

# ON THE NEED FOR AUGMENTATION IN AUTOMATED SURFACE OBSERVATIONS

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## ABSTRACT

*The National Weather Service and the Federal Aviation Administration are developing an Automated Surface Observing System (ASOS). Because an ASOS observation will not totally replicate a manually prepared observation, the question arises as to whether some type of human augmentation of the ASOS observation is necessary. To examine this, two experiments, the Topeka Tower Augmentation Project (TTAP) and the forecast operation portion of the Kansas Pilot Project (KaPP), were conducted.*

*During the TTAP, ASOS-like observations were augmented by control tower personnel at the Topeka airport. These observations were compared to the official observations taken less than a mile away. Only about 15 percent of the two sets of observations contained remarks on the same weather phenomena at the same time. There were even discrepancies in observations that contained thunder.*

*During the KaPP forecast operation, a special forecast shift was implemented at the Weather Service Forecast Office in Topeka. This ASOS forecaster had access to all available data except SAO's. In their stead, the forecaster was provided real time ASOS observations from Kansas stations and regional surface charts which contained plotted pseudo-ASOS observations derived from the official SAO's. The ASOS forecaster produced a 12-hour duration aviation (terminal) forecast for four aerodromes and first period public forecasts for four zones scattered across Kansas. These forecasts were verified along with the official ones. In general, there was very little difference between the test groups of forecasts and the corresponding "official" forecasts.*

## 1. INTRODUCTION

The art of weather observing has changed little over the last hundred years in the sense that the human observer has been designated to visually examine the sky and read a variety of instruments to define the current state of the atmosphere. Some of the instruments have remained unchanged during those 100 years. For example, the eight inch precipitation gage was the standard in 1887 (U.S. Signal Corps, 1887). On the other hand, newer versions of some instruments have eased and enhanced the way observers determine things such as dew point and cloud height.

The development of the Automated Surface Observing System (ASOS) allows the majority of elements currently part of a standard aviation weather observation to be "observed" by a micro-processor rather than a human. However, concerns arise when it is realized that automation cannot completely define all the elements of the current observation. This raises a basic question: "Do we need everything that is currently provided by a surface aviation observation?" In particular, do we need all the additive remarks that are currently appended to an aviation observation? In answering this question, it must be remembered that data from remote sensing systems (satellites, radars, lightning detectors, etc.) are routinely available to the users of weather observations. These data sources were not invented when many of the present rules of observing (U.S. Dept. of Commerce, 1982) were first written.

This paper describes two aspects of the Automation of Surface Observations Program's (ASOP) Kansas Pilot Project (KaPP). These two portions of the KaPP deal with topics directly related to the enhancement of automated observations by human augmentation. Such augmentation would fill the gap between what ASOS senses and the current information content of the surface aviation observation by partially keeping the human in the observing process. The purpose of this paper is to examine the implications of the KaPP results with respect to the need for augmentation.

## 2. ASOS—A BRIEF DESCRIPTION

In July 1985, prototype ASOS equipment was installed at six locations across the state of Kansas (see Fig 1). This prototype equipment was a first attempt to combine a variety of new technologies into one system that "observed" the current state of the atmosphere to a level that could replace the current human weather observation. Listed below are the specific elements that the prototype ASOS "observed." Changes have been made to production system requirements based on the experiences in Kansas. Readers are referred to reports such as National Weather Service (1986) for details of ASOS performance during the KaPP.

### a. Cloud Height

A Laser Beam Ceilometer (LBC) was used to determine the presence of clouds up to 10,000 ft and their height. Clouds

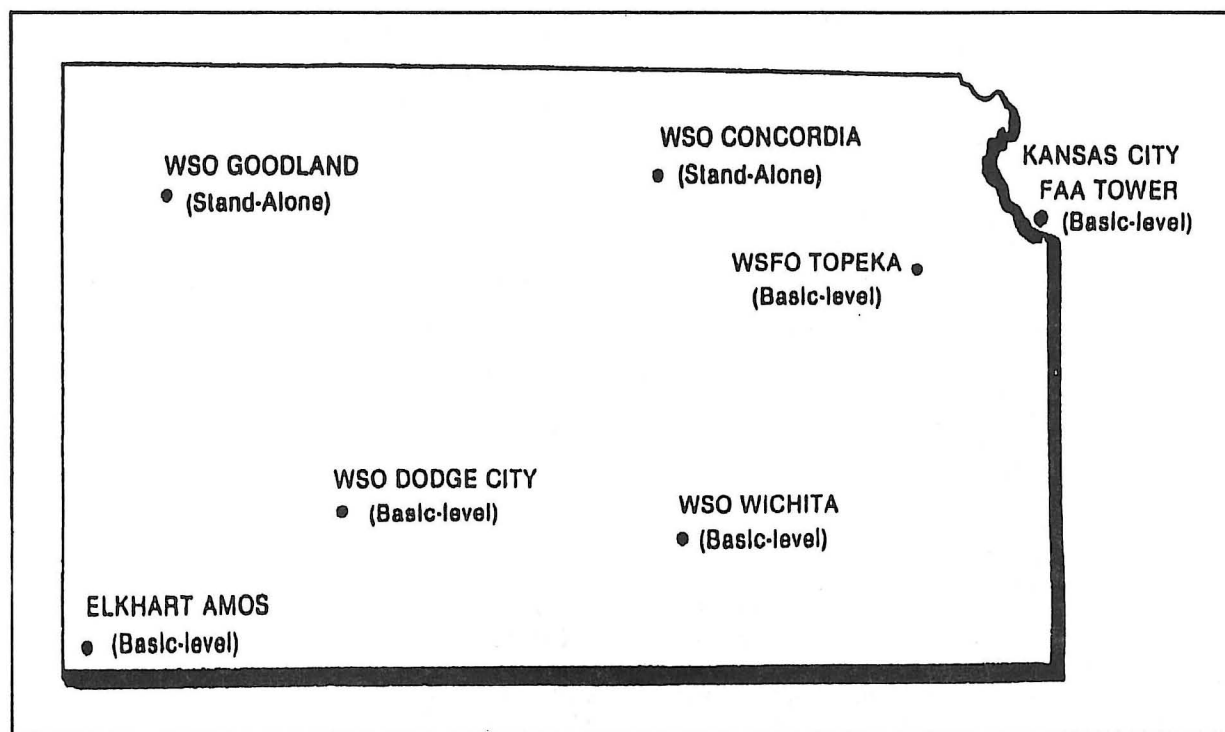


Fig. 1. Kansas Pilot Project (KaPP) prototype ASOS sites.

above 10,000 ft were not sensed by the system. The LBC looked at a narrow column of the atmosphere directly above the sensor. Cloud heights were determined every 30 sec. The cloud amount and height distribution were determined by algorithm from the 60 observations taken during the previous 30 min.

#### b. Visibility

A forward scatter visibility meter was used to determine ASOS visibility. This instrument defined a point visibility instead of the prevailing visibility used in the current aviation observation.

#### c. Present Weather

The determination of present weather was very limited in the prototype system. The system sensed precipitation in a yes/no sense, detected lightning within ten miles, and indicated the occurrence of freezing rain. Precipitation type and intensity were not available in the basic prototype system.

However, during part of the KaPP project, two enhanced present weather sensors were tested. A Laser Weather Identifier (LWI) was used to determine present weather at two sites (Goodland and Concordia). Due to the poor performance of this instrument, it was replaced by a Light Emitting Diode Weather Identifier (LEDWI) at Topeka. This sensor had an ability to sense precipitation type and intensity.

#### d. Hygrothermometer

The newest National Weather Service (NWS) standard hygrothermometer, the HO-83, was used with ASOS. It is fully "automation compatible."

#### e. Wind

A prop-vane design anemometer was employed with ASOS. This equipment was mounted on a ten-meter tower.

ASOS algorithms provided the standard two minute speed and direction averages with gusts and squalls as observed.

#### f. Pressure

Two digital pressure sensors served as the pressure measuring device for ASOS. ASOS stored the corrections necessary for calculating sea level pressure, station pressure and altimeter setting. Two pressure sensors were used in ASOS in order to provide for self-calibration.

#### g. Precipitation Amount

A heated tipping bucket precipitation gage with wind screen was used to measure the amount of precipitation on a minute-to-minute basis.

#### h. Remarks

Those remarks that could be derived from the elements noted above were automatically appended to the ASOS observation. They would include such things as rain began (RBxx), variable cloud amounts (below 10,000 ft), and variable visibility. Other remarks, such as those pertaining to specific cloud types and location (TCU N HRZN), were not available unless augmented manually.

#### i. Specials

ASOS automatically produced a locally-displayed, complete observation every minute. Whenever special criteria were met (based on standard criteria for ceilings, visibility, and precipitation), a special observation (SP) was transmitted. All minute-to-minute observational data were archived for eight hr and provided an excellent data base for evaluation purposes.

#### j. Augmentation

In order to bridge the gap between the information available from ASOS and the current aviation observation, the

capability for a human to augment or add information to the ASOS-generated observation existed.

### 3. KaPP FORECAST PROGRAM

#### a. Forecast Strategy

Although it was realized, *a priori*, that many factors contribute to the forecast decision process, the question still arose as to how ASOS observations would affect forecast operations. Thus, the KaPP included a forecast program. This effort was not intended to be a formal forecast experiment similar to the National Aviation Facilities Experimental Center's (NAFAC) evaluation of the impact of automated surface observations on forecasters in the mid-60s (Entrekin *et al.*, 1969). Rather, it was simply meant to give an indication of how the decreased information content of ASOS observations, as compared to manual observations, would be reflected in subsequent forecasts.

In order to make this assessment, forecast operations in a real-time, ASOS-like environment were conducted at WSFO Topeka from December 30, 1985, through June 6, 1986. This forecast period was divided into three phases during which different amounts of information on the presence of clouds above 10,000 ft., present weather, and remarks not automatically generated were appended to the ASOS observations. These phases were dictated by other parts of the KaPP, but they did allow us to gage the relative quality of the ASOS forecasters against the official forecasters as the degree of augmentation varied.

Phase IIIa lasted from March 3, 1986 through April 18, 1986 (32 forecast days). During this period complete augmentation was performed so that the ASOS forecaster had observations similar to those used by the official forecaster. In contrast, during Phase IIb there was no augmentation and the ASOS forecaster only had totally ASOS created observations to work with. This phase extended from April 21, 1986 to June 6, 1986 (30 forecast days). Finally, a mixture of augmentation levels was available during the 22 forecast days of Phase IIb which included the period from December 30, 1985, to February 28, 1986.

On each day of ASOS forecaster prepared two sets of forecasts. Terminal forecasts (FT) for Goodland (GLD), Dodge City (DDC), Wichita (ICT), and Topeka (TOP) were made for the 12-hr. period starting at 2200 UTC. Also, public forecasts for zones 1 (GLD), 6 (DDC), 12 (ICT) and 15 (TOP) were issued for the first period of the 4:00 p.m. CST forecast.

#### b. Rules of Engagement

In order to isolate the ASOS forecaster from the routine forecast process, Rules of Engagement were established (Table 1). These rules allowed the ASOS forecaster to examine all data available on AFOS except surface observations (SAO's), both in Kansas and out-of-state. Only Kansas ASOS observations could be examined directly when surface information was desired. Other service observations could be examined indirectly via a special AFOS plot which filtered the standard SAO so that it looked like an ASOS observation from a basic-level system. This approach simulated an ASOS-only environment. Further, in order to reduce biases, the ASOS forecaster was prohibited from conversing with the duty forecasters on forecast topics. While this "ban" was not monitored, the element of competition between the ASOS forecaster and the "official" forecaster minimized

**Table 1. Rules of engagement for ASOS forecasts.**

OBJECTIVE: To make FT and Public Forecasts from ASOS observations.

While preparing and amending forecasts:

- (a) Use all available data (numerical model output, MOS, RAOB's, satellite, etc.) except surface observations (SA);
- (b) use only ASOS surface observations from Kansas;
- (c) when interested in surface observations from outside Kansas, use only the surface plot that simulates ASOS observations (do not use the out-of-state SA's); and
- (d) do not look at the forecasts prepared by the duty forecasters or the forecast discussion by the public forecaster.

violations and helped reduce the influence of one forecaster on the other.

The rules of engagement tended to isolate the ASOS forecaster from the regular forecast process. This approach had some drawbacks. For example, the routine forecast process allows the public and aviation forecasters to exchange ideas on the current weather situation via "across-the-desk" discussions. This frequently improves the final forecast. The ASOS forecaster was also limited to an AFOS work station with one alpha-numeric terminal and one graphic display while the duty forecaster had multiple graphic displays available. The additional graphics displays make graphic examination and comparisons much easier.

#### c. Forecast Verification

##### (1) Aviation Ceiling Forecasts

Both the regular and ASOS FT's were verified at +3, +6, +9 and +12 hr after issue time. The forecast versus observed matrix approach was employed. The prevailing forecast values were categorized by flight category. The standard flight categories of LIFR, IFR and MVFR were used. In addition, VFR was subdivided into two categories: VFR (ceilings less than 10,000 ft) and HVFR (unlimited ceilings or ceilings 10,000 ft and above). Both VFR categories require visibilities of greater than five mi.

HVFR conditions dominated all three forecast phases. The percentages for correct forecasts, forecasts one category off, etc., are shown in Table 2. Comparison of the routine aviation forecast values with ASOS values show little significant dif-

**Table 2. Ceiling forecast statistics (in percent).**

	CORR	1 OFF	2 OFF	3 OFF	4 OFF	5 OFF
Phase IIb:						
Public	83.1	11.5	3.6	1.5	0.3	—
ASOS	81.6	12.7	3.3	2.1	0.3	—
Phase IIIa:						
Public	65.3	23.6	9.3	1.2	0.6	—
ASOS	69.4	24.8	4.5	0.8	0.4	—
Phase IIb:						
Public	66.7	19.9	11.6	0.9	0.9	—
ASOS	62.5	25.7	10.0	0.9	0.9	—



ferences. The phase-to-phase variations are due mainly to variations in weather conditions during the forecast project.

## (2) Visibility

Only eight days had visibility restrictions during ASOS forecast operations. As a result, all hours (out to +12 hr from issue time) were verified via the forecast versus observed matrix approach. Two matrices (not shown) were prepared: one described what was observed when ASOS forecasts indicated a restriction; the other described what was forecast when a restriction was observed. There was very little difference between the ASOS-based forecasts and the routine forecasts; however, all forecasters had a tendency to forecast visibility less than observed.

## (3) Temperature Forecasts

The regular and ASOS minimum temperature forecasts were verified along with the corresponding statistical guidance. Table 3 shows the mean absolute errors (MAE), the percentage of absolute errors less than or equal to 5 degrees, and the percentage of absolute errors greater than 10 degrees. The differences are small, implying that neither the public nor ASOS forecaster was essentially better.

## (4) Sky Cover Forecasts

Sky cover amounts were verified via the forecasts versus observed matrix approach. Amounts were listed by increasing cloud amount: clear, mostly clear, fair, partly cloudy, mostly cloudy, and cloudy. It should be noted that the term "fair" overlaps several of the other sky cover terms in coverage. Table 4 shows the percentages for correct forecasts,

**Table 3. Temperature verification statistics.**

	Mean	% ≤5	% >10
Phase IIb:			
Public	3.5	77.6	4.7
ASOS	4.1	74.1	7.1
MOS	4.3	72.9	7.1
Phase IIIa:			
Public	3.7	73.8	2.5
ASOS	3.7	75.2	1.6
MOS	4.2	71.3	2.5
Phase IIIb:			
Public	3.3	81.4	1.8
ASOS	3.1	86.7	1.8
MOS	3.5	77.9	1.8

**Table 4. Sky cover forecast statistics (in percent).**

	CORR	1 OFF	2 OFF	3 OFF	4 OFF	5 OFF
Phase IIb:						
Public	48.2	30.6	14.1	4.7	1.2	1.2
ASOS	51.8	27.0	16.5	2.4	2.4	0
Phase IIIa:						
Public	41.8	33.6	12.3	8.2	2.5	1.6
ASOS	40.2	31.9	15.6	5.7	3.3	3.3
Phase IIIb:						
Public	32.7	41.6	17.7	6.2	1.8	0
ASOS	36.3	38.9	16.8	7.1	0.9	0

forecasts one category off, etc. Once again, the differences are small.

## (5) Other Variables

Forecasts of precipitation and weather that obstructs the visibility by the ASOS forecaster and the official forecaster were quite similar. The use of probabilistic terms in the zone forecasts and qualifying periods in aviation forecasts severely limits the value of verification for these elements over the relatively small number of forecasts (even when forecasts made during all three phases are combined, there still are only 336 zone forecasts and 336 FT's) available. Thus, no verification statistics were computed.

## 4. TOPEKA TOWER AUGMENTATION PROJECT

### a. Background

The KaPP forecast study results implied that, for typical weather situations, remarks appended to surface aviation observations do not markedly affect the quality of forecasts. Since this is contrary to conventional wisdom, it was decided to study augmentation further. During early 1988, plans for the Topeka Tower Augmentation Project (TTAP) were developed. The objectives of the TTAP were to establish contrasts for the augmentation of ASOS observations by on-site tower personnel, to evaluate ASOS augmentation procedures, and to determine the effectiveness of the resulting augmentation.

Initial plans were to have augmentation at two sites in Kansas. At one site non-tower personnel would be contracted to do the augmenting, while at the other non-FAA tower personnel would perform the duties. Problems immediately were apparent since at many smaller airports the only facility operating 24 hr a day was the National Weather Service Office (WSO). Thus, 24 hr a day augmentation by on-site personnel is only possible at larger airports. Accordingly, the airport manager at Wichita, Kansas was contacted. After the project was explained to him, he declined to participate. One of the primary reasons was a ruling by the U.S. Department of Labor that augmentors were entitled to an hourly wage compatible with that of a fully functioning Meteorological Technician. However, for a fee, the contractor running the part-time, non-FAA air traffic control tower (ATCT) at Topeka's Philip Billard Airport was willing to participate in the program.

Since the Topeka tower is located within three-quarters of a mile of the NWS Forecast Office's (WSFO) observation site (Fig. 2), the TTAP provided an excellent data set for the comparison of weather conditions noted by the official observer and those noted by the ATCT controller augmentors.

### b. Project Equipment

A simulated ASOS operator interface device (OID) was installed in the tower, and a list of 17 specific weather conditions ranging from a tornado to breaks in the overcast (Table 5) for which augmentation was to be performed was developed. It was agreed that augmentation would be performed between 7:00 a.m. and 7:00 p.m. from August 1, 1988 through June 30, 1989. A detailed Training and Operation Guide for the program was prepared from existing NWS training materials and meteorology textbooks. Further, each ATCT controller was given one hour of one-on-one training which included overviews of the aviation observation and the Training and Operation Guide, an explanation of the



received, the computer logged the observation as a "time out" and resumed normal operations with the next transmission of ASOS one minute data.

### c. Response and Augmentation Times

During the eleven months of TTAP operations there were 4996 observations created by the computer. Of these, only 702 (14 percent) failed to elicit a response from the controllers before the computer timed out. For the remaining 4294 observations, the mean response time (defined as the number of seconds between the operator alert and the time the augmentor pressed the first key) was 22 sec with 775 (18 percent) of the responses occurring within 20 sec.

The ATCT controllers actually added remarks to only 195 observations during the TTAP. Thus, in over 95 percent of the cases, controllers did not see a need to include any of the remarks listed in Table 5, and the augmentation process consisted simply of the single key response needed to validate the pseudo-ASOS observation. The augmentation time (defined as the time in sec between the controller's first key stroke and the time of observation was posted) was 27 sec.

The reader is referred to Sunkel and Townsend (1989) for a complete listing and analysis of the response and augmentation times as a function of meteorological conditions, aircraft traffic, and controller status.

### d. Comparison with NWS Observations

Comparison of the ATCT augmented observations to the official NWS observations is complicated by many factors. For instance, when ceilings or visibilities vary around one of the values which require the taking of a special observation, the ASOS would typically produce more observations than the human observers. This occurs because the timing and number of special observations by the ATCT was determined objectively by the ASOS equipment, while the NWS specials are determined by the subjective judgment of the observer.

Only WSFO surface aviation observations taken while the tower was augmenting were considered in the comparison. A remark by either the WSFO observer or the ATCT controller was counted only once per hour. Thus, if several observations with a thunderstorm were entered during a particular hour, only one thunderstorm remark was tallied. On the other hand, if a single observation contained reference to multiple events (e.g., thunder, lightning, and distant precipitation), credit was given for each remark type. The information is summarized in Figures 3 and 4. For these presentations the tallies are divided into three categories: (1) tower only, (2) WSFO only, and (3) both tower and WSFO. So, to find the total number of remarks entered by the tower, the "Tower" and the "Both" groups must be summed.

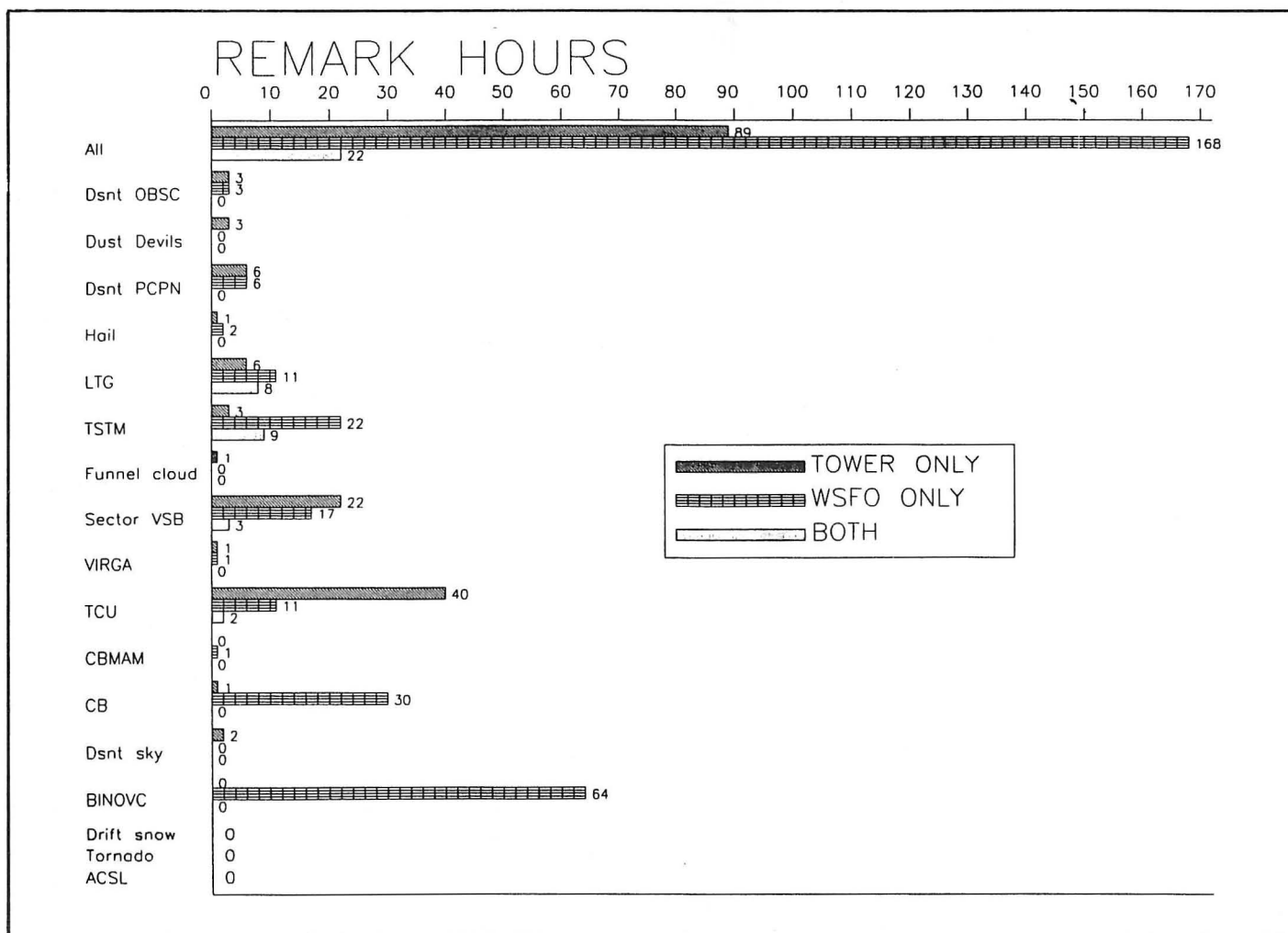


Fig. 3. Distribution of remark hours by weather event—numbers to right of bars give count of report hours.

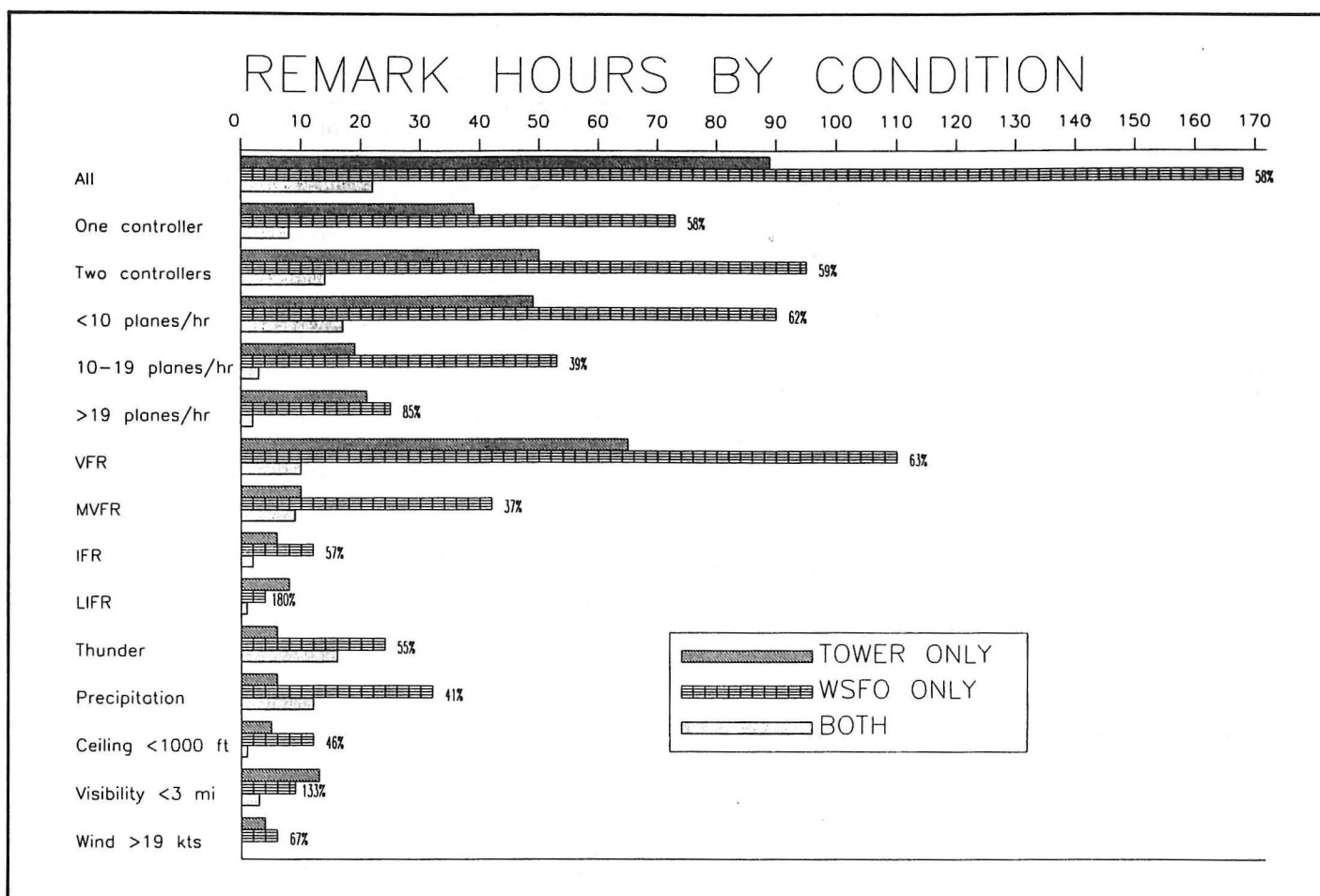


Fig. 4. Distribution of remark hours by condition—number to right of WSFO bar is the ratio of remark hours by tower to remark hours by WSFO for the appropriate category.

When total "remark hours" are examined (Fig. 3), it is seen that the WSFO appended significantly more remarks (171 percent) to their observations than did the ATCT. However, this varied markedly according to the type of event. During the 11 months of the project, the controllers never noted breaks in the overcast. In contrast, sector visibility was reported 25 times by the tower and only 20 times by the WSFO. Another striking feature was the contrast between the ratio of towering cumulus remarks by the tower to the Weather Service (42:13) and the ratio for cumulonimbus remarks by the ATCT and the WSFO (1:30). Perhaps the most surprising difference is that while the tower noted 12 occurrences of thunder and the WSFO heard thunder 31 times, only nine of these observations were during the same hours! It is hard to attribute this to the presence of background noise when it is noted that similar counts were obtained for lightning (total ATCT 14, total WSFO 19, common event eight) which is visually observed.

Categorizing the tallies of report hours by condition (Fig. 4) shows that the ratio of ATCT remarks to WSFO remarks remained virtually the same no matter if one controller (58 percent) or two controllers (59 percent) were on duty. However, this ratio shows a strong dependence on traffic rate. The tower, as compared to the WSFO, appended few remarks to the observations when moderate traffic was present. In light traffic, the tower appended more frequently, and in heavy

traffic conditions the number of tower remarks was quite close to the number of WSFO remarks. The only times that the tower added more remarks than the weather service was in LIFR conditions and/or when the visibility was less than three miles. It must be noted that these numbers lose much of their significance when it is noted that no condition existed in which the number of remarks noted by both the ATCT and the WSFO exceeded the number of remarks made by either of the two groups of observers independently!

## 5. IMPLICATIONS FOR FORECASTING

Surface observations are only a small subset of the data that are used by a forecaster in diagnosing the present state of the atmosphere. Other sources include satellite and radar imagery, pilot reports, rawinsondes, etc. The information content of much of these data is redundant. Further, the step between diagnosis and prognosis is rather ill defined. For public and aviation forecasts, it is an inherently human process that cannot be objectively quantified. However, for lack of an alternative, we are taking as axiomatic the idea that a forecaster's need for additive remarks on surface observations can be assessed by comparing forecasts made with and without such remarks.

During the KaPP, two groups of forecasters used data sets that varied only by the quality of surface aviation observa-



tions. One group used the official NWS FMH-1 based observations, while the other used ASOS type observations with no notation on clouds above 10,000 ft and limited present weather. Verification statistics for the two groups were comparable. While such statistics do not allow us to evaluate all aspects of the two sets of forecasts, they do indicate they were of comparable worth. Thus, while the KaPP forecast effort was admittedly limited, it provided no evidence that the information contained in the remarks appended to surface aviation observations is essential for the issuing of day-to-day forecasts.

Perhaps the reason for this lies in the TTAP finding that remarks taken by two different groups of people at the same location and the same time very seldom noted the same phenomena. Remarks that are appended to the surface observations are as much a factor of the observers interests as they are of the weather situation. Conditions directly related to aviation (i.e., visibility differing around the horizon) were reported more by controllers than by NWS observers. While events of more interest to the meteorological community (i.e., BINOVC) were reported more often by the NWS. The lack of a remark on an observation does not mean that an event is not occurring! Remarks may be lacking because the observer either did not note the event, or did not consider it significant enough to merit a report.

Admittedly, many scenarios in which augmented observations should help the forecaster were not addressed during the KaPP. For instance, the inability of infrared satellite imagery to distinguish opaque nocturnal clouds from translucent ones may very well lead to a cold bias in maximum temperature forecasts made during the early morning hours on nights when thin cirrus clouds are present. Also, Novak (1989) documented that the appearance of breaks in the overcast (BINOVC) while a major snow episode is occurring at Colorado Springs, Colorado indicate with a high degree of certainty that the storm will end within 32 minutes (Novak, 1989). Similar arguments can be made for noting the presence

of lenticular clouds (ACSL), altocumulus castellanus (ACC), fog immediately upwind from the observation site (F NW), smoke over the city (KOCTY), etc. However, the lack of consistency in additive remarks from observer-to-observer detracts from their value. Since such remarks are subjectively obtained, there is no assurance that all events which should be noted in the remarks are indeed noted, or that an event which is noted in remarks is actually occurring.

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## FOLKLORE

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**"WHEN THE NIGHT GOES TO BED WITH A  
FEVER, IT WILL AWAKE WITH A WET HEAD"**

**American Indian Saying**

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**Sue Mroz**

An approaching storm system will carry warm air northward in its advance. When the temperature steadily increases from about 8 or 9 p.m. to midnight, it is a good indication that a storm is brewing and rain will follow.