ETAC

THE NATIONAL AIR POLLUTION POTENTIAL FORECAST PROGRAM

A Reprint of
ESSA WBTM NMC 47 (MAY 70)

by
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U. S. Department of Commerce
Environmental Science Services Administration
Weather Bureau
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USAF ETAC TN 70-9

FOREWORD

AFR 161-22 "Environmental Pollution Control," 23 September 1970, makes Air Weather Service responsible to (1) develop and maintain procedures to interpret and tailor for USAF installations the available air-pollution potential (APP) forecasts of the National Meteorological Center and (2) issue forecasts and warnings as required to support Air Force global environmental-pollution-control operations. Through AFGWC, AWS is developing the capability to use the NMC forecasts in conjunction with the boundary-layer model to produce tailored APP forecasts for the USAF. In the interim, the NMC teletype air-pollution-potential bulletin (described on page 22 of this Technical Note) will be transmitted on COMET III. This Technical Note reprints WBTM NMC 47 and is provided to assist AWS detachments in the interpretation of the NMC bulletin. Further information will be provided as we learn more about the problems involved in this new area of support.

The AWS gratefully acknowledges NOAA's permission to reprint this NMC report.

Thomas D. Potter
THOMAS D. POTTER, Lt Colonel, USAF
COMMANDER
THE NATIONAL AIR POLLUTION POTENTIAL FORECAST PROGRAM

By Edward Gross

I. Introduction

The Donora, Pennsylvania, incident of October 27-31, 1948, demonstrated that lethal air pollution can occur in the United States. This disaster provoked a demand by the public that the Federal Government prevent similar hazardous events. The National Air Pollution Potential forecasting service conducted by ESSA meteorologists, with Public Health Service sponsorship, was created in response to recurrent severe episodes of high air pollution potential.

During periods of atmospheric stagnation, in which there is limited vertical or horizontal mixing, extensive control action may be required. A warning service for air pollution episodes usually is built around a series of alert levels corresponding to different degrees of severity of the problem. The first level may indicate meteorological conditions. It is within this realm of the Weather Bureau's mission that the National Air Pollution Forecast Program is dedicated. It must be emphasized that the forecasts prepared are for pollution potential and not for specific pollutant concentrations. The potential for high air pollution concentrations, given the existence of pollutant sources, is increased under specific meteorological conditions.

An experimental program to forecast air pollution potential began on a year round basis for the area east of 105°W, in August of 1960. The purpose then, as now, was to forecast meteorological conditions which are not favorable for the rapid and effective dilution of contaminants in the atmosphere, and to disseminate these forecasts to public and private interests for appropriate action. The program is supported by the National Air Pollution Control Administration.

Niemeyer (1960), Boettiger (1961), Miller and Niemeyer (1963), Korshover (1967) and others found that the meteorological conditions favorable for the accumulation of atmospheric pollutants are:

(1) A slow moving anticyclone with a small horizontal pressure gradient.

(2) Light surface winds not exceeding seven knots and winds aloft not exceeding 25 knots.

(3) Subsidence in the lower layers of the atmosphere. This phenomenon with its attendant warming and drying effect produces stabilization and the formation of inversions which limit vertical mixing.

The greatest variations of air pollution potential are those of short duration due to the systematic variation of wind and stability between night and day.
Holzworth (1962) in a climatological study of air pollution potential for the Western States also found that the quasi-stationary anti-cyclone was most conducive to poor air quality. In October 1963, the Air Pollution Potential Forecast Program was expanded to include all the contiguous United States.

Miller (1967), using statistically derived specification equations, developed an objective means to forecast mixing heights and transport winds in 12-hour increments out to 36-hours. Expanding upon Miller's work, Stackpole (1967) developed an operational numerical program to produce these forecasts on a routine daily basis. It was found that a large limitation on the usage of these objectively forecasted mixing heights is that the estimates are based on the assumption that the only significant changes in the thermal structure within the boundary layer arise from the redistribution (adiabatic) of heat input at the ground. Under synoptic scale air mass stagnation, this assumption is usually satisfied to permit the use of persistence as a forecast aid. The development of the stagnation index in 1968 and its encouraging results has led to the present state of the Air Pollution Potential Forecast Program.

Definitions

Air Pollution Potential (APP) - A measure of the inability of the atmosphere to adequately dilute and disperse pollutants emitted into it, based on values of specific meteorological parameters of the macroscale features.

Mixing Height - The height to which relatively vigorous mixing occurs (meters).

Transport Wind Speed - A measure of the average rate of the horizontal transport of air within the mixing layer (meters per second).

Ventilation - The product of the mixing height and the transport wind speed. A measure of the volume rate of horizontal transport of air within the mixing layer, per unit distance, normal to the wind (meters$^2$ second$^{-1}$).

Stagnation Area - A combination of stable stratification, weak horizontal wind speed components and little, if any, significant precipitation. It is usually associated with a warm core type anticyclone.

Stagnation Index - An objective index of meteorological parameters used in delineating areas of large scale stagnation in a numerical program.
II. Delineation of Stagnation Areas

A. To delineate salient areas of stagnation, a series of meteorological parameters independent of mixing height and the transport wind speed are indexed in a numerical program on a CDC 6600 computer. The input data are wind, temperature and stability information from the 0000Z and 1200Z RAOBS, plus the morning (near sunrise) urban low level sounding. Forecast information is based on data bilinearly interpolated from the grid points of the 0000Z run of the 6-layer Primitive Equation Model (PE). The critical values of these parameters are arbitrary, but independent studies indicate that during previous high air pollution potential episodes these conditions are generally observed.

B. Parameters and Critical Values for Delineating Stagnation Areas

Wind Speed - Interpolated from RAOBS and PE winds to 5000 feet above the station. Wind Speed must be less than or equal to 10 meters/second.

Temperature Change - Interpolated from the RAOBS and PE FD temperatures to 5000 feet above the station. Temperature change during the last 12 hours must be greater than or equal to -5°C.

500-mb Absolute Vorticity - Interpolated to the stations from the 0000Z PE run (baroclinic). Absolute vorticity must be less than or equal to $100 \times 10^{-6}$ sec$^{-1}$.

500-mb Absolute Vorticity Change - Interpolated to the stations from the 0000Z PE run. Twelve-hour absolute vorticity change must be less than or equal to $+30 \times 10^{-6}$ sec$^{-1}$.

Precipitation or Relative Humidity - Observed precipitation during the last six hours obtained from synoptic reports at 0000Z and 1200Z must be less than or equal to .01 inch or the average relative humidity from the surface to 500 mb, interpolated to the stations from the 0000Z PE run, must be less than or equal to 80%.

Other parameters are being investigated for future inclusion in the stagnation index, they are:

1. Boundary layer (50 mb above the PE surface) wind speed and direction obtained from RAOBS and the PE 0000Z run.
2. 850-mb vertical velocity (microbars/second).
3. Lifted index (middle of the boundary layer to 500 mb) computed from RAOBS and PE 0000Z run.
4. Deformation, divergence, and vorticity fields derived from the u and v components of the boundary layer winds.
C. Output Products

Figure 1 A-E is an example of the computer printouts used to delineate the stagnation areas from yesterday afternoon until 0000Z the day after tomorrow.

Figure 2 is an objectively derived composite stagnation map, i.e., an area where stagnation is observed this morning and forecasted to continue until 0000Z the day after tomorrow. This objective output is adjusted by the air pollution specialist at NMC, using the latest prognostic and observed data available.

For definitions of numbers and symbols used in Figures 1 A-E and 2, see Appendix A.

III. Calculation of Mixing Height and Transport Wind Speeds

Once the stagnation areas have been determined, the next step is to calculate the mixing height and the transport wind speed. This is also done objectively on the CDC 6600 computer. The mixing heights and transport wind speeds are calculated for the morning and afternoon for all stations, but are only depicted on the facsimile package within areas of large-scale stagnation.

Yesterday Afternoon's Observed Mixing Height - The geometric height above the ground (meters) of the sounding adiabat intersection based on the 1200Z sounding from yesterday morning and the observed maximum temperature from the 0000Z synoptic report.

Yesterday Afternoon's Transport Wind Speed - The 0000Z observed average wind speed through yesterday afternoon's mixing layer (meters/second). The calculations include only those RAOB winds (surface winds are included) actually observed within the mixing layer. The unweighted mean of these winds form the average.

Yesterday afternoon's ventilation (product of yesterday afternoon's mixing height and the transport wind speed) should be less than or equal to 6000 meters²/second and the wind speed must be less than or equal to 4 mps within stagnation areas.

Yesterday afternoon's mixing height, transport wind speed and ventilation are not depicted on the facsimile product, but is utilized by the NMC air pollution specialist in preparing his advisory and in the verification program.

Urban Morning Mixing Height - See Fig. 7 - The geometric height above the ground of the 1200Z sounding - adiabat intersection drawn from the surface minimum temperature observed plus 3° or 5°C depending on the station location. This 3° or 5°C is thought of as a measure of the urban heat island effect during the first two hours of so after sunrise. Three degrees are added to the minimum temperature when the RAOB or urban low level sounding site is within the confines of the urban heat island. Five degrees are added to the minimum temperature when the RAOB or urban low
level sounding is taken at a rural site. If the observed minimum
temperature is missing, the 1200Z sounding temperature plus 3° or 5°C
is used to calculate the mixing height.

Morning Transport Wind Speed - See Fig. 7 - The observed average
wind speed through the urban morning mixing layer (mps). The calculations
include only those winds, both RAOB and Surface, actually observed within
the mixing layer. The unweighted mean of these winds form the average.

Criteria - The Urban Morning Mixing Height must be less than or equal
to 500 meters and the transport wind speed must be less than or equal to
4 mps within stagnation areas.

Afternoon Mixing Height - See Fig. 8 - The geometric height above
the ground (meters) of the sounding - adiabat intersection drawn from the
Klein-Lewis maximum temperature forecast from the 1200Z barotropic run and
the 1200Z sounding.

Afternoon Transport Wind Speed - See Fig. 8 - The 1200Z observed
average wind speed through the afternoon mixing layer forecast (mps). The
calculations include only those RAOB winds (surface winds included) actually
observed within the mixing layer. The unweighted mean of these winds form
the average.

Criteria - This afternoon's ventilation must be less than or equal to
6000 meters$^2$ sec$^{-1}$, and the transport wind speed must be less than or equal
to 4 mps within stagnation areas.

Note: The ventilation criteria can be modified to a critical value of
8000 meters$^2$ sec$^{-1}$ with wind speeds less than or equal to 4 mps within
stagnation areas, if yesterday's ventilation and transport wind speed
within a stagnation area were less than or equal to 6000 meters$^2$/second
and 4 meters per second for the respective station, or after the commence-
ment of a National Air Pollution Potential advisory.

Within delineated stagnation areas, persistence should be used as a
determining factor in subjectively predicting the 24- and 36-hour mixing
height and transport wind speed values. There will be some fluctuations
in the mixing height, due primarily to surface heating and subsidence, but
the wind speed criterion should remain generally less than 4 mps.

Figure 3 is a schematic representation of how the mixing height and
transport wind speed can be calculated manually. This same method can be
applied in preparing forecasts of the mixing height and the transport wind
speed out to 36 hours within stagnation areas.

Figure 4 A-D is an example of the computer printouts used in
determining the mixing height and transport wind speed. Figure 4D is a
composite chart showing where criteria are satisfied for this morning's
and this afternoon's mixing height and transport wind speed.
Figure 1 E

Figure 2
Explanation of the Symbols on Figure 4D

MN - Only the morning mixing height and transport wind speed criteria satisfied.

AF - Only the afternoon mixing height and transport wind speed criteria satisfied.

APP - Both the morning and afternoon mixing height and transport wind speed criteria satisfied.

* - Mixing height and transport wind speed data for both this morning and afternoon exceed critical values.

These data are only valid within delineated stagnation areas corresponding to the respective times for the mixing height and transport wind speed data.

IV. Criteria for the Issuance of a National Air Pollution Potential Advisory by the National Meteorological Center

A. A stagnation area must be observed this morning and be forecasted to continue for at least 36 hours. This stagnation area is delineated by satisfying all of the following criteria:

1. Wind speed 5000 feet above the station must be \( \leq \) 10 mps.

2. The temperature change during the past 12 hours 5000 feet above the station must be \( \geq -5°C \). This check eliminates areas of cold air advection.

3. 500-mb absolute vorticity must be \( \leq 100 \times 10^{-6} \) sec\(^{-1}\).

4. 500-mb absolute vorticity change during the past 12 hours must be \( \leq +30 \times 10^{-6} \) sec\(^{-1}\). This check eliminates areas of positive vorticity advection.

5. Observed precipitation must be \( \leq 0.01 \) inches or the PE relative humidity (surface to 500 mb) must be \( \leq 80\% \).

B. Within stagnation areas, the mixing height, transport wind speed and the ventilation must satisfy the following criteria:

1. The morning mixing height must be \( \leq 500 \) meters and the morning transport wind speed must be \( \leq 4 \) meters per second.

2. The afternoon ventilation must be \( \leq 6000 \) m\(^2\) sec\(^{-1}\) and the afternoon transport wind speed must be \( \leq 4 \) meters per second. The afternoon ventilation can be modified to a critical value of 8000 m\(^2\) sec\(^{-1}\)
with wind speeds less or equal to 4 meters per second after the commence-
ment of a National Air Pollution Potential advisory.

C. For an initial issuance of a national advisory, the affected
area must be at least as large as a 4 degree latitude-longitude square
(58,000 nautical square miles). The area criterion may be reduced when
very large population centers are involved.

D. An alert area must continue for at least 36 hours from the time
of the initial issuance of an advisory, i.e., an atypical case of diurnal
nighttime pollution buildup and normal daytime ventilation. Once an area
has been started, air pollution potential criteria may be adjusted or
modified based on guidelines available to the air pollution specialist (e.g.,
vorticity, ventilation, windspeed).

E. After an initial issuance of an advisory, areal additions or
reductions can be made without regard to the size of these reductions.
For the subsequent enlargement of an affected area, the temporal criterion
is reduced to 24 hours.

Figure 5 shows the number of forecasted High Air Pollution
Potential days for the Western and Eastern United States. Stagnation
situations in the Eastern United States concentrate in a long arc from
Alabama to Eastern Pennsylvania, roughly following the Appalachian High-
lands. The greatest number of episode days occur over the Western Carolina
and Northern Georgia areas. In the Western United States, the greatest
number of stagnation situations occur in the Great Basin region and over
most of California.

Figure 6 is a map and list of stations in the contiguous United
States for which Air Pollution Potential data is prepared.

V. Output of Information

A. Facsimile

The data depicted on the facsimile product will be the basis of
NMC's National Air Pollution Potential Advisory and should be used as
guidance by field stations for the issuance of local statements based on
meteorological and air quality parameters (as per Chapter 30, Part C of
the Weather Bureau Operations Manual). A Weather Bureau Handbook will be
published shortly describing, in detail, the National Air Pollution
Potential Program of the Weather Bureau and the National Air Pollution
Control Administration.

B. The Product

A 4-panel facsimile transmitted over the Facfax circuit. The
input data will be wind, temperature and stability information available
from the 0000Z and 1200Z RAOBS, plus the morning (near sunrise) urban low
level soundings.
Forecast information will be based on data interpolated to stations from grid points of the 0000Z run of the 6-layer Primitive Equation Model (PE). The objective output will be adjusted by the air pollution specialist at NMC using the latest prognostic and observed data available.

The facsimile package will consist of:

1. Stagnation areas out to 36 hours in 12-hour increments from this morning's observed data.

2. A composite stagnation area for the period from 1200Z this morning through 0000Z the day after tomorrow.

3. Mixing height and transport wind speed information for this morning and this afternoon, only in the vicinity of stagnation areas.
RAOB STATIONS AND NESSA METEOROLOGICAL SUPPORT UNITS (ESSU'S)

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Note: Stations 78526 KJSU, San Juan, P.R., and 91165 THNL, Lihue, Hawaii, will be added to this list.

Figure 6.

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Stippled Area - Stagnation Area - based on observations at 1200Z.

Solid Lines - Urban Morning Mixing Height (meters) - based on observed data for 1200Z in the vicinity of stagnation areas. Only the 500, 1500, 2500, and 3500 (meter) isopleths are depicted.

Dashed Lines - Transport Wind Speed observed in the mixing layer this morning (MPS) in the vicinity of stagnation areas. Only the 4 meter per second isotach is depicted.
Stippled Area - Stagnation Area forecast V.T. 0000Z tomorrow.

Solid Lines - Afternoon Mixing Height forecast V.T. 0000Z tomorrow (meters) in the vicinity of stagnation areas.

Dashed Lines - Transport Wind Speed in the afternoon mixing layer forecasted to verify at 0000Z tomorrow (mps) in the vicinity of stagnation areas.
Figure 9.

Stippled Area - Stagnation Area V.T. 1200Z tomorrow morning.
Cross Hatched Area - Composite Stagnation Area - All stagnation criteria are satisfied throughout period from 1200Z this morning to 0000Z the day after tomorrow (36 hours).

Stippled Area - Stagnation Area V.T. 0000Z the day after tomorrow (36 hours).
C. **Teletypewriter Transmission Changes in FKUS, FKUS1**

The NMC guidance format of the FKUS, FKUS1 transmitted on Service C is described in WBOM Chapter C-30. This format was changed as follows on March 2, 1970:

1. **FKUS1, Air Pollution Potential Data.**
   a. The 5-digit data groups are increased to 6-digit groups.
   b. The third group, "Tomorrow Afternoon" data, is deleted.
   c. A group containing the observed mixing height and average wind speed for "Yesterday Afternoon" is added.

   The following is the sequential arrangement and breakdown of the new code:

   **FKUSI KWBC XX1720**
   Air Pollution Potential Data

   IIIIII MxMyWyWyWy
   MnMnMnMnMnMn
   MnMnMnMnMnMn

   IIIIII The block number and station number

   MxMxWxWxWx
   HyMyWxWx
   The afternoon mixing height for "Yesterday Afternoon" in decameters

   WyyjWyWx
   The average wind speed within the mixing layer for "Yesterday Afternoon" in meters per second and tenths of meters per second

   MxMxMxMxMx
   The morning mixing height for "This Morning" in decameters

   WxWxWxWxWx
   The average wind speed within the mixing layer: for "This Morning" in meters per second and tenths of meters per second.

   MxMxMxMxMx
   The afternoon mixing height for "This Afternoon" in decameters

   WxWxWxWxWx
   The average wind speed within the mixing layer: for "This Afternoon" in meters per second and tenths of meters per second.

2. **FKUS Air Pollution Potential Advisory.**

   The abbreviated plain language narrative will be prepared and issued daily. The narrative will discuss the following:

   a. The general synoptic situation as it applies to air pollution potential (APP) including possible high APP areas that do not currently meet spatial or temporal criteria for issuance of an advisory.
This portion of the narrative will concern itself with the next 24-36 hour period.

b. The highlights of the stagnation index forecast.

c. The NMC Air Pollution Potential Advisory (if any). When the data indicates that an advisory of high air pollution potential should be issued, the message delineates the affected areas. The daily message will also indicate any changes in the boundaries of the advisory areas, including termination of an episode.
D. Sample Teletypewriter Transmission Transmitted Daily at 12:20 p.m.,
EST, to U. S. Weather Bureau Stations via Teletype Service "C"

ZCZC
FKUS
AIR POLLUTION POTENTIAL ADVISORY
NONE TODAY. ABSENCE OF LARGE UPPER RIDGE CONTINUES TO PREVENT THE
FORMATION OF MAJOR LARGE SCALE STAGNATION AREAS. A SURFACE RIDGE
HOWEVER EXTENDING FROM THE PACIFIC COAST SOUTHEASTWARD TO TEXAS WILL
RESULT IN LIGHT WINDS AND LOCAL STAGNATIONS FROM SOUTHERN CALIFORNIA
TO WESTERN TEXAS. POOR VENTILATION WILL ESPECIALLY BE NOTICEABLE IN
THE UPPER RIO GRANDE VALLEY. AN UPPER RIDGE IS AT PRESENT FORECAST
TO MOVE INLAND FROM THE PACIFIC DURING SUNDAY AND MAY START TO AFFECT
PORTIONS OF CALIFORNIA ON SUNDAY.

FKUSI KXBC 111320
AIR POLLUTION POTENTIAL DATA
72201 999999 147046 147046 72202 093045 091040 133037
72208 999999 062036 062036 72211 078047 090073 106072
72213 999999 070059 180097 72226 023041 064067 078067
72235 068065 105060 118060 72240 999999 083074 099064
72248 999999 112081 136088 72250 999999 081089 111082
72255 999999 102082 131091 72259 999999 095055 160048
72261 000099 100069 136079 72265 999999 082048 176076
72270 086048 061021 253127 72274 340073 010031 215040
72280 999999 999999 999999 72290 358088 003036 144035
72291 999999 012999 113054 72304 999999 024062 035088
72311 051999 049033 112051 72317 042041 055046 059060
72327 107072 130036 139040 72340 999999 112045 146062
72334 999999 116048 144045 72363 063034 147083 210836
72355 127999 138026 244026 72374 363093 064061 254079
72385 999999 009999 360082 72393 999999 999999 999999
72402 049999 049069 154112 72403 043018 052089 130109
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72415 039062 999999 999999 72429 041118 149053 152102
72433 111113 041036 151051 72434 999999 999999 999999
72445 999999 027028 111053 72451 999999 049048 170050
72456 999999 010021 162021 72469 999999 017013 189051
72475 295039 031051 242045 72486 226044 007999 237999
72483 309048 062028 081028 72503 999999 999999 999999
72506 261062 999999 999999 72518 999999 091014 156113
72520 059158 184140 194140 72528 050094 179180 159138
72532 106129 020031 118050 72534 999999 999999 999999
72533 170077 012021 097040 72562 117056 007093 102093
72572 259045 020072 254089 72576 276044 011051 132017
72583 999999 064999 273999 72597 149043 006000 197079
72606 022036 086103 097121 72637 073151 144177 144177
72645 061096 017067 020067 72654 999999 999999 999999
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72661 172051 088089 269113 72694 098139 132041 205046
72712 176057 146114 104104 72736 023023 019044 067067
72747 088058 999999 999999 72764 123046 020959 124098
72768 181057 088173 081173 72775 251112 201081 310088
72785 135063 012031 235073 72797 042036 095036 149036
74486 016067 999999 999999 74768 999999 058999 065999

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Conclusion

Our experience has found that the forecasts of macroscale meteorological phenomena can be used to determine periods of high air pollution potential for a large portion of the United States. It is anticipated that the increase in guidance material available to the NMC air pollution specialists will be most useful in the preparation of National Air Pollution Potential advisories. The daily facsimile and teletype transmissions should increase the confidence level among WBFO forecasters and other users in the preparation of local statements of high air pollution potential. This can be especially true during those periods when temporal and/or spatial considerations prevent a National Air Pollution Potential advisory for a particular area.
References


APPENDIX A

STAGNATION INDEX

If the index is:

00 All stagnation criteria are satisfied.

01 12-hour temperature change 5000 feet above the station equals or exceeds -5°C.

02 Wind speed 5000 feet above the station equals or exceeds 10 mps.

03 Observed precipitation in the past 6 hours equals or exceeds .01 inch or the PE relative humidity equals or exceeds 80%.

04 Combination of 01 plus 02.

05 Combination of 01 plus 03.

06 Combination of 02 plus 03.

07 Combination of 01 plus 02 plus 03.

10 to Combinations of 12-hour vorticity change equalling or exceeding $+30 \times 10^{-6}$/second and items 01 through 07, respectively.

17 17

20 to Combinations of vorticity equalling or exceeding $100 \times 10^{-6}$/

27 second and items 01 through 07, respectively.

30 to Combinations of both vorticity and vorticity change equaling or exceeding limits and items 01 through 07, respectively.

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M00 All stagnation criteria satisfied, but with some data fields missing.

STAG*36 Stagnation is observed from 1200Z this morning and forecasted to continue until 0000Z the day after tomorrow.
Air Pollution Potential (APP) is definable as a measure of the inability of the atmosphere to adequately dilute and disperse pollutants emitted into it based on values of specific meteorological parameters of the macroscale features. To delineate areas on the macroscale in which high APP has the greatest probability of occurring, a stagnation index has been developed independent of mixing height and transport wind speed data. The associated stagnation conditions are usually manifested by stable stratification, weak horizontal wind speed components and little, if any, significant precipitation. We describe the numerical and subjective means by which stagnation areas are delineated, mixing height and transport wind speed calculated, and how high APP conditions are transmitted to our users via facsimile and teletypewriter. The resulting program is a joint effort of the Development Division of the National Meteorological Center (NMC) and the Division of Meteorology of the National Air Pollution Control Administration (NAPCA).
# List of USAF ETAC Technical Notes

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