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ARMY RESEARCH LABORATORY

Enhanced Met Message for Fire Control

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A computer aided battlefield meteorology management system is presented that would provide a significant improvement in the met data needed for the determination of field artillery aiming data. To minimize the transmission of data, an enhanced met message is presented that adds to the existing met message linear temporal and spatial met variations.

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1. INTRODUCTION

The U.S. Army Atmospheric Sciences Laboratory (ASL) and the Firing Tables Branch (FTB) of the Ballistic Research Laboratory (BRL) are pursing a joint effort to produce a computer assisted meteorology management system since current met messages may not meet the future needs of the field artillery.

Computer Aided Meteorology for Fire Control (CAMFC) is a proposed battlefield meteorology management system which will provide the field artillery with a significant improvement in met data for the determination of the gunnery solution. Figure 1 illustrates the features of CAMFC. The enhanced met message transmitted by the Met Data Management Computer (MDMC) will be the current met message with additional data containing linear temporal and spatial met variations. This enhanced met message will be forwarded to the Fire Control Computers (FCCs). The MDMC will monitor the meteorological conditions and will forward an updated enhanced met message to the FCCs when significant changes from the projected met data occurs.

2. MET DATA COLLECTION

Presently, the met station collects the meteorological data, formulates the standard computer met message (NATO Army Armaments Group, STANAG 4082, June 1969), and sends this information to the FCCs. The FCCs use the met message until a new met message is received. This can result in degraded fire control solutions due to temporal and spatial changes in the meteorological conditions. The atmospheric parameters measured at the met station represent the conditions at the met station at an earlier time and do not necessarily simulate the met conditions which affect the artillery projectile's trajectory. Figure 2 illustrates how stale met data affects the probable error (PE) in range in mean point of impact. The figure shows the increase in the mean point of impact probable error as the met data becomes older. As noted in the Field Artillery Manual Cannon Gunnery (TC 6-40), accurate meteorological data is one of the five requirements for accurate first round fire for effect; therefore, the met data needs must represent the atmospheric conditions at the firing location and firing time. Met data management will help to achieve this goal.

Figures presented for temporal and spatial variations are from unpublished works by Mr. Joseph W. Kochenderfer. They are primarily based on the following references: Arnold and Bellucci (1957), Lowenthall (1969), and TARE (1961). In addition, information is included from the Air Weather Service, the Field Artillery School, NATO, and Germany (MEPPEN).

2.1 Temporal Met Variations. Time is an important factor when considering met data for fire control solutions. Weather changes occur as a function of time; therefore, it is advantageous to eliminate time staleness in the meteorological data. Time staleness is minimized by accounting for the effect of time on weather. All of the met parameters may be affected by time. Figure 3 illustrates the increase in the percentage probable error in density as time increases from when the met data were measured. After a certain amount of time has passed, the met data will be considered obsolete, and a new met message will be required. An example of another met parameter affected by time is illustrated in Figure 4. The probable error in component wind increases as the actual time from when the met data were measured increases.

2.2 Spatial Met Variations. Distance is also an important factor when utilizing met data for fire control solutions. The location of the met data measurements is different from the projectile's flight path. This spatial met variation may result in a decrease in accuracy in the met data. Several met parameters may be affected by spatial variations. Figure 5 illustrates the increase in the probable error in component wind as the distance between the met collection location and target increases.

3. ENHANCED MET MESSAGE FOR FIRE CONTROL

3.1 Methodology. The Met Data Management Computer receives data from various sources and at various times. The various information sources are: balloon borne sensors (MDS and MMS), met satellite data, wind profiling radar, temperature profiler, etc. Using the available met data a standard computer met message is determined for a reference grid location. An example of the computer met message is illustrated in Table 1(TC 6-40). Table 2 illustrates the zone structure of the computer met message (TC 6-40, FM 6-15, and STANAG 4082). For example, line number 16 in the table would supply met data for an altitude of 10,000 meters. The met data is transmitted from the met data management computer to the field artillery computer as illustrated in Figure 1. Therefore, there is no change to the current met message format and transmission procedure. Supplemental data estimating linear temporal and spatial variations for the met data, with limits, will be added to the transmission to be used by the Fire Control Computers. The supplemental data will be provided in a manner that will not interfere with computers that have not been programmed to use the additional data. The Met Data Management Computer will monitor the meteorological conditions and will forward an updated enhanced met message to the Fire Control Computers when a significant change from the projected met conditions occurs. A standardized format for transmission of the enhanced met message from the Met Data Management Computer to the Fire Control Computers will be proposed.

The Fire Control Computers can then use the standard computer met message for the reference grid location and make adjustments for temporal and spatial met variations. In addition, the Fire Control Computers can extend the met data to higher altitudes which may be required for future artillery systems. In cases where the supplemental data are not available to compensate for the spatial and temporal met variations, the standard met message would be used in its current form.

3.2 Met Data Management Computer. The MDMC determines the reference grid location around which the enhanced met message (reference met message) will be created. Differences in the respective easting and northing coordinates between the desired fire control solution and the reference grid location, in addition to any time differences, will be accommodated. Figure 6 illustrates a desired fire control solution location showing the positive and negative, easting and northing directions.

Compensation for spatial and temporal met variations is accomplished by applying changes in the reference met message values due to changes in easting and northing location and time (partials). The MDMC determines these partials within certain limits so that the reference met message data is not adjusted to extremes. The spatial met partials adjust the met data for variations in the respective easting and northing coordinates between the desired fire control solution location and the reference grid location. In this report, the change in wind is being addressed in the vector sense, i.e., the change in wind magnitude (speed) and direction due to spatial and temporal variations. However, an alternate approach would be to utilize the change in wind magnitude in the easting and northing directions if it is advantageous in the met management process.

The spatial met easting, increase and decrease partials are defined as follows:

$\left(\frac{\partial WD}{\partial E_I}\right)_i$ change in wind direction for an increase in grid easting for the ith line number

$\left(\frac{\partial WS}{\partial E_I}\right)_i$ change in wind speed for an increase in grid easting for the ith line number

$\left(\frac{\partial T}{\partial E_I}\right)_i$ change in atmospheric air temperature for an increase in grid easting for the ith line number

$\left(\frac{\partial P}{\partial E_I}\right)_i$ change in atmospheric air pressure for an increase in grid easting for the ith line number

$\left(\frac{\partial WD}{\partial E_D}\right)_i$ change in wind direction for a decrease in grid easting for the ith line number

$\left(\frac{\partial WS}{\partial E_D}\right)_i$ change in wind speed for a decrease in grid easting for the ith line number

$\left(\frac{\partial T}{\partial E_D}\right)_i$ change in atmospheric air temperature for a decrease in grid easting for the ith line number

$\left(\frac{\partial P}{\partial E_D}\right)_i$ change in atmospheric air pressure for a decrease in grid easting for the ith line number

The spatial met northing, increase and decrease partials will be defined as follows:

$\left(\frac{\partial WD}{\partial N_I}\right)_i$ change in wind direction for an increase in grid northing for the ith line number

$\left(\frac{\partial WS}{\partial N_I}\right)_i$ change in wind speed for an increase in grid northing for the ith line number

$\left(\frac{\partial T}{\partial N_I}\right)_i$ change in atmospheric air temperature for an increase in grid northing for the ith line number

$\left(\frac{\partial P}{\partial N_I}\right)_i$ change in atmospheric air pressure for an increase in grid northing for the ith line number

$\left(\frac{\partial WD}{\partial N_D}\right)_i$ change in wind direction for a decrease in grid northing for the ith line number

$\left(\frac{\partial WS}{\partial N_D}\right)_i$ change in wind speed for a decrease in grid northing for the ith line number

$\left(\frac{\partial T}{\partial N_D}\right)_i$ change in atmospheric air temperature for a decrease in grid northing for the ith line number

$\left(\frac{\partial P}{\partial N_D}\right)_i$ change in atmospheric air pressure for a decrease in grid northing for the ith line number

The temporal met partials are defined as follows:

$\left(\frac{\partial WD}{\partial t}\right)_i$	change in wind direction for a change in time for the ith line number
$\left(\frac{\partial WS}{\partial t}\right)_i$	change in wind speed for a change in time for the ith line number
$\left(\frac{\partial T}{\partial t}\right)_i$	change in atmospheric air temperature for a change in time for the ith line number
$\left(\frac{\partial P}{\partial t}\right)_i$	change in atmospheric air pressure for a change in time for the ith line number

Tables 3 through 6 illustrate the format of the spatial met partials and Table 7 illustrates the temporal met partials. These formats are proposed for standardized transmission of the supplemental data from the Met Data Management Computer to the Fire Control Computers; no change is required for the standard met message for the reference grid location.

A level of confidence can be established for the adjusted met data for a determined area around the reference grid location and time of utilization in order to manage the met system. The Met Data Management Computer should monitor the meteorological conditions and forward an updated enhanced met message to the Fire Control Computers when the met conditions exceed the established level of confidence for the current enhanced met message.

3.3 <u>Fire Control Computers</u>. The field artillery Fire Control Computers will then determine the met data based on the enhanced met message, which is the current standard met message referenced to a given grid location with adjustments for spatial and temporal met variations.

3.3.1 Wind Direction. The wind direction for the ith line number (WD_i) is determined as follows:

$$WD_i = (WD_r)_i + (\Delta WD_E)_i + (\Delta WD_N)_i + (\Delta WD_t)_i \qquad (1)$$

where:

$(WD_r)_i$ is the wind direction from the enhanced met message referenced at a given grid location for the ith line number and $(\Delta WD_E)_i$, $(\Delta WD_N)_i$, and $(\Delta WD_t)_i$ have the forms:

$$(\Delta WD_E)_i = \Delta E_I \left(\frac{\partial WD}{\partial E_I}\right)_i \text{ or } \Delta E_D \left(\frac{\partial WD}{\partial E_D}\right)_i \quad (2)$$

where:

ΔE_I represents an increase in the easting direction, and ΔE_D represents a decrease in the easting direction from the reference grid location. The partial represents the change in wind direction as the easting changes.

$$(\Delta WD_N)_i = \Delta N_I \left(\frac{\partial WD}{\partial N_I}\right)_i \text{ or } \Delta N_D \left(\frac{\partial WD}{\partial N_D}\right)_i \quad (3)$$

where:

ΔN_I represents an increase in the northing direction, and ΔN_D represents a decrease in the northing direction from the reference grid location. The partial represents the change in wind direction as the northing changes.

$$(\Delta WD_t)_i = \Delta t \left(\frac{\partial WD}{\partial t}\right)_i \quad (4)$$

where:

Δt represents the change in time. The partial represents the change in wind direction as time changes.

3.3.2 Wind Speed. The wind speed for the ith line number (WS_i) is determined as follows:

$$WS_i = (WS_r)_i + (\Delta WS_E)_i + (\Delta WS_N)_i + (\Delta WS_t)_i \quad (5)$$

where:

$(WS_r)_i$ is the wind speed from the enhanced met message referenced at a given grid location for the ith line number and $(\Delta WS_E)_i$, $(\Delta WS_N)_i$, and $(\Delta WS_t)_i$ have the forms:

$$(\Delta WS_E)_i = \Delta E_I \left(\frac{\partial WS}{\partial E_I}\right)_i \text{ or } \Delta E_D \left(\frac{\partial WS}{\partial E_D}\right)_i \quad (6)$$

where:

ΔE_I represents an increase in the easting direction, and ΔE_D represents a decrease in the easting direction from the reference grid location. The partial represents the change in wind speed as the easting changes.

$$(\Delta WS_N)_i = \Delta N_I \left(\frac{\partial WS}{\partial N_I}\right)_i \text{ or } \Delta N_D \left(\frac{\partial WS}{\partial N_D}\right)_i \tag{7}$$

where:

ΔN_I represents an increase in the northing direction, and ΔN_D represents a decrease in the northing direction from the reference grid location. The partial represents the change in wind speed as the northing changes.

$$(\Delta WS_t)_i = \Delta t \left(\frac{\partial WS}{\partial t}\right)_i \tag{8}$$

where:

Δt represents the change in time. The partial represents the change in wind speed as time changes.

3.3.3 Atmospheric Air Temperature. The atmospheric air temperature for the ith line number (T_i) is determined as follows:

$$T_i = (T_r)_i + (\Delta T_E)_i + (\Delta T_N)_i + (\Delta T_t)_i \tag{9}$$

where:

$(T_r)_i$ is the atmospheric air temperature from the enhanced met message referenced at a given grid location for the ith line number, and $(\Delta T_E)_i$, $(\Delta T_N)_i$, and $(\Delta T_t)_i$ have the forms:

$$(\Delta T_E)_i = \Delta E_I \left(\frac{\partial T}{\partial E_I}\right)_i \text{ or } \Delta E_D \left(\frac{\partial T}{\partial E_D}\right)_i \tag{10}$$

where:

ΔE_I represents an increase in the easting direction, and ΔE_D represents a decrease in the easting direction from the reference grid location. The partial represents the change in the atmospheric air temperature as the easting changes.

$$(\Delta T_N)_i = \Delta N_I \left(\frac{\partial T}{\partial N_I}\right)_i \text{ or } \Delta N_D \left(\frac{\partial T}{\partial N_D}\right)_i \tag{11}$$

where:

ΔN_I represents an increase in the northing direction, and ΔN_D represents a decrease in the northing direction from the reference grid location. The partial represents the change in the atmospheric air temperature as the northing changes.

$$(\Delta T_t)_i = \Delta t \left(\frac{\partial T}{\partial t}\right)_i \tag{12}$$

where:

Δt represents the change in time. The partial represents the change in the atmospheric air temperature as time changes.

3.3.4 Atmospheric Air Pressure. The atmospheric air pressure for the ith line number (P_i) is determined as follows:

$$P_i = (P_r)_i + (\Delta P_E)_i + (\Delta P_N)_i + (\Delta P_t)_i \tag{13}$$

where:

$(P_r)_i$ is the atmospheric air pressure from the enhanced met message referenced at a given grid location for the ith line number, and $(\Delta P_E)_i$, $(\Delta P_N)_i$, and $(\Delta P_t)_i$ have the forms:

$$(\Delta P_E)_i = \Delta E_I \left(\frac{\partial P}{\partial E_I}\right)_i \text{ or } \Delta E_D \left(\frac{\partial P}{\partial E_D}\right)_i \tag{14}$$

where:

ΔE_I represents an increase in the easting direction, and ΔE_D represents a decrease in the easting direction from the reference grid location. The partial represents the change in the atmospheric air pressure as the easting changes.

$$(\Delta P_N)_i = \Delta N_I \left(\frac{\partial P}{\partial N_I}\right)_i \text{ or } \Delta N_D \left(\frac{\partial P}{\partial N_D}\right)_i \tag{15}$$

where:

ΔN_I represents an increase in the northing direction, and ΔN_D represents a decrease in the northing direction from the reference grid location. The partial represents the change in the atmospheric air pressure as the northing changes.

$$(\Delta P_t)_i = \Delta t \left(\frac{\partial P}{\partial t}\right)_i \tag{16}$$

where:

Δt represents the change in time. The partial represents the change in the atmospheric air pressure as time changes.

3.3.5 Met Data at Altitudes Greater Than 20,000 Meters. The standard met message (STANAG 4082) provides met data for altitudes up to 20,000 meters. However, met data at altitudes greater than 20,000 meters may be required to support future field artillery systems. The Met Data Management and Fire Control Computers should provide the capability to extend the met data to an altitude of at least 30,000 meters.

4. DELIVERY ACCURACY DEMONSTRATION TESTING

An evaluation of the met data management system and the improvement in artillery delivery accuracy can be demonstrated by firing at targets using both the current and the enhanced met message for the determination of the aiming data. The testing would be used to evaluate: (1) the capability of the met data management methodology to predict the linear temporal and spatial partials, (2) the transmission of the met message between the Met Data Management and the Fire Control Computers, and (3) the effect on artillery delivery accuracy.

5. CONCLUSIONS

A cost effective means of providing the artillery person with the optimum met message should be offered. Computer Aided Meteorology has the potential to significantly improve the delivery accuracy of the field artillery by analyzing all of the available met data on the battlefield and providing a method to compensate for the spatial and temporal met variations. In addition, a plan is formulated to provide met data for higher altitudes which may be required for future field artillery systems. These concepts can be accomplished by enhancing and expanding the current met message.

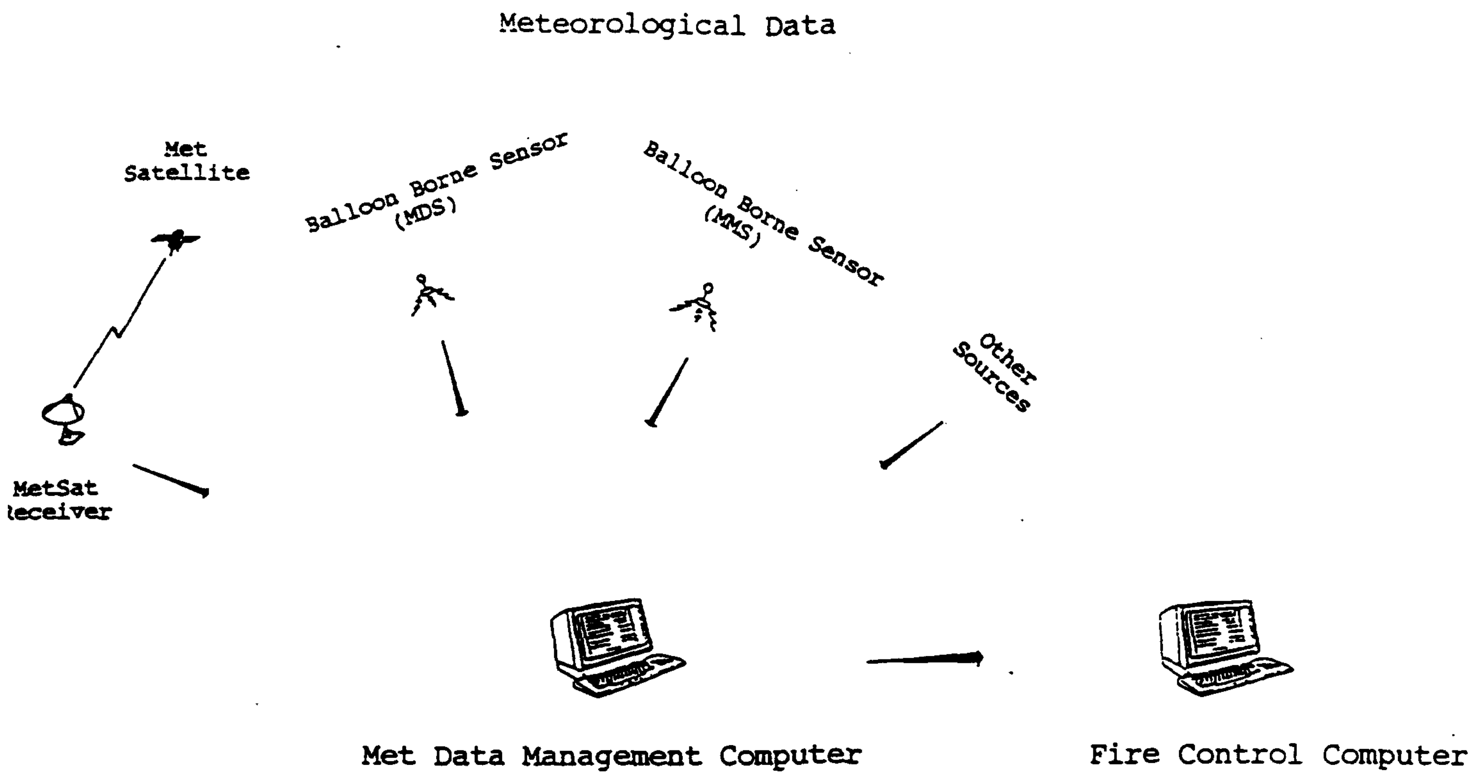

Figure 1. Features of Computer Aided Meteorology for Fire Control.

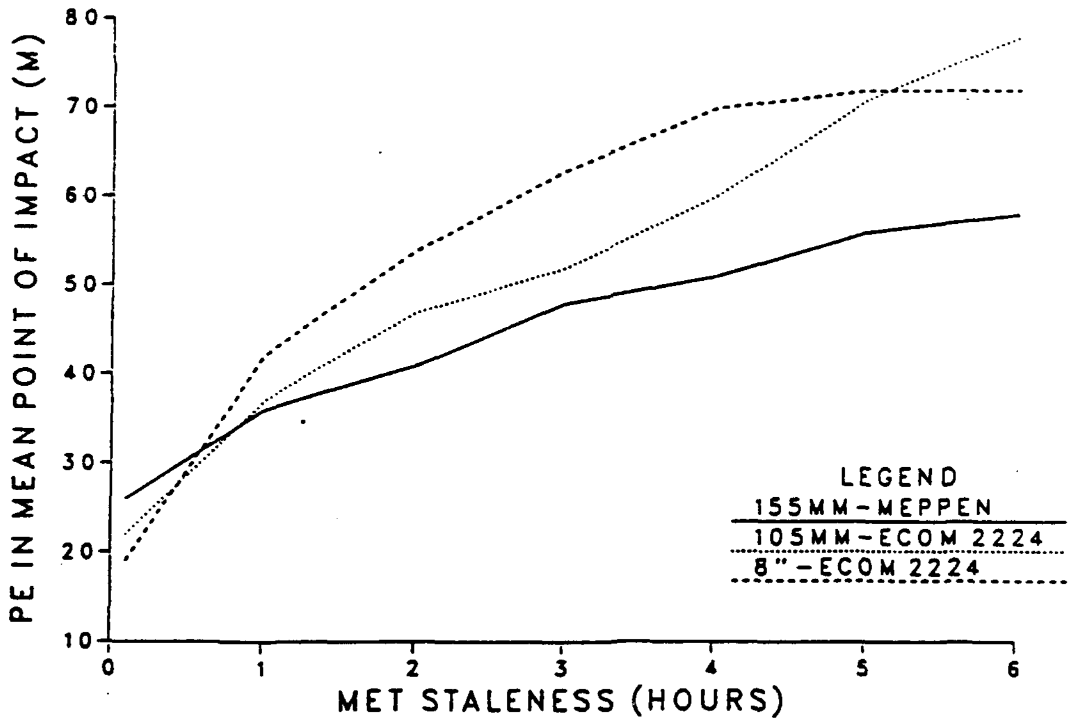

Figure 2. Probable Error (PE) in Mean Point of Impact vs. Met Staleness.

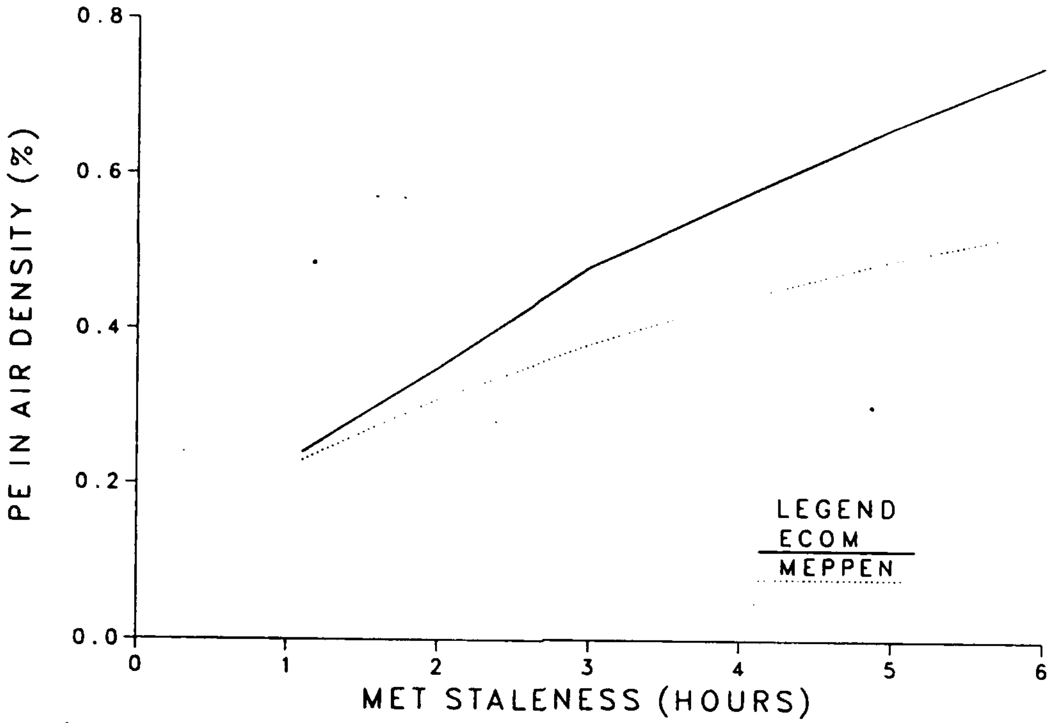

Figure 3. Probable Error (PE) in Air Density vs. Met Staleness.

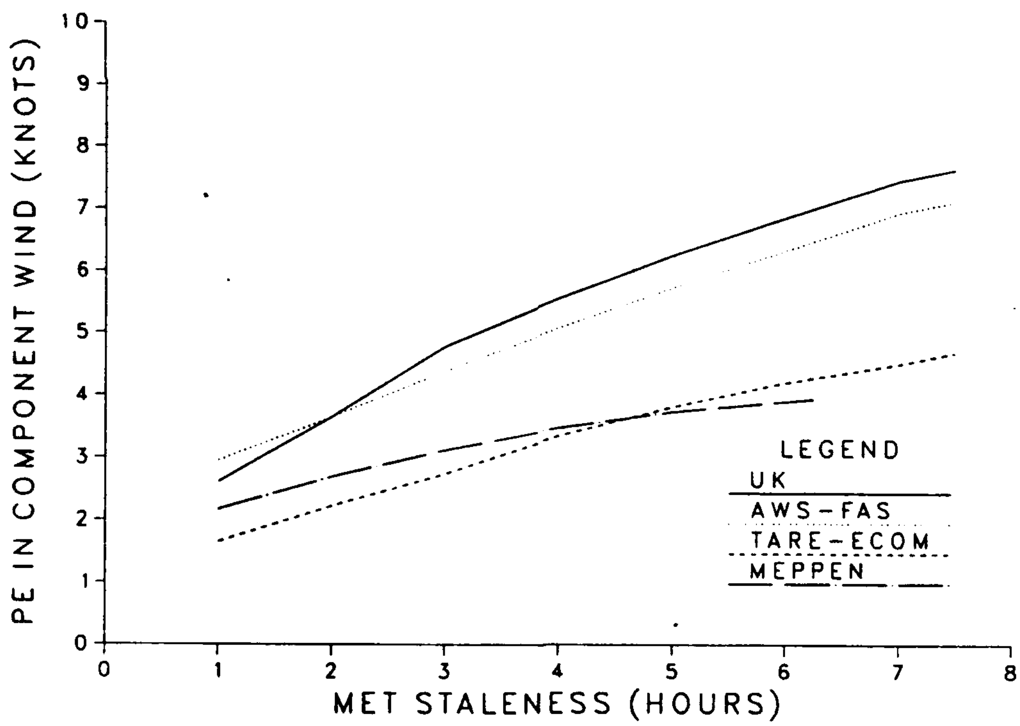

Figure 4. Probable Error (PE) in Component Wind vs. Met Staleness.

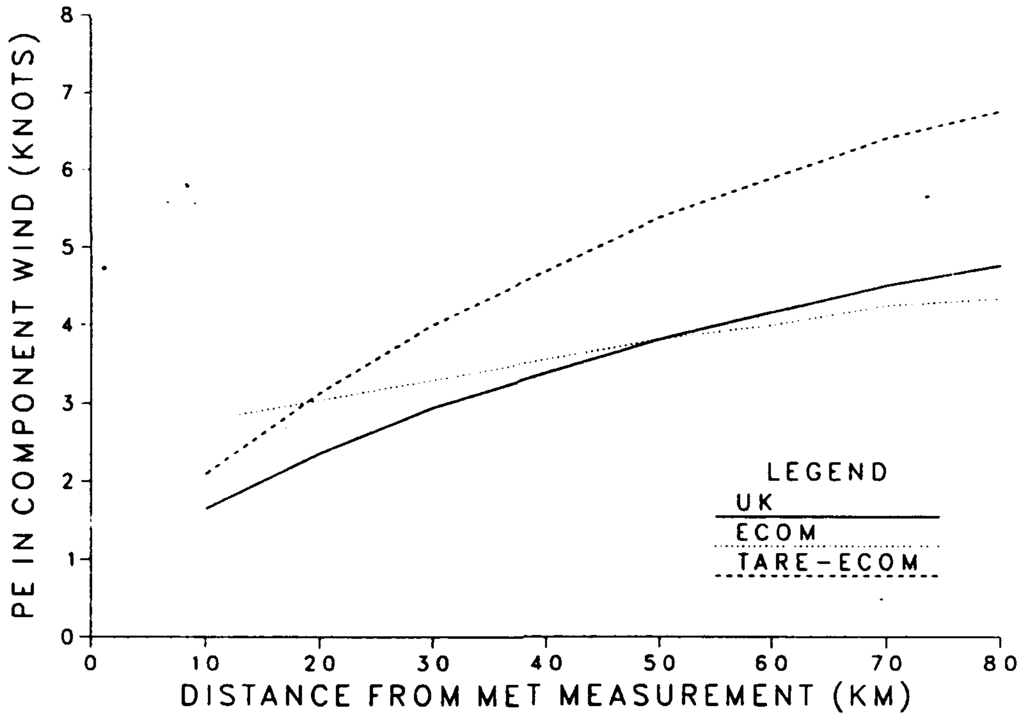

Figure 5. Probable Error (PE) in Component Wind vs. Distance from Met Measurement.

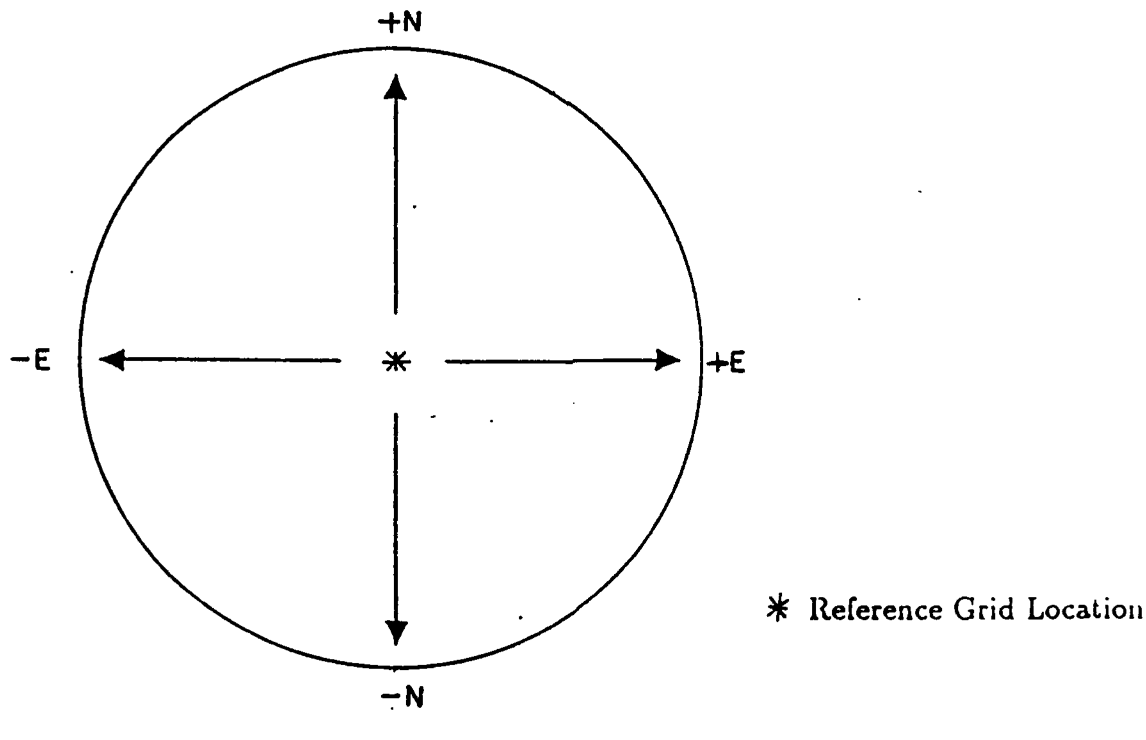

Figure 6. Reference Grid Location with Easting and Northing Directions.

Table 1. Computer Met Message.

COMPUTER MET MESSAGE					
OCTANT Q	LOCATION $L_aL_aL_a$ $L_oL_oL_o$ or or xxx xxx	DATE TIME (GMT) YY $G_oG_oG_o$	DURATION (HOURS) G	STATION HEIGHT (10's M) hhh	MDP PRESSURE MB's $P_dP_dP_d$
1	512 018	07 095	0	049	987

LINE NUMBER ZZ	ZONE VALUES			
	WIND DIRECTION (10's M) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10K) TTTT	PRESSURE MILLIBARS PPPP
00	260	018	2698	0978
01	260	018	2689	0974
02	270	022	2674	0955
03	300	025	2660	0900
04	310	030	2651	0848
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

Table 2. Zone Structure of Computer Met Message.

Height (meters)	Line Number
Surface	0
200	1
500	2
1000	3
1500	4
2000	5
2500	6
3000	7
3500	8
4000	9
4500	10
5000	11
6000	12
7000	13
8000	14
9000	15
10000	16
11000	17
12000	18
13000	19
14000	20
15000	21
16000	22
17000	23
18000	24
19000	25
20000	26

Table 3. Spatial Met Partials for the Positive Easting Direction.

LINE NUMBER ZZ	Zone Values			
	WIND DIRECTION (10's M) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10K) TTTT	PRESSURE MILLIBARS PPPP
00	$(\partial WD/\partial E_I)_0$	$(\partial WS/\partial E_I)_0$	$(\partial T/\partial E_I)_0$	$(\partial P/\partial E_I)_0$
01	$(\partial WD/\partial E_I)_1$	$(\partial WS/\partial E_I)_1$	$(\partial T/\partial E_I)_1$	$(\partial P/\partial E_I)_1$
02	$(\partial WD/\partial E_I)_2$	$(\partial WS/\partial E_I)_2$	$(\partial T/\partial E_I)_2$	$(\partial P/\partial E_I)_2$
03	$(\partial WD/\partial E_I)_3$	$(\partial WS/\partial E_I)_3$	$(\partial T/\partial E_I)_3$	$(\partial P/\partial E_I)_3$
04	$(\partial WD/\partial E_I)_4$	$(\partial WS/\partial E_I)_4$	$(\partial T/\partial E_I)_4$	$(\partial P/\partial E_I)_4$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

Table 4. Spatial Met Partials for the Negative Easting Direction.

LINE NUMBER ZZ	Zone Values			
	WIND DIRECTION (10's M) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10K) TTTT	PRESSURE MILLIBARS PPPP
00	$(\partial WD/\partial E_D)_0$	$(\partial WS/\partial E_D)_0$	$(\partial T/\partial E_D)_0$	$(\partial P/\partial E_D)_0$
01	$(\partial WD/\partial E_D)_1$	$(\partial WS/\partial E_D)_1$	$(\partial T/\partial E_D)_1$	$(\partial P/\partial E_D)_1$
02	$(\partial WD/\partial E_D)_2$	$(\partial WS/\partial E_D)_2$	$(\partial T/\partial E_D)_2$	$(\partial P/\partial E_D)_2$
03	$(\partial WD/\partial E_D)_3$	$(\partial WS/\partial E_D)_3$	$(\partial T/\partial E_D)_3$	$(\partial P/\partial E_D)_3$
04	$(\partial WD/\partial E_D)_4$	$(\partial WS/\partial E_D)_4$	$(\partial T/\partial E_D)_4$	$(\partial P/\partial E_D)_4$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

Table 5. Spatial Met Partials for the Positive Northing Direction.

LINE NUMBER ZZ	Zone Values			
	WIND DIRECTION (10's M) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10K) TTTT	PRESSURE MILLIBARS PPPP
00	$(\partial WD/\partial N_I)_0$	$(\partial WS/\partial N_I)_0$	$(\partial T/\partial N_I)_0$	$(\partial P/\partial N_I)_0$
01	$(\partial WD/\partial N_I)_1$	$(\partial WS/\partial N_I)_1$	$(\partial T/\partial N_I)_1$	$(\partial P/\partial N_I)_1$
02	$(\partial WD/\partial N_I)_2$	$(\partial WS/\partial N_I)_2$	$(\partial T/\partial N_I)_2$	$(\partial P/\partial N_I)_2$
03	$(\partial WD/\partial N_I)_3$	$(\partial WS/\partial N_I)_3$	$(\partial T/\partial N_I)_3$	$(\partial P/\partial N_I)_3$
04	$(\partial WD/\partial N_I)_4$	$(\partial WS/\partial N_I)_4$	$(\partial T/\partial N_I)_4$	$(\partial P/\partial N_I)_4$
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.	.	.	.	.

Table 6. Spatial Met Partials for the Negative Northing Direction.

LINE NUMBER ZZ	Zone Values			
	WIND DIRECTION (10's M) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10K) TTTT	PRESSURE MILLIBARS PPPP
00	$(\partial WD/\partial N_D)_0$	$(\partial WS/\partial N_D)_0$	$(\partial T/\partial N_D)_0$	$(\partial P/\partial N_D)_0$
01	$(\partial WD/\partial N_D)_1$	$(\partial WS/\partial N_D)_1$	$(\partial T/\partial N_D)_1$	$(\partial P/\partial N_D)_1$
02	$(\partial WD/\partial N_D)_2$	$(\partial WS/\partial N_D)_2$	$(\partial T/\partial N_D)_2$	$(\partial P/\partial N_D)_2$
03	$(\partial WD/\partial N_D)_3$	$(\partial WS/\partial N_D)_3$	$(\partial T/\partial N_D)_3$	$(\partial P/\partial N_D)_3$
04	$(\partial WD/\partial N_D)_4$	$(\partial WS/\partial N_D)_4$	$(\partial T/\partial N_D)_4$	$(\partial P/\partial N_D)_4$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

Table 7. Temporal Met Partials.

LINE NUMBER ZZ	Zone Values WIND DIRECTION (10's M) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10K) TTTT	PRESSURE MILLIBARS PPPP
00	$(\partial WD/\partial t)_0$	$(\partial WS/\partial t)_0$	$(\partial T/\partial t)_0$	$(\partial P/\partial t)_0$
01	$(\partial WD/\partial t)_1$	$(\partial WS/\partial t)_1$	$(\partial T/\partial t)_1$	$(\partial P/\partial t)_1$
02	$(\partial WD/\partial t)_2$	$(\partial WS/\partial t)_2$	$(\partial T/\partial t)_2$	$(\partial P/\partial t)_2$
03	$(\partial WD/\partial t)_3$	$(\partial WS/\partial t)_3$	$(\partial T/\partial t)_3$	$(\partial P/\partial t)_3$
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