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COMPARATIVE VERIFICATION OF GUIDANCE AND LOCAL AVIATION/PUBLIC WEATHER FORECASTS--NO. 2 (APRIL-SEPTEMBER 1976)

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1. INTRODUCTION

This is the second in our series of combined verification of the Techniques Development Laboratory's (TDL's) operational guidance forecasts and National Weather Service (NWS) local forecasts made at Weather Service Forecast Offices (WSFO's). Verification statistics for objective guidance and subjective local forecasts of opaque sky cover, surface wind, ceiling height, and visibility are presented here for the warm season months of April through September of 1976. We previously presented combined verification statistics for the cool season of 1975-76 for the variables above and, in addition, for precipitation type (Carter et al., 1976). Of the 233 stations for which we issue guidance forecasts each day, the 94 shown in Table 1.1 were used for this verification.

TDL's forecasts were based on the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972). Input to our MOS prediction equations came from surface observations and forecast fields from the Limited-area Fine Mesh (LFM) (Howcroft and Desmarais, 1971), Trajectory (TJ) (Reap, 1972), and/or Primitive Equation (PE) (Shuman and Hovermale, 1968) models.

WSFO forecasts were provided to us by the Technical Procedures Branch of the Office of Meteorology and Oceanography in conjunction with the NWS combined aviation/public weather verification system (NWS, 1973). These forecasts were recorded daily for verification purposes under instructions that the value recorded be "...not inconsistent with..." the official weather forecasts. Surface observations as late as two hours before the first verification time may have been used in their preparation.

We obtained observed data to verify the guidance and local weather forecasts from the National Weather Records Center in Asheville, N.C.

2. OPAQUE SKY COVER

Our objective forecasts were generated from a set of warm season final guidance prediction equations described by Carter and Glahn (1976). Forecast fields from both the PE and TJ models are used to obtain estimates for the probability of clear, scattered, broken, and overcast conditions. We convert these four-category probability estimates into single "best category" forecasts so that each category is forecast nearly as often as it occurs. The local forecasts and opaque sky cover observations are converted into categories in the manner shown in Table 2.1.

Table 1.1 Ninety-four stations used for comparative verification of guidance and local aviation/public weather forecasts.

PWM	Portland, Maine
BTV	Burlington, Vermont
CON	Concord, New Hampshire
BOS	Boston, Massachusetts
PVD	Providence, Rhode Island
BUF	Buffalo, New York
SYR	Syracuse, New York
ALB	Albany, New York
JFK	New York (Kennedy), New York
EWR	Newark, New Jersey
ERI	Erie, Pennsylvania
HAR	Harrisburg, Pennsylvania
PIT	Pittsburgh, Pennsylvania
PHL	Philadelphia, Pennsylvania
CLE	Cleveland, Ohio
CMH	Columbus, Ohio
BKW	Beckley, West Virginia
CRW	Charleston, West Virginia
DCA	Washington, D.C.
ORF	Norfolk, Virginia
RDU	Raleigh-Durham, North Carolina
CLT	Charlotte, North Carolina
CHS	Charleston, South Carolina
CAE	Columbia, South Carolina
ATL	Atlanta, Georgia
SAV	Savannah, Georgia
MIA	Miami, Florida
JAX	Jacksonville, Florida
BHM	Birmingham, Alabama
MOB	Mobile, Alabama
TYS	Knoxville, Tennessee
MEM	Memphis, Tennessee
MEI	Meridian, Mississippi
JAN	Jackson, Mississippi
MSY	New Orleans, Louisiana
SHV	Shreveport, Louisiana
IAH	Houston, Texas
SAT	San Antonio, Texas
DFW	Forth Worth, Texas
ABI	Abilene, Texas
LBB	Lubbock, Texas
ELP	El Paso, Texas
LIT	Little Rock, Arkansas
FSM	Fort Smith, Arkansas
TUL	Tulsa, Oklahoma
OKC	Oklahoma City, Oklahoma
ABQ	Albuquerque, New Mexico
GTF	Great Falls, Montana
TCC	Tucumcari, New Mexico
SSM	Sault Ste Marie, Michigan
DTW	Detroit, Michigan
SBN	South Bend, Indiana
IND	Indianapolis, Indiana
LEX	Lexington, Kentucky
SDF	Louisville, Kentucky
MSN	Madison, Wisconsin
MKE	Milwaukee, Wisconsin
ORD	Chicago (O'Hare),Illinois
SPI	Springfield, Illinois
STL	St. Louis, Missouri
MCI	Kansas City, Missouri
TOP	Topeka, Kansas
DDC	Dodge City, Kansas
DEN	Denver, Colorado
GJT	Grand Junction, Colorado
SHR	Sheridan, Wyoming
CYS	Cheyenne, Wyoming
BIS	Bismarck, North Dakota
FAR	Fargo, North Dakota
RAP	Rapid City, South Dakota
FSD	Sioux Falls, South Dakota
BFF	Scottsbluff, Nebraska
OMA	Omaha, Nebraska
MSP	Minneapolis, Minnesota
DSM	Des Moines, Iowa
BRL	Burlington, Iowa
INL	International Falls, Minnesota
FLG	Flagstaff, Arizona
PHX	Phoenix, Arizona
CDC	Cedar City, Utah
SLC	Salt Lake City, Utah
LAS	Las Vegas, Nevada
RNO	Reno, Nevada
SAN	San Diego, California
LAX	Los Angeles, California
FAT	Fresno, California
SFO	San Francisco, California
PDX	Portland, Oregon
PDT	Pendleton, Oregon
SEA	Seattle (Tacoma), Washington
GEG	Spokane, Washington
BOI	Boise, Idaho
PIH	Pocatello, Idaho
MSO	Missoula, Montana

Table 2.1 Categories used to verify opaque sky cover forecasts.

Category Number	Tenths of Opaque Sky Cover
1	0-1
2	2-5
3	6-9
4	10 (Includes Obscured)

Four-category, forecast-observed contingency tables were prepared from the transformed local and best category guidance predictions. Using these tables we computed the percent correct, skill score, and bias by category (i.e., the number of forecasts in a particular category divided by the number of observations in that category).

Tables 2.2-2.6 show the comparative verification scores for April through September of 1976 for three different projections. The guidance forecasts were made from 0000 GMT data and projections were 18, 30, and 42 hr; however, the 18-hr forecasts used 0500 GMT surface observations in addition to forecast fields from the numerical models.

Table 2.2 is a summary of the results for all the stations combined. The percents correct and skill scores indicate that the local forecasts were slightly better than the guidance forecasts for the 18-hr projection. At 30 and 42 hr the guidance forecasts held the advantage. For all three periods, the bias by category scores show the local forecasts strongly overestimated scattered conditions and, to a lesser extent, broken clouds. The guidance forecasts tended to underforecast these two categories--especially at 30 hr.

Tables 2.3-2.6 give the verification scores for the NWS Eastern, Southern, Central, and Western Regions, respectively. These results exhibit the same general characteristics as those for all 94 stations combined.

Regarding comparative skill, these findings are similar to those of our previous verification for April through September 1975 (see Carter, 1976). However, the percents correct and skill scores are higher for the 1976 forecasts because we were able to use warm season equations during the entire period. Unfortunately, due to implementation problems, the guidance forecasts during April through July of 1975 were generated from cool season equations.

We have also verified our 0000 GMT cycle 18-hr early guidance opaque sky cover forecasts for May 27 through September 29, 1976. These predictions were based primarily on LFM forecast fields. The regression equations are described by Carter and Glahn (1976).

Table 2.2 Verification scores for subjective local and objective guidance forecasts of four categories of cloud amount (clear, scattered, broken, and overcast) for 94 stations across the United States during April through September of 1976.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	GUIDANCE	1.00	0.91	1.04	1.09	46	0.28	15245
	LOCAL	0.73 (4785)	1.40 (4428)	1.15 (3266)	0.65 (2766)	48	0.30	
30	GUIDANCE	1.11	0.63	0.78	1.19	53	0.28	15107
	LOCAL	0.73 (7264)	1.82 (2785)	1.59 (1823)	0.57 (3235)	46	0.25	
42	GUIDANCE	1.07	0.78	0.91	1.34	43	0.23	15207
	LOCAL	0.62 (4744)	1.61 (4419)	1.16 (3279)	0.50 (2765)	40	0.18	

Table 2.3 Same as Table 2.2 except for 24 stations in the Eastern Region.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	GUIDANCE	1.04	0.94	1.06	0.98	44	0.25	3867
	LOCAL	0.68 (815)	1.38 (1148)	1.19 (921)	0.65 (983)	46	0.27	
30	GUIDANCE	1.25	0.55	0.68	1.08	53	0.32	3883
	LOCAL	0.80 (1514)	1.59 (715)	1.57 (499)	0.65 (1155)	47	0.28	
42	GUIDANCE	1.10	0.84	0.99	1.10	41	0.22	3868
	LOCAL	0.62 (802)	1.47 (1150)	1.24 (925)	0.53 (991)	39	0.18	

Table 2.4 Same as Table 2.2 except for 24 stations in the Southern Region.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	GUIDANCE	0.96	0.85	1.17	1.12	46	0.27	3929
	LOCAL	0.69 (989)	1.43 (1346)	1.03 (988)	0.51 (606)	49	0.28	
30	GUIDANCE	1.06	0.59	0.91	1.39	49	0.23	3940
	LOCAL	0.74 (1928)	1.84 (831)	1.33 (487)	0.49 (694)	45	0.22	
42	GUIDANCE	0.91	0.78	1.02	1.61	42	0.22	3910
	LOCAL	0.54 (988)	1.61 (1338)	1.05 (979)	0.33 (605)	42	0.18	

Table 2.5 Same as Table 2.2 except for 28 stations in the Central Region.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	GUIDANCE	1.01	0.93	0.91	1.22	46	0.25	4617
	LOCAL	0.67 (1703)	1.45 (1302)	1.18 (882)	0.74 (730)	46	0.26	
30	GUIDANCE	1.16	0.55	0.69	1.13	56	0.29	4459
	LOCAL	0.64 (2353)	2.17 (722)	1.73 (506)	0.57 (878)	45	0.23	
42	GUIDANCE	1.12	0.75	0.82	1.37	42	0.20	4607
	LOCAL	0.51 (1706)	1.76 (1287)	1.17 (889)	0.59 (725)	37	0.14	

Table 2.6 Same as Table 2.2 except for 18 stations in the Western Region.

PROJECTION (HRS)	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
18	GUIDANCE	1.00	0.96	0.97	1.08	51	0.30	2832
	LOCAL	0.87 (1278)	1.28 (632)	1.28 (475)	0.69 (447)	53	0.34	
30	GUIDANCE	0.95	0.93	0.91	1.28	51	0.26	2825
	LOCAL	0.79 (1469)	1.59 (517)	1.79 (331)	0.50 (508)	48	0.25	
42	GUIDANCE	1.11	0.73	0.68	1.43	46	0.22	2822
	LOCAL	0.83 (1248)	1.55 (644)	1.20 (486)	0.48 (444)	43	0.20	

Table 2.7 Verification scores for subjective local and objective (early and final) guidance forecasts of four categories of cloud amount (clear, scattered, broken, and overcast) for 94 stations across the United States from May 27 through September 29, 1976. All forecasts were valid at 1800 GMT.

NWS REGIONS	TYPE OF FORECAST	BIAS - NO. FCST/NO. OBS				PERCENT CORRECT	SKILL SCORE	NO. OF CASES
		CAT 1 (No. Obs.)	CAT 2 (No. Obs.)	CAT3 (No. Obs)	CAT4 (No. Obs.)			
EASTERN	EARLY GUIDANCE	0.78	1.11	1.11	0.90	48	0.29	2662
	FINAL GUIDANCE	1.11	0.86	1.05	1.06	44	0.25	
	LOCAL	0.72	1.30	1.14	0.65	46	0.26	
		(483)	(871)	(676)	(632)			
SOUTHERN	EARLY GUIDANCE	0.85	1.15	1.11	0.62	49	0.28	2678
	FINAL GUIDANCE	0.85	0.89	1.25	1.08	46	0.26	
	LOCAL	0.61	1.44	0.99	0.48	49	0.26	
		(643)	(983)	(703)	(349)			
CENTRAL	EARLY GUIDANCE	0.89	1.13	1.02	0.97	47	0.26	3168
	FINAL GUIDANCE	0.99	0.94	0.90	1.34	44	0.22	
	LOCAL	0.65	1.45	1.15	0.72	45	0.24	
		(1196)	(962)	(611)	(399)			
WESTERN	EARLY GUIDANCE	1.03	1.06	0.96	0.87	51	0.28	1948
	FINAL GUIDANCE	1.02	0.94	0.89	1.14	52	0.29	
	LOCAL	0.86	1.29	1.29	0.69	54	0.34	
		(915)	(423)	(315)	(295)			
OVERALL AVERAGE	EARLY GUIDANCE	0.91	1.12	1.07	0.85	48	0.29	10456
	FINAL GUIDANCE	0.99	0.90	1.05	1.14	46	0.27	
	LOCAL	0.71	1.39	1.12	0.64	48	0.28	
		(3237)	(3239)	(2305)	(1675)			

Once again, we used both the transformed local and best category guidance forecasts to prepare contingency tables. Table 2.7 shows the results by NWS Region, as well as for all 94 stations combined. Matched sample 18-hr final guidance scores are also given for the purposes of comparison.

The overall results in Table 2.7 indicate that the early guidance and local forecasts had the same level of accuracy and skill. The final guidance forecasts were not as accurate or skillful. This difference may be related to the manner in which our prediction equations were developed. The early guidance equations were derived using opaque sky cover predictand data broken into the categories shown in Table 2.1. The final guidance equations had been developed at an earlier date on less compatible categories of total sky cover.

The scores for the four NWS Regions show the early guidance forecasts did quite well for the Eastern, Southern, and Central Regions. However, the LFM-based early guidance forecasts were slightly less accurate than the final guidance or local forecasts for the Western Region.

3. SURFACE WIND

The objective forecasts were generated using the warm season final guidance prediction equations described by Carter (1975). Most of the predictors for these equations were forecast fields from the PE model. The definition of the objective wind forecast is the same as that of the observed wind: the one-minute average direction and speed for a specific time.

Since the local forecasts were recorded as calm if the wind speed was expected to be less than 8 knots, we verified the forecasts in two ways. First, for all those cases where both the local and guidance 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 local and guidance 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 3.1-3.11 show comparative verification scores for three projections. These are 18, 30, and 42 hr for the guidance forecasts which were made entirely from 0000 GMT cycle data. It should also be noted that all the objective forecasts of wind speed were adjusted using an "inflation" equation involving the multiple correlation coefficient and mean value of wind speed for a particular station and forecast valid time.

The combined results for all 94 stations (see Table 1.1) are given in Tables 3.1 and 3.2. The wind direction MAE scores reveal an advantage for the guidance that increases from 3° at 18 and 30 hr to 5° at 42 hr. The MAE's, skill scores, and percents correct for speed are better for the guidance at all three projections with the greatest advantage being at 30 hr. Both the biases by category in Table 3.1 and the contingency tables in Table 3.2 indicate the 30- and 42-hr local and, to a lesser extent, guidance forecasts have a tendency to underforecast winds stronger than 22 knots (i.e., categories 5, 6, and 7).

Tables 3.3-3.6 show scores for the NWS Eastern, Southern, Central, and Western Regions, respectively. These regional values have the same general characteristics as those overall, except for the Western Region (see Table 3.6) where the 18-hr local forecasts of wind speed are a little better than the guidance.

These findings are similar to those associated with our previous verification of guidance and local wind forecasts during the warm season of 1975 (Carter and Hollenbaugh, 1976). However, the bias characteristics for the guidance forecasts of wind speed have improved considerably through the use of inflation. There has also been a slight decrease in overall skill for the guidance forecasts as a result of this inflation adjustment.

Table 3.7 shows the distribution of wind direction absolute errors by categories--0-30°, 40-60°, 70-90°, 100-120°, 130-150°, and 160-180°--for all 94 stations combined. The guidance had approximately 5% fewer errors of 40° or more for all three projections.

Distributions of direction errors for the individual regions are given in Tables 3.8-3.11. In general, these results are much like those in Table 3.7, except the magnitude of the advantage for the guidance over local forecasts differs from region to region.

Similar to the approach used for opaque sky cover, we also verified a set of 18-hr early guidance surface wind forecasts for the warm season of 1976. These 0000 GMT cycle forecasts were based mainly on the LFM model. The prediction equations are described in NWS, 1976.

MAE's (based on the 8-knot forecast criterion), percents correct, skill scores, and biases by category were calculated for the early guidance and local forecasts for the period April 8 through September 29, 1976. We also verified our final guidance wind forecasts during this same period for comparison purposes. Tables 3.12 and 3.13 show the respective verification scores for each NWS Region, as well as for all the stations combined. The early and final samples were matched for the contingency tables and resulting scores; this is not true for the other scores.

The scores in Table 3.12 indicate clearly that the early guidance forecasts were superior to the local predictions for all but the Western Region where the accuracy and skill were nearly the same.

Table 3.13 shows a similar comparative edge for the final guidance forecasts. Here, the magnitude of the overall advantage for the guidance is not quite as large as in Table 3.12.

A comparison of the percents correct and skill scores in Tables 3.12 and 3.13 indicates that, in general, the early guidance forecasts are slightly better than those from the final guidance system. However, the biases by category are closer to unity for the final guidance.

Table 3.1 Verification scores for subjective local and objective guidance surface wind forecasts for 94 stations across the United States during April through September of 1976.

FCST. PROJ. (HRS)	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
18	Guidance Local	32 35	7901	3.1 3.3	11.9 12.4	11.3	7962	0.27 0.24	53 50	1.06 0.82 (5795)	1.02 1.17 (6293)	0.85 1.03 (2589)	0.87 0.90 (566)	0.87 0.33 (108)	1.09 0.82 (11)	1.00 2.00 (2)	15364
30	Guidance Local	35 38	3375	3.5 3.8	11.0 11.4	9.5	3448	0.31 0.25	68 63	1.02 0.93 (10403)	0.98 1.21 (3947)	0.90 1.01 (866)	0.57 0.57 (174)	0.54 0.21 (39)	0.0 0.40 (5)	* ** (0)	15434
42	Guidance Local	41 46	7448	3.5 3.6	11.7 12.0	11.0	7512	0.22 0.16	49 46	1.09 0.83 (5819)	1.02 1.24 (6277)	0.81 0.90 (2566)	0.79 0.63 (554)	0.78 0.32 (98)	0.64 0.14 (14)	0.50 0.50 (2)	15330

* This category was neither forecast nor observed.
** This category was forecast six times but was never observed.

Table 3.2 Contingency tables for subjective local and objective guidance surface wind speed forecasts for 94 stations across the United States during April through September of 1976.

18-Hr Forecasts

GUIDANCE FCST

OBS	1	2	3	4	5	6	7	T
1	3747	1825	203	20	0	0	0	5795
2	2116	3279	802	85	9	2	0	6293
3	251	1186	899	219	31	3	0	2589
4	19	112	275	130	27	1	2	566
5	3	11	30	36	23	5	0	108
6	0	1	3	2	4	1	0	11
7	1	0	1	0	0	0	0	2
T	6137	6414	2213	492	94	12	2	15364

LOCAL FCST

OBS	1	2	3	4	5	6	7	T
1	2970	2476	326	22	1	0	0	5795
2	1565	3574	1037	111	4	0	2	6293
3	195	1176	997	208	11	1	1	2589
4	15	145	274	119	9	4	0	566
5	1	13	36	44	9	4	1	108
6	0	1	4	4	2	0	0	11
7	0	1	1	0	0	0	0	2
T	4746	7386	2675	508	36	9	4	15364

30-Hr Forecasts

GUIDANCE FCST

OBS	1	2	3	4	5	6	7	T
1	8514	1719	159	7	4	0	0	10403
2	1902	1679	327	34	5	0	0	3947
3	209	396	217	35	9	0	0	866
4	20	76	60	17	1	0	0	174
5	7	12	13	5	2	0	0	39
6	1	2	1	1	0	0	0	5
7	0	0	0	0	0	0	0	0
T	10653	3884	777	99	21	0	0	15434

LOCAL FCST

OBS	1	2	3	4	5	6	7	T
1	7655	2464	260	19	3	0	2	10403
2	1745	1809	353	36	2	1	1	3947
3	214	424	196	29	1	1	1	866
4	31	80	51	11	1	0	0	174
5	7	14	11	4	1	0	2	39
6	0	3	2	0	0	0	0	5
7	0	0	0	0	0	0	0	0
T	9652	4794	873	99	8	2	6	15434

42-Hr Forecasts

GUIDANCE FCST

OBS	1	2	3	4	5	6	7	T
1	3599	1889	299	28	4	0	0	5819
2	2283	3109	764	109	12	0	0	6277
3	400	1198	751	179	33	5	0	2566
4	34	177	239	84	17	2	1	554
5	3	24	26	35	8	2	0	98
6	0	4	5	3	2	0	0	14
7	1	0	1	0	0	0	0	2
T	6320	6401	2085	438	76	9	1	15330

LOCAL FCST

OBS	1	2	3	4	5	6	7	T
1	2692	2711	384	28	4	0	0	5819
2	1720	3537	900	102	7	0	1	6277
3	378	1289	758	127	12	2	0	2566
4	43	231	207	66	7	0	0	554
5	5	28	43	21	1	0	0	98
6	1	4	7	2	0	0	0	14
7	0	1	0	1	0	0	0	2
T	4849	7801	2299	347	31	2	1	15330

Table 3.3 Same as Table 3.1 except for 24 stations in the Eastern Region.

FCST. PROJ. (HRS)	TYPE OF FCST.	DIRECTION		SPEED													
		MEAN ABS. ERROR (DEG)	NO. OF CASES	MEAN ABS. ERROR	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.)	
18	Guidance Local	32 34	2288	3.0 3.1	12.0 12.3	11.3	2299	0.24 0.20	50 48	1.06 0.86 (1160)	0.99 1.11 (1790)	0.90 1.02 (780)	1.07 0.78 (138)	1.41 0.09 (22)	0.0 0.0 (1)	* *** (0)	3891
30	Guidance Local	36 36	849	3.3 3.8	10.8 11.5	9.1	862	0.33 0.27	71 65	0.98 0.85 (2826)	1.09 1.43 (878)	0.93 1.26 (180)	1.33 0.86 (21)	0.40 0.60 (5)	* * (0)	* **** (0)	3910
42	Guidance Local	41 45	2139	3.2 3.2	11.7 11.8	11.0	2153	0.20 0.14	47 45	1.13 0.86 (1180)	1.01 1.21 (1768)	0.81 0.83 (775)	0.84 0.53 (135)	1.05 0.10 (21)	1.50 0.0 (2)	* ** (0)	3881

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

Table 3.4 Same as Table 3.1 except for 24 stations in the Southern Region.

FCST. PROJ. (HRS)	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	SKILL SCORE	PERCENT FCST. CORRECT	CONTINGENCY TABLE 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
18	Guidance Local	31 34	1749	2.9 3.2	11.1 11.9	10.4	1759	0.28 0.22	56 52	1.12 0.73 (1776)	0.93 1.25 (1681)	0.82 1.11 (456)	0.97 1.26 (70)	0.73 0.64 (11)	*** * (0)	0.0 0.0 (2)	3996
30	Guidance Local	34 36	616	3.3 3.4	11.1 11.2	9.9	627	0.36 0.29	75 70	1.06 1.00 (2904)	0.85 1.09 (885)	0.83 0.74 (177)	0.39 0.50 (44)	1.60 0.20 (5)	0.0 0.50 (2)	* * (0)	4017
42	Guidance Local	39 45	1746	3.1 3.4	11.1 11.6	10.0	1756	0.23 0.15	53 48	1.06 0.71 (1779)	0.99 1.30 (1673)	0.79 1.02 (455)	1.09 0.99 (67)	0.80 0.70 (10)	** * (0)	0.0 0.0 (2)	3986

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

Table 3.5 Same as Table 3.1 except 28 stations in the Central Region.

FCST. PROJ. (HRS)	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.)	
18	Guidance Local	31 35	2874	3.1 3.4	12.1 12.8	11.9	2896	0.26 0.20	50 46	1.10 0.70 (1346)	1.08 1.23 (1906)	0.81 1.04 (1044)	0.72 0.88 (271)	0.75 0.32 (59)	0.67 0.56 (9)	** * (0)	4635
30	Guidance Local	34 39	1240	3.5 3.9	10.8 11.4	9.8	1273	0.27 0.22	63 57	1.07 0.85 (2882)	0.94 1.34 (1343)	0.76 1.12 (334)	0.52 0.52 (66)	0.24 0.19 (21)	0.0 0.0 (3)	* * (0)	4649
42	Guidance Local	41 47	2666	3.6 3.7	11.9 12.3	11.8	2683	0.18 0.14	45 43	1.20 0.72 (1340)	1.05 1.31 (1919)	0.77 0.94 (1023)	0.63 0.61 (265)	0.51 0.18 (55)	0.18 0.09 (11)	* * (0)	4613

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

Table 3.6 Same as Table 3.1 except for 18 stations in the Western Region.

FCST. PROJ. (HRS)	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
18	Guidance Local	37 38	990	3.6 3.5	12.1 12.1	10.8	1008	0.26 0.27	56 57	0.95 1.00 (1513)	1.11 1.05 (916)	0.96 0.92 (309)	0.92 0.84 (87)	0.69 0.50 (16)	2.00 4.00 (1)	** * (0)	2842
30	Guidance Local	36 40	670	3.8 4.0	11.3 11.2	9.3	686	0.25 0.19	60 59	0.96 1.06 (1791)	1.08 0.93 (841)	1.18 0.81 (175)	0.47 0.58 (43)	0.75 0.0 (8)	* ** (0)	* * (0)	2858
42	Guidance Local	45 47	897	4.2 4.2	12.4 11.9	10.2	920	0.23 0.15	54 50	0.98 1.05 (1520)	1.03 1.04 (917)	0.99 0.74 (313)	0.97 0.55 (87)	1.50 1.00 (12)	1.00 1.00 (1)	** * (0)	2850

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

Table 3.7 Distribution of absolute errors associated with subjective local and objective guidance forecasts of surface wind direction for 94 stations in the United States during April through September of 1976.

FCST. PROJ. (HRS.)	TYPE OF FCST.	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		0-30°	40-60°	70-90°	100-120°	130-150°	160-180°
18	Guidance	68.9	18.7	5.9	3.1	1.9	1.5
	Local	64.2	20.5	7.7	3.5	2.4	1.7
30	Guidance	67.8	16.5	7.1	3.3	2.7	2.6
	Local	63.0	18.8	8.1	4.6	3.0	2.5
42	Guidance	59.4	20.2	9.0	5.1	3.7	2.6
	Local	53.5	21.6	10.8	6.2	4.5	3.4

Table 3.8 Same as Table 3.7 except for 24 stations in the Eastern Region.

FCST. PROJ. (HRS.)	TYPE OF FCST.	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		0-30°	40-60°	70-90°	100-120°	130-150°	160-180°
18	Guidance	66.5	21.5	6.5	3.3	1.4	0.8
	Local	62.8	22.5	8.3	3.4	2.1	0.9
30	Guidance	64.8	19.2	7.7	4.4	2.3	1.6
	Local	63.1	20.7	7.3	5.2	1.8	1.9
42	Guidance	57.2	22.5	9.8	5.7	3.1	1.7
	Local	52.4	23.5	11.6	6.1	4.3	2.1

Table 3.9 Same as Table 3.7 except for 24 stations in the Southern Region.

FCST. PROJ. (HRS.)	TYPE OF FCST.	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		0-30°	40-60°	70-90°	100-120°	130-150°	160-180°
18	Guidance	70.5	17.7	5.8	2.9	1.6	1.5
	Local	64.8	21.3	7.0	3.3	1.9	1.7
30	Guidance	68.8	15.9	7.5	2.6	2.9	2.3
	Local	64.0	17.5	8.6	4.9	3.2	1.8
42	Guidance	61.1	19.9	8.8	5.0	3.4	1.8
	Local	54.5	21.9	10.1	5.4	4.6	3.5

Table 3.10 Same as Table 3.7 except for 28 stations in the Central Region.

FCST. PROJ. (HRS.)	TYPE OF FCST.	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		0-30°	40-60°	70-90°	100-120°	130-150°	160-180°
18	Guidance	70.9	17.7	5.2	2.8	1.9	1.5
	Local	64.6	20.0	7.7	3.8	2.1	1.8
30	Guidance	69.1	15.6	6.9	3.2	2.5	2.7
	Local	61.6	19.0	9.3	4.4	3.5	2.2
42	Guidance	59.1	20.5	9.3	4.6	3.6	2.9
	Local	51.6	22.2	11.5	7.4	3.9	3.4

Table 3.11 Same as Table 3.7 except for 18 stations in the Western Region.

FCST. PROJ. (HRS.)	TYPE OF FCST.	PERCENTAGE FREQUENCY OF ABSOLUTE ERRORS BY CATEGORY					
		0-30°	40-60°	70-90°	100-120°	130-150°	160-180°
18	Guidance	66.1	16.6	7.1	3.8	3.3	3.1
	Local	65.5	16.1	7.2	3.0	4.7	3.5
30	Guidance	68.5	15.1	6.4	3.0	3.1	3.9
	Local	64.5	17.2	6.3	4.3	3.1	4.6
42	Guidance	61.7	14.7	6.9	5.7	5.8	5.2
	Local	59.5	14.6	8.4	4.8	6.6	6.1

Table 3.12 Verification scores for subjective local and objective "early" guidance surface wind forecasts for 94 stations across the United States from April 8 through September 29, 1976. All forecasts were valid at 1800 GMT.

NWS REGION	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	SKILL SCORE	PERCENT FCST. CORRECT	CONTINGENCY TABLE 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
EASTERN	Guidance	30	2062	2.7	11.5	11.4	2070	0.27	53	1.20	0.99	0.76	0.80	0.33	0.0	*	3749
	Local	34		3.1	12.4			0.20	49	0.86 (1137)	1.10 (1745)	1.03 (726)	0.89 (119)	0.10 (21)	0.0 (1)	**** (0)	
SOUTHERN	Guidance	29	1542	2.8	11.0	10.7	1549	0.30	58	1.21	0.87	0.72	0.75	0.64	***	0.0	3833
	Local	32		3.2	12.1			0.23	52	0.73 (1704)	1.25 (1617)	1.13 (432)	1.27 (67)	0.64 (11)	* (0)	0.0 (2)	
CENTRAL	Guidance	27	2586	3.0	11.9	12.3	2600	0.27	51	1.26	1.04	0.72	0.60	0.60	0.78	**	4466
	Local	33		3.4	13.0			0.20	46	0.69 (1302)	1.23 (1839)	1.06 (1000)	0.88 (258)	0.31 (58)	0.44 (9)	* (0)	
WESTERN	Guidance	35	859	3.4	11.9	11.2	867	0.26	56	1.04	1.02	0.83	0.72	0.36	0.0	*	2737
	Local	37		3.4	12.3			0.27	56	1.00 (1456)	1.05 (883)	0.93 (298)	0.82 (85)	0.57 (14)	4.00 (1)	* (0)	
OVERALL AVERAGE	Guidance	29	7049	2.9	11.6	11.5	7086	0.29	54	1.18	0.98	0.75	0.68	0.52	0.91	0.50	14785
	Local	34		3.2	12.5			0.24	50	0.81 (5599)	1.17 (6084)	1.05 (2456)	0.92 (529)	0.34 (104)	0.73 (11)	2.00 (2)	

* 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 3.13 Same as Table 3.12 except for subjective local and objective "final" guidance surface wind forecasts.

NWS REGION	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
EASTERN	Guidance	32	2190	3.0	12.0	11.2	2201	0.24	50	1.06	0.98	0.91	1.11	1.43	0.0	*	3749
	Local	35		3.1	12.3			0.20	49	0.86	1.10	1.03	0.89	0.10	0.0	***	
										(1137)	(1745)	(726)	(119)	(21)	(1)	(1)	
SOUTHERN	Guidance	31	1686	2.9	11.1	10.4	1696	0.28	57	1.12	0.93	0.83	0.96	0.73	***	0.0	3833
	Local	34		3.1	11.9			0.23	52	0.73	1.25	1.13	1.27	0.64	*	0.0	
										(1704)	(1617)	(432)	(67)	(11)	(0)	(2)	
CENTRAL	Guidance	31	2775	3.1	12.1	11.9	2796	0.26	50	1.11	1.08	0.81	0.74	0.74	0.56	**	4466
	Local	35		3.4	12.8			0.20	46	0.69	1.23	1.06	0.88	0.31	0.44	*	
										(1302)	(1839)	(1000)	(258)	(58)	(9)	(0)	
WESTERN	Guidance	37	967	3.6	12.1	10.8	985	0.26	55	0.94	1.12	0.98	0.93	0.79	2.00	**	2737
	Local	38		3.5	12.1			0.27	56	1.00	1.05	0.93	0.82	0.57	4.00	*	
										(1456)	(883)	(298)	(85)	(14)	(1)	(0)	
OVERALL AVERAGE	Guidance	32	7618	3.1	11.9	11.2	7678	0.27	53	1.06	1.02	0.86	0.88	0.88	1.00	1.00	14785
	Local	35		3.2	12.4			0.24	50	0.81	1.17	1.05	0.92	0.34	0.73	2.00	
										(5599)	(6084)	(2456)	(529)	(104)	(11)	(2)	

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

4. CEILING AND VISIBILITY

We computed verification scores for these two elements from final guidance and local forecasts at both the 0000 GMT and 1200 GMT cycles. Our guidance forecasts were generated from the warm season equations described in NWS Technical Procedures Bulletin No. 120 (NWS, 1974). The equations are made up of predictors from surface observations, the PE model, and the TJ model.

We also computed verification scores for persistence forecasts of ceiling and visibility. Persistence forecasts were determined from the last surface airways observation available to the WSFO forecaster before the aviation terminal forecast (FT) filing deadline. The ceiling and visibility values which existed in that observation were used for each verification time that followed.

Our guidance forecasts are expressed as the probability of each of five categories for both ceiling and visibility; the category definitions are shown in Table 4.1. The probability forecasts are transformed into a categorical forecast and presented as the "best category" in the forecast message. The transformation is made such that the verification score for the NWS scoring matrix (NWS, 1973) is maximized. For comparative verification, we used this categorical forecast, since the local and persistence forecasts are for specific values of ceiling and visibility and can be assigned to a category for direct comparison.

Table 4.1 Ceiling and visibility categories used for MOS five-category aviation guidance forecasts.

Category	Ceiling (ft)	Visibility (mi)
1	$\leq$ 100	$\leq$ 3/8
2	200-400	1/2-7/8
3	500-900	1-2 1/2
4	1000-1900	3-4
5	$\geq$ 2000	$\geq$ 5

Our MOS system generates ceiling and visibility guidance forecasts for projections of 12, 18, 24, and 30 hr from the numerical model runs at both 0000 GMT and 1200 GMT; we have computed verification statistics for the first three projections. FT's are expressed in a form which covers all hours of the 24-hr period for which they are valid; officially, they are verified at 12, 15, and 21 hr after 0000 GMT or 1200 GMT. Therefore, direct comparison between the guidance and local forecasts was possible only at the 12-hr projection.

For all the forecasts involved in this comparative verification, we constructed contingency tables which were than used to compute several different verification scores: bias by category, percent correct, and the NWS matrix score.

We have summarized the scores in Tables 4.2 through 4.5. Each table covers one element for one cycle time, for all forecast systems, arranged by projection.

For 12-hr projections, the tables show persistence and local forecasts were superior to our guidance forecasts for both elements at both cycles, all scores considered. We have encountered results like these in previous comparative verifications of ceiling and visibility for this projection (e.g., Crisci et. al., 1976; Carter et. al., 1976); they occur because of the advantage persistence and the local forecasters have over the MOS system for the first projection. The last observation which the local forecaster sees before the FT filing deadline is two or three hours (depending on the cycle and region) before the first valid time; the same observation is used for the persistence forecasts. The MOS equations use, in addition to the numerical model forecasts, predictors from surface observations taken 7 hr prior to the valid time of the first projection. This is necessary because of time constraints imposed by operational deadlines. Therefore, persistence and local forecasts use data which are 4 to 5 hr more recent than the MOS system and this handicap is too much for our guidance forecasts to overcome in the first projection. Indeed, even the local forecasts lost to persistence across the board for what is considered to be a short-range forecast.

18-hr and 24-hr guidance forecasts, in the 0000 GMT cycle, were significantly better than persistence. In this cycle, persistence can be saddled with an early morning ceiling or visibility condition that has much lower frequency of occurrence in the afternoon and evening hours and is therefore less likely to verify.

In the 1200 GMT cycle, 18-hr and 24-hr guidance and persistence forecasts scored about the same. The guidance forecasts were slightly better, in terms of percent correct, at the 18-hr projection but not quite as good at 24-hr. Matrix scores were better for the guidance forecasts in all cases.

Overall, our guidance forecasts displayed the same bias characteristic we have seen before: very few forecasts of the lower two or three categories, especially at the 18- and 24-hr projections. We have addressed this feature in the past (Crisci, 1976) and we expect the problem has been largely corrected in our present system (NWS, 1977) with the use of threshold probabilities. Notice that 18- and 24-hour persistence forecasts in the 0000 GMT cycle are also quite biased for the lower two or three categories, but in the opposite sense--far too many forecasts. This occurs, of course, for the reason discussed above. In the 1200 GMT cycle, peristence forecasts have generally better bias scores than our guidance forecasts for all projections with the least difference evident at the 24-hr projection.

5. CONCLUSIONS

This verification shows TDL's aviation/public weather guidance forecasts compare very favorably with local forecasts produced at WSFO's. In particular, automated guidance is better than the local predictions for opaque sky cover and surface wind for the 30- and 42-hr projections. While both the objective and subjective estimates of ceiling and visibility are poorer than persistence forecasts for the initial (12-hr) projection, they are generally more

Table 4.2 Comparative verification of persistence, MOS guidance, and local ceiling forecasts, 0000 GMT cycle, for the period April-September 1976, for 94 stations. PC is percent correct, MS is NWS matrix score.

Projection (Hr)	Type	Bias by Category					PC	MS
		1	2	3	4	5		
12	Guidance	.29	.49	.55	.91	1.05	37.9	66.0
	Persistence	.87	.77	.79	.87	1.02	89.8	67.3
	Local	.40	.85	.82	1.11	1.01	89.1	67.1
15	Local	.30	.48	.48	.79	1.05	87.9	66.8
	Persistence	5.13	1.36	.86	.57	1.03	86.9	66.4
18	Guidance	.00	.06	.24	.69	1.04	92.3	67.9
	Persistence	15.43	3.15	1.63	.87	.97	88.2	66.3
21	Local	.22	.29	.30	.74	1.02	94.8	68.5
	Persistence	13.22	3.92	2.29	1.51	.94	88.6	66.0
24	Guidance	.00	.13	.27	.39	1.03	95.7	68.5
	Persistence	8.62	3.38	2.44	1.84	.94	88.8	66.0

Table 4.3 Same as Table 4.2 except for visibility forecasts.

Projection (Hr)	Type	Bias by Category					PC	MS
		1	2	3	4	5		
12	Guidance	.17	.44	.61	.69	1.08	82.6	64.8
	Persistence	.81	.56	.39	.71	1.09	85.0	66.1
	Local	.49	.91	.44	1.37	1.02	83.4	66.1
15	Local	.56	.80	.23	.85	1.04	88.9	67.1
	Persistence	4.44	2.23	.85	.88	1.00	86.7	66.3
18	Guidance	.00	.06	.07	.29	1.05	94.0	68.2
	Persistence	8.88	5.29	1.51	1.47	.96	88.3	66.4
21	Local	.71	.25	.19	.59	1.03	94.4	68.4
	Persistence	21.71	4.04	1.77	1.77	.95	88.2	66.3
24	Guidance	.00	.00	.03	.30	1.05	94.3	68.3
	Persistence	10.92	3.60	1.46	1.69	.95	88.0	66.3

Table 4.4 Same as Table 4.2 except for the 1200 GMT cycle.

Projection (Hr)	Type	Bias by Category					PC	MS
		1	2	3	4	5		
12	Guidance	.07	.49	.66	.91	1.01	95.1	68.6
	Persistence	.71	.87	1.10	1.15	1.00	95.8	69.0
	Local	.43	.60	.86	1.20	1.00	95.8	69.0
15	Local	.23	.61	.73	1.25	1.00	94.2	68.5
	Persistence	.33	.68	.88	1.00	1.01	94.0	68.3
18	Guidance	.00	.53	.46	.92	1.03	92.5	67.6
	Persistence	.19	.39	.67	.82	1.02	92.1	67.4
21	Local	.22	.39	.74	1.44	1.01	88.5	66.3
	Persistence	.09	.28	.45	.66	1.05	89.5	66.2
24	Guidance	.02	.22	.41	1.12	1.05	86.9	65.2
	Persistence	.08	.20	.36	.56	1.08	87.1	64.9

Table 4.5 Same as Table 4.3 except for the 1200 GMT cycle.

Projection (Hr)	Type	Bias by Category					PC	MS
		1	2	3	4	5		
12	Guidance	.00	.22	.28	1.09	1.01	93.6	68.4
	Persistence	.62	1.30	.83	.98	1.00	95.2	68.2
	Local	.77	.78	.42	1.12	1.01	94.9	68.8
15	Local	.70	1.17	.77	1.27	.99	93.3	68.5
	Persistence	.35	1.25	1.19	.99	1.00	93.9	68.5
18	Guidance	.04	.00	.29	.87	1.03	92.7	68.0
	Persistence	.15	.83	.82	.86	1.01	92.4	67.8
21	Local	.23	.77	.90	1.55	.98	86.0	66.3
	Persistence	.06	.37	.53	.62	1.05	89.0	66.5
24	Guidance	.00	.09	.43	1.29	1.05	80.4	64.1
	Persistence	.04	.20	.21	.44	1.15	81.7	63.5

accurate for longer periods. However, the bias characteristics of the objective estimates are unsatisfactory and require improvement to meet the needs of users of these two products.

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