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Understanding Weather Essentials for Smoke Management

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Prescribed burning has frequently been used as a valuable tool in forestry and agricultural residue management. If used properly, it can be ecologically and economically beneficial. Where there is fire, however, there is smoke. Hence, the use of fire must be planned carefully to keep the smoke produced at acceptable levels.

Why Smoke Management?

- 70 percent of particulate matter emissions in smoke are fine particles.
- Fine particles have the potential to significantly impair human health when people are exposed to high levels.
- Fine particles can also reduce visibility on highways, as well as in federally mandated Class I areas such as Caney Creek Wilderness Area and Upper Buffalo Wilderness Area in Arkansas.

Goal of Smoke Management

- Limit public safety hazards posed by smoke intrusion into populated areas
- Prevent deterioration of air quality
- Limit visibility impairment at Class I areas

Smoke management planning helps reduce smoke impact on roadways, nearby towns and sensitive areas like schools, nursing homes, churches and other facilities. In reality, a smoke management plan includes minimizing the impact of particulate matter released into the atmosphere by estimating fuel tonnage that may be burned in a given day in an area (called airshed). In addition, knowing what smoke will do under certain weather conditions is critical in making burn decisions. This fact sheet explains the essential elements of atmosphere to mix and transport smoke throughout a vertical layer (called boundary layer) and over large distances.

Basic Meteorology

The earth's atmosphere is about 100 miles deep. Ninety-five percent of this air mass is within 12 miles of the earth's surface. The 12 mile-deep layer, called the troposphere, is where we have our weather, where the pollutants are emitted and contains the air we breathe.

Weather patterns determine how air contaminants are dispersed and move through the troposphere, and thus determine the concentration of a particular pollutant that is breathed or the amount deposited on the ground and vegetation.

The air we breathe consists of two major components nitrogen (78 percent) and oxygen (20.95 percent), which are relatively constant. Other components

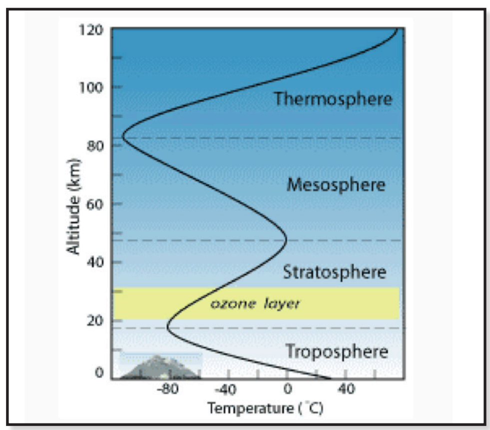

Figure 1. The layers of earth's atmosphere and the change of temperature with altitude

(called trace gases) such as argon (0.93 percent), carbon dioxide (0.04 percent) and water vapor (<1 percent), are only a small fraction of the air. These trace gases are the gases, including air pollutants, that impact our health and welfare.

Air in the troposphere circulates as do air pollutants. Air movement is caused by solar radiation and the irregularity of the earth's surface (land and sea, mountains and valleys). The irregularity of the earth's surface causes unequal absorption of heat by the earth's surface and the atmosphere. The unequal heat absorption creates a dynamic system of the earth's atmosphere, which yields differences in barometric pressure. In general, high-pressure systems bring sunny and calm weather – stable atmospheric conditions, while low-pressure system allow condensation and precipitation (i.e., rain and snow).

Solar radiation warms the earth and the air above it. This heating is most effective at the equator and least at the poles. Warm air at the equator tends to rise, cools while rising and then sinks at the poles. In addition, the rotation of the earth generates a horizontal air pressure gradient as well as the vertical pressure gradient. This is why global wind patterns exist. Wind is probably the most important meteorological factor in the movement and dispersion of air pollutants, or simply, pollutants move predominantly downwind. The second important meteorological factor is the atmospheric stability.

The stability class qualifies the degree to which vertical motion of the atmosphere is enhanced. Stability classes are dependent upon the amount of incoming solar radiation along with forecasts of wind speed and cloud cover. Atmospheric stability offers some clue as to how readily a pollutant will be dispersed. A stability class of B or C is preferred for efficient smoke dispersion.

Temperature Inversion

The rate of change of temperature with altitude

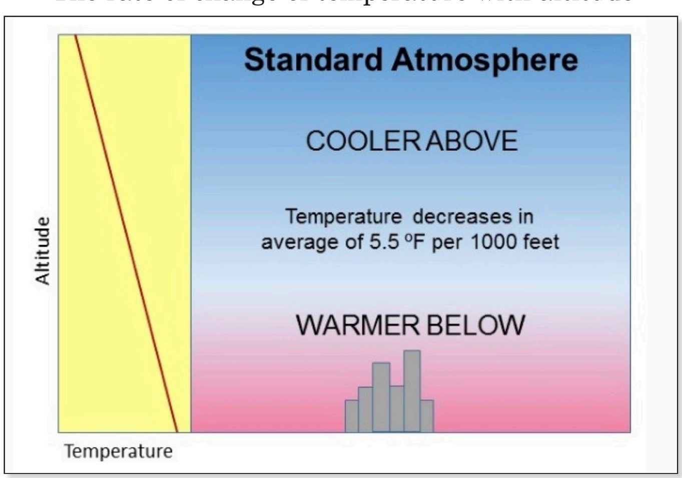

Figure 2. Temperature in the lower atmosphere, with ground and the air immediate above ground warmer due to daytime solar radiation.

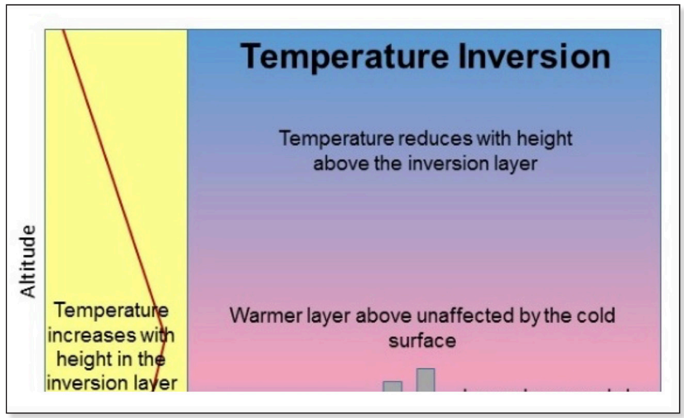

Figure 3. Temperature inversion developed close to the ground due to ground radiating heat back to the night sky.

has a substantial effect on mixing of air pollutants. The daily and seasonal solar cycles essentially control the temperature profile of the lower atmosphere. During the day, the temperature in the lower atmosphere typically decreases with height (figure 2). In the evening as the ground cools (net heat loss from earth), the lower levels of the atmosphere will also cool.

Temperature inversion is a thin layer of the atmosphere where the normal decrease in temperature with height switches to the temperature increasing with height. A radiation inversion, also called surface inversion, is a type of temperature inversion. It develops close to the ground on clear and relatively calm nights because the ground is a better radiator of heat than the air above it. Radiation from the ground to the clear night sky causes more rapid cooling at the surface than higher in the atmosphere. The result is that the air close to the ground is cooled more than the air above, yielding a temperature profile similar to the one shown in figure 3. That's why temperature inversion occurs frequently at night and early morning. After sunrise, the ground is heated and the inversion disappears.

The combination of a strong temperature inversion and light winds may lead to a layer of cold, stagnant air near the ground. This stagnant condition means little vertical mixing and causes ground-level pollutants to build up. Activities such as aerial pesticide applications and agricultural residue burning should be avoided when temperature inversion is in the weather forecast. Temperature inversion is common in colder months. In winter, it can last all day with overcast conditions.

Fire Weather Forecast

Knowledge of weather is the key to proper management of smoke produced by burning. An understanding of weather and its effects on fire is essential to any prescribed and agricultural burn. The mixing height, transport wind, ventilation rate and category day, which are routinely forecasted by the fire weather forecasting at the National Weather Service website, are some of the important elements to consider for executing a good burn.

- Mixing height is the projected height (in feet or meters) above ground level (AGL) or mean sea level (MSL) through which vigorous mixing will take place. It is the height at which smoke will lose its buoyancy and stop rising. A well-mixed layer is a layer in the atmosphere in which temperatures drop roughly 5.5 degrees per 1000 feet of elevation.
- Transport wind signifies the average of wind speed (knots or meters per second) throughout the depth of the mixed layer.
- Ventilation rate (VR) equals the product of the above two (knotfeet or m*m/s) and represents the ability of the boundary layer to get rid of the smoke. When VR values are low, there is not much mixing potential, and surface air quality suffers. When VR values are consistently low (day and night), it is possible to "smoke in" large areas for several days.
- Based on these variables, a Category Day classification system has been developed relating ventilation rate to smoke dispersal. A set of burning guidelines based on the ventilation rate and category day has been developed and is shown below.

CATEGORY DAY	VENTILATIONS RATE[#]	BURNING GUIDELINES
1	< 2,000	No burning
2	2,000 – 4,000	No burning until 11 am and not before surface inversion has lifted; fire out by 4 p.m.
3	4,000 – 8,000	Daytime burning only after surface inversion has lifted
4	8,000 – 16,000	Burning anytime
5	>16,000	Unstable and windy. Excellent smoke dispersal but burn with caution!

[#]unit = m * m/s

Why Burning Should Be Over by 4 p.m. on Low Category Days

- As evening hours approach, the mixing layer begins to lower. Residual smoke still within the mixing layer will become more concentrated as the layer compresses. This increase in concentrations can result in health impacts and could affect areas of 20 to 30 miles downwind.

Figure 4 shows a map of the regional forecast of fire weather in Arkansas. An example of the fire weather forecast of the Memphis Zone 2 area is shown in figure 5. Note the 20-foot wind (not transport wind) is wind at 20 feet above the ground or above the average height of vegetation. The wind direction is forecast to eight compass points and wind speed is expressed in miles per hour. All fire relevant elements are included in the forecast.

Figure 4. Regional fire weather forecast map for Arkansas National Weather Service (https://www.weather.gov/lzk/forest2.htm)

For further information about row crop burning guidelines in Arkansas, please refer to "*Arkansas Voluntary Smoke Management Guidelines for Row Crop Burning*" (link to https://www.uaex.uada.edu/environment- nature/air-quality/smoke-management.aspx).

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Crittenden-Cross-Lee AR-Phillips-St. Francis-
603 AM CST Mon Mar 5 2018

                        Today        Tonight      Tue

Cloud Cover             MCldy        MClear       Clear
Precip Chance (%)       60           20           0
Precip Type             tstms        showers      NONE
Precip Amount (in)      0.20         0.00         0.00
Precip Dur (hrs)        9
Precip Begins           6 AM
Precip Ends             6 PM
Temp (24h Trend)        65 (+5)      40 (-7)      63
RH % (24h Trend)        67 (+21)     93 (0)       27
AM 20 ft Wind (mph)     SE 8-12                   W 3-7
PM 20 ft Wind (mph)     S 8-12 G17   NW 4-8       W 11-15 G21
Mixing Hgt (m-agl)      644                       2342
Mixing Hgt (ft-agl)     2112                      7683
Mixing Hgt (m-msl)      706                       2404
Mixing Hgt (ft-msl)     2316                      7887
Transport Wnd (m/s)     SW 10                     W 14
Transport Wnd (mph)     SW 22                     W 31
Vent Index (m2/s)       7060                      33656
Category Day            3                         5
500m Mix Hgt Temp (F)   65                        57
500m Tspt Wind (m/s)    S 11                      W  7
500m Tspt Wind (mph)    S 24                      W 16
Dispersion Index        35           15           70
LAL                     3            1            1
LASI                    2            4            5
Stability               C            F            C
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Figure 5. Example of fire weather forecast of five counties in Memphis Zone 2 area

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