Weather Note

LOW-LEVEL TROPOSPHERIC OZONE

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Air pollutants are meteorological variables that are becoming increasingly important in the agro-economy of all countries. Strong oxidizing agents in the vicinity of metropolitan and industrial areas, particularly on the west coast, in the Northeast, and in southern Canada, cause eye irritation, rubber cracking, and crop damage [1, 2, 4, 5, 8, 9, 14]. Haagen-Smit [4] has proposed that ozone is the major oxidizing agent in these polluted atmospheres. He established that hydrocarbons and nitrogen dioxides, products of automobile exhausts and industrial establishments, result in ozone formation when exposed to ultraviolet light.

Plant damage induced by ozone and the agronomic importance of the problem have been variously reported [2, 5, 7, 11] and summarized by Rich [10]. Not all ozone-induced plant damage, however, is confined to those localities normally associated with air pollution from industrialization and automobiles. Periodically the same type of plant injury has been noted in localities far removed from heavy urbanization and man-made air pollutions. In these areas, temporary increases in natural low-level tropospheric ozone are responsible for tissue damage to plants. The contiguous area of northern Florida and southern Georgia is one of these predominantly rural areas where tobacco, tomatoes, and other crops periodically show tissue damage similar to that observed in polluted atmospheres. Within this area this type of damage is not believed to be a new problem, since there have been reports of similar tissue damage on shade-grown and flue-cured tobacco for a number of years. Dean [3] using

FIGURE 1.—Small white spots on tobacco leaves, known as "weather fleck," developed when low-level tropospheric ozone increased to 9 pphm in late April 1965.

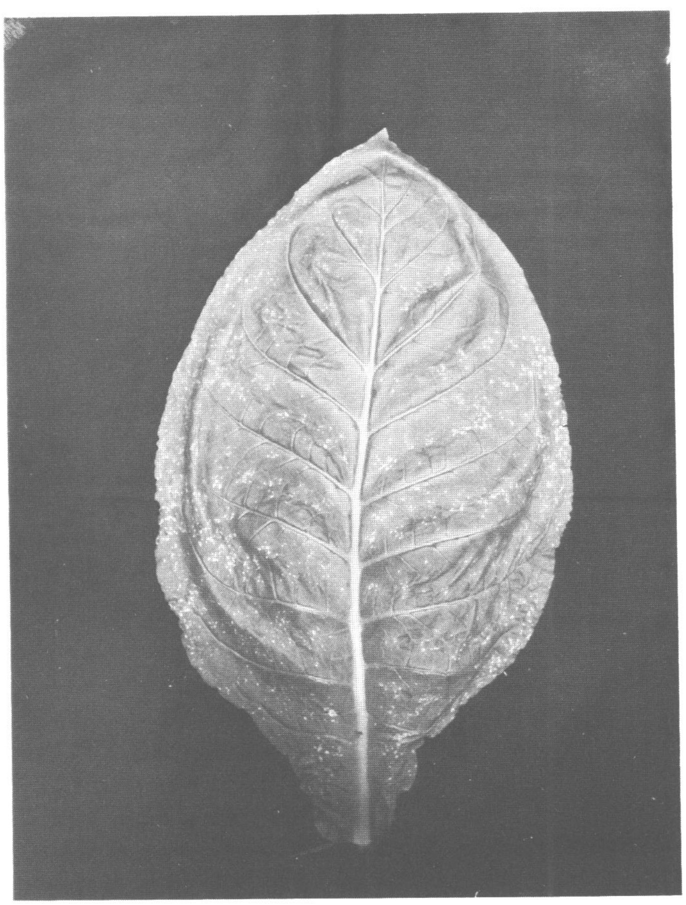

FIGURE 2.—Close-up of tobacco leaf showing ozone-induced damage.

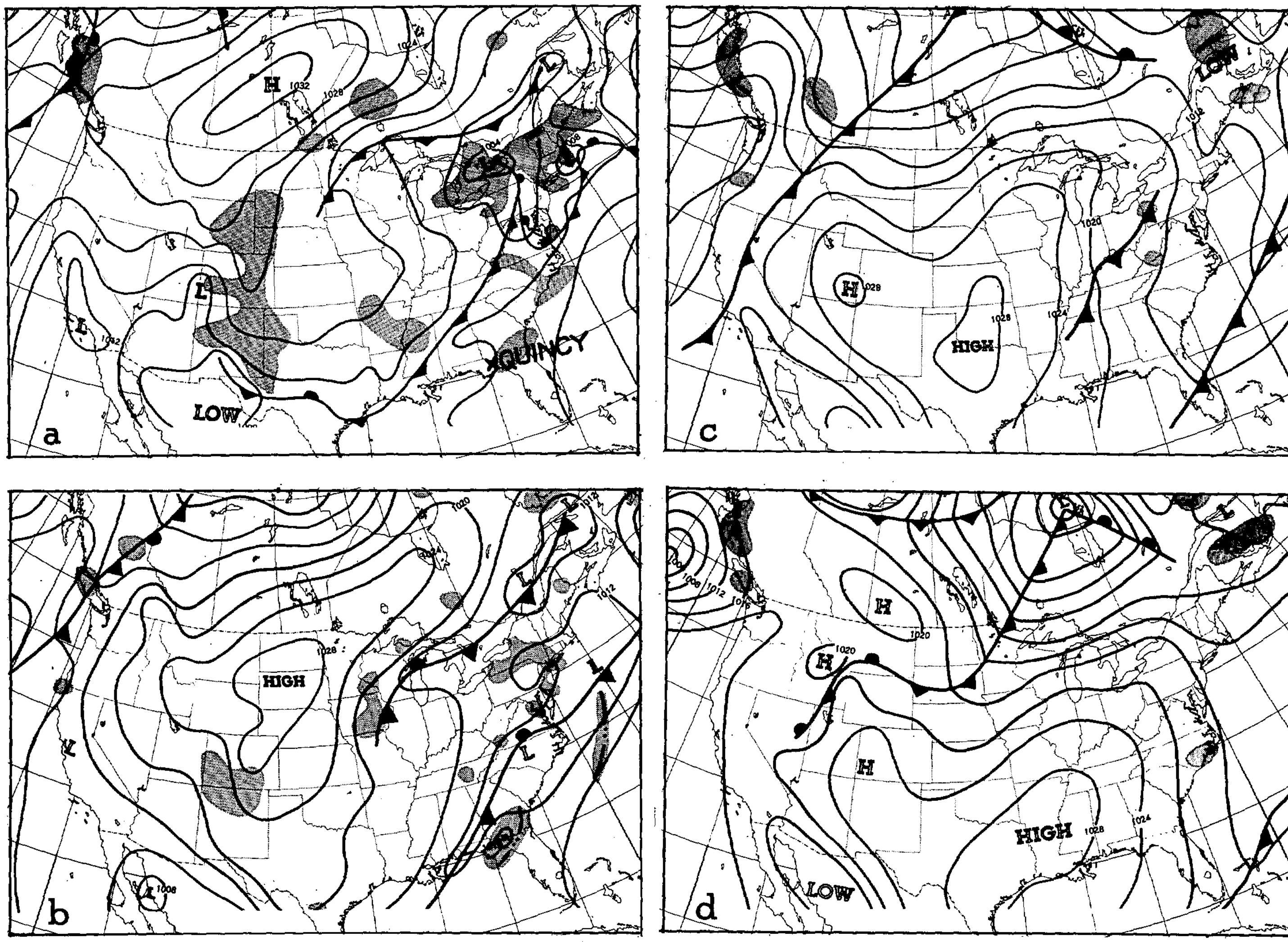

FIGURE 3.—Surface weather maps for 1300 EST during the period April 26–29, 1965, when low-level tropospheric ozone concentrations were increasing at North Florida Experiment Station, Quincy, Fla. (a) April 26, (b) April 27, (c) April 28, (d) April 29.

the rubber strip method for ozone measurement, was able to show that ozone was the inciting agent responsible for tobacco leaf damage known as "weather fleck" or simply "fleck" in North Florida.

In 1963, an ozone observation program was started at the North Florida Experiment Station. The object of the observation program was to gain information on low-level ozone concentrations in the hope that the source of the damaging concentrations might be identified. Additional objectives of the study were to develop a procedure for forecasting rises in ozone concentration, and finally to define the best measures to protect vegetation from ozone damage.

A Mast ozone meter, Model 725–4, of the Mast Development Corporation, was put into operation on May 10, 1963. In March 1965, a modified Model 138101 Beckman Ozone Monitor of Beckman Instruments, Inc., was added to substantiate the readings from the Mast sensor. Both instruments use an electrochemical ozone detector cell and measure coulometrically the oxidation of an iodide solution. The Beckman instrument is more specific for ozone as it utilizes a scrubber solution of chromium trioxide and sulfuric acid to eliminate responses to sulfur dioxide and nitrogen dioxide. Both instruments read in parts per hundred million (pphm) by volume.[1]

An increase in low-level ozone concentrations during the latter part of April 1965 was responsible for heavy flecking of the high quality shade-grown cigar-wrapper type tobacco which is grown locally on the Georgia-Florida border (see figs. 1 and 2). Based on the 1964 average prices for cigar-wrapper tobacco, the value of the leaves damaged ranged as high as $900 per acre. Significant damage was noted on more than 800 acres of the crop where the total value of leaves damaged was estimated at $284,000. These 800 acres represent about one-seventh of

[1] Mention of trade name and/or manufacturer is for identification only and does not imply endorsement by the Weather Bureau, the Environmental Science Services Administration, or the Department of Commerce.

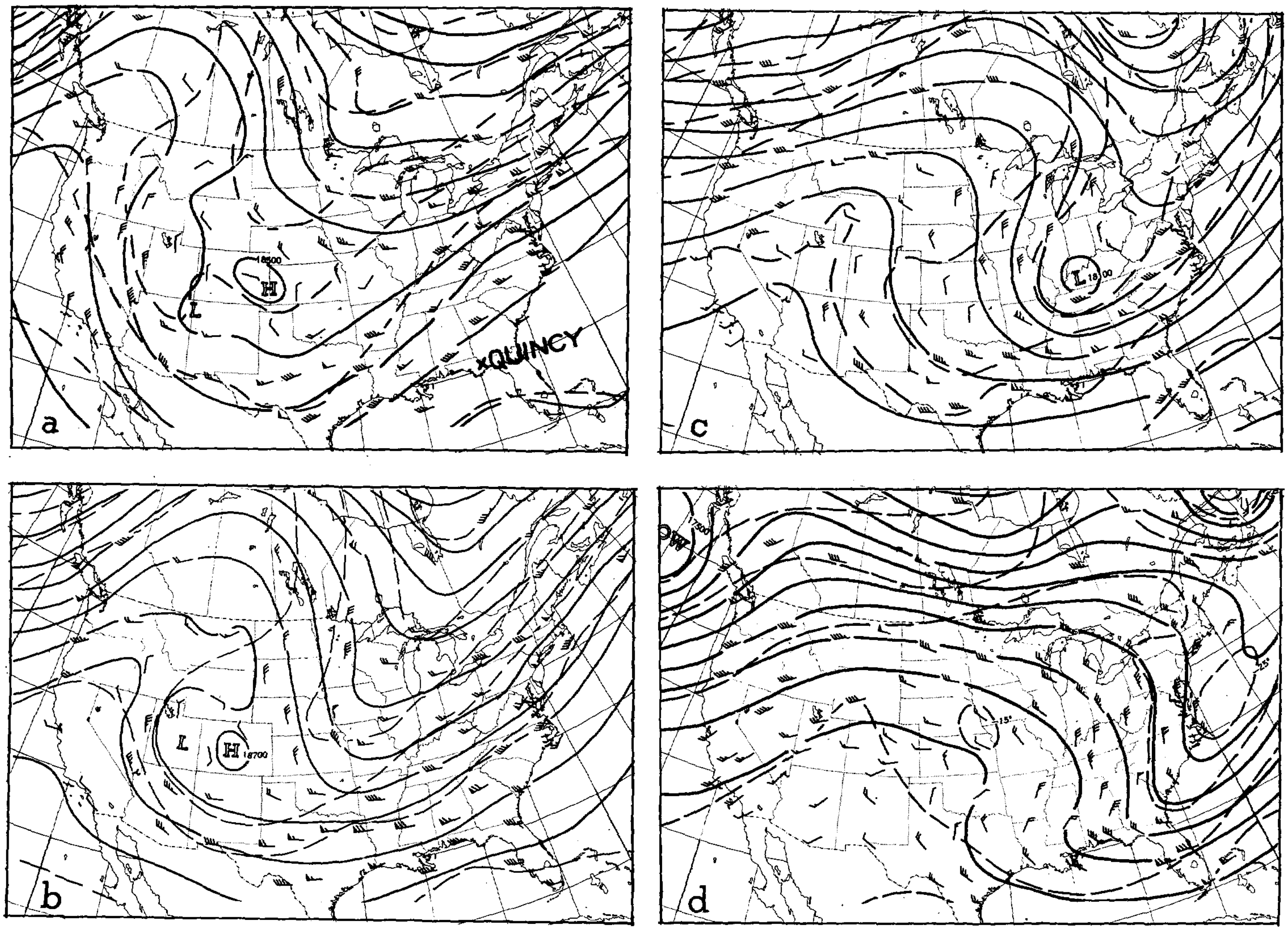

FIGURE 4.—500-mb. height contours 1900 EST, April 26–29, 1965. (a) April 26, (b) April 27, (c) April 28, (d) April 29.

the total acreage planted in cigar-wrapper tobacco in this area. Late planting and difference in varieties grown were the primary reasons that the damage was not significant on the remainder of the acreage devoted to tobacco.

The daily maximum ozone concentrations, previous to the rise which was responsible for the crop damage, had been in the range of 0 to 4 pphm by volume. On April 26 and 27, the ozone concentrations reached 5 pphm, moving up to 7 pphm on April 28, and 9 pphm on April 29. The peak of 10 pphm occurred on April 30, after which there was a decrease back to normal springtime values of less than 5 pphm. Fleck was observed in some shade-grown tobacco throughout the area on April 30. Since ozone damage to vegetation is not readily evident for about 24 hr. following exposure, the concentration of 9 pphm recorded on April 29 was the first occurrence sufficiently high to produce fleck. Ordinarily an ambient ozone concentration of 9 pphm would not be sufficiently high to damage tobacco materially. Tobacco leaves are most susceptible to this type of damage at one stage of development [6]. Neither immature nor over-mature leaves are susceptible to fleck damage. In this case, many fields of tobacco contained plants with leaves at precisely the most susceptible stage of growth. High soil moisture seems to predispose tobacco to ozone injury, and even resistant varieties may fleck under this condition [13]. General rains of 4 to 10 in. over the entire area on April 25, 26, and 27 created conditions of excessive soil moisture and, consequently, plants were very susceptible.

The ozone record at the North Florida Experiment Station shows that most of the sharp increases in the ozone concentrations above the normal values of 0 to 4 pphm have occurred in the spring and were associated with thunderstorms or with extratropical disturbances. In this particular case, a cold front was oriented northeast-southwest to the northwest of the Quincy area on April 26, the first day on which ozone concentrations reached 5 pphm (see fig. 3). By 1300 EST April 27, the front was nearing the Quincy area but did not reach the observing station until near midnight. As the 500-mb. trough shifted to the east of the Quincy observation point (see fig. 4), concentrations continued to rise, finally peaking on April 30 at 10 pphm.

Regarding this particular instance of ozone buildup and consequent flecking of tobacco, it is believed that the ozone was stratospheric in origin, having been transported to the lower troposphere by the extratropical storm. The mechanisms by which it is possible for stratospheric matter to move into the lower troposphere in association with frontal systems have been described in detail by Staley [12]. Both the surface and upper-air map configurations of the April storm, with which the ozone increase was associated, were similar to those of the March 1957 disturbance which Staley studied. He evaluated the potential-vorticity changes near the tropopause and the related vertical motions, vertical advection of vorticity, and transfer of radioactive debris from the stratosphere to the troposphere. His data showed that thermal discontinuities are not material surfaces, that mass exchange may proceed without the benefit of an indistinct tropopause or "gap," and that mass outflow from the stratosphere may be associated with any of the extratropical disturbances.

Observations to date of low-level ozone flux in North Florida show a diurnal variation, day-to-day variation, seasonal variation, and yearly variation. Concentrations are lowest in the late summer and fall. Highest values occur in the spring in association with some, but not all, thunderstorms and occasionally in association with extratropical disturbances as previously discussed. The agricultural industry, especially the tobacco interests, could profit from an accurate forecast of ozone flux when concentrations are expected to reach critical levels. A better understanding is needed, however, of the meteorological parameters which are responsible for these diurnal, day-to-day, seasonal, and yearly variations in concentration before an effective operational ozone forecast can be a reality.

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