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THE AIR POLLUTION POTENTIAL FORECAST PROGRAM

John D. Stackpole

NATIONAL METEOROLOGICAL CENTER

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LASON
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ABSTRACT

Air Pollution Potential (APP) is definable as a set of meteorological conditions conducive to the accumulation of atmospheric pollutants. The meteorological conditions considered are those that effect the dispersion of pollutants that typically may be emitted from myriad low level sources. The national APP forecasting program considers the occurrence of such conditions on the synoptic scale; i.e., over large areas. These poor dispersion conditions are generally associated with a stagnating anticyclone. We describe the particular numerical-objective and subjective means by which these high APP conditions are rapidly detected and forecast for purposes of preparing national APP forecasts.

I. INTRODUCTION

In view of the growing national concern over man's contaminants of his own environment and, in particular, the pollution of the air around us, it is only to be expected that the Weather Bureau should undertake to forecast those elements of the pollution problem that fall within its competence and mission. Studies supported by the National Center for Air Pollution Control (Public Health Service) have now resulted in the regular preparation of air pollution potential (APP) forecasts for the contiguous United States. It must be emphasized right at the start that the forecasts are of pollution potential, not the actual occurrence of dirty or otherwise contaminated air. In other words, the forecasts are of those meteorological conditions which, given the existence of multiple pollutant sources would be conducive to the accumulation of contaminates irrespective of whether or not such sources exist in the region in question.

The meteorological conditions for high APP over large areas have been known for some time (Niemeyer, 1960) and can generally be associated with a stagnating anticyclone: relatively light winds from the surface to 500 mb, subsidence with possibly an inversion near the ground, no rain; and these conditions forecast to persist for 36 hours or more over a large area. Experience, using specific numerical criteria derived from these general conditions (Boettger, 1961; Miller and Niemeyer, 1963), indicated the success of the subjective methods then developed for pinpointing APP areas over the central and eastern portions of the United States.

With the extension of APP forecast area to include the western portions of the country (Holzworth, 1962; Miller, 1964) it became apparent, however, that additional criteria were necessary and appropriate, and indeed that these new criteria were equally applicable to the remainder of the United States. These new criteria did not represent a departure from the general one of a stagnating anticyclone but were merely another way of detecting it by its physical manifestations. They are the existence of sufficiently shallow afternoon and morning urban mixing depths coupled with sufficiently light winds through these depths. As before, these conditions must be observed and forecast to persist for 36 hours or more over a relatively large area.

The afternoon mixing depth for any particular location is defined as the geometric height (above ground) of the intersection of the 12Z sounding at that station and the dry adiabat drawn from the forecast afternoon maximum surface temperature. It is a rough but adequate measure of the maximum depth of the atmosphere near the ground through which pollutants (and anything else) would be dispersed during the day.

The preparation of an APP forecast, and indeed the determination of whether there should be one or not, although straight-forward for one skilled in the procedures, was rather an arduous task, particularly when it became necessary to determine mixing depths for a relatively large number of stations. Also, it appeared that forecasts of actual mixing depths were not feasible by subjective means. For these and other reasons, including speed of preparation of forecast material, an effort was undertaken to automate and make objective as much of the forecast procedure as possible using the computer facilities, observations, and forecasts available at the National Meteorological Center. A portion of this task involved development of yet other variations on the criteria theme so that the essentially subjective meteorological phenomenon of a stagnating anticyclone could be recognized by the computer in an entirely objective manner. Fortunately, also, the newer criteria of mixing depths and average winds were more amenable to computer calculation and forecasts than the earlier criteria set.

The criteria currently considered, the means of their calculation and their routine utilization constitute the body of this memorandum.

II. APP CRITERIA

A. Machine Computations

The APP criteria currently in use, which are easily identifiable as manifestations of a stagnating anticyclone, can be summarized quite briefly:

1. The morning urban mixing depth (precise definitions follow) must be no greater than 500 meters, and the observed wind speed averaged through this depth must be no greater than four meters/sec.

2. The numerical product of the afternoon mixing depth and the forecast average wind speed through this depth must be no greater than 6000 m^2/sec, and the forecast average wind itself must not exceed 4m/sec.

3. The thirty-hour forecast of tomorrow afternoon's mixing depth and average wind speed (Miller, 1967) must meet the same criteria as in number two above.

4. The observed (at 12Z), 12-hour, 24-hour, and 36-hour forecast 500 mb vorticities must not exceed a relative vorticity value of 0.25×10^{-4} sec^{-1}.

5. The absolute value of any of the forecast 12-hour changes of vorticity (up to 36 hours) should not exceed 0.3×10^{-4} sec^{-1}.

The above set of criteria (which is not the complete set — more follow below) are all calculated by machine for each city of the contiguous United States for which radiosonde data are available, once per day using 12Z data observations and forecasts based on them. Specific definitions of the quantities involved and details of their calculation follow.

The morning urban mixing depth, like the afternoon depth, is the geometric height (above ground) of the sounding-adiabat intersection, but in this case the adiabat is drawn from a surface temperature given by the observed minimum temperature reported at 12Z for the station in question plus 5°C. If, due to the vagaries of automatic data processing, the observed minimum temperature is not available, the surface temperature from the sounding itself is substituted and 5°C is added to it. This 5°C increment to the temperature may be thought of as a measure of the urban heat island effect upon the sounding and associated mixing depths.

The calculation of the average wind in the morning mixing depth includes only those winds, both pibal and surface, actually observed within the previously computed depth. The unweighted mean of these winds forms the average.

The afternoon mixing depth is defined above; the maximum temperature used in the calculation is the so-called FM Shippers' Bulletin maximum-minimum temperature forecast. The "First FM," the forecast for this afternoon's maximum, is used without modification in the mixing depth calculation.

The forecast mean wind speed in the mixing layer is calculated using statistically derived specification equations described by Miller (1967). In essence, what Miller did was find a relationship for each upper air station between the 00Z observed mean wind and the 00Z pibal observation which fell closest to the center of the afternoon mixing layer. In use, a forecast of the wind speed is obtained for the corresponding pibal level and the mean wind obtained from the equations. At present the wind forecast is based on the FD winds aloft forecasts (Badner and Kulawiec, 1965) for 3000 and 5000 feet (and above). The 12-hour FD forecast speeds are linearly extrapolated down (or interpolated) to the appropriate pibal level within the previously calculated mixing layer. The FD forecasts are in turn based upon the operational barotropic-mesh numerical weather prediction model (Gustafson, 1964) run at one hour and thirty minutes after the 12Z data observation time.

The forecast of tomorrow afternoon's mixing depth is a somewhat more involved calculation. It is based again upon a set of statistical equations derived by Miller (1967). The equations were derived (using entirely observed data, of course) such that there were two equations for each city: one for when the top of the mixing layer was observed between 1000 and 850 mbs, the other when the depth was topped between 850 and 500 mbs. The predictands were, of course, the mixing depths; the predictors were the afternoon observed maximum temperatures minus the mean virtual temperatures of the layer (1000-850 mbs or 850-500 mbs) in question as observed at 12Z. Note the time lag from the 12Z observation time to the afternoon mixing depth time is built into the prediction equations. In use, the appropriate layer is first determined by calculating the 24-hour surface pressure for the station in question. This is derived from the 24-hour sea-level pressure forecast (Reed, 1963) and the average of the first maximum and the first minimum FM temperature forecast by hydrostatically "unreducing" the sea-level pressure back to the station (surface) pressure. Then this pressure is used in conjunction with the 30-hour FM forecast maximum to derive the maximum potential temperature of the surface. If this potential temperature is less than the 24-hour FD temperature forecast for the 850 mb surface, the 1000-850 mb layer equations are used to specify the mixing depth with the appropriate mean virtual temperature of the layer (given by the thickness) subtracted from the afternoon forecast maximum as the predictor. If the surface potential temperature has a value between that forecast for the 850 and 500 mb surfaces, the upper-layer equations are called into play. If the surface potential temperature exceeds the 500 mb temperature, there are no forecast equations available and the forecast height of the 500 mb surface (above the station) is substituted for the mixing depth.

The average wind speeds through tomorrow afternoon's mixing depth are calculated with the same statistical equations as the forecasts for this afternoon's winds except, of course, the 36-hour FD wind forecast is used.

The vorticity and vorticity change calculations are taken directly from the barotropic-mesh model.

The computing machine output, used in determining the satisfaction of the criteria, is prepared in a series of plotted charts with the numerical values of the various quantities appearing at the appropriate observation or forecast locations. In addition, maps indicating which criteria are satisfied at the particular locations are prepared. The complete package of computer output is then turned over to the APP forecaster at NMC as guidance for his preparation of the APP advisory for that day.

B. Forecasters' Criteria

With the machine output in hand and other NMC analysis and forecast products available, the APP forecaster considers these further criteria:

6. The affected area must be no smaller than an area equivalent to a 4° latitude-longitude square, approximately the size of Nebraska.

7. There must be no significant precipitation or frontal passages observed or anticipated for the next 36 hours or so.

8. The surface winds at stations in the area must not average more than five knots and/or no more than three individual hourly speeds to exceed eight knots during a 24-hour period. The FT-2 (Terminal Forecasts) are used for this purpose.

9. From time to time in marginal cases or if there is a machine failure, the forecaster may plot a few soundings and calculate mixing depths as necessary.

10. Finally, the forecaster will bring to the fore his accumulated synoptic experience to guide him in deciding whether this or that particular area will experience high APP. In cases where the meteorological criteria are <u>not quite</u> satisfied on consecutive days, the forecaster may consider modifying the criteria. Forecast material is treated as guidance material whose validity is judged in light of the applicability of the forecasting techniques to the particular situation. In preparing an APP forecast the primary criteria are 1, 2, 3 (mixing depth, wind speed, persistence), and 6 (minimum area). Criteria 7 (significant precipitation) is often difficult to forecast, especially in cases of air mass showers; it may be considered satisfied when the precipitation forecast probability is less than 40%. Criteria 8 (surface wind speed) is difficult to evaluate because of terrain irregularities; it is extremely important, however, where local winds such as the sea breeze occur over a significant area.

Once the APP area, if any, has been outlined (criterion 8 is most frequently used to define the edges), an advisory message defining the affected area by listing weather stations on the perimeter is prepared for transmission on the normal weather teletype circuits. If no area of high APP is specified, the message is "none today." In addition the daily message may continue, terminate, or modify an existing area of high APP.

In addition to the APP advisory, NMC daily transmits the machine computed mixing depths and average winds for the three times calculated (this morning, this afternoon, and tomorrow afternoon) as an aid for local air pollution control people not directly concerned with the large area pollution potential as is NMC.

III. A NOTE ON THE APP PROGRAM PHILOSOPHY

The perceptive reader, experienced in synoptic meteorology, may have noted that the ten or so criteria above are rather stringent — the occurrence of an APP event is relatively infrequent. An individual living, for example, in or near a large city would experience annoyingly perceptible levels of air pollution concentration far more often than he would find that the Weather Bureau had placed him within an APP area. On the other hand, he may take heart in the observation that if the pollution levels he is experiencing become rather severe and of considerable duration, his area, and a large area around him, more than likely had been designated an APP region some time before the severity became great.

This conservatism on the part of the APP forecaster is by design. In simple terms, he does not wish to be accused of crying "Wolf!" The social and economic consequences of a substantial air pollution episode (Lynn, et al., 1964) are sufficiently great such that the APP forecaster would rather miss a few marginal cases than attempt to forecast all possibilities and cry "APP" when none came to pass. He would soon be ignored, to the eventual detrement of the ignorers. Rather he would prefer that his forecasts came to be trusted so that preventative measures, reducing smoke production, changing fuel types, generally restricting pollutant production, could be undertaken to avoid the possibly disasterous consequences of a failure to act.

At present nothing seemingly can be done about changing the Potential; however, adequate warning coupled with firm measures can go a long way toward eliminating the Air Pollution in an Air Pollution Potential episode.

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