COURSE: Prescribed Fire Planning and Implementation

TOPIC: Smoke Management (Unit 5B)

LESSON B: Quantifying and Achieving Smoke Management Objectives

SUPPLEMENTAL MATERIAL 1: Smoke Management Weather Review

DISPERSION METEOROLOGY TERMINOLOGY

A. Atmospheric stability is the degree to which vertical motion in the atmosphere is enhanced or suppressed. An unstable atmosphere enhances vertical motions, hence increases mixing and the dispersion of smoke. A stable atmosphere suppresses vertical mixing, thereby limiting the dispersion of smoke. Neutral stability results in a smoke particle remaining at an altitude to which it was displaced.

B. Temperature lapse rate is the change in temperature with increasing altitude in the ambient atmosphere. It is expressed as degrees F (or C) per 1,000 feet (or 100 m).

C. The adiabatic lapse rate is the change in temperature of a parcel of air due to expansion as the parcel is lifted to a higher altitude. By definition, lapse rate is a negative value, so the dry adiabatic lapse rate is 5.5EF per 1,000 feet (1.0 degrees C per 100 m), or a decrease in temperature with height. The dry adiabatic lapse rate applies when the relative humidity remains less than 100 percent.

D. Atmospheric stability is determined by the relationship of the lapse rate that exists in the free atmosphere (ambient lapse rate) to a standard adiabatic lapse rate.

Unstable. Lapse rate is greater than 5.5EF/1,000 feet (i.e., 5.6EF/1,000 feet).

Stable. Lapse rate is less than 5.5EF/1,000 feet (i.e.,5.0EF/ 1,000 feet).

Neutral. Lapse rate equals 5.5EF/1,000 feet.

E. Inversion

1. A layer of the atmosphere where temperature <u>increases</u> with height. That is, a temperature lapse rate > 0EF/1,000 feet.

2. May be caused by warming aloft, like that associated with subsidence, or by cooling from below, as occurs at night at the surface (radiation inversion).

3. Cold air advection at the surface (e.g., marine air intrusion, or warm advection e.g., warm front, aloft can create an inversion.

4. Cloud cover--less warming and slower break in inversion. Clear moving--fast break in inversion.

F. Subsidence Inversion

1. Caused by downward or sinking air motion that occurs, usually, over a large geographic area.

2. Causes warming aloft, thereby producing a stable layer or an inversion.

3. Often associated with high pressure aloft, particularly high pressure that is becoming stronger (building) with time, or one that is moving into an area. In high pressures you have falling air.

G. Lifting Processes

1. Upward vertical motion in the atmosphere.

    a. surface heating--common during the afternoon or on sunny days.

    b. orographic--pertains to air flow over mountainous terrain.

    c. convergence--converging winds e.g., areas between two bodies of water, etc.

    d. frontal--cold front lifting is stronger than warm front lifting.

H. Mixing Height

1. Mixing height (or depth) is the height above ground through which relatively vigorous vertical mixing occurs. The layer between the ground and the mixing height is also referred to as the <u>mixing layer</u>.

2. Mixing height varies throughout the day--normally lowest rate at night or early morning, and highest during mid to late afternoon.

3. Mixing is a process by which there is an upward and downward exchange of air.

    Stable air--lower mixing height
    Unstable air--higher mixing height

I. Winds

1. Transport wind--The mean wind (speed and direction) in the mixing layer.

2. Surface/Local Winds--Twenty feet above vegetation height FLI/ROS; immediate smoke dispersal.

3. General Winds--One to 2,000 feet above ground control column and smoke transport; mixing.

4. Wind Shear--A sharp or marked change in wind speed or direction with height. (Is often associated with the temperature discontinuity marking the base and/or top of an inversion).

J. Dispersion

1. Distribution of a given quantity of pollutant throughout a volume of atmosphere--i.e., how smoke is distributed both in the vertical and horizontal.

2. Depends upon the depth of the mixing layer and the strength of the transport wind. Plumes may be characterized according to the atmospheric conditions.

3. Dispersion and ventilation are interchangeable terms.

4. Ventilation/Dispersion--Mixing depth and transport wind speed along with other factors are formulated in different areas of the country to produce indices of dispersion e.g., ventilation index in the Southwest, dispersion index in the Southeast, etc.

HOW WEATHER FACTORS AFFECT SMOKE BEHAVIOR

A. Stability

1. A stable atmosphere is associated with high pressure areas; an unstable atmosphere is associated with low pressure areas. Smoke accumulates over wide areas in stable (stagnant) weather patterns, but durations are likely to be short and localized.

2. The lower atmosphere is generally more stable at night than during the day. Lingering smoke may concentrate at night after good dispersal conditions during the day.

3. Marine air tends to have higher moisture content and lower temperatures than continental air. This generally results in increased stability. Higher moisture content combined with smoke can reduce visibility.

4. Light surface and transport-level winds are associated with a stable atmosphere. Local topography may result in an exception to this

generalization. Burning into a strengthening wind pattern is preferred for dispersion purposes.

5. A temperature inversion will limit vertical dispersion of smoke originating from below the inversion. The possibility of acceptable dispersion above the inversion may exist, but local meteorologists should be consulted. Stable conditions may persist above the inversion. Dispersion conditions above an inversion may be very different than those below.

B. Mixing

1. A low mixing height will limit dispersion, causing smoke to concentrate in low levels of the atmosphere. Conversely a high mixing height will improve dispersion.

2. A forecast of strong high pressure moving into or building over an area will mean decreasing mixing heights. Conversely, increasing mixing heights can be expected when low pressure is predicted.

C. Winds

1. Transport-level and surface winds govern the direction and downwind dilution of smoke. Winds may be completely different at different altitudes. The intensity of the burn helps determine which wind regime carries the smoke.

2. The stronger the winds are, the better the dispersion is as the smoke travels downwind. Locally high concentrations of smoke may occur near a burn due to lack of plume rise.

3. Local winds are influenced by topography; upslope during the day and downslope at night in the case of mountainous terrain or onshore during the day and offshore at night adjacent to the coast. Smoke from smoldering or low intensity burns is most affected by topographically influenced wind.

   a. Nighttime drainage winds, when vertical dispersion is limited, will tend to bring high concentration of smoke into valleys. Burning in valleys during the day may bring smoke up slope or up valley - though smoke may be more dispersed vertically, as compared to down slope winds.

   b. Diurnal wind shifts that occur at the land-ocean (or large lake) interface complicate the smoke behavior prediction problem. The timing, strength, and penetration of the onset of anchor and offshore winds is essential in determining how far smoke will travel and how well it disperses.

4. Frontal passages may either allow or prohibit burning due to changing wind direction or trapping of smoke under frontal inversions.

5. Weak winds are associated with high pressure; stronger winds associated with low pressure. Mesoscale weather patterns, in conjunction with local terrain, may create significant high wind events, i.e., Chinook, Santa Ana.

D. Relative Humidity

1. A very dry airmass with clear skies will allow strong radiational cooling at night--increasing the chance for development of a nighttime inversion.

2. Very dry air along with good dispersion may result in good visibility.

3. High humidity may result in poorer visibility as smoke particles absorb moisture, expand, and reduce visibility.

SITE MEASUREMENTS AND VISUAL INDICATORS

A. Sling psychrometer gives temperature and relative humidity.

1. Taking temperature readings up slope can be used to estimate the temperature lapse rate, hence the stability.

2. Knowing when the relative humidity increases to above 80 percent, one can anticipate the formulation of fog in smokey areas.

B. Hand held anemometer gives eye-level wind speeds. Eye-level wind may be quite different than the transport wind. Eye-level wind gives site readings and may not be indicative of overall wind flow patterns that will carry the smoke from burns.

C. Pilot Balloons (PIBAL'S) are used to estimate wind directions and speeds aloft. Other remote sensing devices are available to gather upper air temperature and wind information, but they are expensive to operate and require expertise in data interpretation.

D. Aircraft can be used to obtain temperature soundings.

E. Cloud movement, especially at lower altitudes, can indicate what direction smoke will move. They may also indicate the limit of vertical mixing. Cloud bases may be good indicators of the limits of vertical mixing when clouds have limited vertical development.

F. Visual indicators of stability.

1. Indicators of stable atmosphere and poor dispersion are:

    a. Clouds are layered--no vertical motion and development

    b. Stratus type clouds

    c. Smoke column drifts apart after limited rise

    d. Poor visibility in lower levels due to accumulation of haze and smoke.

    e. Fog

    f. Light and steady winds.

2. Indicators of an unstable atmosphere and good dispersion are:

    a. Good vertical growth of clouds

    b. Cumulus type clouds

    c. Upward and downward currents--gusty winds

    d. Good visibility

    e. Vortices (e.g., dust devils).

WEATHER FORECASTS USED IN SMOKE MANAGEMENT

A. General--Discuss weather patterns such as highs and lows, fronts, etc.

B. Spot Forecast--Provide more specific information for the burn site.

C. Smoke Management Forecast--Provide dispersion or ventilation data including wind and stability information.

BREAKDOWN OF VENTILATION

EXCELLENT	....	150,000 KNOT FEET AND GREATER
VERY GOOD	....	100,000 TO 149,999 KNOT FEET
GOOD	....	60,000 TO 99,999 KNOT FEET
FAIR	....	40,000 TO 59,999 KNOT FEET

POOR .... LESS THAN 40,000 KNOT FEET

VISUAL INDICATORS OF STABLE AND UNSTABLE AIR

STABLE	UNSTABLE
POORLY DEFINED SMOKE COLUMN	WELL DEFINED SMOKE COLUMN
COLUMN AND SMOKE DRIFTS APART AFTER LIMITED RISE	
VISIBILITY OFTEN POOR DUE TO ACCUMULATIONS OF SMOKE, DUST, OR HAZE	GOOD VISIBILITY
LIGHT AND/OR STEADY WINDS	STRONGER AND/OR GUSTY WINDS
COOL TEMPERATURES	WARM TO HOT TEMPERATURES
STRATUS CLOUDS OR FOG	BUILDING CUMULUS CLOUDS OR ALTOCUMULUS CASTELLANUS CLOUDS IN THE EARLY MORNING
	DUST DEVILS OR FIRE WHIRLS.