NWS-CR-TA-89-16

CRH SSD
MAY 1989

CENTRAL REGION TECHNICAL ATTACHMENT 89-16

ASSESSING THE EFFECTS OF THE CITY WIND ON THE ACCURACY OF MOS LOW TEMPERATURE FORECASTS FOR INDIANAPOLIS

Mark P. DeLisi
National Weather Service Forecast Office
Indianapolis, Indiana

1. Purpose

Forecasters at WSFO Indianapolis (WSFO IND) have been hesitant to forecast overnight low temperatures below MOS when winds were blowing from the city. The belief was that MOS generally tended to underforecast low temperatures on such nights, because MOS likely did not handle the local warm air advection off the urban heat island adequately. The purpose of this study was to establish the statistical validity of that belief.

2. General Screening

MOS forecasts were obtained for WSFO IND from January 1, 1987 through August 21, 1988. Since downtown Indianapolis is about 60 degrees relative to WSFO IND at a distance of about 12 kilometers, the data were first screened to ensure that at least two of the three MOS-predicted wind directions for the period 00Z through 12Z were between 020 and 090 degrees inclusive. Observations from the cases were then screened to ensure that winds in fact blew from the city.

For the 13 hourly overnight observations (00Z through 12Z) taken at WSFO IND each night, eight had to have associated wind directions between 020 and 090 degrees inclusive. Further, five of the last seven observations (06Z through 12Z) had to have such wind directions.

On clear or nearly clear nights when the wind slows to nearly calm, the temperature often drops below the MOS forecast due to radiational cooling. Moreover, the effects of thermal advection off the city are cut off on such nights. In an effort to ensure nights like the ones described above were not used in the study, the remaining dates were further screened to ensure that the average wind speed over the last seven observations was greater than or equal to five knots. Further, only one calm wind was allowed in the last seven observations, and none were allowed in the last four (09Z through 12Z).

The remaining dates were further screened to ensure that MOS did a reasonable job of predicting overnight cloud cover. If the average opaque cloud cover for the 13 overnight observations indicated a mean value of five or less (scattered or clear), then the average of the three MOS preferred cloud cover predictions for the overnight period had to be less than 2.5 (scattered or clear). If the average opaque cloud cover from the overnight observations indicated broken or overcast conditions, then the average MOS prediction had to be broken or overcast.

The screening process left 50 cases of 24 hour low temperature forecasts and 48 cases of 36 hour low temperature forecasts. These two groups were tested using "Student's t" test to determine if the mean of the individual differences between the MOS forecasts and the actual overnight low temperatures were significantly different from zero.

In statistical terminology, this study tested the null hypothesis that MOS low temperature forecasts were not statistically different from actual low temperatures on nights when winds blew from the city of Indianapolis. The values of this and subsequent tests are given in Table 1. It was found that there is no basis for rejecting the null hypothesis. In general, MOS does not underforecast WSFO IND overnight lows when winds blow off the city of Indianapolis.

3. Seasonal Screening

It can be hypothesized that during the warmer months of the year, the city of Indianapolis might absorb excessive radiation during the day and give it back at night, and that MOS might underforecast the overnight lows by not adequately accounting for this phenomenon. To examine this, the study concentrated only on the mean of the individual differences from the months of May through September. This was done for the 24 hour forecast group and the 36 hour forecast group separately. There were 18 cases of 24 hour forecasts and 19 cases of 36 hour forecasts from the warmer months.

As seen in Table 1, the null hypothesis again could not be rejected. No general rule about MOS underforecasting minimum temperatures at WSFO IND exists when there is surface flow off the city during the warm season.

Upon request from several forecasters at WSFO IND, the study then concentrated only on the mean of the individual differences from the months November through March. Again, this was done for the 24 hour and the 36 hour forecast groups separately.

The idea here was that heat generated by the city itself (the heat island) might be advected to WSFO IND at night. During the colder months of the year, such heat advection might affect overnight lows at WSFO IND. MOS might not adequately account for this phenomenon and underforecast the overnight lows. There were 25 cases of 24 hour forecasts and 23 cases of 36 hour forecasts from the colder months. The study again proved inconclusive as the null hypothesis could not be rejected.

4. Screening by Previous Day's Insolation

Next, the study concentrated on mean differences from nights following days when there had been good insolation. Good insolation is defined as days when

Table 1: Student's t test values for each set of cases tested. If MOS underforecasted the overnight temperature, the value is positive. If the t value is significant, the confidence level is given in parentheses. If the value is not significant, "I" is in parentheses. Values in the left column test whether the MOS error for the specific set of cases was significantly different from zero; values in the right column test whether the MOS error for the specific set of cases was significantly different from the overall MOS error.

Cases (number)	Versus Zero	Versus Overall MOS Error
All 24 hour (50)	-1.497 (I)	-1.651 (I)
All 36 hour (48)	-0.440 (I)	-1.175 (I)
May through September 24 hour (18)	0 (I)	-0.079 (I)
May through September 36 hour (19)	0 (I)	-0.462 (I)
November through March 24 hour (25)	-0.976 (I)	-1.108 (I)
November through March 36 hour (23)	0.486 (I)	-0.045 (I)
Good Insolation 24 hour (28)	-0.244 (I)	-0.365 (I)
Good Insolation 36 hour (27)	-0.129 (I)	-0.798 (I)
Good Insolation May through September 24 hour (13)	2.051 (90)	1.940 (90)
Good Insolation May through September 36 hour (13)	2.419 (95)	1.747 (I)
Good Insolation May through September 24 and 36 hour (26)	3.194 (99)	2.673 (95)
Good Insolation November through March 24 hour (11)	-0.962 (I)	-1.045 (I)
Good Insolation November through March 36 hour (11)	-1.139 (I)	-1.536 (I)
Good Insolation November through March 24 and 36 hour (22)	-1.524 (I)	-1.885 (90)

the average hourly opaque cloud cover from the 13 daytime observations (12Z through 00Z) is five or less.

The effect that was searched for when the study focused on the warmer months of May through September would be enhanced when the days before the overnight periods were generally sunny days. In the interest of thoroughness, the study also looked at such nights from the colder months, and from all months of the study.

There were 28 cases of 24 hour forecasts and 27 cases of 36 hour forecasts from all months when nights followed days of good insolation. There were 13 such cases each of 24 hour and 36 hour forecasts from the warmer months of May through September. There were 11 such cases each of 24 hour and 36 hour forecasts from the colder months of November through March.

Although Student's t test is designed to handle relatively small data sets, its reliability decreases with the size of the data group. Therefore, after having been tested separately, the 24 hour and 36 hour groups were combined for the warmer months and again for the colder months.

This resulted in a group of 26 cases for the warmer months and a group of 22 cases for the colder months of nights following days of good insolation. Statistics show that during the warm season, the null hypothesis can be rejected.

The rule is that MOS underforecasts overnight temperatures at Indianapolis during the warmer months (May through September) on nights after days when there was good insolation. Winds must remain fairly steady and from the city, and MOS should give an accurate cloud cover forecast.

5. Accounting for any Systematic MOS Bias

It is possible that the results from all of the above tests could have been exaggerated or obscured by a systematic bias in MOS overnight temperature forecasts for WSFO IND. To account for this possibility, 42 dates corresponding to 84 overnight temperature forecasts (42 each of the 24 hour and 36 hour forecasts) were chosen at random from the study period. These cases were not restricted by any screening procedures.

A mean error was derived for the 24 hour forecasts, the 36 hour forecasts, and all forecasts combined. For the 24 hour forecasts, the mean error was 0.07 degrees above the actual temperature. For 36 hour forecasts, the mean error was 0.38 degrees above the actual temperature. It was 0.23 degrees above for all forecasts combined.

None of these values was significantly different from zero. Nonetheless, all of the means from the previously described groups were then tested against the means from the random dates to determine if there were statistically significant differences. The results from these tests generally were compatible with those reported above. The only significant MOS errors were for nights following days with good insolation. During the warm season, significant MOS errors occurred in two out of three forecast groupings (24 hour and combined) when the general MOS bias was taken into account. The only other significant result showed up in the group of nights from the colder months after days of good insolation. Further, it only showed up after the 24 hour and 36 hour forecast mean errors were grouped together and tested with the general MOS bias taken into account. Note that the minus sign indicates that MOS overforecasted the the overnight low temperature for these cases.

Table 2 shows the mean errors and their standard deviations for the 24 hour forecasts, the 36 hour forecasts, and all the forecasts combined when the results of the t tests were significant. All other results were not statistically significant.

Table 2: The mean errors (Error) and standard deviations (SD) of the MOS forecasts in degrees Fahrenheit for overnight low temperatures. If MOS underforecasted the overnight low, the mean error is positive. Values given correspond only to the cases that yielded significant results.

Cases	Versus Zero		Versus Overall MOS Error	
	Error	SD	Error	SD
Good Insolation May through September 24 hour	1.39	2.34	1.31	2.34
Good Insolation May through September 36 hour	1.39	1.98		
Good Insolation May through September All	1.39	2.17	1.16	2.17
Good Insolation November through March All			-1.18	2.87

6. Support for the Urban Heat Advection Concept

For cases indicating that MOS did underforecast the overnight low temperature, a method is needed to support the idea that the underforecasting was due to urban heat advection. It was decided to compare observed overnight low temperatures from nights that fit into the appropriate groups to a control group of overnight low temperatures.

Several constraints were placed on the control group of overnight low temperatures. Since little or no synoptic scale warm air advection occurs when winds blow from the northeast at Indianapolis, it would create an invalid comparison if temperatures from nights when winds had a southerly component were included in the control group. Therefore, only nights when winds generally blew from 270 degrees through 010 degrees were used. The technique of constraining wind direction in the control group was similar to that used with the urban heat advection group. Eight out of 13 overnight observations and five of the last seven observations from a night in the control group had to contain wind directions from 270 to 010 degrees inclusive.

Since radiational cooling nights were screened out of the urban heat advection group, they were also screened out of the control group. The average wind speed over the last seven observations of a night in the control group had to be equal to or greater than five knots; only one calm was allowed in the last seven observations, and none in the last four.

Further, it would be invalid to compare overnight low temperatures from the warmer months to overnight low temperatures from dates throughout the year, so the control group had to come from the same period as the seasonal subgroup.

No attention was paid to previous day insolation in the control group, because this was assumed to be a contributing factor to the urban heat advection effect that the study was testing. Also, since observed temperatures were being compared to observed temperatures rather than observed temperatures to MOS forecasts, it did not matter whether or not MOS accurately predicted wind direction or overnight cloud cover when picking nights for the control group.

As mentioned above, there were 13 cases each of thermal advection off the city following days of good insolation for the 24 hour and 36 hour groups. This is not to say there were only 13 nights when advection off the city occurred after days of good insolation. Rather, there were only 13 times when the event occurred and the MOS 24 hour forecast met the screening criteria described previously. Also, there were only 13 times when the event occurred and the MOS 36 hour forecast met the screening criteria. There was a great deal of overlap between the two groups, so that there were 14 nights when the event occurred and either the 24 hour, the 36 hour, or both MOS forecasts met the screening criteria.

More than 14 nights were needed to conduct a reliable test, so the period of review was expanded to include the warm season months on 1986. It did not matter whether or not MOS met the screening criteria at this point, so there quite likely were more nights in the study period that could have been used. However, it arbitrarily was decided to expand the period.

As a result, there were 24 cases in the test group and 29 cases in the control group from the warmer months of 1986 through 1988.

Although the nights from the two groups came from the same months and the same years, they could not come from the same days. In some instances, dates from one group were clustered somewhat more toward the beginning and end of the warmer season than they were in the other group. Consequently, the t test was used to compare departures from normal low temperatures rather than temperatures themselves.

The average of the 29 departures from the control group was 4.69 degrees below normal. This value was compared using the t test to the departures from the 24 overnight lows in the test group. The average of the departures in the test group was 1.96 degrees below normal, or some 2.73 degrees warmer than the average departure in the control group. The result of the t test was that the difference was significant at the 95 percent confidence level. This gave an indication that urban heat advection is responsible for MOS underforecasting overnight lows.

7. Conclusions

There are cases during which there is reason to systematically refrain from cutting MOS 24 or 36 hour low temperature forecasts. Those cases occur on nights during the months of May through September. Winds must be from the city of Indianapolis, especially during the early morning hours. Moreover, winds must not go calm, and there must be good insolation on the previous day. The reason MOS underforecasts overnight lows in such cases appears to be urban heat advection off of downtown Indianapolis.

There was also a possible indication that MOS actually overforecasts the overnight temperatures when winds blow from the city of Indianapolis (020 to 090 degrees) during any but the very specific set of circumstances defined above. Twenty of the 28 t test results in Table 1 indicated this, although 19 were not significant. The indication is significant during the colder months of November through March following days of good insolation. The Techniques Development Laboratory, where MOS is developed and tested, noted during a telephone conversation that MOS has a slight warm bias when winds have a northeast component. They attributed this bias to the shallow cool air that advects into areas east of the Rocky Mountains with northeast winds.

8. Acknowledgments

Thanks to the people at WSFO Indianapolis who made comments and suggestions during the course of this study. Thanks also to the people at the Techniques Development Laboratory for the data. Special thanks to Eli Jacks of the Techniques Development Laboratory for some invaluable information and suggestions.

9. References

Jacks, E., August, 1988: Telephone conversation between WSFO Indianapolis and the Techniques Development Laboratory, Silver Spring, MD.

Panofsky, H. A. and G. W. Brier, 1958: Some Applications of Statistics to Meteorology, Pennsylvania State University, University Park, PA.