Determining whether to call an *Ozone Action!* Day in Michigan involves the evaluation of many factors. Specific meteorological parameters play a significant role in the formation and transport of ground-level ozone (photochemical smog). These include:

- solar insolation (ultraviolet radiation)
- cloud cover
- temperature
- wind direction
- wind speed
- the presence or absence of precipitation

Emission factors also contribute to ozone formation. These are not measured on a continuous basis as ambient ozone monitor concentrations are. The emission information taken into consideration is based upon general knowledge and historic data. For example, we know that emission factors differ during weekdays and weekends and this affects ozone formation.

**METEOROLOGICAL FACTORS**

**Solar Insolation**

Significant ultraviolet radiation is required to initiate the ozone forming photochemical reactions. There are rules of thumb governing the amount of ultraviolet radiation needed to produce the chemical transformation, however this information is not a typical product recorded at surface observation stations. The number of days before or after the summer equinox is what is considered when addressing solar radiation. At summer equinox, the total available solar radiation and consequently, number of hours of daylight, is at its peak. High ozone days are typically linked to the two months on either side of the solar equinox (May through August). Solar insolation provides the energy needed for the photochemical reaction to take place.

**Cloud Cover**

The amount solar insolation available on any given day is directly dependent upon the amount of cloud cover. There are differing degrees of cloud cover and differing types of clouds, so a totally clear sky is not necessarily needed. Sky conditions with less than $\frac{3}{10}$ obscured by cloud cover are generally considered favorable to the formation of ozone. Cumulus clouds provide the greatest potential to obscure and cirrus clouds provide the least. A sky covered by more
than \frac{3}{10} of cirrus clouds does not necessarily mean unfavorable conditions since these types are thin in nature and up to 25,000 feet above the earth's surface. On the other hand, cumulus clouds may exist only a few hundred feet above the surface and extend vertically for thousands of feet therefore reducing solar insolation to levels unfavorable to ozone formation. Another consideration is the time of day. Peak ozone production occurs during peak UV insolation. This means days with full sunshine during midday have the potential to produce more ozone than one with cloud cover.

**Temperature**

The daily maximum temperature is closely correlated with the daily maximum ozone concentration. When the daily high temperature is expected to exceed 90° F, there is good reason to suspect that elevated levels of ozone will occur in the region. High temperatures enhance ozone formation chemistry and increase the evaporative emissions of Volatile Organic Compounds. These organic compounds are chemical precursors that react with oxides of Nitrogen in the presence of ultraviolet radiation to form ozone. Since a temperature greater than 90° F is easier to attain close to the solar equinox, greater consideration must be given to cloud cover during June and July.

**Wind Direction**

Wind direction is important both on the synoptic (larger) and meso (middle) scales. On the synoptic scale, south to southwest winds are normally associated with high ozone days. Southwesterly winds carry hot summertime temperatures into the area and also transport ozone from industrial areas upwind of West Michigan. On the mesoscale, a phenomenon known as the lake breeze develops during hot summer days when there is a large difference in temperature between the land and adjacent waters. This feature plays an active role in producing high concentrations of ozone. In this situation, large scale southerly winds during the morning and early afternoon hours can transport precursors of ozone into the stable layer of Lake Michigan. Light winds and high solar insolation accelerate the chemical reactions leading to ozone formation in this layer. Winds along the lakeshore then turn and become perpendicular to the shoreline for the remainder of the afternoon and early evening and move high concentrations of ozone onshore. This phenomenon is common during the summer and the situation requires serious consideration. Monitors within a few miles of the lake have recorded large (30-50 ppb) increases in ground level ozone within a time span of just an hour or two.

**Wind Speed**

Low wind speeds (less than about 10 mph) are necessary for the accumulation of precursors and subsequent formation of high concentrations of ozone. At speeds above about 10 mph, emissions are diluted too rapidly for ozone to accumulate significantly. However, at higher wind speeds, previous day residual ozone from industrial areas well upwind from west Michigan can be transported into the area.
Precipitation

The occurrence of widespread showers has been proven to cleanse the atmosphere of ozone. However, scattered showers and thunderstorms that are only expected to occur in a few areas are not substantial enough to eliminate ozone. A brief rain event can temporarily wash the immediate area clean of ozone. Upon the passing of this rain event, ozone from upwind can quickly be transported back to the area and return concentrations to levels near that prior to the rain.

MAN-MADE SOURCES OF VOCs

Man-made emission sources that produce volatile organic compounds include motor vehicles, industrial manufacturing and painting facilities, and large printing (lithographic) operations. Tremendous reductions in air pollution emissions have occurred over the past three decades which have led to decreases in ozone concentrations on a regional and a national scale. Two of the “dirtiest” remaining precursor sources are the lawnmower and the outboard motor. Small outboard engines have been shown to produce emission levels up to eleven times that of the automobile.

Since the quantity emissions are directly dependent upon human activity, consideration must be given to day of week and social stimuli. Social stimuli such as concerts, festivals, parades, or any other event that could potentially prompt a large gathering of the general public must be considered. A well advertised or popular seasonal event can cause an unusually high amount of vehicular traffic thus increasing emissions beyond what might normally occur. Furthermore, weekday emissions are generally larger than normal weekend emissions due to travel to and from places of business and the increases in production rates of these facilities. Temporal and spatial emission patterns differ from weekday and weekend.

OXIDES OF NITROGEN (NOx)

Oxides of Nitrogen emissions are compounds involved in the production (and depletion) of ground level ozone. The contribution must be addressed at both local and regional levels. Factors such as ultraviolet radiation, time of day, temperature, wind direction, and wind speed are all critical and directly affect whether NOx produces or destroys ozone. During daylight hours NOx and Hydrocarbons react in the presence of sunlight to form ozone. Conversely, at night NOx reacts with ozone and destroys it. Reductions of NOx concentrations in one area can decrease ozone in downwind regions, while the source area can experience increases in ozone concentrations.

It is noteworthy to mention that Michigan’s coal-fired utilities alone have reduced NOx emissions by 85% from 1990 levels.
BIOGENICS

Biogenic sources include all vegetation that emit naturally release VOCs and are the most difficult of all ozone precursor sources to quantify. Studies have shown that these emissions do contribute to ozone formation. Improved knowledge of land use - both locally and regionally - is needed to properly address biogenic contributions. Human activities such as lawn mowing increase biogenic emissions. The fresh “cut grass” smell occurring after a newly mowed lawn is actually due to the VOCs emanating from the cut grass blades.

SUMMARY

Now that you have a clearer understanding about the complex nature of Ozone Action! forecasting, you understand that predicting pollutant levels is not equivalent to weather forecasting. It is a complicated process that requires knowledge of weather, air pollution emissions, current pollutant concentrations, and mathematical calculations covering large geographic areas.

Unhealthy levels of ozone have become more difficult to predict. When the more stringent 8-hour standard replaced the one-hour ozone standard, the bar that represents “healthy air quality” was lowered. Ozone Action! Day forecasting is no longer simply a prediction of an hourly peak in ozone; it involves predicting a broader lower level concentration of ozone. Each subsequent year of forecasting experience provides meteorologists with a greater understanding of the predictive processes. DEQ staff builds upon this knowledge to improve pollution forecasting throughout Michigan.