4.0	11.7			0.13	46	1.38	0.84	0.54	0.35	2.00	*	*	
										(237)	(228)	(85)	(23)	(1)	(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 was never observed.
**** This category was forecast four times but was never observed.

Table 6. 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 CASE
0000 TODAY	OBJ.	35	81	3.4	12.6	11.4	81	0.09	39	0.95	0.90	1.48	0.75	0.0	*	*	146
	SUBJ.	24		3.2	13.0			0.33	56	0.95 (42)	0.97 (70)	1.08 (25)	1.00 (8)	1.00 (1)	*** (0)	* (0)	
1200 TONITE	OBJ.	43	51	4.7	11.3	8.9	55	0.20	55	0.91	1.28	0.76	1.33	*	*	*	150
	SUBJ.	46		6.0	13.6			0.14	41	0.49 (91)	1.69 (39)	1.71 (17)	2.33 (3)	*** (0)	** (0)	* (0)	
0000 TOMRW	OBJ.	47	73	4.4	12.7	10.9	74	0.08	38	1.14	0.86	1.19	0.89	*	*	*	146
	SUBJ.	50		3.9	12.1			0.16	46	1.05 (42)	1.07 (69)	0.81 (26)	0.78 (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 7. Same as Table 5 except for Juneau, 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 CASE
										CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)	
0000 TODAY	OBJ.	28	69	3.8	13.3	12.8	69	0.10	37	1.21	0.92	0.94	0.75	2.00	*	*	152
	SUBJ.	23		3.1	13.9			0.28	49	1.45	0.82	0.77	0.83	2.00	**	*	
										(42)	(62)	(35)	(12)	(1)	(0)	(0)	
1200 TONITE	OBJ.	23	25	5.8	11.8	9.3	29	0.21	62	1.11	0.94	0.53	0.60	*	*	*	149
	SUBJ.	33		6.6	13.9			0.17	53	0.85	1.36	1.00	1.00	***	*	*	
										(96)	(33)	(15)	(5)	(0)	(0)	(0)	
0000 TOMRW	OBJ.	46	56	4.0	12.2	10.6	57	-0.03	31	1.45	0.85	0.79	0.44	0.0	**	*	151
	SUBJ.	50		4.7	11.9			0.02	36	1.30	1.09	0.59	0.0	2.0	*	*	
										(47)	(65)	(29)	(9)	(1)	(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 excpet for Fairbanks, 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 CASE
										CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)
0000	OBJ.	59	24	4.3	11.3	8.3	25	0.21	56	0.80	1.62	0.73	0.50	*	*	*	166
TODAY	SUBJ.	60		4.2	11.0			0.09	60	1.25	0.64	0.33	0.0	*	*	*	
										(107)	(42)	(15)	(2)	(0)	(0)	(0)	
1200	OBJ.	55	6	4.2	11.0	6.8	6	0.10	74	1.03	0.89	0.50	*	*	*	*	161
TONITE	SUBJ.	92		5.3	11.8			0.18	76	1.03	0.68	3.50	*	*	*	*	
										(131)	(28)	(2)	(0)	(0)	(0)	(0)	
0000	OBJ.	85	12	4.8	12.2	8.7	12	0.27	59	0.84	1.47	0.69	1.50	*	*	*	162
TOMRW	SUBJ.	98		3.4	10.4			0.01	58	1.42	0.37	0.13	0.50	*	*	*	
										(101)	(43)	(16)	(2)	(0)	(0)	(0)	

* This category was neither forecast nor observed.

Table 9. 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 CASE
										CAT1 (NO. OBS.)	CAT2 (NO. OBS.)	CAT3 (NO. OBS.)	CAT4 (NO. OBS.)	CAT5 (NO. OBS.)	CAT6 (NO. OBS.)	CAT7 (NO. OBS.)	
0000	OBJ.	42	27	4.0	12.1	11.5	27	0.21	50	1.08	0.81	1.54	0.33	**	*	*	116
TODAY	SUBJ.	52		3.9	12.6			0.11	46	1.60	0.54	0.62	0.67	**	*	*	
										(48)	(52)	(13)	(3)	(0)	(0)	(0)	
1200	OBJ.	85	12	4.8	11.8	7.9	12	0.09	61	1.00	1.00	1.00	*	*	*	*	114
TONITE	SUBJ.	83		6.7	13.4			0.03	58	0.99	0.96	1.13	**	*	*	*	
										(83)	(23)	(8)	(0)	(0)	(0)	(0)	
0000	OBJ.	52	26	3.6	11.8	10.2	26	0.21	50	1.15	0.82	1.21	0.67	*	*	*	115
TOMRW	SUBJ.	56		2.9	10.8			0.02	42	1.66	0.61	0.43	0.0	*	*	*	
										(47)	(51)	(14)	(3)	(0)	(0)	(0)	

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