Western Region Technical Attachment
No. 94-25
July 26, 1994

HOW DOES OZONE AFFECT THE ULTRAVIOLET-B (UV-B) INDEX AND WHY DOES THE UV-B INDEX RARELY CHANGE?

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Several medical studies have linked an increased risk of skin cancer to higher levels of UV-B radiation reaching the surface. As a result, interest in UV-B radiation has increased over the last few years. NOAA, in close coordination with the Environmental Protection Agency, now issues a daily experimental UV-B Index. As many of you have noticed, the UV-B Index does not vary much from day to day, when the skies are clear. While each office has received a memo describing the calculation of the index, many people are not familiar with UV-B radiation. This Technical Attachment summarizes a well-written paper entitled "Operational Forecasting of Daily Total Ozone and Ultraviolet-B Radiation Levels for Canada". The reader is referred to this article for a more in-depth discussion of ozone, UV-B, and the UV-B Index.

The intensity of UV-B radiation reaching the ground during **clear sky conditions** is a function of the solar zenith angle and the total ozone in the column of air above that point. Furthermore, the zenith angle is the dominate factor. Low zenith angles (high sun angle) equates to high levels of UV-B. Therefore, if the total contribution of ozone remains the same, UV-B during local noon will be highest in the summer and lowest during the winter. It also means, that if the total amount of ozone and cloudiness does not change significantly, the index will vary little from day to day.

An increase in the concentration of ozone in a column can reduce the amount of UV-B radiation reaching the surface. Figure 1 (taken from Wilson, et al. 1992) shows the long-term vertical distribution of ozone for Edmonton, Canada. This distribution is similar for most midlatitude locations. Ozone concentration peaks in the stratosphere between 5 and 20 mb. Very little ozone exists in the atmosphere below 200 mb. (Please note: Ozone produced near the surface, as a by-product of urban pollution, is ignored).

The distribution of ozone in the vertical is affected by two primary processes. Above 30 km and above the ozone peak, photochemical processes both create and destroy ozone. In this layer, the ozone photochemical processes are in a state of equilibrium. Since the processes are so active, ozone molecules do not last long enough to be transported far. Below the ozone peak and in the lower stratosphere, the photochemical processes are less active and ozone molecules may have lifetimes of several months. In this layer, meteorological processes can transport ozone great distances.

The total ozone in a column can change under certain meteorological conditions. Ozone concentrations increase when the depth of the troposphere decreases, such as over cold core lows, troughs, and upper-level fronts. Stratospheric intrusions into the troposphere along frontal zones have been well documented in meteorological literature. Under these conditions, ozone from the stratosphere below 30 km is drawn downward and converges as the tropospheric system intensifies. Since the balance of ozone above 30 km is now disrupted, the photochemical processes generate ozone while seeking to restore a balance. This results in increasing the total ozone concentration in the column while the amount of UV-B radiation reaching the surface decreases. For example, the total amount of ozone increases and the UV-B radiation reaching the surface decreases for locales in the near vicinity of a deep 500 mb low. This is one of the primary meteorological reasons that the UV-B Index will change from one day to the next under similar cloud conditions.

Ozone also changes from season to season and varies from north to south. Generally, ozone concentrations over the midlatitudes are highest during the spring and lowest during the late fall. Ozone peaks during the spring as ozone from the tropical latitudes is transported northward by the strong winter meridional flow and, thus, tends to concentrate in this latitude band. Over the course of a year, ozone concentrations are highest at 60° latitude and less near the pole and equator due to convergence and stratospheric intrusions associated with the polar front. Annual and seasonal variability of ozone concentrations are small near the equator and increase toward the poles. Significant local minimums can occur near the poles. Large-scale tropospheric flow, however, is only one process that affects seasonal ozone concentrations. Not all of the processes are fully understood.

Ozone has also received a lot of recent media attention due to satellite measurements that have revealed ozone "holes" over the poles and the thinning of ozone over the rest of the world. The recent ban of the chlorofluorocarbon gas, R-12, in air conditioners is a result of the concern over ozone depletion. Ozone can be indirectly measured by multi-channel sounders on some of the polar orbiter satellites. The amount of UV-B reaching the surface can be measured by a spectrophotometer, but there is a limited supply of these instruments deployed across the U.S. Ozone is the subject of considerable debate among the scientific community. There is still much to be learned about ozone, its distribution, and its impact on UV-B radiation.

Up to this point, the effects of clouds have been neglected in this discussion. Clouds can substantially reduce the amount of UV-B reaching the surface, although the relationship is non-linear. In general, a thicker cloud will cause a greater reduction in the amount of UV-B reaching the surface than a thin cloud. For example, a thin overcast cirrus deck may reduce UV-B by 15 percent while a thick stratus deck may reduce UV-B by up to 75 percent. The issue becomes more complicated for scattered cloud decks or high surface albedos. If the surface albedo is relatively high, e.g., snow cover or beach sand, the amount of UV-B measured at the surface will be higher than for a low albedo surface due to the reflection of UV-B radiation by the surface. In some cases with scattered clouds and a high surface albedo, the amount of UV-B measured at the surface may be higher than for clear sky conditions and a low surface albedo. The effect is caused by a scattered cloud deck only minimally reducing the amount of UV-B reaching the surface and the high surface albedo reflecting the remaining UV-B. This explains how people can get severe sun burns on days when the clouds may appear to be blocking much of the direct sun light.

Summary

Why has the UV-B Index rarely changed this summer? Western Region has been under a large ridge with generally clear skies. Assuming clear sky conditions at noon, the index is dominated by the zenith angle, which changes slowly through the season.

Reference

Wilson, Laurie, M. Vallee, D. Tarasick, J. Kerr, D. Wardle, 1992: Operational Forecasting of Daily Total Ozone and Ultraviolet-B Radiation Levels for Canada. Research Report No. 92-004 (MSRB/ARQX), October 1992.

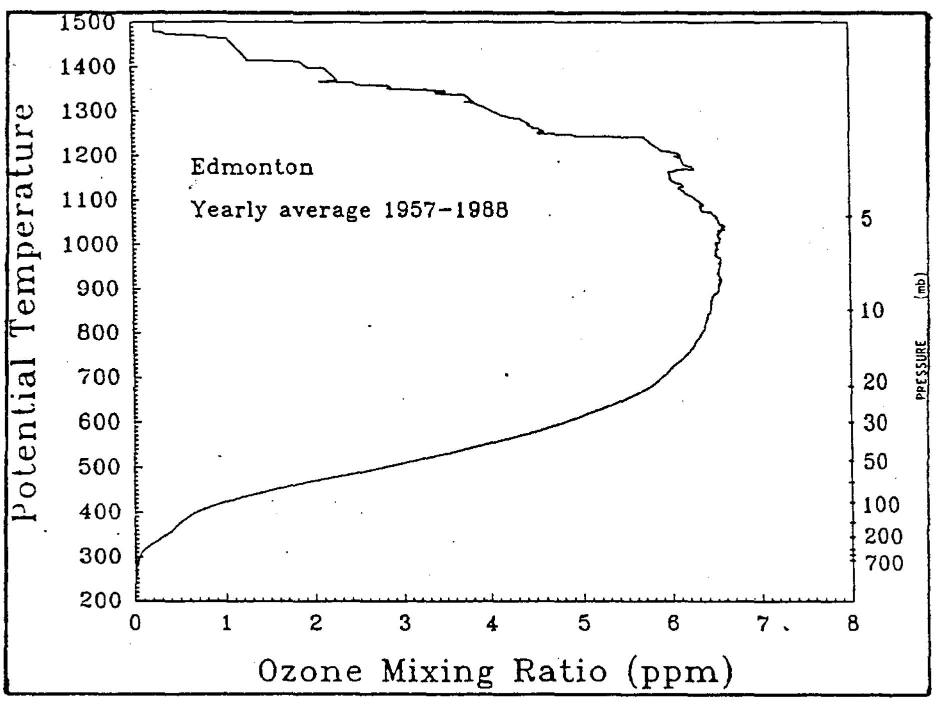

Figure 01: Vertical distribution of ozone in terms of potential temperature. Annual average for Edmonton, Alberta.