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FIELD BEHAVIOR OF NBC AGENTS (INCLUDING SMOKE AND INCENDIARIES)

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Preface

Primary users of this manual are NBC staff officers, staff weather officers, fire support coordination personnel, artillery officers, and others involved in planning NBC operations. These soldiers must understand what effect weather and terrain have on nuclear, biological, and chemical (NBC) operations and smoke. This manual contains general information and the basic principles on how to get the best results. Commanders and staffs involved in planning for use of incendiaries or smoke operations will also benefit from the use of this manual along with other references such as FM 3-50, FM 3-100, FM 3-3, FM 3-4, and FM 3-5.

On the battlefield, the influences of weather and terrain on NBC operations provide opportunities to both sides. To retain the initiative, friendly forces leaders and staff officers must understand how weather and terrain can be used to their advantage.

FM 3-6 implements International Standardization Agreement (STANAG) 2103, Reporting Nuclear Detonations, Radioactive Fallout, and Biological and Chemical Attacks and Predicting Associated Hazards.

This manual explains how weather and terrain influence nuclear, biological, and chemical operations and discusses the following topics for use when planning operations:

- Basic principles of meteorology as they pertain to NBC operations.
- Influence of weather on the use and behavior of NBC agents.
- Local weather predictions and their use.
- Influence of terrain on the behavior of NBC agents.
- US Air Force Air Weather Service (AWS) forecasts and their use in planning for operations in an NBC environment. (The Navy gets meteorological forecasts from components of the Naval Oceanography Command. Meteorological report information is in the NAVOCEANCOMINST 3140.1 publications series. It also contains information on the behavior of smoke clouds and incendiaries. In addition, it discusses the influences of weather and terrain on the thermal, blast, and radiation effects of a nuclear detonation.)

Staffs planning the use of chemical weapons and commanders approving strikes must understand basic weather characteristics. Therefore, weather analyses significantly influence the selection of agents and munitions for employment. The target analyst must know his or her weather data needs and where to get this information in a combat environment. Chapter 1 covers meteorology and the impact of weather on chemical agent use. The remaining chapters address the impact of weather on smoke, incendiaries, biological agents, and nuclear detonations.

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CHAPTER 1

Chemical Agents

The field behavior of chemical agents is dependent on weather variables such as wind, temperature, air stability, humidity, and precipitation. The influence of each variable depends upon the synoptic situation and is locally influenced by topography, vegetation, and soil.

Chemical agents may appear in the field in different forms: vapors, aerosols, or liquids. To understand the impact of chemical agents on the battlefield, the soldier must also understand how these agents are affected by weather and terrain. The following paragraphs give an overview of the basic characteristics of chemical agents and how weather and terrain influence and have specific effects on them.

Basic Characteristics

Vapors and small particles are carried by the winds, while any large particles and liquid drops fall out in a ballistic-like trajectory and are quickly deposited on the ground. Many agents give off vapors that form vapor clouds. The speed at which an agent gives off vapors is called volatility. Agents may be removed naturally from the air by falling out (large particles fall out much more quickly), by sticking to the ground or vegetation, or by being removed by precipitation. Once deposited upon vegetation or other ground cover, volatile agents may be re-released to the atmosphere for further cycles of travel and present a hazard until sufficiently diluted or decontaminated.

During approximately the first 30 seconds, the size and travel of an agent are determined primarily by the functioning characteristic of the munition or delivery system. Thereafter, the travel and diffusion of the agent cloud are determined primarily by weather and terrain. For example, in high temperatures, volatile agents produce maximum agent vapor in 15 seconds. Light winds and low turbulence allow high local concentrations of agents. High winds and strong turbulence reduce the concentration and increase the area coverage by more quickly carrying away and diffusing the agent cloud.

Vapors

When a chemical agent is disseminated as a vapor from a bursting munition, initially the cloud expands, grows cooler and heavier, and tends to retain its form. The height to which the cloud rises, due to its buoyancy, is called the height of the thermally stabilized cloud. If the vapor density of the released agent is less than the vapor density of air, the cloud rises quite rapidly, mixes with the surrounding air, and dilutes rapidly. If the agent forms a dense gas (the vapor density of the released agent is greater than the vapor density of air), the cloud flattens, sinks, and flows over the earth's surface. Generally, cloud growth during the first 30 seconds is more dependent upon the munition or delivery system than upon surrounding meteorological conditions.

Nevertheless, the height to which the cloud eventually rises depends upon air temperature and turbulence. These determine how much cooler, ambient air is pulled into the hot cloud (and, hence, determines its rate of cooling). The agent concentration buildup is influenced by both the amount and speed of agent release and by existing meteorological conditions.

Shortly after release, the agent cloud assumes the temperature of the surrounding air and moves in the direction and at the speed of the surrounding air. The chemical cloud is subjected to turbulence forces of the air, which tend to stretch it, tear it apart, and dilute it. The heavier the agent, the longer the cloud retains its integrity. Under conditions of low turbulence, the chemical agent cloud travels great distances with little decrease in agent vapor concentration. As turbulence increases, the agent cloud dilutes or dissipates faster.

Aerosols

Aerosols are finely divided liquid and/or solid substances suspended in the atmosphere. Sometimes dissolved gases are also present in the liquids in the aerosols. Chemical agent aerosol clouds can be generated by thermal munitions and aerosol spray devices or as by-products of liquid spray devices and bursting munitions.

Airborne aerosols behave in much the same manner as vaporized agents. Initially, aerosol clouds formed from thermal generators have a higher temperature than clouds formed from other types of munitions. This may cause some initial rise of the cloud at the release point. Aerosol-generated clouds are heavier than vapor clouds, and they tend to retain their forms and settle back to earth. Being heavier than vapor clouds, they are influenced less by turbulence. However, as the clouds travel downwind, gravity settles out the larger, heavier particles. Many particles stick to leaves and other vegetative surfaces they contact.

Liquids

When a chemical agent is used for its liquid effect, evaporation causes the agent to form into vapor. Depending upon volatility, vapor clouds are usually of low concentration, have about the same temperature as the surrounding air, and tend to stay near the surface because of high vapor density. Additionally, vapor density governs the extent that the vapor will mix with the air. Liquid agents with high vapor density impact at ground level with very little evaporation of the agent. These agents are termed persistent agents. While drops are airborne, and after impacting, the liquid continues to evaporate. Agent vapor pressure will govern the rate at which the liquid will evaporate at a given temperature and pressure. Initial concentrations are lower, since the vapor source is not instantaneous as a vapor agent is but evolves over a long period (until the liquid source is gone). Liquid agents may be absorbed (soaked into a surface) and adsorbed (adhered to a surface), and they may also evaporate. Once the liquid is no longer present on the surface, desorption (going back into the air) begins. The vapor concentration over areas contaminated with a liquid agent tends to be less than with newly formed vapor clouds, and downwind agent concentrations are not nearly as great as with other types of agents.

Atmospheric Stability

One of the key factors in using chemical weapons is the determination of the atmospheric stability condition that will exist at the time of attack. This determination can be made from a meteorological report or by observing field conditions.

When a meteorological report is available, it should contain a description of the current or projected atmospheric stability condition. If the data given are based on an atmospheric description, Figure 1-1 may be used to convert the data into traditional atmospheric stability categories/conditions. When meteorological reports are not readily available, the stability condition can be derived by using the stability decision tree shown in Figure 1-2. Figure 1-2 is entered at the top with the current observed weather conditions (or estimated weather conditions). Follow the decision tree to determine the stability condition. The stability condition plus the wind speed indicates the dispersion category of an agent vapor cloud.

DISPERSION CATEGORY	ATMOSPHERIC DESCRIPTION	TRADITIONAL ATMOSPHERIC CONDITIONS
1	Very Unstable	Lapse
2	Unstable	Lapse
3	Slightly Unstable	Neutral
4	Neutral	Neutral
5	Slightly Stable	Neutral
6	Stable	Inversion
7	Extremely Stable	Inversion

Figure 1-1. Atmospheric stability categories and conditions.

Unstable conditions will cause lower concentrations and/or poorer target coverage. Stable conditions will cause greater agent stability and higher concentrations. Use Figure 1-2 as guidance for employing an agent by starting in the upper left corner at the word START. Follow the arrowed line to the first question. Answer the question "Is it nighttime?" by selecting, in

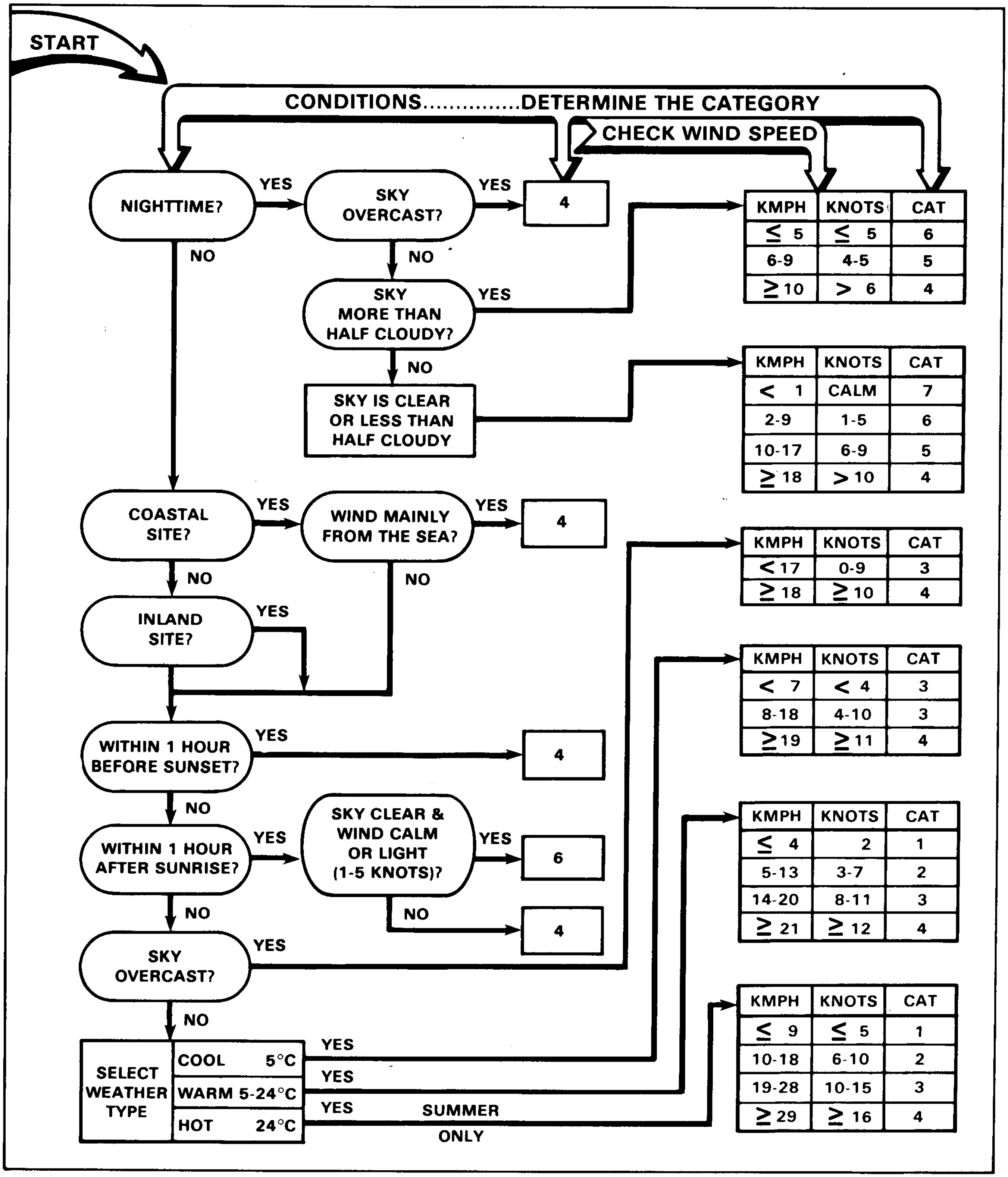

Figure 1-2. Stability decision tree.

accordance with the facts, the yes or no arrow indicating your decision. At each branch in the arrows, follow the arrow most nearly correct for the conditions under which the stability category is required. As questions are encountered along your path, answer each and proceed along the most nearly correct path until a dispersion category is identified. The result from Figure 1-2 is the stability category. An example of the use of Figure 1-2 is if you are inland one hour before sunset and the winds are calm, the stability category is neutral (N) (category 4).

The dispersion category, the wind speed in knots, and the wind direction are the most important meteorological data for deciding the influence of weather on vapor cloud dispersion. For any given dispersion category, a lower wind speed will produce higher dosages, smaller area coverage, and, consequently, higher toxic effects. This is because when the wind speed is lower, the cloud moves more slowly past the individual in the target area; and the individual is in the cloud longer, yielding a higher dose of the agent. See Table 1-1 for the dispersion categories and wind speeds during which atmospheric conditions are either generally favorable, marginal, or unfavorable for employment of chemical agents. Factors such as agent toxicity, target vulnerability, and the amount of the agent released will determine the actual doses, casualties, and other effects. Elevated agent releases will alter the table results somewhat, but the same trends occur. The main effect to be considered for elevated release effectiveness over a specific target is that the agent must be released further upwind to compensate for the drift as the agent comes down.

Table 1-1 is a general reference tool to provide an estimate, based on dispersion category and wind speed, when it would generally be most effective to employ a chemical agent vapor. Table 1-2 indicates the typical cloud widths at given downwind distances from a point source release for a chemical agent vapor cloud. Note that the cloud width depends upon dispersion category and not directly upon wind speed. The cloud width distances represented in Table 1-2 are the dosage contours for 0.01 milligram-minutes per cubic meter (mg-min\M^3). If the agent is released from a line source (spray system), the line length should be added to the cloud width (Table 1-2) to determine total cloud width for travel distances up to 1 kilometer. For longer travel distances, the length of the line source loses its importance (due to dissipation), and the total cloud width is represented by the values in Table 1-2. The chemical cloud widths listed in Table 1-2 are estimates. The widths will vary depending on the weather and terrain of a specific area.

The following examples are cited to explain further the use of Table 1-2. Based on a chemical agent vapor being released from a point source in dispersion category 4, the chemical cloud width at 7 kilometers downwind would be approximately 2.3 kilometers. Based on a chemical agent vapor being released from a line source that is 0.1 kilometer in length (dispersion category 2), the chemical cloud width at a 0.5 kilometer downwind distance would be .850 kilometer (0.75+0.1).

Table 1-3 presents the relative center line dosages (mg-min/M^3) at different distances downwind for different dispersion categories and wind speeds. Remember, low wind speeds at the same dispersion category give higher dosages. The dosages listed in Table 1-3 are estimates and will vary depending on the estimated category and wind speed in the target area. The dosage values in Table 1-3 are based on 100 kilograms of the nonpersistent nerve agent (GB) being released at ground level from a point source.

The information reflected in Table 1-3 is the dosage that would be incurred if the target were stationary. The dosage would decrease if the target were moving through the downwind cloud hazard area. Additionally, in general, if the source strength (100 kg) were doubled, the dosage would also double, and if the source strength were halved, the dosage would also decrease approximately one-half.

To aid in using Table 1-3, the following example is provided. With dispersion category 4, wind speed 8 knots, and a downwind distance of 2 kilometers, the center line dosage would be 18.91 mg-min/M^3. With dispersion category 2, wind speed 3 knots, and at a downwind distance of 4 kilometers, the center line dosage would be 1.030 mg-min\M^3.

Vapor Concentration and Diffusion

Agent concentration is governed by the volume of the agent cloud. Since clouds

Table 1-1. Relative effectiveness of vapor agent usage for different wind speeds and dispersion categories.

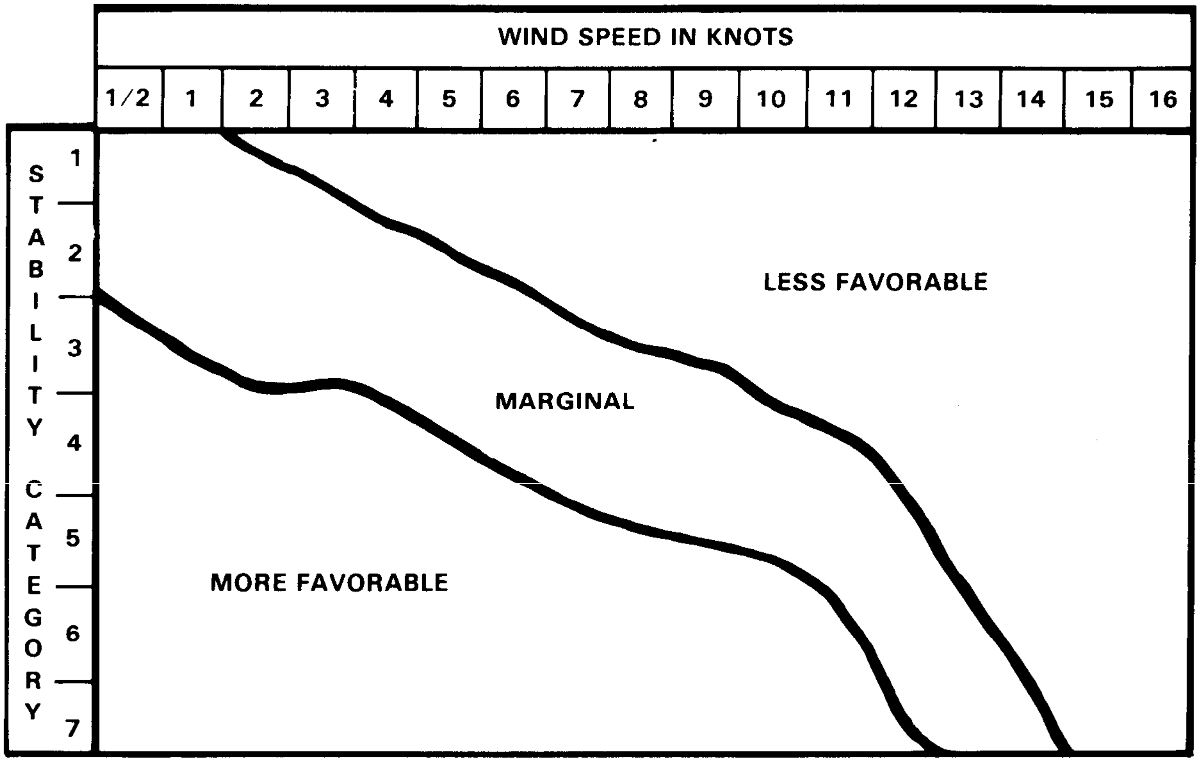

Table 1-2. Chemical cloud width.

STABILITY CATEGORY	DOWNWIND DISTANCE IN KM												
	.5	1	2	3	4	5	6	7	8	9	10	20	30
1	.9	1.6	2.8	3.9	5.0	6.0	6.9	7.8	8.6	9.4	10.2	15.4	19.0
2	.75	1.3	2.4	3.2	4.1	4.8	5.4	6.0	6.6	7.3	7.8	12.9	16.4
3	.5	.9	1.7	2.4	3.1	3.7	4.2	4.7	5.2	5.7	6.2	9.7	12.8
4	.3	.5	.9	1.2	1.5	1.8	2.1	2.3	2.6	2.8	3.1	4.9	6.4
5	.2	.3	.5	.7	1.0	1.0	1.1	1.3	1.4	1.5	1.6	2.6	3.3
6	.1	.2	.3	.3	.4	.5	.5	.6	.6	.7	.7	1.1	1.4
7	VERY LITTLE INCREASE IN CLOUD WIDTH WITH DOWNWIND DISTANCE												

Table 1-3. Center line dosages at different distances downwind for different dispersion categories and wind speeds for a unit source.

Stability Category	Wind Speed	.5	1	2	4	6	10	20	30
		DOWNWIND DISTANCE IN KM — DOSAGES (mg-min/M³)							
1	1	57.82	10.960	2.4820	1.2070	.8048	.48290	.24140	.16100
	3	19.15	3.628	.8224	.3998	.2665	.15990	.07995	.05330
	5	11.47	2.174	.4928	.2396	.1597	.09582	.04791	.03194
2	3	65.93	16.480	4.121	1.0300	.4671	.22840	.11360	.07575
	6	32.86	8.215	2.054	.5135	.2328	.11380	.05663	.03775
	10	19.75	4.938	1.235	.3087	.1400	.06843	.03404	.02269
3	3	172.60	46.26	12.400	3.321	1.5370	.5825	.18010	.11510
	7	73.86	19.79	5.302	1.421	.6576	.2492	.07703	.04925
	12	43.09	11.55	3.094	.829	.3837	.1454	.04494	.02874
4	3	572.4	170.20	50.590	15.040	7.398	3.0260	.8997	.44450
	8	213.9	63.61	18.910	5.622	2.765	1.1310	.3363	.16620
	16	107.1	31.84	9.467	2.814	1.384	.5662	.1683	.08318
5	2	1,837.0	606.0	199.90	65.94	34.470	15.220	5.021	2.6250
	5	736.2	242.9	80.12	26.43	13.810	6.101	2.012	1.0520
	9	408.7	134.8	44.47	14.67	7.668	3.387	1.117	.5839
6	1	10,080.0	3,691.0	1,351.0	494.50	274.70	131.00	47.930	26.630
	3	3,339.0	1,222.0	447.4	163.80	90.96	43.37	15.870	8.818
	5	2,001.0	732.4	268.1	98.12	54.51	25.99	9.5120	5.284
7	HIGHER DOSAGES THAN ABOVE								

continually expand, agent concentration levels decrease over time. Wind speed determines the downwind growth of the cloud. Vertical and horizontal turbulence determines the height and width of the cloud. The rate at which the downwind, vertical, and horizontal components expand governs the cloud volume and the agent concentration.

To be effective the agent cloud, at a specific concentration level, must remain in the target area for a definite period. Wind in the target area mixes the agent and distributes it over the target after release. For ground targets, high concentrations and good coverage can best be achieved with low turbulence and calm winds when the agent is delivered directly on target. A steady, predictable wind drift over the target is best when the agent is delivered on the upwind side of the target. Conditions other than these tend to produce lower concentrations and/or poorer target coverage. However, unless weather conditions are known within the target area, the effects of the agent on target will be approximations.

The concentration and diffusion of a chemical agent cloud are also influenced by the factors of hydrolysis, absorption, adsorption, lateral spread, drag effect, and vertical rise.

Hydrolysis is the process of the agent reacting with water vapor in the air. It does not influence most agent clouds in tactical use because the rate of hydrolysis is too slow. However, hydrolysis can be important for smoke screens. See the discussion of the effect of humidity on increasing smoke screen effectiveness in Chapter 2.

Absorption is the process of the agent being taken into the vegetation, skin, soil, or material. Adsorption is the adding of a thin layer of agent to vegetation or other surfaces. This is important in dense vegetation. Both absorption and adsorption of chemical agents may kill vegetation, thus defoliating the area of employment.

When a chemical cloud is released into the air, shifting air currents and horizontal turbulence blow it from side to side. The side-to-side motion of the air is called meandering. While the agent cloud meanders, it also spreads laterally. Lateral spreading is called lateral diffusion. Figure 1-3 shows a cloud with lateral spread and meandering. Table 1-2 indicates the amount of lateral spread that occurs under different dispersion categories and distances downwind. In more unstable conditions, the lateral spread tends to be greater than in stable conditions.

Wind currents carry chemical clouds along the ground with a rolling motion. This is caused by the differences in wind velocity. Wind speeds increase rapidly from near zero at the ground to higher speeds at higher elevations above the ground. The drag effect by the ground, together with the interference of vegetation and other ground objects, causes the base of an agent cloud to be retarded as the cloud stretches out in length. When clouds are released on the ground, the drag amounts to about 10 percent of the vertical growth over distance traveled over grass, plowed land, or water. It amounts to about 20 percent over gently rolling terrain covered with bushes, growing crops, or small patches of scattered timber. In heavy woods, the drag effect is greatly increased. The vertical spread of the cloud is illustrated in Figure 1-4.

Wind speeds can vary at different heights. The wind direction can also change with an increase in height. This is known as wind shear. Because of wind shear, a puff (or chemical cloud) may become stretched in the downwind direction and may travel in a direction different from that of the surface wind. Additionally, a chemical cloud released in the air may be carried along faster than it can diffuse downward. As a result, air near the

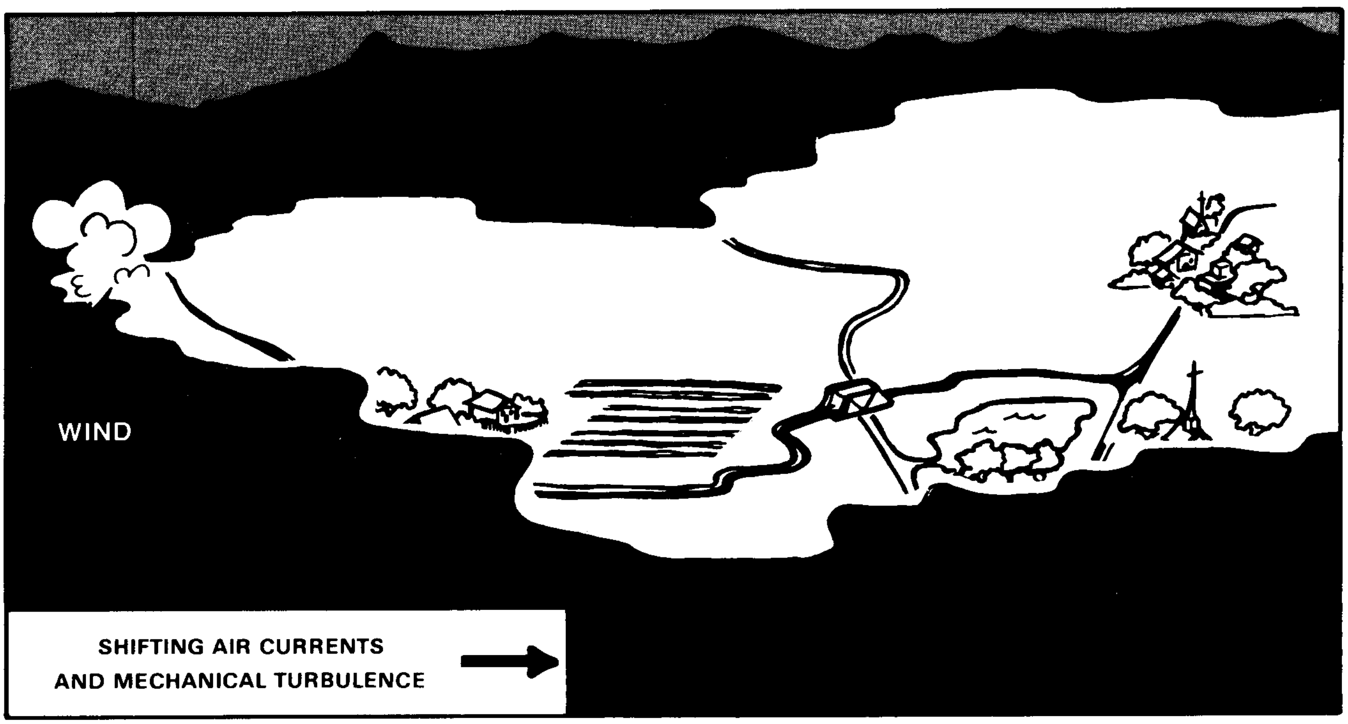

Figure 1-3. Lateral spread of a chemical cloud with some meandering.

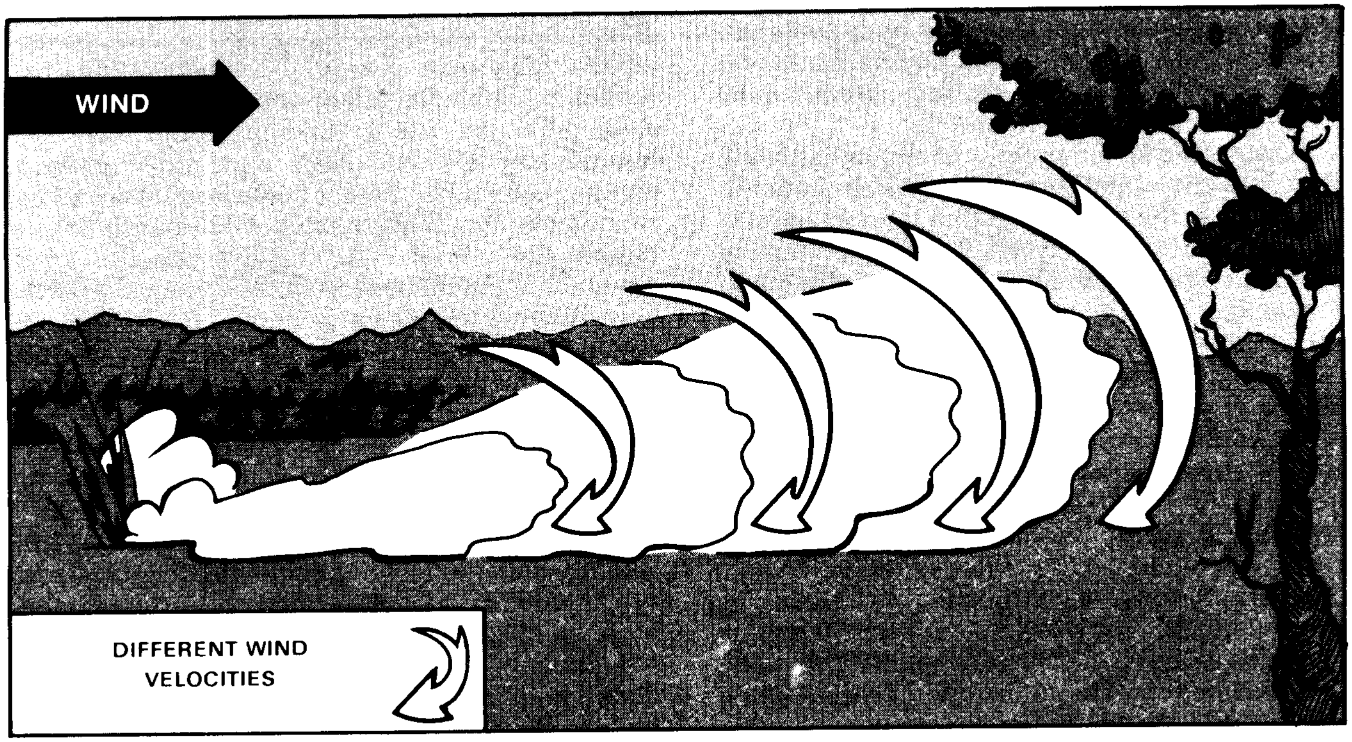

Figure 1-4. Vertical spread of a chemical cloud with drag effect.

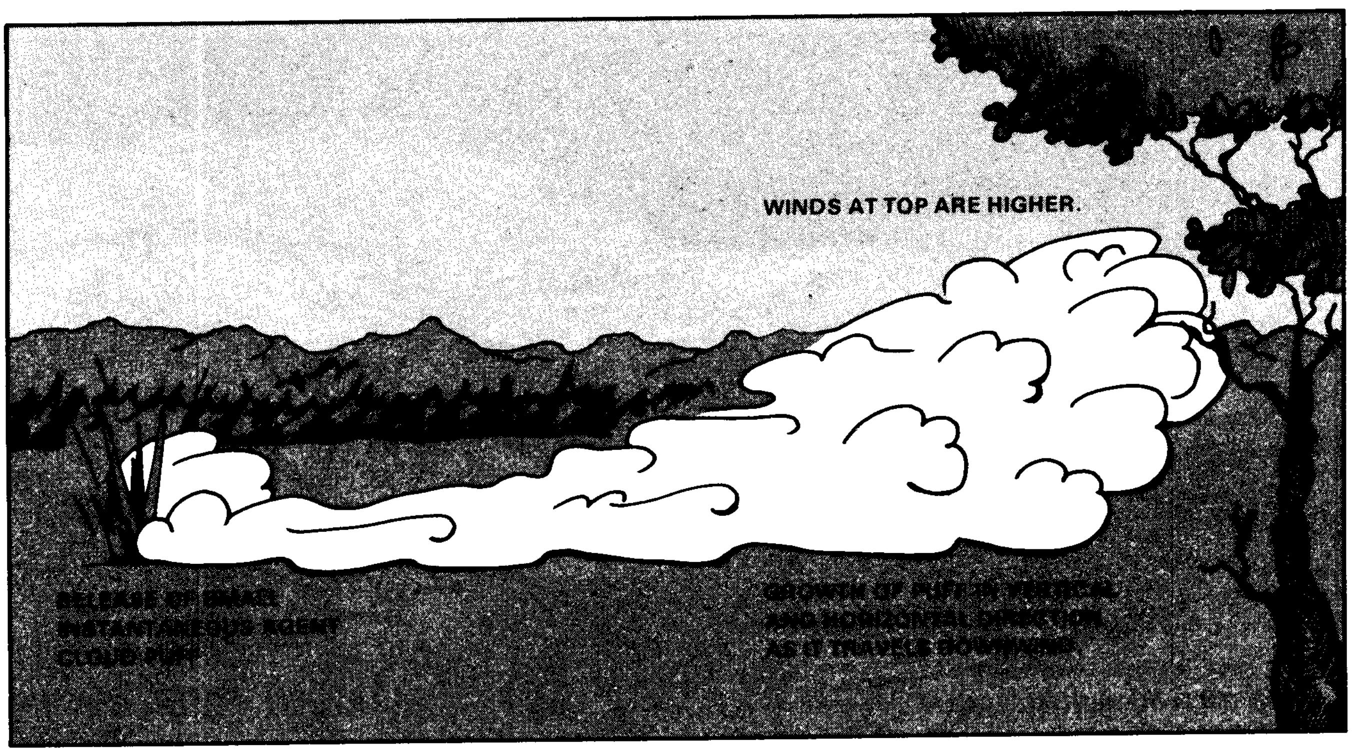

Figure 1-5. Horizontal and vertical spread of a cloud puff.

ground on the forward edge of the cloud may be uncontaminated, while the air a few feet up may be heavily contaminated. This layering effect becomes more pronounced and increases proportionately with the distance of the forward edge of the cloud from the source. Figure 1-5 illustrates this. A small puff of agent cloud released from its source some time earlier has tilted forward, while the bottom has been retarded due to slower winds caused by drag.

The vertical rise of a chemical cloud depends upon weather variables, such as temperature gradient, wind speed, and turbulence, and the difference between the densities of the clouds and the surrounding air. As mentioned earlier, the temperature of both the cloud and the air influences their relative densities. Hotter gases are less dense and, therefore, lighter than cooler gases and air. Therefore, they rise until they are mixed and somewhat diluted and attain the same temperature and approximately the same density as surrounding air.

The vapor cloud formed by an agent normally employed for persistent effect rises in a similar manner, but vapor concentrations build up more gradually.

Vapors and Aerosols

Wind, temperature, humidity, precipitation, terrain contours, and surface cover influence the field behavior of vapors and aerosols. For example, in a chemical attack on US forces (lst Division) 26 February 1918 in the Ansauville section, extremely stable conditions, calm winds, and heavy underbrush in the target area contributed to the overall effectiveness of a chemical attack. Several additional casualties resulted due to the increased chemical agent persistency caused by the favorable weather conditions. Favorable and unfavorable weather

Table 1-4. Summary of favorable and unfavorable weather and terrain conditions for tactical employment of chemical agent vapor or aerosol. (The stability condition listed for the south slope is for the northern hemisphere; due to solar loading on the slope, the situation would be reversed for the southern hemisphere.)

FACTOR	UNFAVORABLE	MODERATELY FAVORABLE	FAVORABLE
Wind	Artillery employment if speed is more than 7 knots. Aerial bombs if speed is more than 10 knots.	Steady, 5 to 7 knots, or land breeze.	Steady, less than 5 knots, or sea breeze.
Dispersion Category	Unstable (lapse).	Neutral.	(Stable) inversion.
Temperature	Less than 4.4°C.	4.4° to 21.1°C.	More than 21.1°C.
Precipitation	Any.	Transitional.	None.
Cloud Cover	Broken, low clouds during daytime. Broken, middle clouds during daytime. Overcast or broken, high clouds during daytime. Scattered clouds of all types during daytime. Clouds of vertical development.	Thick, low overcast. Thick, middle overcast.	Broken, low clouds at night. Broken, middle clouds at night. Overcast or broken, high clouds at night. Scattered clouds of all types at night. Clear sky at night.
Terrain	Hilltops, mountain crests. South slopes* during daytime.	Gently rolling terrain. North slopes at night.	Even terrain or open water.
Vegetation*	Heavily wooded or jungle.	Medium dense.	Sparse or none.

*Cloud dissemination occurs above the canopy.

and terrain conditions for tactical employment of a chemical aerosol or vapor cloud are summarized in Table 1-4.

If a chemical cloud is to be placed directly on an occupied area, the best possible weather conditions are calm winds with a strong, stable temperature gradient. Under these conditions, the cloud diffuses over the target with minimum dilution and does not move away. Such conditions are most apt to occur on a calm, clear night. If a small amount of air movement is required to spread the cloud evenly over the target area, a low wind speed and stable or neutral conditions are most favorable. These conditions most often occur on a clear night, a cloudy night, or a cloudy day.

When the desired effect is for the chemical cloud to travel, the most favorable conditions are stable or neutral conditions with a low to medium wind speed of 3 to 7 knots. These conditions may be present on a clear night, a cloudy night, or a cloudy day. The presence of low to medium wind speeds keeps the cloud traveling over the area without too much diffusion, and the stable or neutral conditions keep the agent concentration high and the cloud close to the ground.

Favorable terrain conditions for a chemical cloud are smooth or gently rolling contours or wooded areas. Unfavorable conditions for chemical clouds (usually found on clear days) are extreme or marked turbulence, wind speeds above 10 knots, an unstable dispersion category, rain, and rough terrain.

Wind

High wind speeds cause rapid dispersion of vapors or aerosols, thereby decreasing effective coverage of the target area and time of exposure to the agent. In high winds, larger quantities of munitions are required to ensure effective concentrations. Agent clouds are most effective when wind speeds are less than 4 knots and steady in direction. The clouds move with the prevailing wind as altered by terrain and vegetation. Steady, low wind speeds of 3 to 7 knots enhance area coverage unless an unstable condition exists. With high winds, chemical agents cannot be economically employed to achieve casualties. The chart at Figure 1-2 indicates the effect of wind on stability categories. Tables 1-1, 1-2, and 1-3 indicate the effects of wind and dispersion categories upon dosage and area coverage.

Unstable conditions, as indicated in Figure 1-2 and Tables 1-1, 1-2, and 1-3, are the least favorable conditions. Unstable conditions (such as many rising and falling air currents and great turbulence) quickly disperse chemical agents. Unstable is the least favorable condition for chemical agent use because it results in a lower concentration, thereby reducing the area affected by the agent. Many more munitions are required to attain the commander's objectives under unstable conditions than under stable or neutral conditions.

Stable conditions (such as low wind speeds and slight turbulence) produce the highest concentrations. Chemical agents remain near the ground and may travel for long distances before being dissipated. Stable conditions encourage the agent cloud to remain intact, thus allowing it to cover extremely large areas without diffusion. However, the direction and extent of cloud travel under stable conditions are not predictable if there are no dependable local wind data. A very stable condition is the most favorable condition for achieving a high concentration from a chemical cloud being dispersed.

Neutral conditions are moderately favorable. With low wind speed and smooth terrain, large areas may be effectively covered. The neutral condition occurs at dawn and sunset and generally is the most predictable. For this reason, a neutral dispersion category is often best from a military standpoint.

Temperature

There will be increased vaporization with higher temperatures. Also, the rate of evaporation of any remaining liquid agent from an exploding munition can vary with temperature. Generally, the rate of evaporation increases as the temperature increases. See FM 3-9/AFR 355-7 for specific information on chemical agents, such as their boiling and freezing points and vapor density.

Humidity

Humidity is the measure of the water vapor content of the air. Hydrolysis is a process in which compounds react with water resulting in a chemical change. Chemical agents with high hydrolysis rates are less effective under conditions of high humidity.

Humidity has little effect on most chemical agent clouds. Some agents (phosgene and lewisite) hydrolyze quite readily. Hydrolysis causes these chemical agents to break down and change their chemical characteristics. If the relative humidity exceeds 70 percent, phosgene and lewisite can not be employed effectively except for a surprise time-on-target (TOT) attack because of rapid hydrolysis. Lewisite hydrolysis by-products are not dangerous to the skin; however, they are toxic if taken internally because of the arsenic content. Riot control agent CS (see glossary) also hydrolyzes, although slowly, in high humidities. High humidity combined with high temperatures may increase the effectiveness of some agents because of body perspiration that will absorb the agents and allow for better transfer.

Precipitation

The overall effect of precipitation is unfavorable because it is extremely effective in washing chemical vapors and aerosols from the air, vegetation, and material. Weather forecasts or observations indicating the presence of or potential for precipitation present an unfavorable environment for employment of chemical agents.

Terrain Contours

Terrain contours influence the flow of chemical clouds the same as they influence airflow. Chemical clouds tend to flow over low rolling terrain and down valleys and settle in hollows and depressions and on low ground. Local winds coming down valleys at night or up valleys during the day may deflect the cloud or reverse its flow. On the other hand, they may produce conditions favorable for chemical cloud travel when general area forecasts predict a calm.

A chemical cloud released in a narrow valley subjected to a mountain breeze retains a high concentration of agent as it flows down the valley. This is because of minimal lateral spread. Hence, high dosages are obtained in narrow valleys or depressions. High dosages are difficult to obtain on crests or the sides of ridges or hills. After a heavy rain, the formation of local mountain or valley winds is sharply reduced. In areas of adjacent land and water, daytime breezes from the water and nighttime breezes from the land control chemical cloud travel.

Surface Cover

Ground covered with tall grass or brush retards flow. Obstacles, such as buildings or trees, set up eddies that tend to break up the cloud and cause it to dissipate more rapidly. However, street canyons or spaces between buildings may have pockets of high concentrations. Flat country (during a neutral or inversion condition) or open water promotes an even, steady cloud flow. Figure 1-5 illustrates the horizontal and vertical spread of a cloud over flat country.

The amount and type of vegetation in the area of the chemical operation also influence the travel of a chemical cloud. Vegetation, as it relates to meteorology or diffusion, is called vegetative canopy or just canopy. The effects of canopies are considered below.

Woods are considered to be trees in full leaf (coniferous or deciduous forests). The term "heavily wooded canopy" denotes jungles or forests with canopies of sufficient density to shade more than 90 percent of the ground surface beneath. For chemical operations, areas containing scattered trees or clumps of bushes are considered to be open terrain although drag is somewhat increased. In wooded areas where trees are not in full leaf or where foliage has been destroyed by previous attack so that sunlight strikes the ground, the diffusion (stability) category will be similar to those in the open.

When bombs are dropped into a wooded area, some may be expected to burst in the treetops. Although the released aerosol and vapor settle toward the ground, some of the agent is lost, depending upon the thickness and height of the foliage. The initial burst and pancake areas of chemical clouds released within woods or jungles are smaller than those released in the open. However, concentrations within the initial clouds are higher in wooded areas, sometimes three times that of bursts in the open. The magnitude of concentration from ground bursts depends upon the density of undergrowth and trees.

Generally, when conditions in the open are most favorable for the use of chemical agents, conditions also are favorable in heavily wooded areas if dispersion occurs below the canopy. Low wind speeds under the canopies spread agent clouds slowly in a downwind and downslope direction. Areas of dense vegetation also increase the potential surface area for the deposition of chemical agents. If there are gullies and stream beds within the woods, clouds tend to follow these features. This flow may be halted or diverted by upslope winds.

Vegetation absorbs some agents. However, for an attack against troops poorly trained in NBC defense (where lethal dosages may be obtained in 30 seconds or less), the amount of agent absorbed by foliage will have little or no effect on the success of the attack. High concentrations of chemical agents may destroy vegetation, since the leaves absorb some of the agent. In some instances, the absorbed agent may be released or desorbed when the vegetation is disturbed or crushed, creating a secondary toxic hazard.

Liquids

Weather, terrain contours, vegetation, soil, and some other surfaces affect the rate of evaporation. That, in turn, influences the persistence of a chemical agent liquid and the concentration of the vapor. Most weather conditions do not affect the quantity of munitions needed for an effective initial liquid contamination. Table 1-5 summarizes favorable and unfavorable weather and terrain conditions for the employment of a liquid chemical agent.

When a liquid agent is used to cause casualties through contact with the liquid in crossing or occupying the area, its duration of effectiveness is greatest when the soil temperature is just above the agent's freezing point. This limits the rate of evaporation of the liquid. Other favorable conditions are low wind speed, wooded areas, and no rain.

Conversely, unfavorable conditions are high soil temperature, high wind speed, bare terrain, and heavy rain.

Favorable and unfavorable conditions for liquid agents for vapor concentration effects are much the same as those for chemical clouds. In woods, however, a high temperature with only a very light wind gives the highest vapor concentrations.

Weather

Duration of the effectiveness of initial liquid contamination may be affected by wind speed; stability, mixing height, and temperature; and precipitation.

Wind Speed

Wind direction is important in determining the upwind side of a target for release purposes but has little impact on the duration of effectiveness, regardless of the method of release The vapor created by evaporation of the liquid agent, however, moves with the wind. Therefore, the vapor concentration is greatest on the downwind side of the contaminated area. Vapors are moved by the wind as discussed earlier in this chapter.

Evaporation due to wind speed depends on the amount of the liquid exposed to the wind (the surface of the liquid) and the rate at which air passes over the agent. Therefore, the duration of effectiveness is longer at the places of greater liquid agent contamination and in places where the liquid agent is sheltered from the wind.

The rate of evaporation of agents employed for persistent effect in a liquid state is proportional to the wind speed. If the speed increases, evaporation increases, thus shortening the duration of effectiveness of the contamination. Increased evaporation, in turn, creates a larger vapor cloud. The vapor cloud, in turn, is dispersed by higher winds. The creation and dispersion of vapor are a continuous process, increasing or decreasing in proportion to wind speed.

Releasing agents for persistent effect by point dispersal via bombs, shells, rockets, or land mines results in an unevenly distributed contaminant. Heavier concentrations of the liquid are found around the point of burst. Lighter concentrations result farther from the bursting position. There probably will be small areas between the points of burst that are not contaminated, depending upon the number of munitions used and the uniformity of dispersal.

Liquid agents released in the form of a spray are fairly evenly distributed, exposing the maximum surface area of the contaminant to the wind. This results in a more rapid evaporation than when the liquid agent is unevenly dispersed (as with bursting munitions). With spraying, the duration of effectiveness decreases, and there is a corresponding increase in the vapor concentration downwind from the sprayed area.

Some chemical agents have no significant vapor pressure, and, consequently, their rates of evaporation are not affected by wind speed. Also,

Table 1-5. Summary of favorable and unfavorable weather and terrain conditions for liquid agent employment.

FACTOR	UNFAVORABLE	MODERATELY FAVORABLE	FAVORABLE
Liquid Agents Employed for Liquid Contamination			
Wind	High wind speeds, except liquid agents with little vapor pressure, which are only slightly affected. High turbulence.	Moderate wind speeds.	Low wind speeds for agents with a significant vapor pressure. Higher wind speeds for agents with little vapor pressure. Little or no turbulence.
Dispersion Category	Unstable.	Neutral.	Stable.
Temperature	High soil temperature.	Intermediate.	Surface temperature just above the freezing point of the agent when used for contamination effect.
Humidity	Low.	Intermediate.	High.
Precipitation	Heavy.	Light rain.	None.
Vegetation *	Heavily wooded; jungle canopy.	Intermediate.	Sparse or none.
Soil	Bare, hard ground.	Porous surface.	Intermediate.
Liquid Agents Employed as Aerial Spray for Casualty Effect			
Wind	High wind speeds and high turbulence.	Intermediate.	Low wind speeds with a small degree of turbulence.
Dispersion Category	Unstable.	Inversion if released below the inversion cap.	Neutral.
Temperature	Low.	Intermediate.	Intermediate to high.
Humidity	Low.	Intermediate.	High.
Precipitation	Heavy.	Transitional.	None.
Vegetation	Heavily wooded; jungle canopy.		
Liquid Agents Employed for Vapor Concentrations			
Favorable and unfavorable conditions are much the same as those for chemical agents, vapors, or aerosols (Table 1-4).			

*Cloud dispersal occurs above the canopy.

some of these agents are extremely toxic, so even a very slight surface concentration represents a massive overkill dosage. When agents of this category are released from spray munitions under low wind speeds, they cover only a narrow zone. When released under higher wind speeds, they cover wider areas more effectively. Thus, when downwind safety is not a limiting consideration, high wind speeds may be more desirable than low wind speeds for these very persistent agents.

With agents that vaporize readily, high wind speeds may cause complete vaporization before the agent reaches the ground, creating only a vapor hazard. The resulting vapor cloud is nonpersistent and dissipates quite rapidly due to the high degree of mechanical turbulence associated with high wind speeds.

Turbulence has the same effect on agents employed for persistent effect, whether released from bombs, rockets, artillery shells, or land mines. Turbulence tends to reduce the duration of effectiveness in the liquid state by helping to increase the rate of evaporation. Temperature, rather than turbulence, has the greater effect on the duration of effectiveness of liquid agents. However, a contaminated area that has been subjected to pronounced turbulence does not remain contaminated as long as one that has been subjected to only slight turbulence with low wind speeds.

Turbulence also influences the spraying of agents employed for persistent effect. High winds and air movements divert the drops from the target or spread them over a larger area. Steep mountain regions sometimes produce large-scale eddies that prevent effective coverage of the target. Any vapor concentrations built up from sprayed areas are slight when the degree of turbulence is high.

Stability, Mixing Height, and Temperature

Unstable conditions are characterized by warmer surfaces. The solar heating then causes evaporation to be more rapid.

Temperature, velocity, and turbulence also affect the dispersion of spray. When stable (inversion) conditions prevail, there usually is little or no thermal turbulence, wind speeds are low, and the degree of mechanical turbulence is also low. Often stable conditions exist continually only near the ground. Above the top of the stable surface layer, wind speed and turbulence are increased. Wind direction here also may be substantially different from the surface wind direction. A chemical spray released below the top of the inversion falls fairly quickly. The height of the top of an inversion varies throughout the period of the surface inversion existence, and it may vary rapidly over large hills and mountains.

The mixing height is the capping inversion at the top of the mixing layer and serves as a lid. It prevents further upward vertical growth of a chemical vapor. A mixing height can also exist above unstable or neutral surface stability conditions. In radiation inversions, which commonly form at night, the top of the surface-based (mixing) stable layer is very close to the earth's surface shortly after the neutral condition changes to a stable condition (soon after sunset). As the surface stable layer intensifies, its top rises, reaching its maximum elevation between 0200 and 0400 hours local time. Maximum elevation may be 400 meters in a very intense stable layer. In the morning, solar radiation heats the surface and causes a good mixing condition close to the ground. The mixing height and turbulence condition increase until they destroy the stable layer. The mixing height can extend from the earth's surface up to 2 kilometers in elevation on a hot summer day. On a calm, clear night, the mixing height may extend only 50 to 100 meters above the earth's surface.

If a chemical agent is released above the surface stable layer, most of the agent remains aloft in the turbulence layer, and most of it will dissipate before settling low enough to be effective. For this reason, most spray missions are flown at either sunrise or sunset to take advantage of a neutral temperature gradient. With this gradient, there is some vertical exchange of air, and the chemical spray, being relatively heavy, has a natural tendency to settle to the ground. The Air Weather Service or an assigned meteorologist can provide information on the mixing height and the height of the top of the surface stable layer.

Under unstable conditions, convection currents often catch many very small droplets and carry them upward above the level of release. As a result, the spray takes longer to reach the ground, and much of it may dissipate before reaching the target area.

Temperature is one of the most important factors affecting the duration of effectiveness and vapor concentration of liquid agents. Agents employed for persistent effect acquire the temperature of the ground and the air they contact. Their evaporation rates are proportional to the vapor pressure at any given temperature. The temperature of the ground surface in winter in temperate zones closely follows the air temperature with a range of only 10 to 20 degrees between day and night. In the summer in temperate zones, the surface temperature may be much higher than that of the air in the daytime and much cooler at night. Turbulence usually accompanies a high ground temperature. The result is that although the vapor concentration in the immediate area may be very high, it falls off rapidly a short distance away. Temperature of vehicles, buildings, and other surfaces may be warmer. This is because of internal heat sources and/or higher solar heating.

From a defensive viewpoint, a dangerous situation is likely to occur on a summer evening when the ground temperature is still high and a stable condition has started to set in. Under these conditions, a heavy vapor cloud produced by evaporation could be dangerous downwind to a distance of 2,000 meters or more. With ordinary concentrations, however, danger from vapor is somewhat less.

Another important temperature factor to consider is that people perspire freely and wear lightweight clothing in a warm climate. Thus, they are more susceptible to the action of chemical agents.

For effective tactical employment of bombs, shells, rockets, and land mines in releasing liquid chemical agents, the actual temperature of the agent itself is vitally important. Generally, liquid agents are not effective when used at temperatures below their freezing points. However, liquid agents can produce casualties when the frozen particles thaw.

Humidity has little effect on how long liquid agents are effective. However, high relative humidity, accompanied by high temperatures, induces body perspiration and, therefore, increases the effectiveness of these agents. Also, permeable protective clothing is less resistant when sweat-soaked than when dry. Since sweaty skin is more susceptible to the action of vapor, lower vapor dosages produce casualties when the humidity is high.

Precipitation

Light rains distribute persistent agents more evenly over a large surface. Since more liquid is then exposed to the air, the rate of evaporation may increase and cause higher vapor concentrations. Precipitation also accelerates the hydrolysis effect. Rains that are heavy or of long duration tend to wash away liquid chemical agents. These agents may then collect in areas previously uncontaminated (such as stream beds and depressions) and present an unplanned contamination hazard.

The evaporation rate of a liquid agent reduces when the agent is covered with water but returns to normal when the water is gone. Precipitation may force back to the surface some persistent agents that have lost their contact effectiveness by soaking into the soil or other porous surfaces. These agents may again become contact hazards.

Snow acts as a blanket, covering the liquid contaminant. It lowers the surface temperature and slows evaporation so that only very low vapor concentrations form. When the snow melts, the danger of contamination reappears.

Terrain Contours

Terrain relief has little direct effect on a liquid agent. However, a slope affects temperatures and winds, and these influence the evaporation rates of liquid agents. However, the slope or contour may affect the delivery means capable of most efficiently delivering the agent on an area (for example, reverse slopes are normally not good for artillery employment, and mountainous terrain may restrict use of spray tanks).

Vegetation

When persistent agents are used in vegetated areas, some of the contaminant clings to grass and leaves. This increases the surface agent exposed to the air and, hence, the rate of evaporation. Personnel become most susceptible to liquid chemical agents in vegetated areas, because they are more apt to come in contact with the agent by brushing against the foliage. Within shaded woods, however, despite the greater surface covered by the liquid chemical agent (because of the vegetation), the reduction in surface temperature and wind speed increases the duration of effectiveness.

When bombs or shells burst in woods, usually most of the liquid falls near enough to the ground to be effective. An exception is bursts in virgin forests with dense canopies that may extend to 50 meters high.

A thick jungle or forest canopy usually prevents liquid agent spray from airplanes from reaching the ground in quantities sufficient to produce significant casualties. When stable conditions exist above the forest canopy, however, enough vapor penetrates the canopy to cause casualties.

Soil

The soil on which liquid agents are placed influences the evaporation rate and the duration of effectiveness. Bare, hard ground favors short-term effectiveness and high-vapor concentration. If the surface is porous, such as sand, the liquid agent quickly soaks in; and the area no longer appears to be contaminated.

The rate at which liquid agents evaporate from a sandy or porous surface is about 1/3 less than the evaporation rate from nonabsorbent surfaces. Extended contact with a contaminated porous material is dangerous if unprotected. However, if there is no free liquid on the surface, the danger from brief contact is relatively small if protected. If a porous surface on which liquid contamination falls has been wet by rain, the contaminant does not soak in as readily, and the surface is initially more dangerous to touch than it would be if the liquid agent had soaked in. When a mustard agent (HD) falls onto a wet surface, it stays in globules; and a thin, oily film spreads over the surface, making contamination easier to detect.

Other Surfaces

Persistence of liquids on painted surfaces of vehicles is much shorter than on most terrain. This is due to a number of factors, including increased surface temperature, turbulence of airflow over the vehicles or other equipment, and greater spread of drops to give more surface area for evaporation.

Persistence varies greatly with surface material. Absorption, adsorption, and resorption also vary with surface material. Rubber absorbs most agents rapidly and desorbs slowly. Chemical agent resistant coating (CARC) absorbs very little agent.

CHAPTER 2

Smoke and Incendiaries

Smoke and incendiaries are combat multipliers. Their effective use on a target can provide tactical advantages for offensive and defensive operations. For example, smoke has long been employed as a means of concealing battlefield targets. Additionally, incendiary fire damage causes casualties and materiel damage and can also impact psychologically.

Smoke

Chemical smokes and other aerosol obscurants can degrade the effectiveness of sophisticated antitank guided missiles (ATGMs). The precision guidance systems of ATGMs are typically electro-optical devices and generally operate in the near-, mid-, or far-infrared portions of the electromagnetic spectrum, rather than in the visible light band of the spectrum. The use of smoke in the target area can be a convincing combat multiplier offensively and a dynamic countermeasure defensively. Smoke should be of primary interest to all commanders and staff planners because the proper use of smoke can provide many operational advantages.

Smoke has four general uses on the battlefield—obscuring, screening, deceiving, and identify ing/signalling. Obscuring smoke is placed on an enemy to reduce vision both at, and out from, the position. Screening smoke is used in friendly operational areas or between friendly units and the enemy. Deceiving smoke is used to mislead the enemy. Identifying/signalling smoke is a form of communication that has multiple uses. Overall, the objective of smoke employment is to increase the effectiveness of Army operations while reducing the vulnerability of US forces. Specifically, smoke can be used to accomplish the following:

- Deny the enemy information.
- Reduce effectiveness of enemy target acquisition.
- Disrupt enemy movement, operations, command, and control.
- Create conditions to surprise the enemy.
- Deceive the enemy.

During offensive operations, smoke can screen the attacker while an attack is carried out. Some offensive applications include concealing movement of military forces and equipment; screening locations of passages through barriers; and helping to secure water crossings, beachheads, or other amphibious operations.

For defensive operations, smoke can be effectively used to blind enemy observation points to deprive the enemy of the opportunity to adjust fire, to isolate enemy elements to permit concentration of fire and counterattack, and to degrade the performance of threat ATGMs.

There are generally two categories of smoke operations on a battlefield-hasty and deliberate smoke. Hasty smoke operations are conducted with minimum prior planning, normally to counter some enemy action or anticipated action of immediate concern to a commander. Hasty smoke is usually used on small areas, is of short duration, and is most often used by battalion or smaller units. Deliberate smoke is planned in much greater detail. It is often employed over a large area for a relatively long period by brigades, divisions, or corps. For further information on hasty and deliberate smoke operations, refer to FM 3-50.

The following paragraphs on smoke operation contain information on smoke characteristics, diffusion of smoke, weather effects, hasty and deliberate smoke operations, and tactical considerations.

Characteristics

Smoke is an aerosol that owes its ability to conceal or obscure to its composition of many small particles suspended in the air. These particles scatter or absorb the light, thus reducing visibility. When the density or amount of smoke material between the observer and the object to be screened exceeds a certain minimum threshold value, the object cannot be seen.

The effectiveness of smoke used to obscure or conceal depends primarily on characteristics such as the number, size, and color of the smoke particles. Dark or black smoke absorbs a large proportion of the light rays striking individual smoke particles. In bright sunlight, a large quantity of black smoke is required for effective obscuration because of the nonscattering properties of the particles. At night or under low visibility conditions, considerably less smoke is needed.

Grayish or white smoke obscures by reflecting or scattering light rays, producing a glare. During bright daylight conditions, less white smoke than black smoke is required to obscure a target. Years of experience with smoke screen technology have shown that white smoke is superior to black smoke for most applications. Available white smoke includes white phosphorus (WP) and red phosphorus (RP) compounds, hexachloroethane (HC), and fog oil (SGF2). WP, RP, and HC are hydroscopic—they absorb water vapor from the atmosphere. This increases their diameters and makes them more efficient reflectors and scatterers of light rays. Fog oils are nonhygroscopic and depend upon vaporization techniques to produce extremely small diameter droplets to scatter light rays. The reflecting and absorbing qualities of smoke are illustrated in Figure 2-1.

Smoke, when placed between a target and a viewer, degrades the effectiveness of target-acquisition and aiming systems. The amount of smoke necessary to defeat aiming and acquisition systems is highly dependent upon the prevailing meteorological conditions, terrain relief, available natural light, visibility, and the attenuation effects of natural particles in the atmosphere. Other factors that must be considered include smoke from battlefield fires and dust raised by maneuvering vehicles and artillery fire.

The ability to detect and identify a target concealed by such a smoke screen is, in turn, a function of target-to-background contrast. Additionally, the amount of available natural light, the position of the sun with respect to the target, the reflectance of the smoke screen and the target, and the portion of the electromagnetic spectrum to be attenuated below the threshold contrast for detection will impact on detecting and identifying a target.

Diffusion

The diffusion of smoke particles into the surface and planetary boundary layers of the

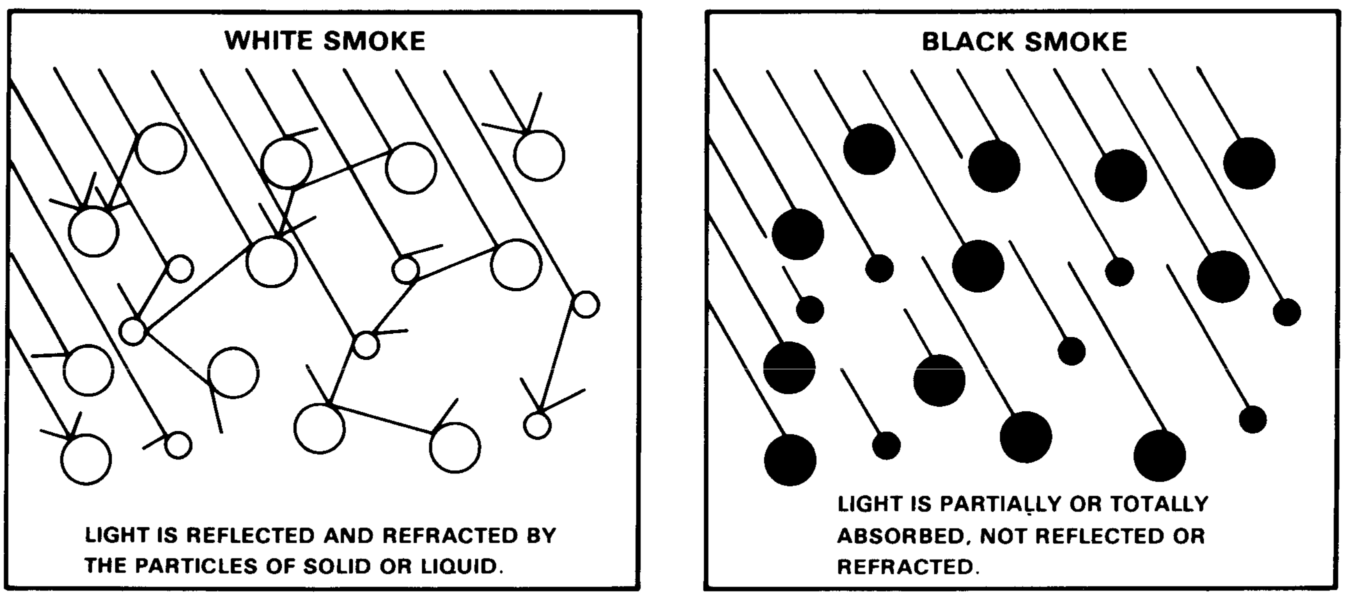

Figure 2-1. Action of smoke particles on light radiation.

atmosphere generally obeys physical laws. Diffusion is governed by wind speed, turbulence, stability of the atmosphere, and terrain. The diffusion of smoke, as used on the battlefield, originates from four basic source configurations. These may be defined as continuous point sources, instantaneous point sources, continuous line sources, and area sources. A continuous point source may bethought of as a smoke release from a single smoke generator or smoke pot. The bursting of a projectile containing WP is considered to be an instantaneous source. A series of generators, set up crosswind, represent a line source. Munitions which scatter smoke-generating submunitions in an area are considered an area source.

Weather Effects

Meteorological conditions that have the most effect on smoke screening and munitions expenditures (including the deployment of smoke generators) include wind direction, relative humidity, visibility, and atmospheric stability. To be effective, an obscuring screen must be placed in an advantageous position with respect to the prevailing wind direction. The target area to be screened must be defined in terms of whether the prevailing wind direction is considered to be a head or tail wind, a quartering wind, or a flank wind. Figure 2-2 illustrates these conditions. It must be remembered that flanking winds can be from either the right or left side of the screening area and that there are four quartering-wind directions. Wind direction is critical for determining the adjustment or aim point for screens deployed by artillery or mortars and also for the placement of generators if used to produce either hasty or deliberate smoke.

As smoke is released into the atmosphere, it is transported and diffused downwind. The plume is depleted quite rapidly by atmospheric turbulence. The obscuration power of the plume becomes marginal at relatively short downwind distances and must be replenished at each point where the attenuation of a line of sight approaches a minimum. The transport wind speed and direction for a diffusing plume in the surface boundary layer of the atmosphere occurs at a height of about half of the plume height. Usually, this would be a height of about 10 meters. For smoke operations, then, speeds and directions should be obtained for a height of about 10 meters above the surface.

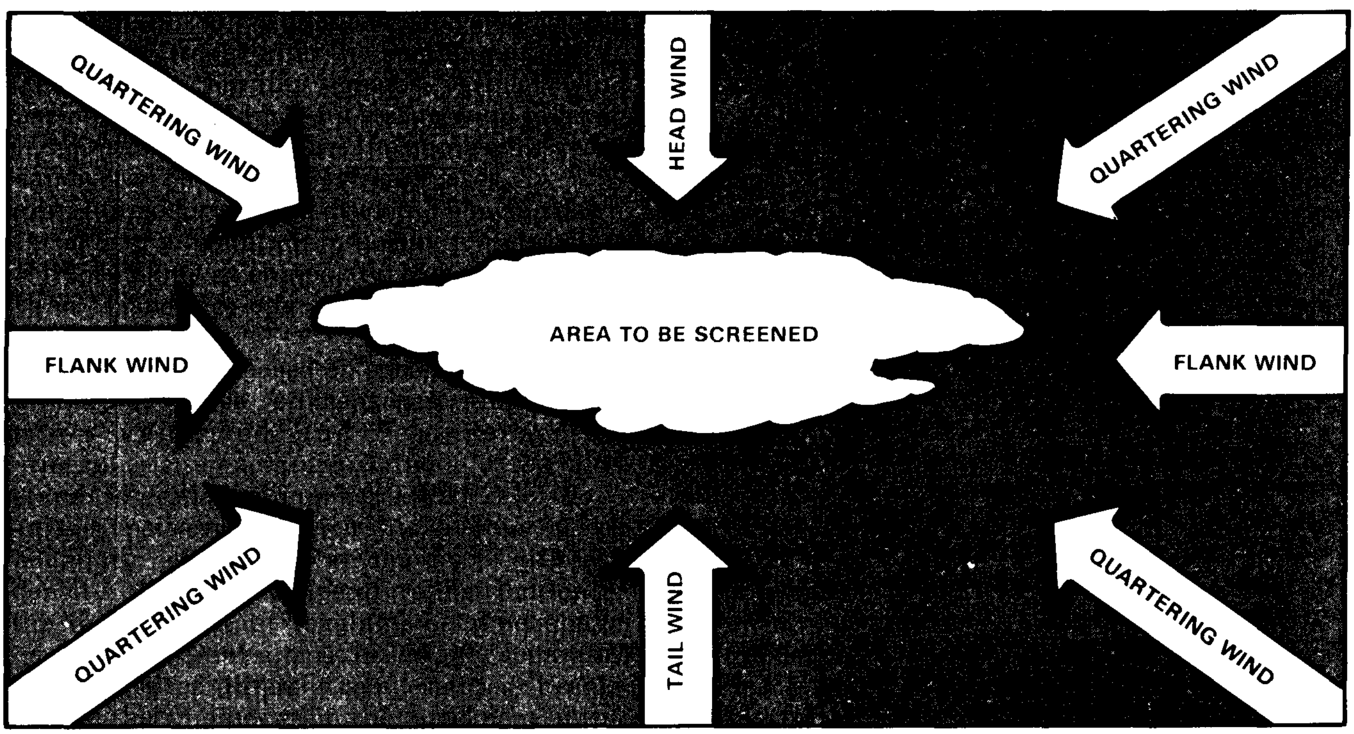

Figure 2-2. Prevailing wind directions.

The relative humidity of the atmosphere is important to the use of smoke on a battlefield. As previously stated, WP, RP, and HC smoke compounds are hydroscopic—they absorb moisture from the atmosphere. As relative humidity increases, the amount of screening material available for target obscuration increases. For example, the HC compound is considered to be only about 70-percent efficient; that is, for every 100 grams of HC in a munition, only 70 grams are available for screening. If the relative humidity yield factor is then added in, the screening power of HC increases. This is shown in Table 2-1. Applicable technical references indicate the amount of HC or WP contained in various munitions. For example, the 105-millimeter WP (M416) round contains 6 pounds of WP; the 155-millimeter HC (Ml16A1) round contains 5.45 pounds of HC; and the 76-millimeter WP (M361A1) round contains 1.38 pounds of WP (453.6 grams equals 1 pound).

Table 2-1. Smoke yields for HC and WP in various relative humidities.

RELATIVE HUMIDITY %	100 g HC (70% efficient)		100 g WP (100% efficient)	
	YIELD FACTOR	YIELD	YIELD FACTOR	YIELD
10	1.46	102 g	3.53	353 g
20	1.52	106	3.72	372
30	1.59	111	3.91	391
40	1.73	121	4.11	411
50	1.89	132	4.34	434
60	2.11	148	4.65	465
70	2.40	168	5.10	510
80	3.25	228	5.88	588
90	5.72	400	7.85	785

Phosphorous compounds are considered to be better screening agents than HC. This is because WP and RP have large yield factors for various relative humidities. Yields for WP are also shown in Table 2-1. Upon ignition, WP burns at a temperature of about 800°C to 850°C. As a consequence, the smoke from a WP munition pillars, creating an excellent vertical screen, especially with high relative humidities. However, only about 10 percent of the smoke generated from WP munitions is available for screening near the ground. This should be considered when planning smoke missions.

Battlefield visibility can be practically defined as the distance at which a potential target can be seen and identified against any background. Reduction of visibility on a battlefield by any cause reduces the amount of smoke needed to obscure a target.

Turbulence, atmospheric instability, and wind speed can have an adverse effect upon smoke expenditures. Unstable conditions are usually considered to be unfavorable for the use of smoke. Under calm or nearly calm conditions, the use of smoke is also sometimes unsatisfactory. In general, if the wind speed is less than 3 knots or greater than 20 knots, smoke can be an unsatisfactory countermeasure on the battlefield.

Operations

Smoke operations are of two types: hasty and deliberate.

Hasty Smoke

Hasty smoke generally is placed in the area to be screened by artillery, smoke pots, or mortar projectiles. Obscuring smoke usually is employed on enemy forces to degrade their vision both within and beyond their location. Screening smoke is used in areas between friendly and enemy forces to degrade enemy ground and aerial observation and to defeat or degrade enemy electro-optical systems. Screening smoke also may be employed to conceal friendly ground maneuver. Deception or decoy smoke is used in conjunction with other measures to deceive the enemy regarding friendly intentions. Decoy smoke can be used on several approaches to an objective to deceive the enemy as to the actual avenue of the main attack.

In the offense, hasty smoke may be used to establish screens, enabling units to maneuver behind or under screens and deny the enemy information about strength, position, activities, and movement. Ideally, a screen should be placed approximately 500 to 800 meters short of the enemy to allow for maximum visibility for mounted forces during the final assault. Hasty screens on the flanks also can be used. Flanking screens can be produced with mechanized generators. Hasty obscuring smoke also may be placed on enemy strongpoints.

On defense, hasty smoke may be used to impede and disrupt enemy formations. It also may be used beyond the forward line of own troops (FLOT) to silhouette Threat targets as they emerge through the smoke and are engaged. Smoke screens also may be used to conceal defensive positions and cover disengaging and moving forces. Mechanized smoke generator units are ideal for this type of hasty smoke.

Figure 2-3 shows the positioning of an obscuring hasty smoke cloud on enemy forces for tail wind and head wind conditions. Figure 2-4 illustrates screening smoke for flank and quartering winds ahead of an advancing force. Figure 2-5 is an example of mechanized units generating a smoke screen for a counterattacking force.

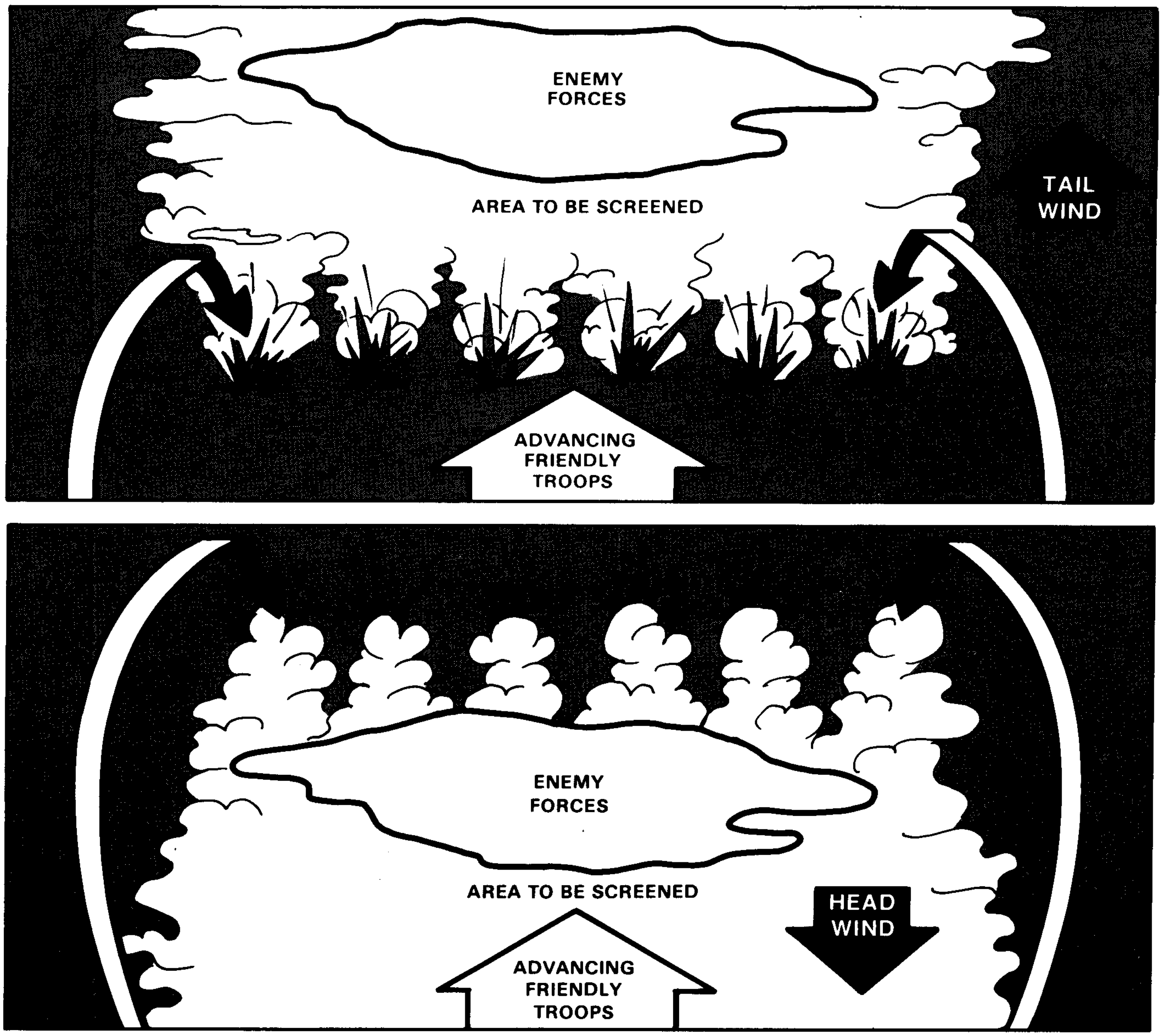

Figure 2-3. Obscuring smoke clouds for tail and head wind conditions.

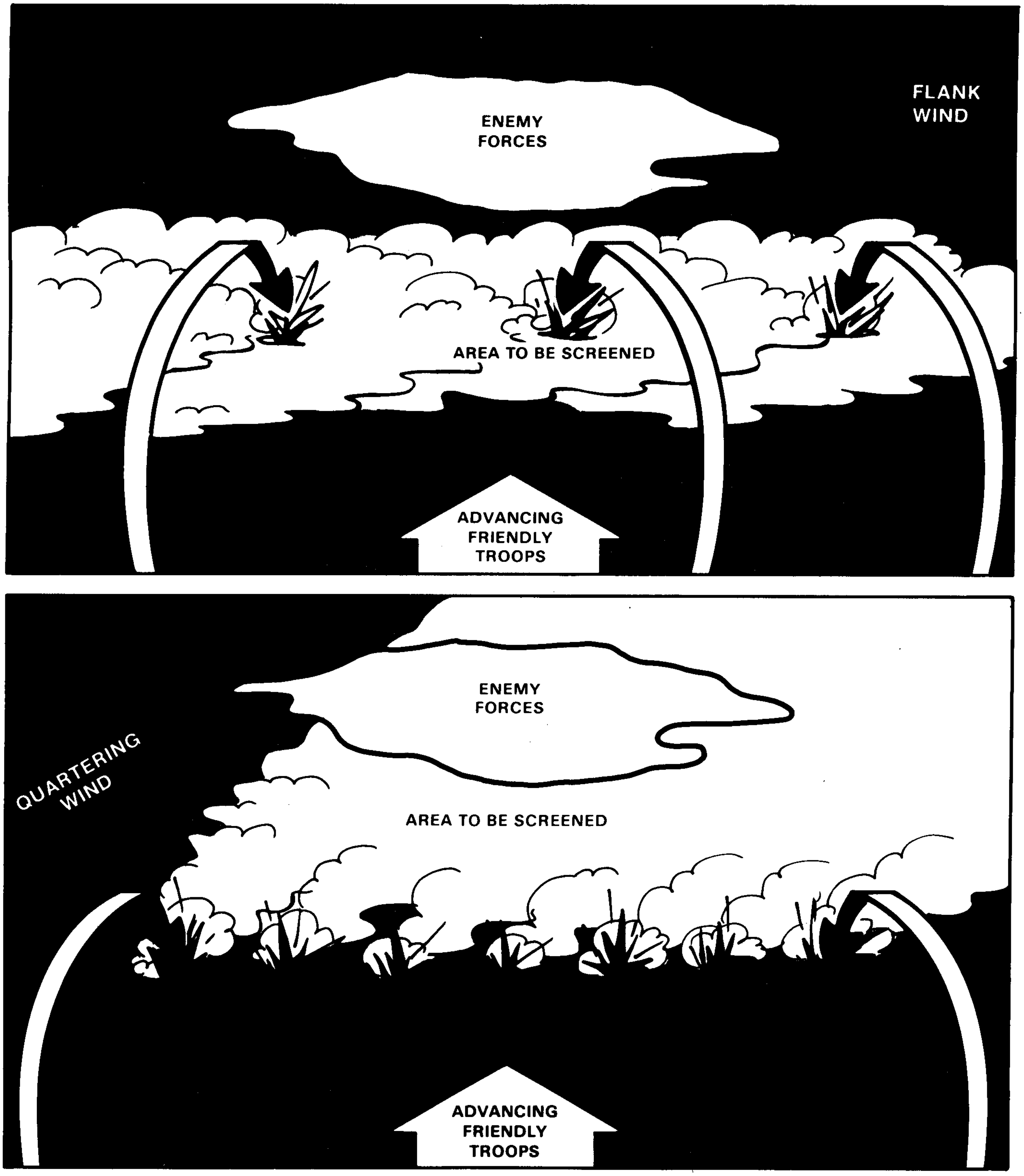

Figure 2-4. Screening smoke cloud for flank and quartering wind conditions.

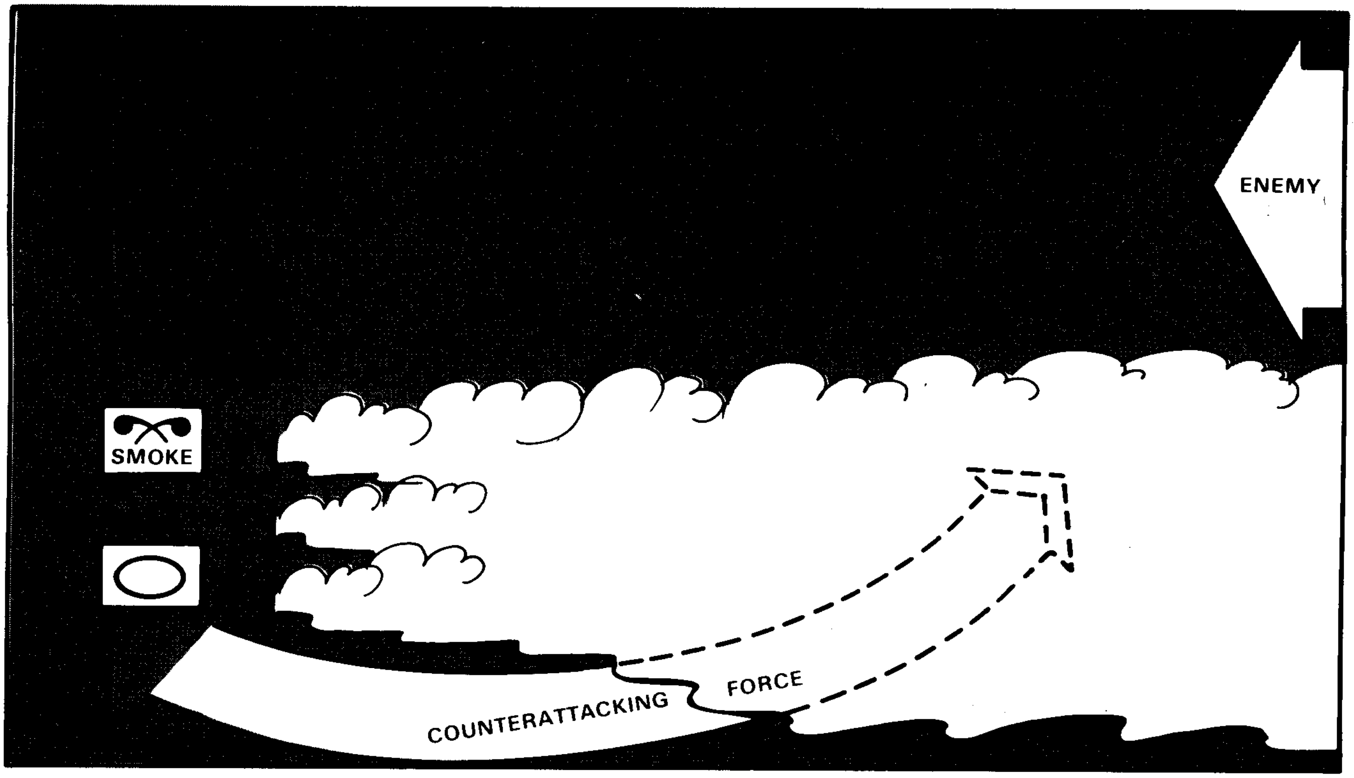

Figure 2-5. Mechanized smoke vehicles screening a counterattacking force.

Deliberate Smoke

Large area smoke screens generally fall within the realm of deliberate smoke in that they are usually planned well in advance of the operation. Large area screening or the establishment of a smoke blanket or haze is generally carried out by the use of smoke generators. Generators usually are positioned in a line source configuration at a right angle to the prevailing wind direction. Usually, if the terrain allows it, the generators are evenly spaced along the smoke line. Generators are ideal for screening river crossings if the prevailing wind direction is upstream, downstream, or a tail wind.

The employment of large smoke is probably most effective if the screen is generated before sunrise when stable conditions and light-to-moderate winds are most likely. Screens generated in these conditions will remain close to the ground with only moderate vertical diffusion. Screens also reduce incoming solar radiation reaching the ground so that convective turbulence is suppressed, similar to overcast weather conditions. Thus, smoke hazes and blankets can be maintained and remain useful for longer time periods.

The use of large area smoke screens in any area depends upon the prevailing wind direction. Operators must be prepared to shift their generators to preselected locations if the wind direction changes.

Tactical Considerations

In addition to the importance of wind direction, relative humidity, visibility, stability, and turbulence to the successful completion of a smoke mission, the effects of terrain and soil conditions should be considered. Terrain effects discussed in Appendix C apply to smoke as well as NBC agents. A diffusing smoke plume also tends to follow the terrain-influenced surface winds. Also, in forests and jungles smoke has a tendency to be more evenly dispersed and to persist longer than over more open terrain.

The condition of the soil influences the effectiveness of artillery-delivered and mortar-delivered smoke but has very little direct effect upon screening or obscuring smoke. An impacting smoke munition bursting in soft soil loses effectiveness since part of the filling compound is driven into the dirt. In some cases, totally ineffective screens result if smoke munitions are delivered to a boggy or swampy target area.

A last point to consider involves wind direction effects upon smoke screens. Munitions expenditures for a screen deployed in quartering wind conditions must be increased by a factor of about 1.5 over a flank wind direction condition. For head and tail winds, expenditures are three to four times those for flank winds. Thus, reduction in expenditures owing to visibility and relative humidity effects may be negated by wind directions.

Incendiaries

Weather conditions have little influence on incendiary munitions themselves. Wind and precipitation, however, may greatly influence the combustibility of the target and its susceptibility to fire spread. The purposes of incendiaries are to cause maximum fire damage on flammable materials and objects and to illuminate. Initial action of the incendiary munition may destroy these materials, or the spreading and continuing of fires started by the incendiary may destroy them. Incendiary materials used include gasoline gels, burning metals, incendiary mixes, and white phosphorus.

To be effective, incendiary munitions should be used against targets susceptible to fire or heat damage. A considerable part of the target must be flammable, so the fire can spread. Fire walls and cleared lanes offer some resistance to the spread of fires.

Winds assist in the effectiveness of incendiaries, increase the rate of combustion, and can spread fires downwind more rapidly. Actually, each large fire can create a wind system of its own. This wind system results from the tremendous heat generated and the resulting vertical wind currents. Incoming winds can feed more air to the fire. This increases the rate of combustion, which, in turn, can increase the wind. In extreme cases, this wind is called a fire storm and sometimes exceeds 60 knots.

Smoke, sparks, and flames fly in the direction of the wind. Incendiary strikes (at successive targets) should be planned to begin with the farthest downwind target and proceed upwind. This will prevent aiming points from becoming obscured by smoke traveling downwind of initial fires. Additionally, the position of friendly forces or facilities that must not be damaged must be considered (in relation to the wind direction) when planning incendiary strikes.

Temperature, temperature gradient, and clouds have little if any effect on incendiaries. Humidity also has little effect upon incendiary munitions but may affect combustible material. Wood, vegetation, and similar material absorb some moisture from the air over a period. If relative humidities have been high for some time, as in the tropics, it may be more difficult to achieve combustion from incendiary action.

Rain or snowfall, even when light, can render grass and brush quite incombustible and make a continuing fire unlikely. Heavy timbers are not affected unless they have been exposed to long periods of precipitation. Combustible materials exposed to rain may be susceptible to fire damage, such as in mass incendiary attacks. In these attacks, the heat of combustion may be sufficient to dry combustible materials in the target area.

In regions of high humidities, such as the tropics, mass incendiary attacks generate tremendous amounts of heat, causing vertical wind currents. This rising air can cause thunderstorms, counteracting the effects of the incendiaries.

It is difficult to extinguish burning metals with water; a spray actually speeds the burning. Water surrounding the area of burning metals prevents fire spread. Water extinguishes burning phosphorus, but unconsumed particles will burn again when dry.

Three elements of terrain affect the efficient use of incendiaries. These are soil, vegetation, and topography. The type of soil affects the impacting of the munition; combustibility of the vegetation affects the efficiency of the incendiary; and topography influences wind speed and direction.

CHAPTER 3

Biological Agents and Nuclear Detonations

In a general war, US forces may be faced by an enemy capable of employing nuclear or biological weapons. The effects of weather and terrain on biological agent aerosols and on nuclear weapons follow.

Biological Agents

In a general war, US forces may be faced by an enemy capable of producing and employing biological agents. These include disease-causing microorganisms (pathogens) and toxins. Toxins are biologically derived chemical substances that have desirable characteristics for use as biological warfare agents. Toxins may be natural or synthetic.

Biological agents will most likely be disseminated as an aerosol. Therefore, a basic knowledge of their field behavior is essential for estimating friendly vulnerability. These agents differ from chemical agents in some aspects of field behavior. Pathogens decay as a result of factors such as weathering. They also require time to invade a body and multiply enough to overcome the body's defenses. This is known as the incubation period. This period may vary from hours to months, depending on the type of pathogen.

The following paragraphs discuss biological agent dissemination, weather effects, and terrain influences, and they briefly summarize the influence of these on biological agent field behavior.

Dissemination

Pathogens are most likely to be disseminated as aerosols. Toxins, on the other hand, may be disseminated as either aerosols or large liquid drops. An aerosol is composed of particles containing pathogens or toxins. The force of the wind moves it along. At the same time, the aerosol spreads by turbulent diffusion.

Biological agents that die rapidly are said to have a high decay rate. High wind speeds (10 to 20 knots) carry these agents over more extensive areas during the agent survival period. Multiple wind shifts occur at low wind speeds. These shifts may cause more lateral spread and downwind diffusion than higher speeds. Optimum effect depends on the nature of the agent and atmospheric conditions. Highly virulent (malignant) agents with low decay rates can spread over large areas (by low or high wind speeds) and still present a casualty threat. Virulent agents with higher decay rates employed under the same atmospheric conditions are much less effective.

Weather Effects

Air stability, temperature, relative humidity, pollutants, cloud coverage, and precipitation have an effect on biological agents.

Air Stability

Atmospheric stability influences a biological cloud in much the same way it affects a chemical cloud. However, biological agents may be more effective in lower concentrations than chemical agents. This is because of their high potency. A stable atmosphere results in the greatest cloud concentration and area coverage of biological agents. Under unstable and neutral stability conditions, more atmospheric mixing occurs. This leads to a cloud of lower concentration, but the concentration is sufficient to inflict significant casualties. The coverage area under unstable stability conditions is also reduced.

Temperature

Air temperature in the surface boundary layer is related to the amount of sunlight the ground has received. Normal atmospheric temperatures have little direct effect on the microorganisms of a biological aerosol. Indirectly, however, an increase in the evaporation rate of the aerosol droplets normally follows a temperature increase. There is evidence that survival of most pathogens decreases most sharply in the range of -20°C to -40°C and above 49°C. High temperatures kill most bacteria and most viral and rickettsial agents. However, these temperatures will seldom if ever be encountered under natural conditions. Subfreezing temperatures tend to quick-freeze the aerosol after its release, thus decreasing the rate of decay. Exposure to ultraviolet light—one form of the sun's radiation—increases the decay rate of microorganisms. Ultraviolet light, therefore, has a destructive effect upon the biological aerosol. Most toxins are more stable than pathogens and are less susceptible to the influence of temperature.

Relative Humidity

The relative humidity level favoring employment of a biological agent aerosol depends upon whether the aerosol is distributed wet or dry. For a wet aerosol, a high relative humidity retards evaporation of the tiny droplets containing the microorganisms. This decreases the decay rate of wet agents, as drying results in the death of these microorganisms. On the other hand, a low relative humidity is favorable for the employment of dry agents. When the humidity is high, the additional moisture in the air may increase the decay rate of the microorganisms of the dry aerosol. This is because moisture speeds up the life cycle of the microorganisms. Most toxins are more stable than pathogens and are less susceptible to the influence of relative humidity.

Pollutants

Atmospheric pollutant gases can also affect the survival of pathogens. Pollutant gases have been found to decrease the survival of many pathogens. These gases include nitrogen dioxide, sulfur dioxide, ozone, and carbon monoxide. This could be a significant factor in the battlefield over which the air is often polluted.

Cloud Coverage

Cloud coverage in an area influences the amount of solar radiation received by the aerosol. Thus, clouds decrease the amount of destructive ultraviolet light the microorganisms receive. Cloud coverage also influences factors such as ground temperature and relative humidity, as discussed in Chapter 1.

Precipitation

Precipitation may wash suspended particles from the air. This washout may be significant in a heavy rainstorm but minimal at other times. High relative humidities associated with mists, drizzles, and very light rains are also an important factor, These may be either favorable or unfavorable, depending upon the type of agent. The low temperatures associated with ice, snow, and other winter precipitation prolong the life of most biological agents.

Terrain Influences

Soil, vegetation, and rough terrain influence a biological agent aerosol.

Soil and Vegetation

Soil influences a biological agent aerosol as related to temperature and atmospheric stability. Appendix C discusses the interrelationship between soil and these weather elements.

Vegetation reduces the number of aerosol particles. Impact of the suspended particles upon trees and grass causes some particles to settle, and this settling reduces agent concentration. However, vegetative cover reduces exposure to ultraviolet light, increases relative humidities, and may reduce temperatures (while fostering a neutral temperature gradient). All these factors favor the survival of wet aerosols.

Rough Terrain

Rough terrain creates wind turbulence, and turbulence influences the vertical diffusion of aerosol. This turbulence reduces agent effectiveness and area coverage. Terrain affects the path of the aerosol and the distribution of surface concentration.

Nuclear Detonations

When a nuclear explosion occurs, blast radiation and heat or thermal effects will occur. The influence of weather and terrain on these effects will be discussed in this section. When a nuclear weapon detonates at low altitudes, a fireball results from the sudden release of immense quantities of energy. The initial temperature of the fireball ranges into millions of degrees, and the initial pressure ranges to millions of atmospheres. Most of the energy from a nuclear weapon detonation appears in the target area in the form of three distinct effects. These are nuclear radiation, blast, and thermal radiation.

Nuclear Radiation. Neutron and gamma radiation from the weapon detonation produces casualties and, in many cases, material damage as well. Ionized regions, which may interfere ‘with the propagation of electromagnetic waves associated with communication systems and radars, result when the atmosphere absorbs nuclear radiation.

Blast. A blast wave with accompanying drag effects travels outward from the burst.

Thermal Radiation. Intense thermal radiation emits from the fireball, causing heating and combustion of objects in the surrounding area.

In the detonation of a typical fission-type nuclear weapon, the percentage of the total energy appearing as nuclear radiation, blast, or thermal radiation depends on the altitude at which the burst takes place (subsurface, surface, or air) and on the physical design of the weapon. For bursts within a few kilometers above the earth’s surface, slightly more than 50 percent of the energy may appear as blast, approximately 35 percent as thermal energy, and approximately 15 percent as nuclear radiation.

Certain weather conditions will influence the effects of nuclear weapons. Likewise, different types of terrain will also influence the effects of nuclear weapons. In addition to these considerations, the type of operation can have a direct bearing on weather and terrain effects on nuclear weapons use.

Nuclear Radiation

When a nuclear explosion occurs, one usual result is the well-known mushroom-shaped cloud. This cloud may extend tens of thousands of meters, and in the case of a surface burst or shallow subsurface burst, it is a tremendous vertically developed aerosol cloud bearing radioactive material. The effect of wind speed and direction at various altitudes is of particular interest. These factors are of great importance in predicting the location(s) of the fallout that may result from a nuclear explosion.

The effects of weather and terrain apply to both the initial and residual effects of nuclear explosions, although this section will primarily address the residual aspects. For more information on the effects of weather on both initial and residual effects, refer to FM 3-3.

Precipitation

Precipitation scavenging can cause the removal of radioactive particles from the atmosphere. This is known as rainout. Because of the uncertainties associated with weather predictions, the locations that could receive rainout cannot be accurately predicted. Rainout may occur in the vicinity of ground zero or the contamination could be carried aloft for tens of kilometers before deposition. The threat of rainout especially exists from a surface or subsurface burst. Vast quantities of radioactive debris will be carried aloft and be deposited downwind. However, rainout may cause the fallout area to increase or decrease and also cause hot spots within the fallout area.

For airbursts, rainout can increase the residual contamination hazard. Normally, the only residual hazard from an airburst is a small neutron induced contamination area around GZ. However, rainout will cause additional contaminated areas in unexpected locations.

Yields of 10 kilotons or less present the greatest potential for rainout, and yields of 60 kilotons or more offer the least. Additionally, yields between 10 kilotons and 60 kilotons may produce rainout if the nuclear clouds remain at or below rain cloud height.

Rain on an area contaminated by a surface burst changes the pattern of radioactive intensities by washing off higher elevations, buildings, equipment, and vegetation. This reduces intensities in some areas and possibly increases intensities in drainage systems; on low ground; and in flat, poorly drained areas.

Wind Speed and Direction

Wind speed and direction at various altitudes are two factors that determine the shape, size, location, and intensities of the fallout pattern on the ground because contaminated dirt and debris deposit downwind. The principles and techniques of fallout prediction from winds-aloft data are in FM 3-3. Surface winds also play an important role in the final location of fallout particles. Just as snow falls on pavements or frozen surfaces and surface winds pile it in drifts, so, too, can local winds cause localization of fallout material in crevices and ditches and against curbs and ledges. This effect is not locally predictable, but personnel must be aware of the probability of these highly intense accumulations of radioactive material occurring and their natural locations.

Clouds and Air Density

Clouds and air density have no significant effects on fallout patterns.

Terrain Contours

Ditches, gullies, small hills, and ridges offer some protection against the gamma radiation emanating from the contaminated area. Terrain contours also cause local wind systems to develop. These wind systems will affect the final disposition of fallout on the ground, creating both hot spots and areas of low-intensity within the pattern.

Heavy Foliage

Heavy foliage can stop some of the fallout from reaching the ground. This may reduce the intensity on the ground.

Soil

Soil surface materials (soil) at the burst site determine particle size (large or small). The particle size helps determine when and where most of the fallout will reach the ground, the larger particles settling first. Composition of the soil near ground zero will materially affect the size and decay rate of the pattern of residual radiation induced by neutrons from the weapon.

Type of Operation

Temperature and terrain can also influence the effects of nuclear radiation on tactical operations. The effects of cold weather, desert, jungle, mountain, and urban operations on nuclear defense planning follow.

Cold Weather Operations

Weather conditions limit the number of passable roadways. Radiological contamination on roadways may further restrict resupply and troop movement. Seasonal high winds in the arctic may present a problem in radiological contamination predictions. These winds may reduce dose rates at ground zero. At the same time, they extend the area coverage and create a problem for survey/monitoring teams. Hot spots or areas of concentrated accumulation of radiological contamination may also occur in areas of heavy snow and snow drifts.

Desert Operations

Desert operations present many varying problems. Desert daytime temperatures can vary between 90°F to 125°F (32°C to 52°C). These temperatures create an unstable temperature gradient. However, with nightfall, the desert cools rapidly and a stable temperature gradient results. A possibility of night attacks must be considered in all planning.

Nuclear defense planning in a desert is generally much the same as in other areas, with a few exceptions. Lack of vegetation and permanent fixtures, such as forests and buildings, makes it necessary to plan for and construct fortifications. Construction may be difficult because of inconsistencies of the sand. However, sand, in combination with sandbags, gives additional protection from radiation exposure. Blowing winds and sand make widespread radiological survey patterns likely. The varying terrain may make radiological survey monitoring very difficult.

Jungle Operations

Radiation hazards also may be reduced because some of the falling particles are retained by the jungle canopy. Subsequent rains, however, will wash these particles to the ground and concentrate them in water collection areas. Radiation hot spots will result.

Mountain Operations

In the mountains, the deposit of radiological contamination will be very erratic because of rapidly changing wind patterns. Hot spots may occur far from the point of detonation, and low-intensity areas may occur very near it. Limited mobility makes radiological surveys on the ground difficult, and the difficulty of maintaining a constant flight altitude makes air surveys highly inaccurate.

Urban Operations

Buildings provide a measure of protection against radiological contamination. Taking this into consideration, troops who must move in or through a suspected contaminated urban area should travel through buildings, sewers, and tunnels to reduce contamination risk. However, they should consider the dangers of collapse because of blast. They should also consider hazards of debris and fire storms resulting from ruptured and ignited gas or gasoline lines.

Blast

Most of the materiel damage and a considerable number of the casualties caused by an airburst result from the blast wave. For this reason, it is desirable to consider the phenomena associated with the passage of a blast wave through air.

The expansion of the intensely hot gases at extremely high pressures within the fireball causes a blast wave to form in the air, moving outward at high velocities. The main characteristic of the blast wave is the abrupt rise in pressure above ambient conditions. This difference in pressure with respect to the normal atmospheric pressure is called the overpressure.

Initially, the velocity of the shock front is many times the speed of sound. However, as the front progresses outward, it slows down and moves with the speed of sound.

The magnitude of the air blast parameters is dependent on the yield of the weapon, height of burst, and the distance from ground zero.

The blast wave may last from tenths of a second to seconds, depending on the yield and the distance from the burst. Weather, surface conditions, topography, and the type of operation being conducted all affect the blast wave.

Weather

Rain and fog may lessen the blast wave because energy dissipates in heating and evaporating the moisture in the atmosphere.

Surface Conditions

The reflecting nature of the surface over which a weapon is detonated can significantly influence the distance to which blast effects extend. Generally, reflecting surfaces, such as thin layers of ice, snow, and water, increase the distance to which overpressures extend.

Topography

Most data concerning blast effects are based on flat or gently rolling terrain. There is no quick and simple method for calculating changes hilly or mountainous terrain produce on blast pressures. In general, pressures are greater on the forward slopes of steep hills and are diminished on reverse slopes when compared with pressures at the same distance on flat terrain. Blast shielding is not highly dependent on line-of-sight considerations because the blast waves will bend or diffract around obstacles. The influence of small hills or folds in the ground is considered negligible for target analysis. Hills may decrease dynamic pressures and offer some local protection from flying debris.

Type of Operation

Temperature and terrain can also influence the effect of blast on tactical operations. The effects of cold weather and jungles or forests on operations follow.

Cold Weather Operations

At subzero temperatures, the radius of damage to material targets can increase as much as 20 percent. These targets include such items as tanks, APCs, artillery, and military vehicles. An increased dynamic pressure can result from a precursor wave over heat-absorbing surfaces. However, tundra, irregular terrain features, and broken ice caps break up the pressure wave.

Blast effects can drastically interfere with troop movement by breaking up ice covers and causing quick thaws. These effects can cause avalanches in mountainous areas. In flat lands, the blast may disturb the permafrost to such an extent as to restrict or disrupt movement.

Jungle or Forest Operations

Initial effects of nuclear detonations are not significantly influenced by the dense vegetation. However, the blast wave will probably cause extensive tree blowdown and missile effects. Forests, in general, do not significantly affect the overpressure but do degrade the dynamic pressure of an air blast wave.

Thermal Radiation

Thermal radiation results from the heat and light produced by the nuclear explosion. During a nuclear explosion, the immediate release of an enormous quantity of energy in a very small space results in an initial fireball temperature that ranges into millions of degrees. For a given type of weapon, the total amount of thermal energy available is directly proportional to the yield.

Within the atmosphere, the principal characteristics of thermal radiation are that it—

- Travels at the speed of light.
- Travels in straight lines.
- Can be scattered.
- Can be reflected.
- Can be easily absorbed.

The thermal effects will be influenced by weather, terrain, height of burst, and type of operation.

Weather

Any condition that significantly affects the visibility or the transparency of the air affects the transmission of thermal radiation. Clouds, smoke (including artificial), fog, snow, or rain absorb and scatter thermal energy. Depending on the concentration, they can stop as much as 90 percent of the thermal energy. On the other hand, clouds above the burst may reflect additional thermal radiation onto the target that would have otherwise traveled harmlessly into the sky.

Terrain

Large hill masses, forests, or jungles, or any opaque object between the fireball and the target may provide some protection to a target element. Trucks, buildings, or even another individual may protect an individual from thermal radiation. Foxholes provide good protection. However, personnel protected from direct line-of-sight radiation from the fireball may still receive thermal injury because of reflection from buildings or other objects. Good reflecting surfaces, such as water, snow, or desert sand, may reflect heat onto the target and intensify the thermal radiation effect. Even the backs and sides of open foxholes will reflect thermal energy. The reflective capability of foxhole materials varies from 8 percent for wet black soil to 93 percent for snow. Because of atmospheric scattering and reflections, thermal casualties may result at a greater range than casualties from other effects.

Height of Burst

The amount of thermal radiation that a surface target receives from a nuclear burst of a given yield will vary with the height of burst. The maximum thermal effect at the target will usually be produced by an airburst. A surface burst produces about half the amount of the thermal radiation that would be produced by an airburst because of the interaction of the fireball with the surface. Thermal radiation from a subsurface burst where the fireball is not visible is insignificant.

Type of Operation

Temperature and terrain can also influence the effect of thermal radiation on tactical operations. The effects of cold weather and mountains on thermal radiation follow.

Cold Weather Operations

The high reflectivity of ice and snow may increase the minimum safe distance as much as 50 percent for unwarned troops and even warned, exposed troops. Reflectivity may also increase the number of personnel whose vision is affected by the brilliant flash, or light dazzle, especially at night. The pale colors normally used to cover material in a cold weather environment give an advantage. Their low absorption properties may make personnel less vulnerable to thermal effects. Cold temperatures also reduce thermal effects on materials. Snow, ice, and even frost coverings on combustible materials greatly reduce the tendency of the materials to catch fire. However, thermal effects will dry out exposed tundra areas, and grass fires may result.

Mountain Operations

The clear mountain air extends the range of casualty-producing thermal effects. Within this range, however, the added clothing required by the cool temperatures at high altitudes reduces casualties from these effects.

APPENDIX A

Air Weather Service

The US Air Force Air Weather Service (AWS) provides operational weather service support, as described in AR 115-10 and AFR 105-3. A supporting Air Force weather unit will be assigned to all corps and divisions and to separate brigades, regiments, and groups on request. Assignment is subject to the following:

- When requested in peacetime in accordance with AR 115-12 and in wartime as stated in contingency, mobilization, and war plans.
- When it is jointly agreed that remote weather service will be inadequate.
- When consistent with jointly agreed tactical doctrine and operational support concepts.

Planning and executing a successful operation require timely and accurate weather information. To ensure prompt receipt of weather information and to ensure that both the meteorologist and the NBC officer understand what is required, close and continuous coordination is essential. The NBC officer should establish (through the intelligence officer) and maintain direct contact with the AWS detachment or staff weather officer (SWO) before, during, and after operations.

SWOs can provide the following services:

- Weather observations. Under field conditions, the SWO will not be able to establish a dense observational network. There will usually be areas of concern for which no observations are available. Therefore Army personnel should also be prepared to provide supplemental observations to the AWS weather unit. The SWO also should have access to observations and upper air soundings from artillery meteorological (arty met) units to further supplement weather collection efforts.
- Forecasting services. These services, which can vary considerably, are provided according to local arrangements with the SWO.
- Climatological data (weather history). This planning information can be obtained from the SWO. Those units without an SWO should obtain it from the USAF Environmental Technical Applications Center, Scott AFB, IL 62225 (see DA Pamphlet 115-1).

The dissemination of weather information within Army units is the responsibility of the intelligence officer. The AWS detachment or staff weather officer can supply information directly to the using agency, or the information can be routed through the intelligence officer for dissemination to staff and lower units. The intelligence officer determines the method to be used.

AWS operational support products are defined in terms of long-range planning (usually beyond 48 hours), mission planning (usually 24 to 48 hours), and execution support (usually 0 to 24 hours). For forecast periods in excess of five days, climatological analyses normally are provided. (NOTE: The forecast reliability decreases and the forecast provided becomes less specific as the forecast period increases. Significant changes or modifications may occur after the forecast is issued. The requestor must then inform the AWS facilities of the criteria for significant changes.

The following observation and forecast parameters and elements are normally available; however, additional products may be provided, depending on Army stated requirements and the AWS's ability to satisfy those requirements:

- Sky conditions, including amounts (tenths in CONUS and eighths overseas), type (according to standard classification), and cloud base height (in feet).
- Precipitation and / or obstructions to visibility, including intensity, type, and times of beginning and ending (in coordinated universal time and zone Z).
- Surface visibilities in statute miles and fractions.
- Surface wind direction and speed.
- Surface temperature.
- Temperatures and winds at desired standard levels above the surface.
- Humidity.

Prior to planning an operation, the target analyst should collect AWS climatic studies, other climatological data, and / or forecasts for the operational area valid for the time of the operation. To obtain maximum weather forecast assistance, the NBC officer must provide the AWS facility complete requirements as far in advance as possible. The request should include the following:

- Time period for the forecast and desired delivery time.
- Target or area to be covered by the forecast. Clearly identify an area by map coordinates, aerial photograph grid numbers, or established geographic boundaries.
- Special elements or conditions to be covered.
- Criteria for changes (amendments) in the forecast if desired.

If possible, supplementary forecast information should be obtained from the AWS facility prior to the release of agents when observations indicate the original forecast to be significantly in error; when the release time is appreciably delayed; or when, for any reason, the forecast requires updating.

The target analyst should also evaluate forecasts received. The analyst should use a detailed reconnaissance map, an aerial photograph, or a mosaic or study of the terrain and vegetation in and around these areas and those that might affect the behavior of the agents to be released.

After the operation, the NBC officer should pass to the intelligence officer, SWO, or AWS facility information on adequacy of support and any problems encountered. This information aids AWS forecasters in better tailoring future support.

Using agencies receive weather information in five general types of reports—weather forecasts, current weather observation reports, weather summaries, climatic summaries, and climatic studies.

A weather forecast is a prediction of weather conditions at a point, along a route, or within an area for a specified period. The accuracy and reliability of weather forecasts depend upon factors such as characteristics of the forecast area, age of the data available, reliability of weather communications facilities, length of the forecast period, state of meteorological science, and experience of the forecaster. The reliability and specificity of forecasts generally decreases as the forecast period increases. Also, the forecast becomes less specific as the forecast period increases.

Routine weather forecasts for use by troop units should be in plain language and should be as accurate as possible. Forecasts are Air Weather Service operational support products. These forecasts are defined in terms of long-range planning (usually beyond 48 hours), mission planning (usually 24 to 48 hours), and execution support (usually O to 24 hours). Figures A-1 and A-2 provide an example of a sample forecast containing information elements that could be provide by Air Weather Service or Fleet Weather Service and supporting artillery meteorological sources.

Current weather observation reports are oral, written, or graphic representations of existing weather conditions or specific weather elements. These reports are used in the operation of aircraft; in the employment of nuclear weapons, chemical agents, and smoke; and in other activities.

A weather summary describes the weather along a route or within an area during a specified recent period. Weather summaries are used in analyzing the effects of weather on recent operations. These summaries are also used in estimating the effects of weather on future operations.

Climatic summaries tabulate averages, extremes, and frequencies of weather elements or phenomena. These cover a specified period—a year, season, or month—and a given point, along a route, or within an area.

Climatic studies are analyses and interpretations of climatic summaries. Corps and higher headquarters usually prepare these studies. At the request of the intelligence officer, the supporting AWS unit prepares or obtains climatic studies on specific problems for given areas.

Care must be taken to understand the meanings of the technical terms used in this manual. Some of these terms have a strict technical definition that may be different from the definitions many laymen understand.

Field behavior of NBC agents and smoke depends upon weather variables, which are wind, temperature, vertical temperature gradients, cloud cover, humidity, and precipitation. Local topography, vegetation, and soil affects these variables. The cumulative effect of these variables

OPERATIONAL
NBC WEATHER FORECAST/OBSERVATION
(Available Data From Air Weather Service, Fleet Weather Service and Artillery Meteorological Sources)

1. Area forecasted — Date 16 Jan 86 — Time of forecast (T f) 1200Z
Division 82D
(Other)____________
____

	Time: T f	T f +3 hr	T f + 6 hr	T f + 24 hr
2. Wind (surface speed 5 knots)* Direction from (10° azimuth)*	05/360	10/360	15/290	10/270
3. Temperature gradient--stable, neutral, unstable (vertical between 1.0 and 4 meters)**	NEUTRAL	NEUTRAL	NEUTRAL	NEUTRAL
4. Height of inversion Bases and tops to 1,000 ft altitude**	6000	6000	6000	7000
5. Temperature (5°F at 1.0 meter level)*	70	65	65	60
6. Relative humidity (10%)	80	90	90	85
7. Precipitation (rain or snow) (light, moderate, heavy); depth of snow	LT RAIN	LT RAIN	LT RAIN	LT RAIN
8. Cloud cover (clear, scattered, broken, overcast) height: low (below 6,500 ft); middle (6,500 to 20,000 ft); high (over 20,000 ft)	LOW OVC	LOW OVC	LOW OVC	LOW OVC

9. Fallout winds (T f thru f + 6 hr) **
Direction and Speed
(10° and 5 knots)*
Altitude (1,000-ft units)

Feet		Meters	Feet		Meters
5	______	1.5	55	______	16.5
10	______	3.0	60	______	18.0
15	______	4.5	65	______	19.5
20	______	6.0	70	______	21.0
25	______	7.5	75	______	23.5
30	______	9.0	80	______	24.0
35	______	10.5	85	______	25.5
40	______	12.0	90	______	27.0
45	______	13.5	95	______	28.5
50	______	15.0	100	______	30.0

10. Height of tropopause 20,000 Feet/or__________Meters

* Rounded to the nearest increment

** AWS/FWS does not routinely provide this information. Artillery meteorological sections normally provide the upper wind data. The chemical downwind message (CDM) can also provide other weather information such as the air stability category.

Figure A-1. Sample forecast format (front).

NBC WEATHER PLANNING FORECAST

Valid (T f + 3 hr through T f + 24 hr): 860606 / 1500Z to 860607 / 1500Z
(date/time)

1. Surface wind
(same parameters as preceding format)

2. Vertical temperature gradient

Stable ( ) Neutral (X) Unstable ( )

Time: ____ / ____ / ____ / ____ / ____

3. Temperature

Maximum 70 °F at 860606 / 1500Z (Time); Minimum 60 / °F at 860607 / 1500Z (Time)

4. Relative humidity

Maximum 90 % at 860606 / 1500Z (Time); Minimum 85 % at 860607 / 1500Z (Time)

5. Cloud cover

Clear ( ) Scattered ( ) Broken ( ) Overcast (X)

6. Precipitation

No ( ) Yes ( ) Rain (X) Snow ( )

Beginning 860606 1500Z (Time) End 860607 1500Z (Time)

7. Fallout winds

Significant changes?

No (X)

Yes ( ), as follows:

(Direction and speed as in preceding format)

Feet		Meters	Feet		Meters
10	____	3.0	40	____	12.0
20	____	6.0	50	____	15.0
30	____	9.0	60	____	12.0

8. Height of tropopause 20,000 Feet/or ________ Meters

Figure A-2. Sample forecast format (back).

governs the required quantity and optimum type of chemical agent and smoke best suited to achieve operational objectives. Since weather governs the transport of chemical agents and smoke clouds, it is a primary factor in determining the effectiveness of a specific agent and the extent of the hazard area.

You must understand the basic principles governing weather and have access to accurate forecasts to be able to use chemical agents effectively or to defend against their use by the enemy. You must be capable of using the data provided in weather forecasts and predictions in preparation of plans and estimates. Appendix C discusses weather elements and primary weather factors in further detail for you to work with your forecaster on how best to employ chemical agents, smoke, and other obscurants, or defend against NBC agent use.

APPENDIX B

Units of Measure

This appendix lists the units of measure and their abbreviations commonly used in meteorology. It also contains factors for converting from one unit of measure to another.

	Unit of Measure	Abbreviation	Conversion Formulas
Temperature	Degrees Fahrenheit	°F	9/5 (°C) + 32 = 1.8 (°C) + 32
	Degrees Celsius (Formerly referred to as degrees centigrade)	°C	5/9 (°F - 32) = .556 (°F - 32)

	Metric	Abbreviation	US Equivalent
Length	kilometer	km	1,000 m = .62 mi
	meter	m	1,000 mm = 100 cm = 39.37 in
	centimeter	cm	10 mm = .39 in
	millimeter	mm	.001 m = .04 in
	statute mile	mi	5,280 ft
	nautical mile	naut mi	1.15 mi = 1,852 m
	yard	yd	.9144 m
	foot	ft	30.48 cm
	inch	in	2.54 cm

	Unit of Measure	Abbreviation	Conversions
Velocity	kilometers per hour	kmph	1 knot = 1.84 kmph = 1.15 mph = .514 m/sec
	meters per second	m/sec	1 mph = .447 m/sec = .87 knot
	nautical miles per hour	knots	
	statute miles per hour, or miles per hour	mph	
	feet per second	ft/sec	

	Unit of Measure	Abbreviation
Pressure	atmosphere	atm
	pounds per square inch	psi
	millibars	mb
	inches of mercury	in Hg
	centimeters of mercury	cm Hg
	kilopascal	kP
	grams	gm
	kilograms	kg
	milligram-minutes per cubic meter	mg-min/m^3

APPENDIX C

Weather

Field behavior of NBC agents, smoke, and other obscurants depends upon weather variables, which are wind, temperature, vertical temperature gradients, humidity, and precipitation. The influence of each variable depends upon synoptic or general weather conditions. Local topography, vegetation, and soil affect these variables. Weather also determines the effectiveness of agents and possible downwind hazards.

This appendix discusses weather elements and primary weather factors in further detail for you to work with your forecaster on how best to employ chemical agents, smoke, and other obscurants or to defend against NBC agent use.

Elements

This section will outline several basic weather elements that must be understood. The weather elements discussed will include the atmosphere, wind speed and direction, atmospheric turbulence, air and surface temperatures, humidity, dew point, clouds, precipitation, and atmospheric stability. In this section, each element will be discussed to provide the needed background information for the NBC staff officer.

Atmosphere

The sun is the fundamental source of energy for the earth and its atmosphere; its influence is felt in the radiant energy that is the basic source of heat to the atmosphere. The spherical shape of the earth causes the unequal absorption of this energy by the earth's surface and the atmosphere. The unequal heating results in a strong poleward transport of heat from the equator. Without the transport of heat by the atmosphere and the oceans, temperatures would be much colder at the poles and much warmer in equatorial regions.

A revolution of the earth around the sun takes one year or 365-1/4 solar days. Every fourth year is 366 days long, hence leap year. The revolution of the earth about the sun is associated with four seasonal changes. If the plane of the earth's orbit were in the plane of the equator, there would be only a small seasonal change. Figure C-1 shows an explanation of the four seasons. A season is one of the four quarters into which the year is divided. Figure C-1 shows that the earth wobbles (is inclined) at an angle of approximately 23-1/2 degrees north and south from the equator. This wobble and revolution (tilt and movement) around the sun are responsible for the four seasons. The winter solstice (Tropic of Capricorn) occurs when the sun, with respect to the earth, is farthest south. Conversely, the summer solstice (Tropic of Cancer) occurs when the sun is farthest north. The two points midway between the solstices occur on the equator two times each year when the sun crosses the equator. Day and night everywhere are equal in length. These are known as the spring and autumnal equinoxes (about 21 March and 23 September). A year is divided into 12 months (or one-twelfth of a year). A month equals four weeks or 30 days. A season is composed of 91-1/4 days.

The atmosphere is the envelope of air that surrounds the earth and is bound to it by the earth's gravity. The atmosphere extends from the solid and liquid surfaces of the earth to an indefinite height. It may be subdivided vertically into a number of layers. The most common subdivision divides the atmosphere into a troposphere from the surface to about 10 to 20 kilometers, a stratosphere which extends to about 80 kilometers, and the ionosphere above that height. Each of these layers may be further subdivided.

In tropical latitudes, the troposphere extends from the surface to a height of 15 to 20 kilometers. In polar regions, it may be as low as 10 kilometers. The troposphere also contains about three-quarters of the atmospheric mass. It also contains nearly all of the atmospheric water vapor. Most

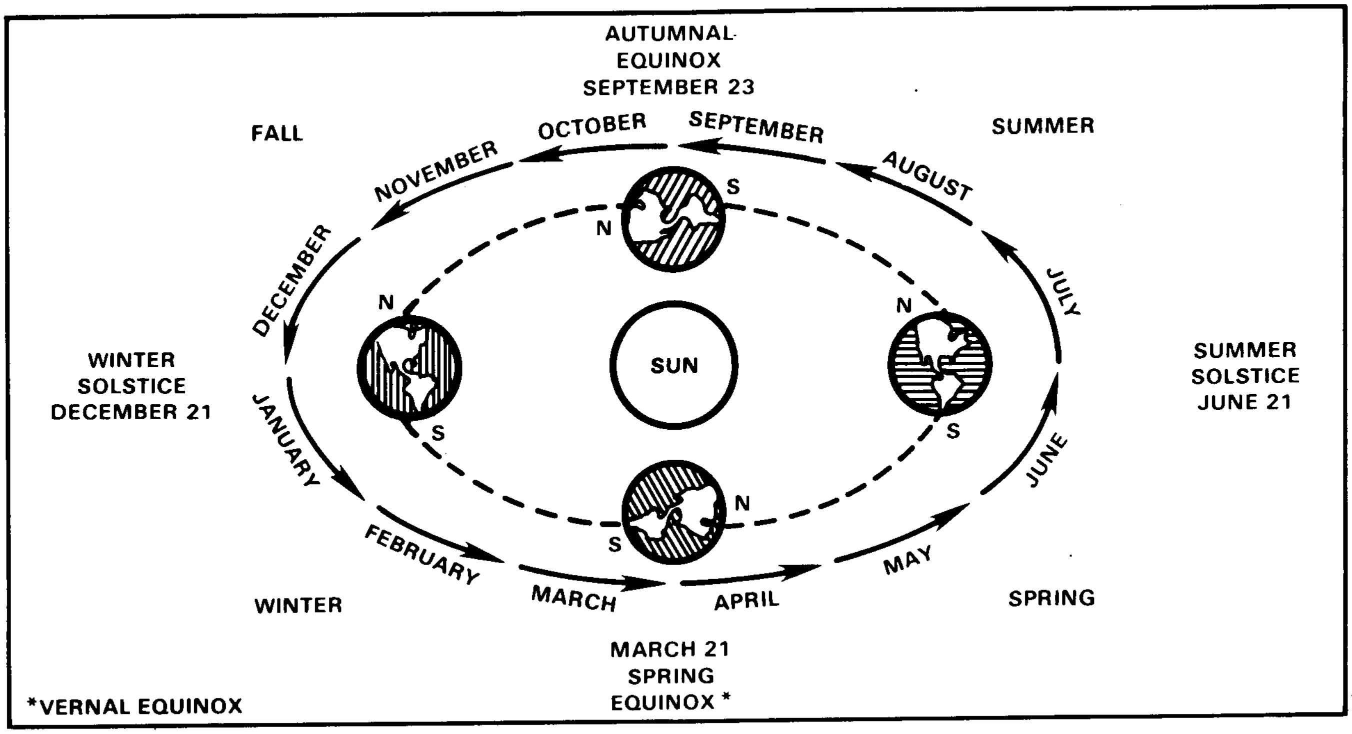

Figure C-1. Revolution of the earth and the seasons.

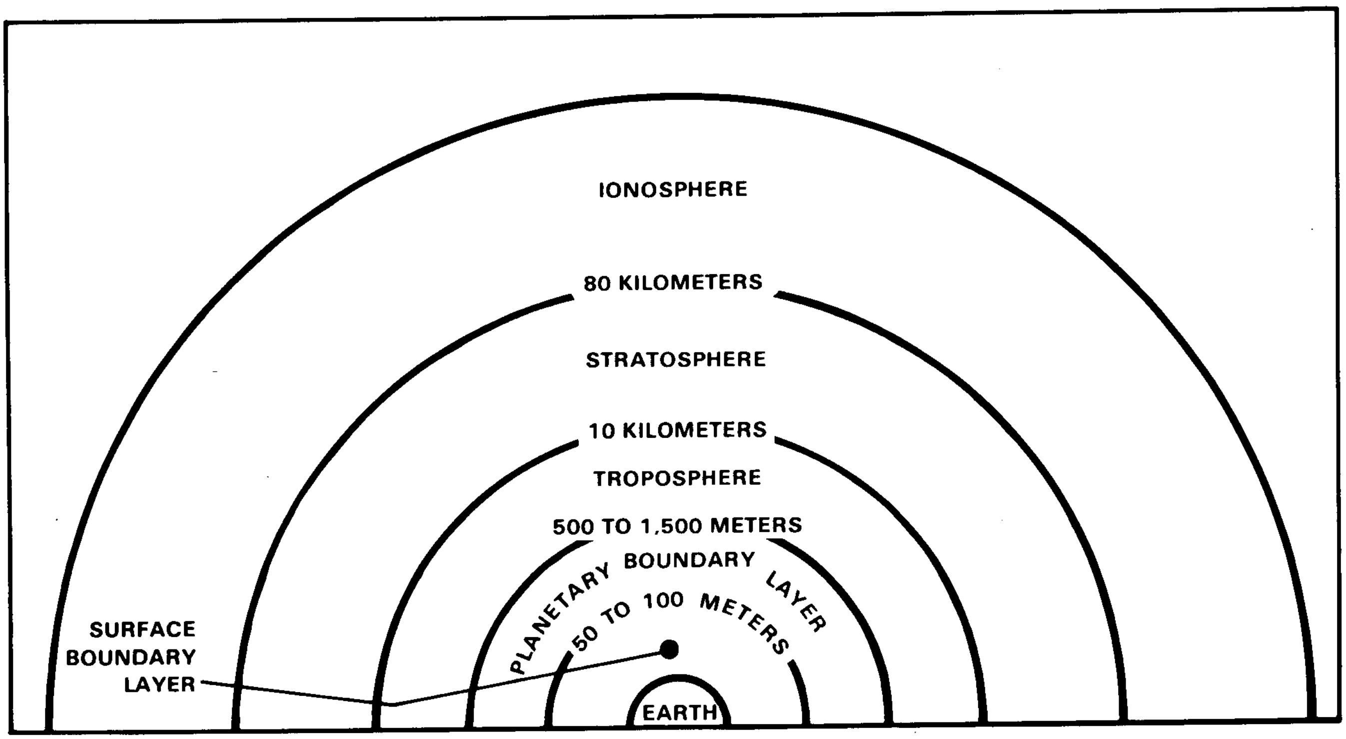

Figure C-2. Layered structure of the atmosphere.

weather events are associated with the troposphere. The troposphere or "region of change" can be characterized by decreasing temperature with height, increasing wind speed with height, and considerable vertical wind motion. Weather changes in the troposphere are a function of the seasonal changes and the poleward transfer of heat. The troposphere may be subdivided into three vertical zones. These zones are the surface boundary layer, the planetary boundary layer, and the free atmosphere. The surface boundary layer extends from the air-earth interface to a height of 50 to 100 meters. The planetary boundary layer extends to heights of 500 to 1,500 meters over fairly level terrain and may be as thick as 3,000 meters over mountainous regions. Above the planetary layer is the free atmosphere. Figure C-2 illustrates the layered structure of the atmosphere.

The surface boundary layer and the planetary boundary layer—also known as the friction zone or Ekman layer—are of primary concern for NBC operations. Nearly all releases of chemical agents and smoke will be near the surface or within the bounds of the surface and planetary layers.

The following paragraphs discuss many of the characteristics of the surface and planetary boundary layers with respect to NBC and smoke operations.

Wind Speed and Direction

Wind is air in motion with respect to the surface of the earth. Vertical components of atmospheric motion are relatively small near the surface. Therefore, the term “wind” is used almost exclusively to define the horizontal speed and direction. NBC agents, smokes, and other obscurants, either deliberately or inadvertently released into the atmosphere, will travel downwind, that is, they will move in the general wind direction. Therefore, you must understand how the air moves in a given situation to be able to predict the dispersion behavior of agents. You need to understand how topography can affect the mean airflow near the surface. You should understand how obstacles such as buildings, hills, trees, and other vegetation generate gusts, updrafts, and downdrafts downwind of the obstructions. Also, you need some basic knowledge of the mean airflow within forests and other vegetative canopies.

The large-scale circulation of the atmosphere is driven by solar heating and radiation cooling and is affected by factors such as topography. Above the surface and planetary layers, large-scale air movements are determined by the general heat balance of the earth. Air is heated from below in the equatorial regions. It rises, loses heat near the poles, and sinks. Figure C-3 shows the general

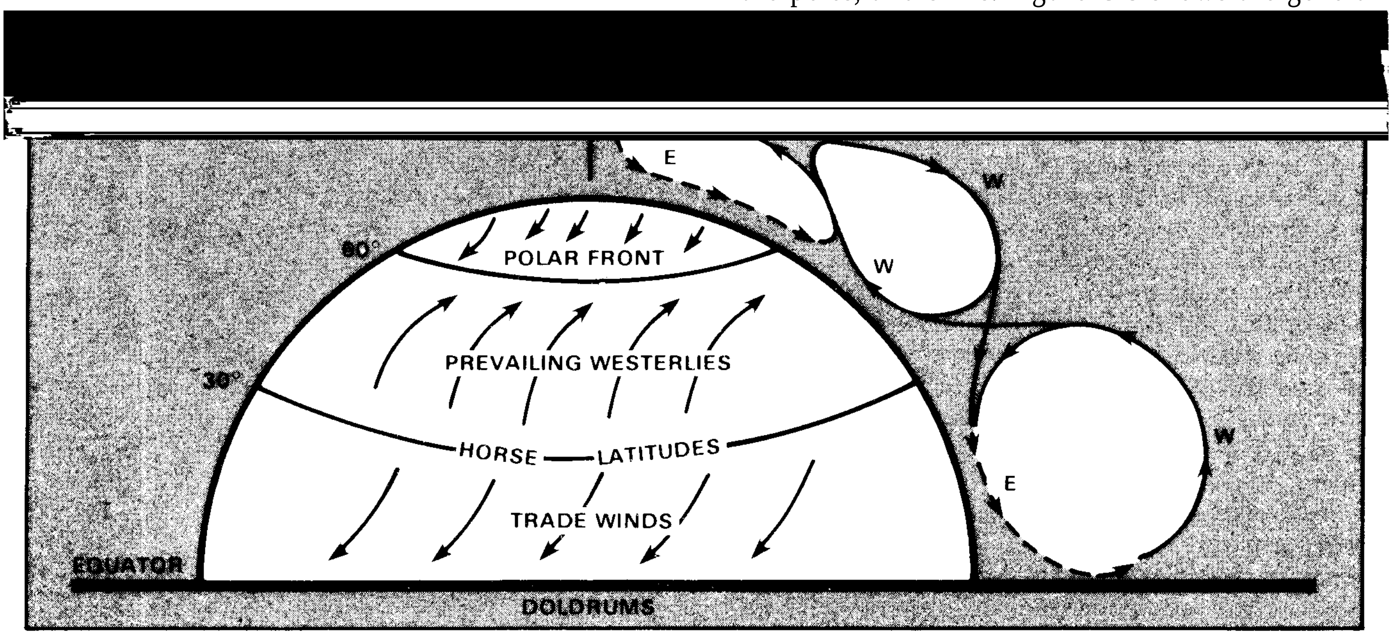

Figure C-3. General horizontal and vertical circulation, northern hemisphere.

circulation of the atmosphere on a rotating earth. In the temperate latitudes, observations show that the surface winds tend to blow from southwest to northeast. In polar latitudes, surface winds generally blow from northeast to southwest. The region between the polar and tropical air masses is the spawning ground for major mid-latitude storms. These storms generally move from west to east. They assist in transporting cold polar air southward and force the warm tropical air to rise and move northward.

It is important to know how wind direction is recorded and reported. Wind direction is the compass direction from which the wind blows. The normal flow of air is not steady. The direction will fluctuate about its mean value, randomly deviating from the prevailing direction. These fluctuations are usually larger in light wind conditions (5 knots or less) than with higher wind speeds. The basic principles governing wind change and how to interpret wind directions are important for the NBC staff officer to understand.

The US Air Force Air Weather Service meteorological forecasts for NBC operations give the direction from which the wind blows to the nearest 10 degrees measured from true north. Winds-aloft reports and aviation forecasts of upper winds also give the direction from which the wind blows to the nearest 10 degrees.

Field artillery ballistic meteorological (met) messages follow the form outlined in FM 6-40 and FM 6-15. Both field manuals give wind directions in increments of artillery mils. One degree of compass direction is equal to approximately 17.8 mils, or 360 degrees equal 6,400 mils. A ballistic met message lists direction to the nearest 100 mils, or about 5.5 degrees. For the recently adopted Standard Biological and Chemical Meteorological Message Quadripartite Standardization Agreement (QSTAG 388 and STANAG 2103), wind directions are reported to the nearest 10 mils measured from true north. In radioactive fallout and computer meteorological messages, direction is also in tens of mils. Line O of these messages refers to a surface value that may not be representative. For the ballistic met message or the computer message, line 1 gives the average wind for the lowest 200 meters of the atmosphere. Line 1 of the fallout message is for the lowest 2,000 meters of the atmosphere. An example of a fallout wind message is in Table C-1.

Table C-1. Fallout wind message.

WIND LAYER (10^3 meters)	WIND DIRECTION (mils)	WIND SPEED (knots)
0-2	1,240	9
2-4	1,420	13
4-6	1,600	18
6-8	1,780	13
8-10	1,960	9
10-12	2,310	9
12-14	2,850	13
14-16	3,200	13
16-18	3,560	18
18-20	3,740	14
20-22	3,820	18
22-24	3,910	27
24-26	3,910	26
26-28	3,910	34
30-Balloon Burst		

Figure C-4 shows the relationships governing the two basic methods of reporting wind directions. The figure also includes the generic method. This consists of the four major and four

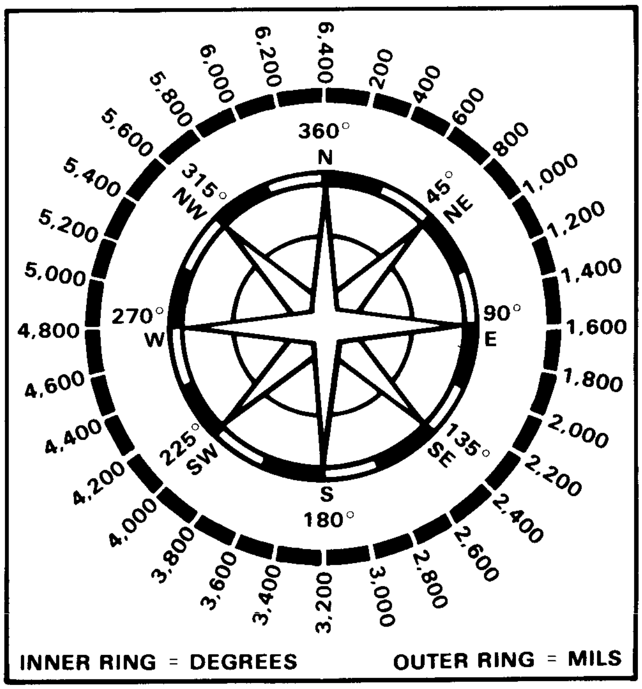

Figure C-4. Designating wind direction by compass points, degrees, and mils.

intermediate points of the compass, that is, north, northeast, east, southeast, south, southwest, west, and northwest.

Surface wind speeds and directions at any specific locale are caused by many factors and forces operating in the atmosphere. Wind speed and direction can be considered to be local phenomena and must be measured directly or observed to be useful for NBC operations and dispersion predictions.

Atmospheric Turbulence

Dispersion of NBC agents and screening smokes in the surface and planetary layers can be directly attributed to atmospheric turbulence. The interaction of weather systems on all scales at any locale results in a three-dimensional wind that varies continuously with time. These continuous fluctuations are defined as turbulence. Atmospheric turbulence results from four factors. These are (1) the mechanical or drag effects of objects such as vegetation, hills, and man-made structures protruding into the airstream; (2) the vertical rate of increase of wind speed plus the turning of the wind with height; (3) the vertical temperature structure of the atmosphere; and (4) the relative moisture content.

If the ground is rough, mechanical turbulence (Figure C-5) results, since the air passing over it rises and falls with the terrain relief or flows around obstacles, generating both vertical and horizontal turbulence. This turbulence is greater with high wind speeds because of the increase of drag. It also decreases with height.

The wind increases in speed and shifts in direction from the surface to the top of the planetary layer. This change of speed and direction with height is known as wind shear.

Atmospheric turbulence also depends upon the vertical temperature gradient. If air is carried upward, air pressure decreases, its volume increases, and there will be a corresponding decrease of temperature. If there is no exchange of heat between the ascending parcel and its surrounding environment, the process is labeled adiabatic.

There are four basic vertical temperature gradient conditions. These are adiabatic, superadiabatic, inversion, and isothermal.

Adiabatic conditions are an idealized state for the earth's atmosphere. The adiabatic lapse rate for such an atmosphere is a temperature decrease with height of 9.8°C per 1,000 meters.

If an ascending parcel of air arrives at some specified height warmer than its environment, then it will continue to rise. An ascending parcel that rises and is cooler than the surrounding air when the lifting process ceases will sink back to its original level. These two processes are known as thermal or static instability and stability, respectively.

If the air next to the ground during the daylight hours is heated by contact with the surface and by conduction until it is warmer than the air above, a heat-energy gradient exists

Figure C-5. Mechanical turbulence.

upward through the atmosphere. The warmer air tends to rise (see Figure C-6). Thus, there is a net upward flow of heat. This is known as convective turbulence. The larger the heat gradient, the greater the rate of convective mixing. Hence, the turbulent transfer is greater.

At night, mechanical turbulence is the dominating feature of the mean wind flow. At night, heat is extracted from the air and transferred to the ground. The cooling of the air next to the surface results in a temperature inversion, that is, an increase of temperature with height. The net result is an absence of buoyant motion or convective turbulence. Under inversion conditions, the mean wind flow shows a tendency to approach nonturbulent flow conditions.

On occasion, a layer of air will exhibit no temperature change with height. This is known as an isothermal condition. During the daylight hours, particularly in the first 100 meters or so of the atmosphere, lapse rates greater than adiabatic will exist. These are termed as being superadiabatic.

Knowledge of the vertical distribution of temperature is particularly important to NBC operations. The height above the ground to which an inversion exists is an important factor for determining the concentration or dosage of chemical agents. In addition, surface-based inversion heights or the height of elevated inversions plays an important role with respect to aerial spray releases or other elevated releases of agents. Dissemination above an inversion layer can result in little if any agent reaching the surface and/or a particular target area.

Atmospheric turbulence is the prime factor controlling the dispersion of NBC agents or screening smokes released into the atmosphere. Extreme turbulence dilutes an expanding puff or plume quite rapidly. Effective downwind distances are thus reduced drastically. You must remember that the most effective use of NBC agents and/or smoke will be in periods when turbulence is low and wind speeds are moderate.

Air and Surface Temperatures

Air temperature is the ambient temperature measured at about 1.5 meters above the surface. Ground temperature for NBC operations is the temperature of the surface(s) on which the agents come to rest. Ground temperatures may be many degrees warmer or cooler than the air temperature. The difference depends on the amount of radiational heating or cooling at the surface. Surface temperatures play a major role in how long liquid contamination on the surface is effective and how concentrated the vapor is above the liquid. Air temperature varies the rate of evaporation of liquid droplets in the atmosphere. Forecasts for NBC operations, therefore, should

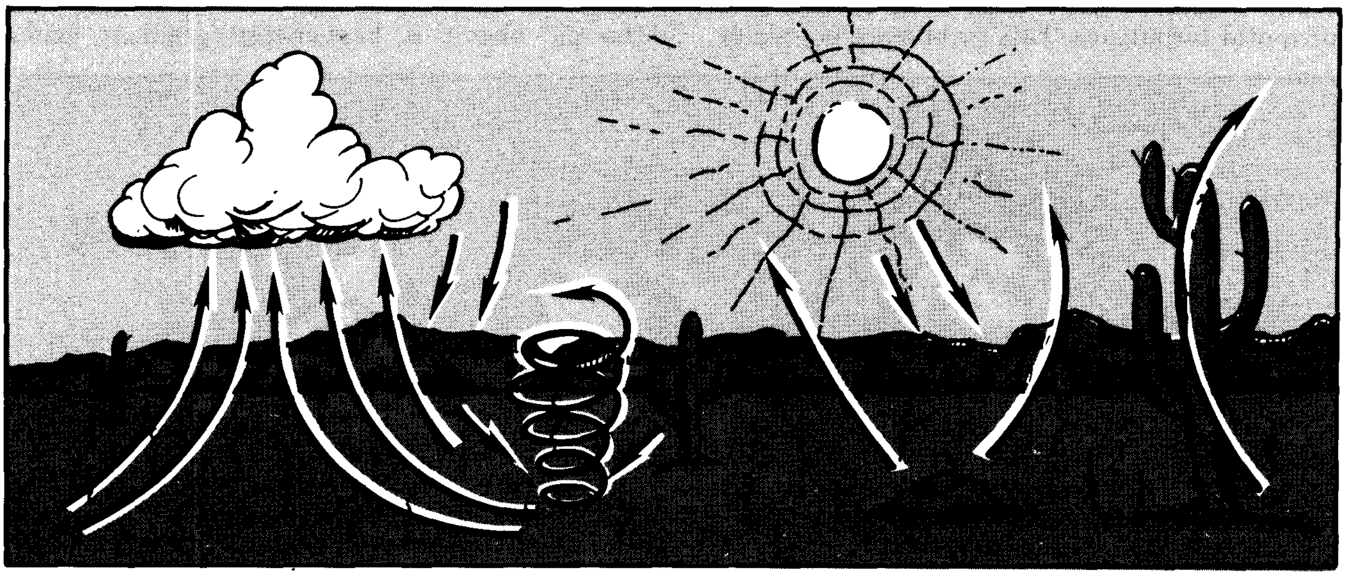

Figure C-6. Thermal turbulence.

include predicted temperatures to the nearest 3°C for air, soil, or water surfaces.

Humidity

In general, humidity is a generic term indicating a measure of the water vapor content of the atmosphere. Popularly, it is interpreted to be the same as relative humidity. Relative humidity expresses the percentage of water vapor actually contained in the air as compared to how much it would contain if saturated at the same temperature and pressure.

The surface and planetary boundary layers contain about half of all the atmospheric water vapor. Water vapor is one of the most important parts of the atmosphere. The amount in the air varies widely because of the great variety of sources of evaporation and "sinks" (condensation sites) that contribute to the hydrologic cycle. Water vapor is not only the raw material for clouds and rain; it also affects the transport of heat energy.

In warm air, high relative humidities indicate a large water vapor content. When air temperatures are low, high relative humidities do not indicate large water vapor contents, since cold air cannot hold as much water vapor as warm air.

For example, blister agents are more effective when both temperature and relative humidity are high. When the water vapor concentration is higher, people perspire more freely and skin becomes more sensitive to the effects of blister agents. Humidity is also an important consideration for use of smoke obscurants. The chemical smokes—hexachloroethane (HC), white phosphorus (WP), and red phosphorus (RP)—are aerosols that absorb water (hydroscopic) vapor from the atmosphere. As smoke particles absorb water vapor, this increases the screening power of the obscuring aerosols. For example, WP smoke screen effectiveness increases by at least 1/3 if the relative humidity increases from 30 to 50 percent.

Dew Point

Dew point is the temperature to which air must be cooled at constant pressure for it to become saturated. The dew point is convenient as an approximate measure of the water vapor present in the air. For example, if the air temperature is 16°C and the dew point is 10°C, the atmosphere would become saturated if the temperature fell to 10°C. As the temperature approaches the dew point, condensation occurs. Dew is one form condensation can take. When the difference between the temperature and the dew point is 2°C or less, fog will likely form. Forecasts for NBC operations should also include the dew point.

Clouds

Cloudiness is another variable that can influence the weather near the ground. If the sky is overcast, the amount of incoming solar radiation reaching the ground is greatly reduced. Effects on surface air temperatures and lapse rates also vary with the degree of cloudiness.

Classification of clouds is based on their form, appearance, and height. The following is a classification of clouds according to their height above ground.

Low clouds	2,000 meters
Middle clouds	2,000 meters to 6,000 meters
High clouds	6,000 meters and higher
Clouds of vertical development	500 meters to highest cloud level

Cloud coverage is the portion of the sky covered by clouds. Coverage is observed and forecast in eighths except in the United States where it is reported in tenths. For most purposes, the descriptions in Table C-2 will suffice.

The thickness of a cloud layer is estimated visually. Thin clouds are those through which the outline of the sun or moon can be seen. Thick clouds obscure the sun and look especially dark when the sun is behind them.

Persistent overcast low clouds usually indicate a neutral condition and small diurnal (daily) variations in weather factors near the ground.

Broken low clouds generally indicate a weak to moderately unstable (lapse) condition during the day and a weak to moderately stable (inversion) condition at night.

Thick, overcast middle clouds generally produce the same neutral conditions as overcast low clouds.

Broken middle clouds usually permit a moderate lapse (unstable) condition during the

Table C-2. Descriptions of cloud coverage.

SKY DESCRIPTION	SKY COVERAGE	INTERPRETATION EFFECTS ON AIR TEMPERATURE AND STABILITY
CLEAR	Less than 1/10 (or 1/8)	Few clouds; sunny day indicative of convective turbulence. Stable, cool nighttime conditions.
SCATTERED	1/10 to and including 5/10 (or 1/8 to and including 4/8)	Cloud effects disregarded if only high clouds present. For other cloud types, little effect upon air temperature or stability.
BROKEN	6/10 to and including 9/10 (or 5/8 to and including 7/8)	Usually smaller than average daily range in temperature. Predictions based upon rate of change indicated in recent reports, modified by the major tendency for rising temperatures until approximately 1400 hours, and decreasing temperatures in the evening and during the night.
OVERCAST	9/10 (or 7/8) to 10/10 (or 8/8)	Atmosphere probably moderately stable or neutral. Make temperature prediction from the trend indicated in the weather reports.

day and a moderate inversion (stable) condition at night.

High clouds, whether overcast or broken, tend to indicate a moderately unstable (lapse) condition during the day and a moderately stable (inversion) condition at night. High clouds are usually of low density and have a limited impact on incoming solar radiation.

Scattered clouds of all types and heights generally indicate a moderate to strong lapse (unstable) condition during the day and a moderate inversion (stable) condition at night.

A clear sky indicates a strong lapse (unstable) condition for most of the day and a strong inversion (stable) condition for most of the night if the surface wind is light or calm.

Weather clouds have no direct effect on chemical vapor or aerosol clouds, but they alter the temperature and stability categories.

Clouds have significant vertical development when their bases form at anywhere from a few hundred to 3,000 meters and extend upward from their bases to as high as 20,000 meters. Vertical development clouds originate from lapse (unstable) conditions beneath them. Under this type of cloud—regardless of its thickness or sky coverage—the temperature gradient may vary considerably. In general, vertically developed clouds over operational areas indicate that a chemical operation must contend with an unfavorable temperature gradient and turbulence. Additionally, when clouds have significant development there is strong likelihood of rain showers.

NOTE:
The AWS routinely reports cloud heights in feet and wind speeds in knots. However, cloud heights may also be reported in meters by other nations. However, kilometers per hour or miles per hour may also be used.

Precipitation

Rain and snow influence NBC operations and must be considered. Precipitation results when cloud droplets or ice crystals grow large enough to fall. It is usually accompanied by neutral or unstable conditions.

Heavy rains or snows reduce the effectiveness of agent clouds by diluting or washing chemical vapors or aerosols from the air, vegetation, and material. Air Weather Service synoptic weather forecasts predict the types, amounts, intensities, and general beginning and ending times of precipitation.

In tropical regions, afternoon showers tend to occur at about the same time each day. This tendency may also be influenced by seasonal factors, such as the monsoons. Such regularity is not common in temperate regions.

Precipitation causes some chemical agents to hydrolyze or to break down into less harmful compounds. Therefore, the amount of precipitation and the hydrolysis rate of some chemicals must be taken into account when considering the use of some chemical agents.

Atmospheric Stability

The criterion for describing the state of the atmosphere consists of dividing stability into three categories-stable (inversion), neutral, and unstable (lapse). Stable conditions are usually a nighttime condition that is assumed to exist from an hour before sunset to an hour after sunrise. The daylight hours from an hour after sunrise to an hour before sunset are presumed to be unstable. Neutral conditions are normally associated with high wind speeds greater than 15 knots or overcast sky conditions for all wind speeds, day or night. The atmosphere also tends toward neutral conditions at sunrise and sunset.

Determination of stability categories is based on the relationships between surface wind speed, incoming solar radiation, vertical transfer of heat in the surface and planetary boundary layers, cloud cover, and the time of day.

On a battlefield, NBC operations may be conducted without the benefit of forecasts or measured surface winds. As a contingency for unavailable wind information, the Beaufort wind

Table C-3. Beaufort wind scale.

BEAUFORT NUMBER (FORCE)	MEAN WIND SPEED, KNOTS	WIND SPEED RANGE, MPH	DESCRIPTION OF WIND	SPECIFICATIONS FOR USE ON LAND
0	0	0-1	Calm	Calm; smoke rises vertically.
1	2	1-3	Light air	Direction of wind shown by smoke drift, but not by wind vanes.
2	6	4-7	Light breeze	Wind felt on face; leaves rustle; ordinary vane moved by wind.
3	11	7-12	Gentle breeze	Leaves and small twigs in constant motion; wind extends light flag.
4	16	13-18	Moderate breeze	Raises dust and loose paper; small branches are moved.
5	22	19-24	Fresh breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	29	25-31	Strong breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	36	32-38	Moderate gale	Whole trees in motion; inconvenience felt when walking against wind.
8	44	39-46	Fresh gale (or gale)	Breaks twigs off trees; generally impedes progress.
9	52	47-54	Strong gale	Slight structural damage occurs (chimney pots and slate removed).
10	60	55-63	Whole gale (or storm)	Seldom experienced inland; trees uprooted; considerable structural damage occurs.
11	69	64-72	Storm (or violent storm)	Very rarely experienced; accompanied by widespread damage.
12 or above	70 and above	73 and above	Hurricane *	Devastation occurs.

*The US uses 74 statute mph as the speed criterion for a hurricane.

scale may be used to estimate wind speeds and is given in Table C-3. The scale provides an estimate of mean wind speed, an associated range about the mean, and a description of the observed wind effect upon easily recognized features of a landscape, such as tree leaves and limbs. Table C-3 is easy to use, even by the inexperienced. It is based on a description of wind conditions and the general specifications for use on land.

Factors

This section outlines factors that must be considered for the analysis of NBC operations. Assessing some of these factors will be difficult under combat conditions because of the probability of very limited observations and intelligence concerning the battlefield and the target area.

The primary factors affecting a forecast are the synoptic (general weather) situation, climatology, topography, vegetation, and soil. In this section, each factor is discussed in relation to its influence on forecasting wind, temperature, relative humidity, and the stability category. All of these must be known in planning NBC and smoke operations. The forecaster needs hourly information about these factors. This person uses this information for analysis, applying established principles.

Some of these principles are described basically in this manual, but they encompass a large part of the whole field of meteorology. Only a trained meteorologist can be expected to understand and fully exploit these principles properly. However, under combat conditions, anyone making a weather analysis must try to collect information on the following items:

- Current general weather (synoptic) situation in the target area.
- Current upper air soundings close to or representative of the target analysis. This information normally comes from artillery meteorology sections. These sections at division and higher echelons transmit upper air data to the nearest AWS detachment.
- Current surface winds in the target area.
- Topography in and around the target area.
- Times of sunrise and sunset.
- Vegetation.
- Types of soil at the target.

The first three factors are constantly changing. The last four factors are relatively constant.

Synoptic Situation

The synoptic situation is the general weather situation over an extensive area. Normally, knowledge of the synoptic situation comes from observations taken at or near the same time to afford an accurate overall picture of weather conditions. You usually receive this information in a synoptic situation map. (See an example in Figure C-7.)

In tropical areas and often in summer in the mid-latitudes, the synoptic situation changes so little or so slowly from day to day, and the sky is so often clear, that the diurnal (daily) weather variations account for much of the weather and are useful in forecasting. However, in the colder seasons of the mid-latitudes, marked day-by-day changes in synoptic situations and weather are

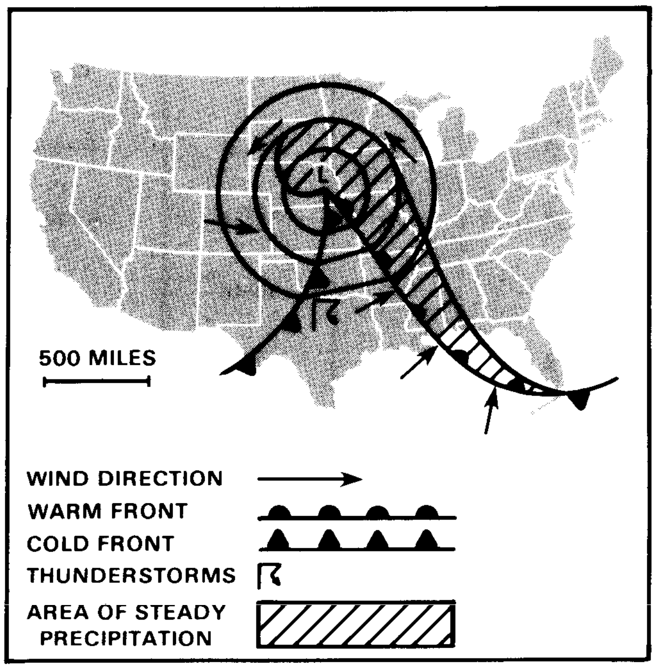

Figure C-7. Synoptic weather map.

the rule. These changes tend to obscure any daily pattern to weather elements.

Estimating changes in the general weather situation is feasible by using only local observations. It is possible to draw conclusions about changing conditions with only a general knowledge of weather prediction. For example, if the weather has been dominated by high pressure (clear skies with light winds), a trend (in the northern hemisphere) to falling pressure; rising winds from the northeast, east, and southeast; and high clouds lowering to middle or low overcast will indicate a storm or disturbance (low pressure system) is approaching and steady rain or snow may be expected in a few hours. A frontal passage followed by clearing skies and much colder air over the region is generally preceded by low overcast skies, precipitation, southerly winds, low pressure, a wind shift to the west or northwest, falling temperature, and rising pressure.

Wind speed, temperature, vertical temperature gradient, and percent of relative humidity normally follow typical day-night (diurnal) patterns as presented in Figure C-8. In Figure C-8 each vertical line represents two hours of time— between midnight to noon or noon to midnight. Low-level wind speeds experience diurnal variations (Figure C-8, A), There is a well-defined maximum wind speed in the afternoon at about the time of maximum lapse. The minimum wind speed, which is not so well-defined, occurs sometime during the night and continues until about sunrise, when the cycle begins again. Actual wind speeds, even when a diurnal variation is evident, vary with the synoptic situation, topography, and vegetation.

There is no diurnal change in wind direction except in valleys and in coastal areas where valley winds or land and sea breezes may influence wind direction and / or speed at certain hours.

Wind speed and direction may change with height. A contaminated cloud (released aloft or at the surface) will be acted upon by the winds in each layer as it passes through that layer. To predict the location and extent of the downwind hazard area, the effects of the wind must be considered within each layer as the material travels to the surface. The final hazard area characteristics (size, concentration, and cloud continuity) are determined by the collective action of each layer through which the cloud passes. (See Figure C-9 for an exaggerated example of this effect.)

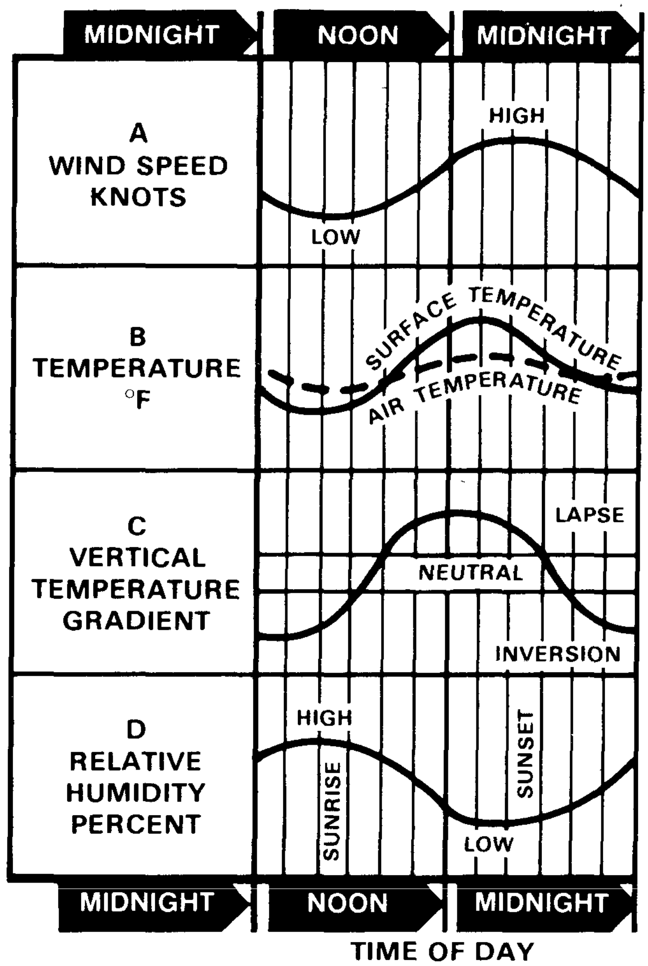

Figure C-8. Normal diurnal variations in weather conditions with reference to local times of sunrise and sunset.

Variations in wind speed and direction determine the lateral spread of a chemical agent cloud. The greatest lateral spread will occur under light wind conditions, because the wind direction is more likely to fluctuate at low wind speeds than high wind speeds. Lateral spread may approach 50 percent of the downwind distance the chemical cloud travels. With steady winds, lateral spread may be only about 15 percent of the distance traveled. Under average conditions, lateral spread is about 20 percent of the distance traveled.

Vertical temperature gradients are functions of the synoptic situation, cloudiness, and wind speed. With clear skies and light winds, strong inversion (at night) and lapse (during the day)

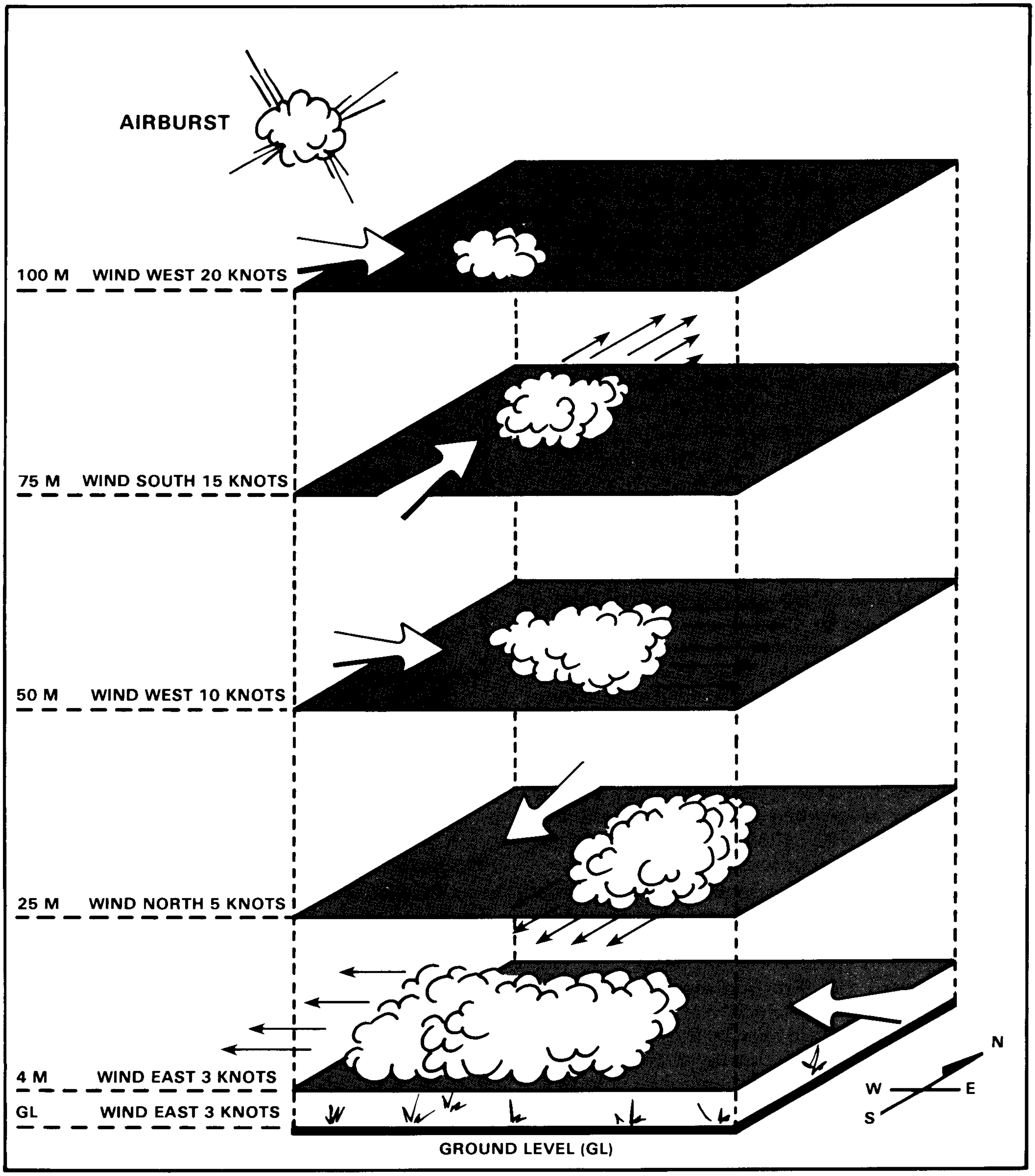

Figure C-9. Vertical wind distribution and its influence on the downwind hazard area at the surface (assumes inversion condition and little turbulence).

conditions exist in the surface and planetary boundary layers.

Overcast skies indicate only a weak inversion at daybreak, with midday temperature gradients reaching values of only 1/5 to 1/4 as great as with clear skies. At night a gradient may form that will be only 1/10 that formed under clear skies.

With partly cloudy skies, temperature gradients are between the just-discussed 1/10 extremes. The temperature gradient is unaffected by cloudiness up to 3/10. With sky cover of 4/10 to 6/10, temperature gradients decrease by amounts of 1/10 to 1/5. With sky cover of 7/10 to 9/10, temperature gradients reduce by 1/5 to 1/2 of the values for clear skies.

There is a large diurnal variation in the type and degree of temperature gradient (Figure C-8, C). The variation is least in winter and decreases with increased cloudiness. In winter with overcast skies, the temperature gradient is substantially neutral throughout the day and night. When the ground is covered with snow or ice, an inversion is more probable than a neutral condition, and a lapse condition is rare regardless of clouds and time of day. The latter is especially true in polar regions.

As the wind speed increases, the strength of the inversion decreases. Ground inversions do not exist in winds over about 20 knots. Strong wind speeds tend to erase vertical temperature gradients at the surface. Strong lapse rates (unstable conditions) can result in variable and gusty winds.

Over the sea, diurnal variation in temperature gradients near the surface is almost absent. This is because of the sameness of the sea surface temperature at a given location.

In mid-latitudes, neither very stable nor very unstable conditions exist with precipitation. This may not be true in tropical or polar regions. With the formation of ground fog, a neutral or weak inversion condition is most probable in the lower layers.

The stability of the air layer above the surface boundary layer does not always indicate the temperature gradient in the lower layer. It is not possible to predict lapse conditions in the lower layer from observation or forecast strong lapse conditions aloft without considering the factors of wind, clouds, and ground temperature. A strong wind tends to stir up any stable air near the ground and thus destroys or prevents formation of an inversion. A light wind favors the formation of inversions. Upper air soundings or radiosondes are thus very useful in forecasting weather.

The intelligence section furnishes the reported surface air temperatures. There is a pronounced diurnal trend of this temperature. The minimum temperature occurs just before dawn and the maximum in the early afternoon. The daily range in temperature increases in the lowest layer; thus, the greatest diurnal variation occurs at the surface of the earth.
The diurnal range of temperature may be as great as 55°C over the desert or as small as 1°C over water; but the actual range depends upon cloudiness, vegetation, and the composition of the earth's surface.

With increasing cloudiness, outward radiation from the earth is blocked by the clouds and temperature ranges are reduced. The lower and denser the clouds, the greater their effect on modifying surface temperatures. Also, the percentage of sky covered by any particular type of cloud is a consideration. If clouds are high and scattered, the outward radiation is only about 4 percent less than that with clear skies; but if clouds are low and the sky is overcast, the outgoing radiation is approximately 90 percent less than with clear skies.

There is a diurnal trend of relative humidity in the surface layer of the atmosphere. (See Figure C-8, D.) The magnitude of the relative humidity is determined by the temperature and the absolute humidity. Maximum relative humidity occurs at the time of minimum temperature, during the early morning hours. Minimum relative humidity occurs in the afternoon, at the time of maximum temperature, if the absolute humidity remains unchanged.

If a pronounced change in weather is taking place, weather change influences the relative humidity more than does the temperature. Thus, if it is raining or there is fog, the relative humidity will be near 100 percent even though it is afternoon when relative humidity is normally at a minimum.

Climatology

Climatology is the science dealing with climate. Climate is a historical average of the

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weather for a place or area over a given period. Current weather is a phase—a single element—in this average.

Personnel can use climatological summaries to determine expected weather conditions within certain probability limits to aid long-range planning. However, they should use current weather information to predict short-range conditions. Climatic and special data summaries are available for locations with weather records. The summaries can provide diurnal variations, frequencies, and correlations between elements. This information should be used as early as possible in the planning stage.

Climatological wind values at a given location are normally available for most cities and airfields but may not be available for small settlements or unpopulated areas. For these, you must estimate expected conditions, using data for nearby areas. Wind data can be obtained for specific hours of the day to show diurnal trends, or they can be averaged to show mean conditions.

An indication of the probability of different stability categories may be forecast from the climatological values of sky cover and wind for the area. Particular attention must be paid to the difference between day and night conditions, because the diurnal trend of temperature gradient under the two conditions varies widely, even though the climatological average of sky cover and wind may not.

Topography

Topography (terrain conditions) influences the wind, temperature gradient, temperature, and humidity.

A topographic (local) wind is usually described in terms of what would occur if the effects of the overall synoptic situation were eliminated. These winds may be thermally or gravitationally induced. Topography influences the wind by thermal effects and by physically diverting and altering the normal flow of wind. Figure C-10 makes use of arrows and fishhooks to show flow of the wind. Arrows and fishhooks are used in other figures to depict wind direction and motion. Air tends to follow the line of a valley. Also, air moving up a hillside does not leave the ground at the hilltop but tends to remain on the ground and travel down the other side of the hill, displaying the normal friction eddies (Figure C-10, A.)

Air crossing the crest of a hill tends to eddy (Figure C-10, B). The sharper the hillcrest and the steeper the drop on the leeward side, the more pronounced the eddy (Figure C-10, C). Heavily contoured terrain or mountainous regions tend to have sharp eddies and pronounced updrafts in the air above them. Mountain ranges may deflect the surface airflow for an appreciable distance. Steep hills split the wind so that there is an eddying around the hill as well as over it. In such cases, if the leeward side is very steep, providing shelter for the air in the valley, airflow in the valley tends to be very slight, speeds are low, and large-scale air movements are unlikely (Figure C-10, D).

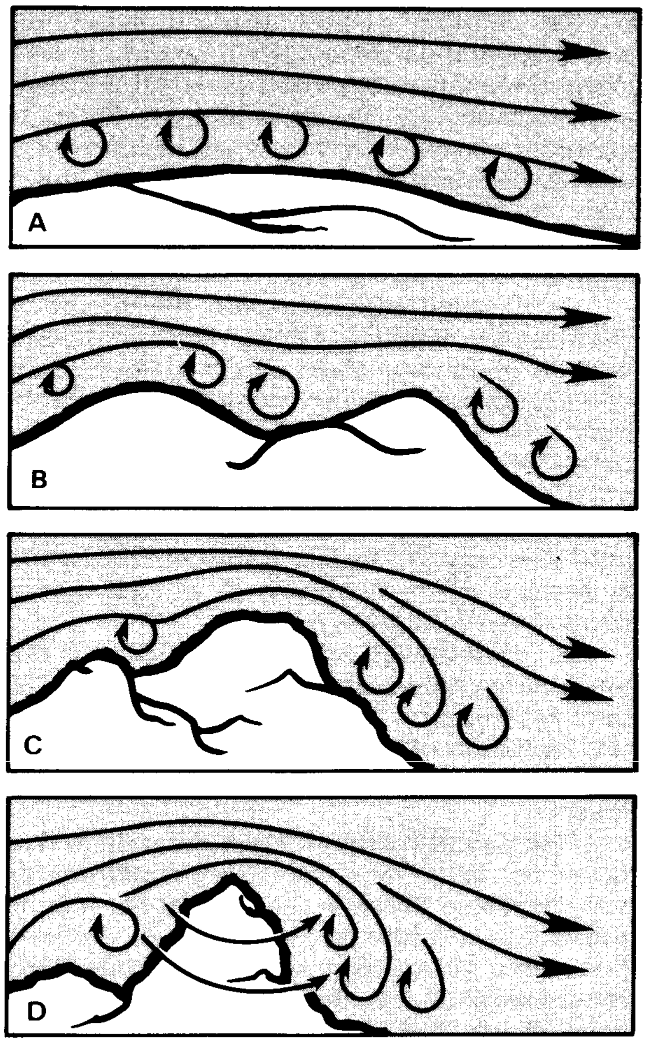


Figure C-10. Effects of terrain on wind.

Obstacles, such as buildings, large rocky outcrops, and groves of small trees, also cause eddies. Such eddies may influence the wind for a downwind distance 15 to 20 times the height of the obstacle producing the eddy. Beyond this distance, these obstacles have little influence (Figure C-11).

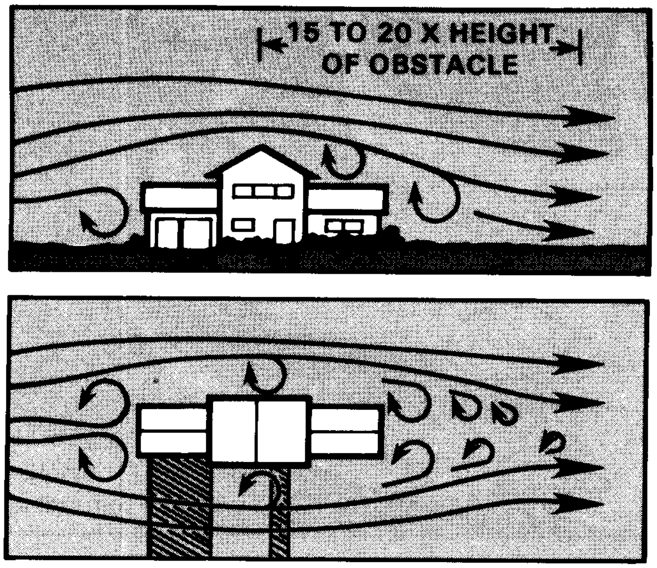


Figure C-11. Eddies around obstacles.

Air moving over a forest is turbulent where the uneven treetops disturb the air flowing over them (Figure C-12, A). Large eddies form where there is a sufficient opening or a well-defined tree line that permits the air to descend to the ground again (Figure C-12, B). The same turbulence may occur if the free air blows at right angles to a forested gully, although air in such gullies or in riverbeds is normally well protected from eddies and turbulence (Figure C-12, C).

Thermally induced topographic winds result from definite temperature differences. Examples of such winds are valley-mountain winds, slope winds, and land-sea breezes. Sea breezes and valley winds result from daytime heating of the earth's surface. Land and mountain breezes result from nighttime cooling of the ground.

Valley winds and slope winds usually are present at all latitudes where there are hills and mountains, regardless of weather conditions (see Figure C-13). However, they develop best with clear skies and weak winds aloft. In the tropics, where seasonal changes are small, such winds develop best during the dry season.

Valley winds develop best in large, broad, U-shaped valleys with gently sloping floors to high ridges, rather than in steep V-shaped valleys.

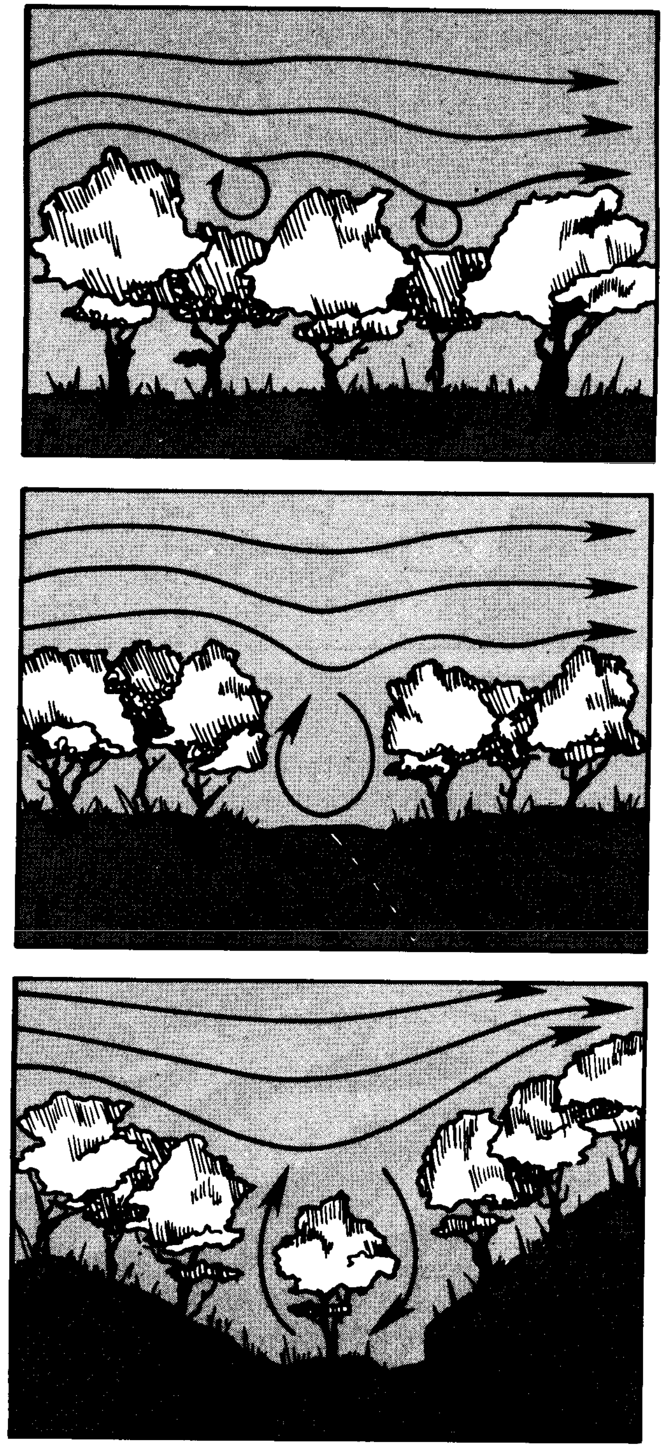


Figure C-12. Effects of forests on wind.

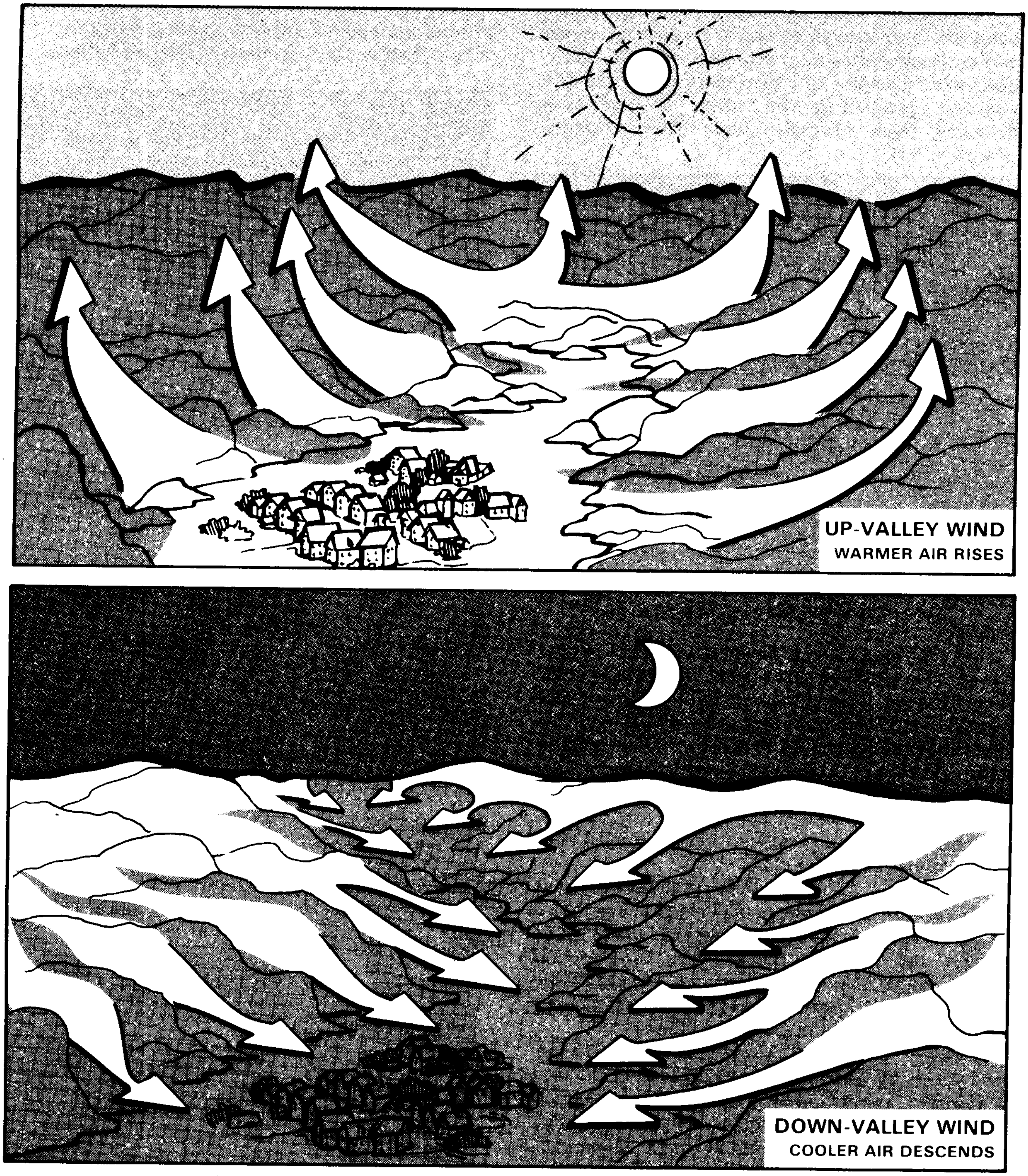


Figure C-13. Up-valley and down-valley winds.

Up-valley winds develop when air, heated by ground radiation, rises and moves up the valley under a layer of cooler air. This cooler air occupies approximately the upper third of the valley air mass. Up-valley winds begin one to four hours after sunrise, earlier in small valleys, and often not in large valleys until late morning. Maximum development is reached in the early afternoon in small or side valleys and at midafternoon in large valleys. Valley winds reach their maximum speed at about one-third of the ridge height. Minimum speed of valley winds occurs at the boundary of the valley system, immediately below the ridge top.

Up-valley winds have greater vertical depth than down-valley winds. Up-valley winds may fill an entire valley to the height of the surrounding ridges. These winds continue until about an hour before sunset.

Down-valley winds, resulting from cooler air flowing down along the cooling ground surface, set in one to three hours after sunset. With favorable conditions of light winds and clear skies, these winds persist until one to two hours after sunrise. They are shallower than up-valley winds, being only about 1/3 to 2/3 as deep. Their horizontal development is limited by the immediate surrounding hills.

The extent and intensity of topographic up-valley and down-valley winds are controlled by the shape of the valley, height of the ridges, sky cover, and gradient winds. Strong surface winds can obliterate topographic valley winds. Valley winds usually have slow air movements but may sometimes combine with another wind system, such as the sea breeze along a coastal valley, to cause a stronger wind. If the mouth of the valley is narrow, the down-valley wind accelerates and this effect may extend outward for several kilometers. The wind speed may increase to 30 knots or more and is difficult to predict.

Slope winds are thermally induced by hill and mountain sides. Upslope winds set in during the day and downslope winds at night (Figure C-14). On clear days, upslope winds begin 15 to 45 minutes after sunrise and stop about sunset, reaching a maximum speed around noon. It is very difficult to predict upslope winds.

Downslope winds usually begin 15 to 45 minutes after sunset and tend to persist throughout the night until shortly after sunrise. In the northern hemisphere, south-facing slopes have the most fully developed slope winds, both in

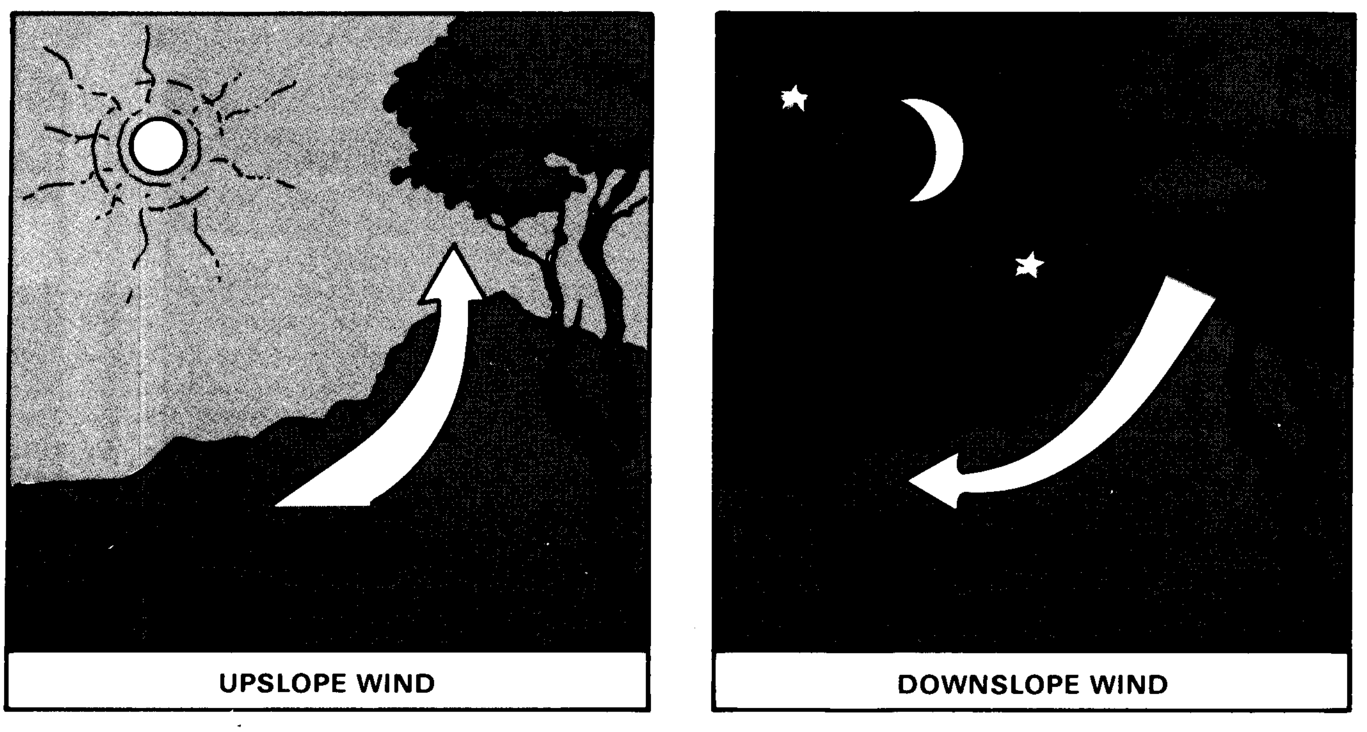


Figure C-14. Upslope and downslope winds.

vertical development and velocity. North-facing slopes have the least-developed slope winds. The maximum depth of slope winds is about 200 meters, which may be attained on large mountain slopes under conditions of clear skies and light gradient winds.

Land and sea breezes occur almost daily in tropical and mid-latitude regions on the coasts of all islands and continents. They occur because the land cools and heats more rapidly than the adjacent water. (See Figure C-15.) Breezes develop quickly during the dry season on clear days with light gradient winds, during any season, and even during bad weather. With little or no surface wind (0 to 4 knots), the sea breeze sets in about two hours after sunrise and increases to its maximum in midafternoon. The sea breeze stops one to two hours before sunset. The land breeze sets in shortly after sunset.

An off-land surface wind of 4 to 9 knots delays the onset of the sea breeze until late morning or midday. If the surface wind is off-land at 9 to 12 knots, the sea breeze will not set in until midafternoon. Under these conditions, the sea breeze starts several kilometers out to sea. It slowly progresses shoreward and arrives on land as a gusty, sharp wind shift. Surface winds of 13 knots or greater neutralize all but the strongest sea breezes.

With a strong surface wind from the sea toward the land, no real land and sea breezes exist. The effect of the land and sea breezes is then a force added to the surface wind. The sea breeze is discernible as a daytime strengthening of the wind, and the land breeze is observed as a nighttime weakening of the wind.

Sea breezes are deeper and stronger than land breezes. They usually begin about midmorning and begin to subside toward evening. Sea breezes establish at approximate right angles to the coast. Sea breezes increase in speed from their onset, with maximum speeds being reached in the afternoon, usually about one hour after the maximum land temperature is reached. Maximum speeds exist just above the surface and ordinarily are not more than 13 knots.

Sea breezes usually extend aloft from 200 to 500 meters, but they have been observed at over 700 meters. On extremely large islands, the movement of air in a sea breeze is quite appreciable

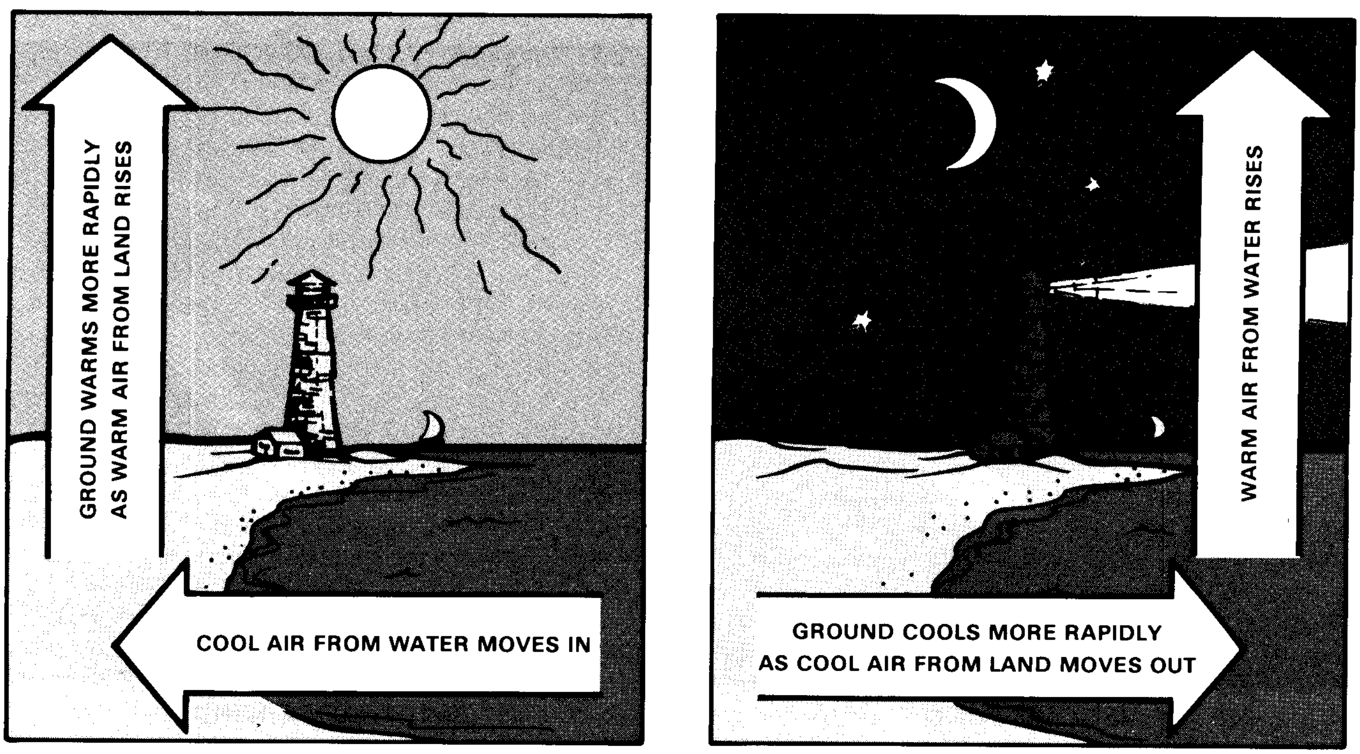


Figure C-15. Land and sea breezes.

at 15 to 20 kilometers from shore. Inland penetration of sea breezes depends on topography; and under favorable conditions such as valleys running inland, they may penetrate 35 to 50 kilometers. Sea breezes are nonturbulent when they first reach the shore but become more and more turbulent in passing over land.

A land breeze is considerably weaker and more shallow than a sea breeze. It usually influences a layer less than 200 meters thick. It starts about an hour after sunset and ends shortly after sunrise. On flat terrain, land breezes rarely exceed 3 knots, but, in combination with down-valley winds, they may attain considerable speed. Because of passage over ground, land breezes are inclined to be turbulent in nature; however, this turbulence is dampened by inversion (stable) conditions normally occurring during this period. Land breezes usually extend only 6 to 8 kilometers out to sea.

At sea, the stability of the surface boundary layer depends upon the relative temperatures of air and water. Warm air moving over cold water results in stable conditions, and cold air moving over warm water creates instability. In shallow water, such as in a lagoon, there is an appreciable warming of the water by the sun; lapse (unstable) conditions may exist in the lower levels but not to the extent of causing large convection currents.

On land, the main influence of topography is slope effects on stability. Since south-facing slopes receive the greatest amount of incoming solar radiation in the northern hemisphere, they develop lapse conditions stronger and more persistent than those on north-facing slopes. In the southern hemisphere, the north-facing slopes attain the strongest lapse conditions. Stable (inversion) conditions are always associated with light, nocturnal downslope or down-valley winds, and unstable (lapse) conditions accompany upslope or strong daytime up-valley winds.

Topography influences temperature by affecting the amount of incoming solar radiation that a parcel of land receives. This is determined primarily by the angle of the slope, direction of its exposure to the sun, latitude, and the season.

South-facing slopes receive the greatest direct incoming solar radiation in the northern hemisphere and reach maximum temperatures. For example, at a latitude of 45 degrees, a north-facing slope of 30 degrees receives no direct solar radiation from November through February. Temperatures are correspondingly lower than on south-facing slopes, which are exposed to solar radiation during these periods. Figure C-16 shows the solar loading situation for the northern hemisphere. The opposite situation occurs in the southern hemisphere.

Two sources of thermal energy affect air temperature. These sources are incoming solar radiation and heat being radiated outward from the earth. Incoming solar radiation peaks on a daily and a seasonal basis. The daily peak occurs one to two hours after noon when the sun is at its highest. The seasonal peak occurs during the summer solstice when the sun reaches its zenith in the summer sky. Incoming solar radiation also shows a seasonal minimum, at the winter solstice, but does not truly have a daily minimum. Instead, from about sunset to about sunrise, the value of the incoming solar radiation is zero. Maximum and minimum air temperature lags are illustrated in Figure C-17.

Relative humidity increases when influenced by nearby watery areas, such as swamps or lakes. Also, when winds move up a high mountain slope, the relative humidity tends to increase, as shown by frequent mountaintop clouds.

Vegetation and Wind

Leaves and branches produce drag on wind blowing through and across the vegetation. The denser the vegetation, the greater the decrease in wind speed. Also, the taller the vegetation, the greater the depth of the friction layer. Finally, the more uneven the top of the vegetation, the greater the turbulence induced in the wind flowing over the vegetation.

In scattered tall shrubs and scrub forests, the sparse vegetation produces only a moderate drag effect; thus, the wind speed is only slightly influenced. The predominant effect is a deflection of the airflow and changes in wind direction. When the vegetation is thick enough to be classified as medium-dense, the wind speed and direction at any given instant will differ from location to location.

In coniferous (evergreen) forests, high wind speeds at the surface are rare and wind direction is extremely variable. This also is true in medium-dense deciduous (seasonal, leafy) forests in full

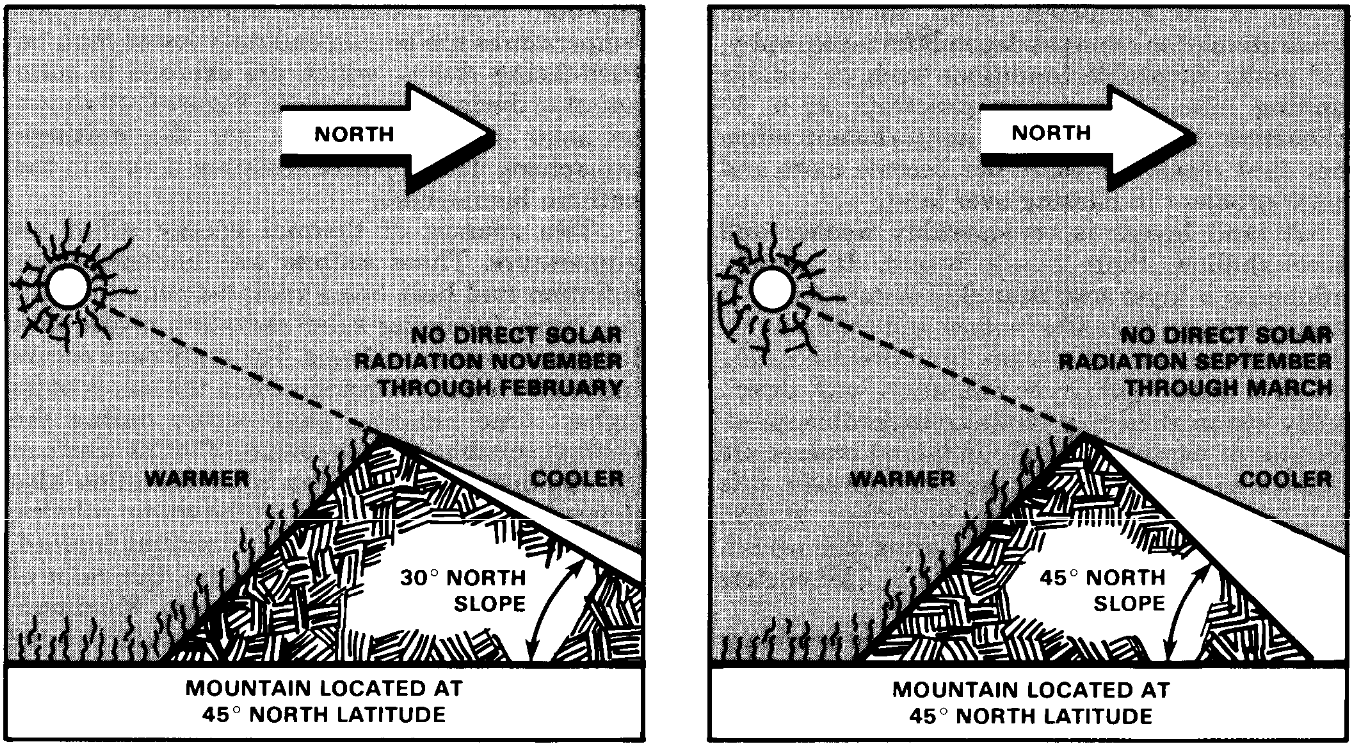


Figure C-16. Solar radiation on north-facing slopes.

leaf. Tropical jungles affect the mean wind flow even more adversely than do temperate latitude forests. The thick, luxuriant growth reduces surface wind speeds to extremely low values, and wind directions become meandering.

Vegetation and Temperature

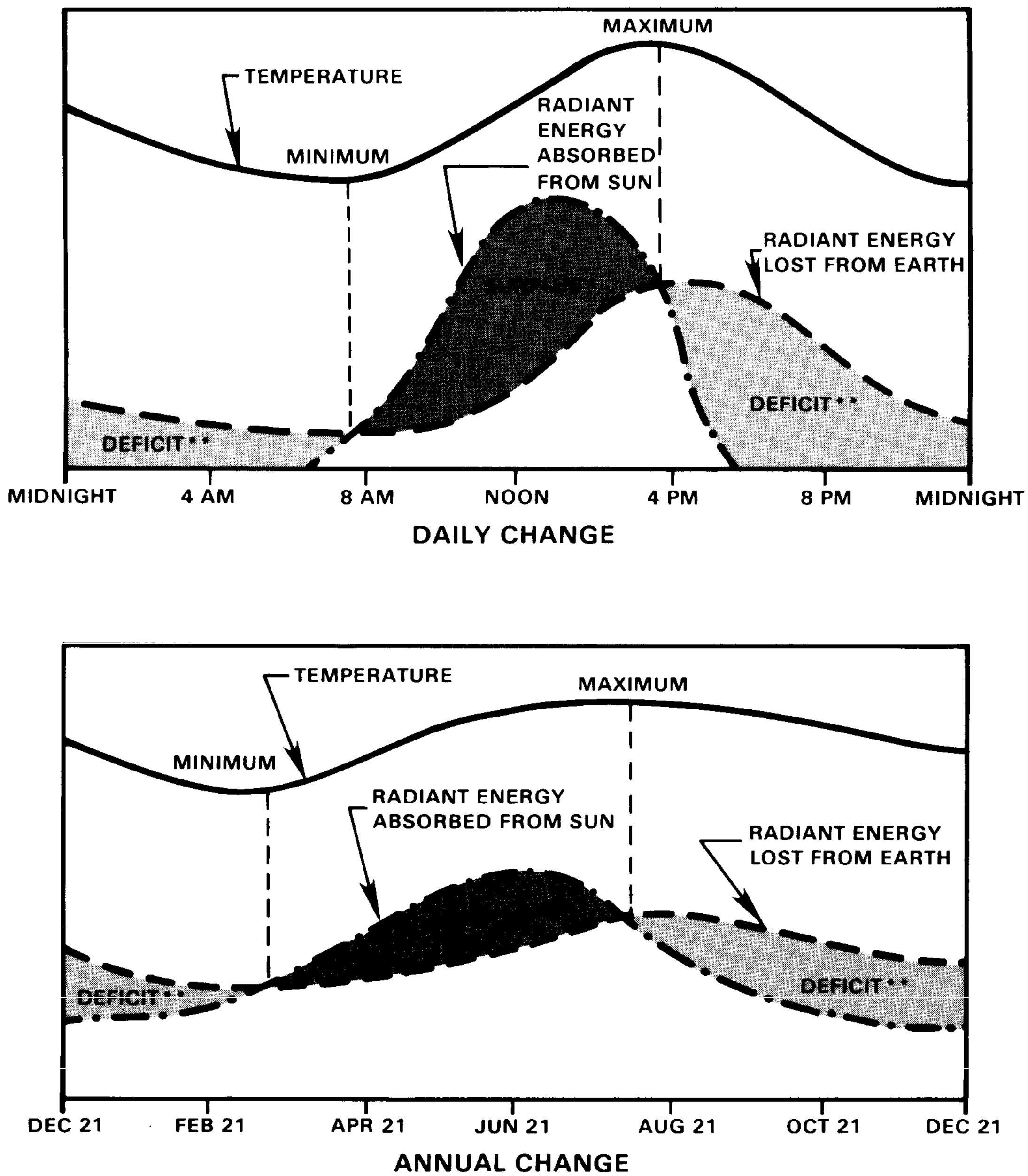
Vegetation influences the temperature gradient by keeping much of the solar energy from penetrating to the ground. It has a blanketing or insulating effect, so that strong lapse or strong inversion conditions are not probable in heavily vegetated areas. The temperature gradient within or below vegetation approaches a neutral condition as the density of the vegetation increases.

In tall shrubs or scrub forests, shading affects the air adjacent to the ground, so that extreme surface temperatures are not reached and strong inversion or lapse conditions are relatively infrequent. In coniferous forests, moderate lapse and inversion conditions can and do occur. However, they are not as frequent or as marked as in the open. Temperature gradients in the forest range from one-third to one-half of the values attained in the open. The tendency is toward neutral temperature gradients.

Vegetation influences temperature by raising the radiating level from the earth's surface to the top of the vegetation, which acts as the cooling and heating surface. Maximum and minimum values are, therefore, reached at or near vegetation top, while the temperatures below this level are modified. Since vegetation has an insulating effect, maximum temperatures are not as high and minimum temperatures are not as low as those in the open. The normal diurnal trend of temperatures continues, but the vegetation causes a time lag in reaching maximum and minimum values. The degree of these effects is determined by the density of the vegetation.

In grass, the lag in reaching maximum and minimum temperatures is small, and temperatures are not appreciably modified. In tall shrubs and scrub forests, also, the lag is slight; but temperatures at 1.5 meters are considerably moderated.

In coniferous and deciduous forests, the time lag between forest temperatures and temperatures



*SURPLUS—PERIOD DURING WHICH SURFACE AIR LAYER IS ABSORBING RADIANT ENERGY BOTH FROM THE SUN AND THE RERADIATED ENERGY FROM THE EARTH. PERIOD OF PEAK AIR TEMPERATURES.

**DEFICIT—PERIOD DURING WHICH THE SURFACE AIR LAYER IS LOSING RADIANT ENERGY BOTH FROM THE SUN AND THE RERADIATED ENERGY FROM THE EARTH'S SURFACE. PERIOD OF MINIMUM AIR TEMPERATURES.

Figure C-17. Maximum and minimum air temperature lags.

in the open is approximately two hours. Forest temperatures are usually 5 to 6 degrees lower at midday than those at corresponding levels in the open. Temperatures in a forest at night are higher than nighttime temperatures in the open.

In a tropical jungle, the lag in reaching maximum temperatures is about one hour. Since the diurnal range of jungle temperature is so small in tropical climates (8°C), the difference between jungle and open temperatures is only 10 to 3°C.

There is a pronounced and regular trend of relative humidities in forests and jungles. Minimum relative humidities occur with maximum temperatures, and maximum relative humidities occur with minimum temperatures. Relative humidities within a forest average between 60 and 90 percent. During the night and forenoon, the relative humidity within a forest is about 5 percent higher than in the open; but in the afternoon, until about sunset, the relative humidity in the forest may be from 15 to 20 percent higher than in the open.

In canopied jungles on tropical islands or near windward tropical coasts, the relative humidity ranges from 65 to 95 percent and is almost always within 5 percent of the relative humidity in the open.

Soil

Soil influences ground burst munitions and ground contamination. Variations in soil types usually do not materially influence winds. The primary effect of soil on temperature gradient is due to the great range of temperatures attained at the soil surface. Compared to other natural surfaces, bare rock attains the highest daytime surface temperature and the lowest nighttime temperature. Bare soil, with the exception of sand, acts like rocks, but to a lesser extent.

On a snow-covered surface, snow is the critical factor in determining the temperature gradient. Inversions (stability) on snow-covered surfaces are strongest about sunrise; but during clear, cold, and calm weather, the temperature inversion is not always completely destroyed during the day. In polar regions, winter inversions may persist for days, or even weeks, because of the low sun or nearly complete darkness.

Soil and vegetation surface temperatures are important because they are a factor in determining the rate of evaporation of agents used for persistent effect. The primary factors in determining rate of evaporation of these agents are surface temperature and the rate at which the substance flows out to the radiating surface. This rate varies with the nature and texture of the surface. Heavy clay soil does not absorb as readily as porous sandy soil. The extent of absorption further depends upon the relative depth of the absorbing topsoils and subsoils, type of soil, and moisture content.

The soil also affects relative humidity values as it alters the temperature. Evaporation from wet soils tends to raise the relative humidity.

Glossary

absolute humidity (also called vapor concentration and vapor density) - in a system of moist air, the ratio of the mass of water vapor present to the volume occupied by the mixture, that is, the density of the water vapor component. It is not commonly used by meteorologists. See relative humidity.

absorption - the process of an agent being taken into the vegetation, skin, materiel, or soil. Important for only a few agents.

active front - the boundary between two different air masses, or a portion thereof, which produces appreciable cloudiness and precipitation and is usually accompanied by significant shifts in wind direction.

adiabatic lapse rate - the rate of decrease of temperature with height of a parcel of dry air lifted upward through the atmosphere with no addition or deletion of heat.

adiabatic process - a thermodynamic change of state of a system in which there is no transfer of heat or mass across the boundaries of the system. In an adiabatic process, compression always results in warming, expansion in cooling. In meteorology the adiabatic process often is also taken to be a reversible process. For many purposes, changes of state in the free atmosphere over periods of two days or less are assumed to be adiabatic.

adsorption - adding a thin layer to vegetation (usually aerosol). Important in dense vegetation.

advection fog - a type of fog caused by the passage of moist air horizontally over a relatively colder surface and the consequent cooling of that air to below its dew point.

adverse weather - weather in which military operations are generally restricted or impeded.

aerology - the study of the air and of the atmosphere. Used in the US Navy until early 1957. The same as meteorology; however, this usage tended to be more administrative than scientific.

aerosol - a colloidal system in which the dispersed phase is composed of either solid or liquid particles and in which the dispersal medium is some gas, usually air. There is no clear-cut upper limit to the size of the particles comprising the dispersed phase in an aerosol, but as in all other colloidal systems, it is rather commonly set at 1 micron. Haze, most smokes, and some fogs may thus be considered aerosols.

air - the mixture of gases comprising the earth's atmosphere. Since the composition of the atmosphere is slightly variable with respect to certain components, the term "pure air" has no precise meaning, but is commonly used to imply freedom from nongaseous suspensoids (dust, hydrometeors) and also freedom from such gaseous contaminants as industrial effluents.

air drainage - general term for gravity-induced, downslope flow of relatively cold air. Winds thus produced are called gravity winds.

air mass - a widespread body of air, the properties of which can be identified as (a) having been established while that air was situated over a particular region of the earth's surface (air-mass source region) and (b) undergoing specific modifications while in transit away from the source region. An air mass is often defined as a widespread body of air that is approximately homogeneous in its horizontal extent, particularly with reference to temperature and moisture distribution; in addition, the vertical temperature and moisture variations are approximately the same over its horizontal extent.

air mass classification - a system used to identify and to characterize the different air masses according to a basic scheme. A number of systems have been proposed, but the Bergeron classification has been the most widely accepted. In this system, air masses are designated first according to the thermal properties of their source regions: tropical (T); polar (P); and less frequently, arctic or antarctic (A). For characterizing the moisture distribution, air masses are distinguished as to continental (c) and maritime (m) source regions. Further classification according to whether the air is cold (k) or warm (w) relative to the surface over which it is moving indicates the low-level stability conditions of the air, the type of modification from below, and is also related to the weather occurring within the air mass. This outline of classification yields the following identifiers for air masses:

cTk	**continental-tropical-cold**
cTw	**continental-tropical-warm**
mTk	**maritime-tropical-cold**
mTw	**maritime-tropical-warm**
cPk	**continental-polar-cold**
cPw	**continental-polar-warm**
cAk	**continental-arctic-cold**
cAw	**continental-arctic-warm**
mAw	**maritime-arctic-warm**
mPk	**maritime-polar-cold**
mPw	**maritime-polar-warm**
mAk	**maritime-arctic-cold**

air mass source region - an extensive area of the earth's surface over which bodies of air frequently remain for a sufficient time to acquire characteristic temperature and moisture properties imparted by that surface. Air so modified becomes identifiable as a distinct air mass. See air mass.

air parcel - an imaginary body of air to which may be assigned any or all of the basic dynamic and thermodynamic properties of atmospheric air. A parcel is large enough to contain a very great number of molecules, but small enough so that the properties assigned to it are approximately uniform within it and so that its motions with respect to the surrounding atmosphere do not induce marked compensatory movements. It cannot be given precise numerical definition, but a cubic foot of air might fit well into most contexts where air parcels are discussed, particularly those related to static stability.

albedo - the fraction of light or the amount of electromagnetic radiation reflected by a body to the amount incident upon it, commonly expressed as a percentage. The albedo is distinguished from the reflectivity, which refers to one specific wavelength (monochromatic radiation). (As the moon, a planet, a cloud, the ground, or a field of snow reflects light.)

altocumulus (abbreviated Ac) - a principal medium-level cloud type, white and/or gray in color, which occurs as a layer or patch with a waved aspect, the elements of which appear as laminae, rounded masses, or rolls. These elements usually are sharply outlined, but they may become partly fibrous or diffuse; they may or may not be merged; they generally have shadowed parts; and, by convection, when observed at an angle of more than 30° above the horizon, subtend an angle between 1° and 5°.

altostratus (abbreviated As) - a principal medium-level cloud type in the form of a gray or bluish (never white) sheet or layer of striated, fibrous, or uniform appearance. Altostratus very often totally covers the sky, and may, in fact, cover an area of several thousand square miles. The layer has parts thin enough to reveal the position of the sun; and if gaps and rifts appear, they are irregularly shaped and spaced.

anabatic wind - an upslope wind; usually applied only when the wind is blowing up a hill or mountain as a result of local surface heating and apart from the effects of the larger scale circulation; the opposite of katabatic wind. The most common type anabatic is the valley wind.

APC - armored personnel carrier.

arctic front - the semipermanent, semicontinuous front between the deep, cold arctic air and the shallower, basically less cold polar air of northern latitudes; generally comparable to the antarctic front of the southern hemisphere.

arty met - artillery meteorological.

ATGM - antitank guided missile.

AWS - Air Weather Service.

bora - a cold, often dry, northeasterly wind which blows, sometimes in violent gusts, down from mountains on the eastern shore of the Adriatic. It also applies to cold, squally, downslope winds in other parts of the world.

CARC - chemical agent resistant coating.

CDM - chemical downwind message.

Celsius (abbreviated C) - (formerly referred to as centigrade) thermometric scale with 100 degrees between freezing and boiling, OC for freezing and 100°C for boiling.

centigrade - see Celsius.

chinook - the name given to the descending, warm, dry wind on the eastern side of the Rocky Mountains. The chinook generally blows from the southwest, but its direction may be modified by topography. When it sets in after a spell of intense cold, the temperature may rise by 20°F to 40°F in 15 minutes due to replacement of a cold air mass with a much warmer air mass in minutes.

cirrocumulus (abbreviated Cc) - a principal high-level cloud type appearing as a thin, white patch of cloud without shadows, composed of very small droplets in the form of grains or ripples. The elements may be merged or separate, and more or less regularly arranged; they subtend an angle of less than 10 when observed at an angle of more than 30° above the horizon. Holes or rifts often occur in a sheet of cirrocumulus.

cirrostratus (abbreviated Cs) - a principal high-level cloud type appearing as a whitish veil, usually fibrous but sometimes smooth, which may totally cover the sky and which often produces halo phenomena, either partially or completely. Sometimes a banded aspect may appear, but the intervals between the bands are filled with thinner cloud veil. The edge of the veil of cirrostratus may be straight and clean-cut, but more often it is irregular and fringed with cirrus. Some of the ice crystals that comprise the cloud are large enough to fall and thereby produce a fibrous aspect. Cirrostratus occasionally may be so thin and transparent as to render it almost indiscernible, especially through haze or at night. At such times, the existence of a halo may be the only revealing feature, such as producing a halo around the moon.

cirrus (abbreviated Ci) - a principal high-level cloud type composed of detached cirriform elements in the form of white, delicate filaments, of white (or mostly white) patches, or of narrow bands. These clouds have a fibrous aspect and/or a silky sheen. Many of the ice crystal particles of cirrus are sufficiently large to acquire an appreciable speed of fall; therefore, the cloud elements have a considerable vertical extent. Wind shear and variations in particle size usually cause these fibrous trails to be slanted or irregularly curved. For this reason, cirrus does not usually tend, as do other clouds, to appear horizontal when near the horizon. Because cirrus elements are too narrow, they do not produce a complete circular halo.

climate - the long-term manifestations of weather. The climate of a specified area is represented by the statistical summary of its weather conditions during a period long enough to ensure that representative values are obtained (generally 30 years).

climatic study - analysis and interpretation of climatic summary data in light of probable impacts on operations, plans, construction, and the like.

climatic summary - tabular data for averages, extremes, and frequencies of weather elements or phenomena for a year, season, month, or other period at a specific location or area.

climatology - the science that deals with climates and investigates their phenomena and causes.

cloud - a collection of very small water droplets or ice crystals or both, with its base above the earth's surface.

colloidal system (also called colloidal dispersion, colloidal suspension) - an intimate mixture of two substances one of which, called the dispersed phase (or colloid), is uniformly distributed in a finely divided state throughout the second substance, called the dispersion medium (or dispersing medium). The dispersion medium may be a gas, a liquid, or a solid, and the dispersed phase may also be any of these, with the exception that one does not speak of a colloidal system of one gas in another. A system of liquid or solid particles colloidally dispersed in a gas is called an aerosol. A system of solid substances or water-insoluble liquids colloidally dispersed in liquid water is called a hydrosol.

coniferous forests - concentrations of evergreen trees normally found on slopes and mountains; for chemical behavior purposes, the same as medium-dense deciduous forests or woods (when in full foliage only).

CONUS – continental United States.

convection - in general, mass motions within a fluid resulting in transport and mixing of the properties of that fluid. Convection, along with conduction and radiation, is a principal means of energy transfer. Distinction is made between free convection (or gravitational convection)—motion caused only by density differences with the fluid-and forced convection—motion induced by mechanical forces such as deflection by a large-scale surface irregularity, turbulent flow caused by friction at the boundary of a fluid, or motion caused by any applied external force.

coriolis force - a force exerted on a parcel of air (or any moving body) due to the rotation of the earth. This force causes a deflection of the body to the right in the northern hemisphere and to the left in the southern hemisphere.

cumulonimbus (abbreviated Cb) - a principal cloud type, exceptionally dense and vertically developed, occurring either as isolated clouds or as a line or wall of clouds with separated upper portions. These clouds appear as mountains or huge towers, at least a part of the upper portions of which are usually smooth, fibrous, or striated, and almost flattened. This part often spreads out in an anvil shape (incus) or vast plume. Under the base of a cumulonimbus, which often is very dark, there frequently exists virga, precipitation, and low, ragged clouds, either merged with it or not. Its precipitation is often heavy and always of a showery nature. The usual occurrence of lightning and thunder within or from this cloud leads to its common names, thundercloud, thunderhead (usually refers only to the upper portion of the cloud), and thunderstorm.

cumulus (abbreviated Cu) - a principal cloud type in the form of individual, detached elements which are generally dense, low-level with vertical development and possess sharp nonfibrous outlines. These elements develop vertically, appearing as rising mounds, domes, or towers, the upper parts of which often resemble a cauliflower. The sunlit parts of these clouds are mostly brilliant white; their bases are relatively dark and nearly horizontal. Near the horizon, the vertical development of cumulus often causes the individual clouds to appear to be merged. If precipitation occurs, it is usually of a showery nature.

current weather report - information on existing weather conditions or specific weather element; may be oral, written, or graphic representations.

cyclone - a system of winds rotating around a center of low atmospheric pressure. A cyclone rotates counterclockwise in the northern hemisphere and clockwise in the southern hemisphere (opposite to that of an anticyclone). Modern meteorology restricts the use of the term cyclone to the cyclonic-scale circulations. But, it is still applied popularly to the more or less violent, small-scale circulations such as tornadoes, waterspouts, and dust devils (which may in fact exhibit anticyclonic rotation), and even, very loosely, to any strong wind. Because cyclonic circulation and relative low atmospheric pressure usually coexist (in the northern hemisphere), in common practice the terms cyclone and low are used interchangeably. Also, because cyclones nearly always are accompanied by inclement (sometimes destructive) weather, they are frequently referred to simply as storms.

deciduous forests - concentrations of seasonal, leafy trees; for chemical behavior calculations, the same as coniferous forests or woods when in full foliage only.

deliberate smoke - smoke operations which are planned with much detail for implementation over large areas or relatively long time periods.

dew - water condensed onto grass and other objects near the ground. Dew forms when temperatures fall below the dew point of the surface air due to radiational cooling during the night but are still above freezing. Hoarfrost (or white frost) forms if the dew point is below freezing. If the temperature falls below freezing after the dew has formed, the frozen dew is known as white dew or jackfrost.

dew point (or dew point temperature) - temperature to which a given parcel of air must be cooled at constant pressure and constant water vapor content for saturation to occur. When this temperature is reached, water is condensed onto grass and other objects contacting the cooled air. When the dew point is below 32°F (0°C), it is sometimes called the frost point. The dew point may be defined as the temperature at which the saturation vapor pressure of the parcel is equal to the actual vapor pressure of the contained water vapor.

diffusion - exchange of airborne media between regions in space in an apparently random motion of a small scale.

diurnal - repeated or recurring daily. Having a daily cycle of completed actions in 24 hours and recurring every 24 hours. Thus, most reference is made to diurnal tasks, cycles, tides, or sunrise to sunset.

dose - amount of agent taken into or absorbed by the body.

dose rate - how fast a dose is absorbed or taken into the body.

drizzle - very small, numerous, and uniformly dispersed water drops, mist, or sprinkle. Unlike fog droplets, drizzle falls to the ground. It is sometimes accompanied by low visibility and fog.

dry-bulb humidity - dryness of the free air as measured by use of two thermometers. One is dry-bulb and the other is wet-bulb. The difference between the two readings is the humidity for surrounding air. (See hygrometer, psychrometer.)

dry-bulb temperature - temperature of the free air as measured with a dry thermometer on a sling psychrometer over a grassy surface at a height of approximately 6 feet (1.8 meters).

easterlies - any persistent wind from the east (usually applied to broad currents or belts of easterly winds). The easterly belts are referred to as the equatorial easterlies, the tropical easterlies, and the polar easterlies.

electromagnetic spectrum - the entire range of wavelengths of all known electromagnetic radiations extending from gamma rays through visible light, infrared, and radio waves. It is divided into 26 alphabetically designated bands.

fire storm - an atmospheric wind system caused by a large fire (as after the bombing of a city). The intense burning creates vertical wind currents, which induces a strong wind to bring in more air to feed the fire. Incoming wind speed can exceed 60 knots in extreme cases.

foehn - name for a warm dry wind blowing down the side of a mountain in northern and central Europe; (same as chinook-type warm dry wind that descends eastern slopes of Rocky Mountains).

fog oil - petroleum based oil specially blended to produce a dense, efficient screening smoke when vaporized and recondensed at atmospheric temperatures. Officially, fog oil is standard grade fuel number 2 (SGF2).

front - in meteorology, generally, the interface or boundary between two air masses of different density. Since the temperature distribution is the most important regulator of atmospheric density, this front almost invariably separates air masses of different temperatures. Fronts receive their names from the movement of the air masses involved. A cold front is the leading edge of an advancing mass of cold air. A warm front is the trailing edge of a retreating mass of cold air. When an air mass boundary is neither advancing nor retreating along the surface, the front is called a stationary front. An occluded front occurs when a cold front overtakes a warm front at the surface and a temperature contrast exists between the advancing and retreating cold air masses.

frost - a cover of minute ice crystals on objects that are exposed to the air. Some of these are tree branches, plant stems, leaves, wires, poles, vehicles, rooftops, or aircraft skin. Frost is the same process by which dew is formed except that the temperature of the frosted object is below freezing. Frost can be light or heavy.

FWS - Fleet Weather Service.

geostrophic - relates to or arises from the deflective force exerted on the atmosphere due to the rotation of the earth.

geostrophic wind - a wind whose direction and speed are determined by a balance of the horizontal pressure gradient force and the force due to the earth's rotation to the left in the northern hemisphere and to the right in the southern hemisphere.

geostrophic wind level (also called gradient wind level) - the lowest level at which the wind becomes geostrophic. In practice, the geostrophic wind level is between 1.2 kilometers (3,928 feet) and 1.6 kilometers (5,238 feet). This wind level probably marks the upper limit of frictional influence of the earth's surface. The geostrophic wind level may be considered to be the top of the planetary boundary layer, that is, the base of the free atmosphere.

glaze - a smooth coating of ice formed on objects due to the freezing of rain.

gradient wind - any horizontal wind velocity tangent to the contour line of a constant pressure surface (or to the isobar of a geopotential surface) at or above 2,500 feet (762 meters).

gravity wind - see air drainage and katabatic wind.

greenhouse effect - the heating effect exerted by the atmosphere upon the earth because the atmosphere (mainly, its water vapor) absorbs and reemits infrared radiation. In detail, the shorter wavelengths of solar radiation are transmitted rather freely through the atmosphere to be absorbed at the earth's surface. The earth then reemits this as longwave (infrared) terrestrial radiation, a portion of which is absorbed by the atmosphere and again emitted. Some of this is emitted downward back to the earth's surface (counterradiation). It is essential, in understanding the concept of the greenhouse effect, to note that the important additional warming is due to the counterradiation from the atmosphere. The glass panes of a greenhouse function the same way as the atmosphere does to maintain high greenhouse temperatures and hence the name.

hasty smoke - smoke operations conducted with a minimum of prior planning usually to counter enemy action or anticipated action of immediate concern to a commander.

HC - hexachloroethane.

head wind - in this manual, wind blowing away from the objective and directly toward your site.

heavily wooded - for chemical behavior purposes, jungles or forests with canopies that shade more than 90 percent of the ground surface beneath.

hoarfrost (commonly called frost, white frost, crystalline frost, or hoar) - a deposit of interlocking ice crystals formed by direct sublimation on objects, usually those of small diameter freely exposed to the air, such as tree branches, plant stems and leaf edges, wires, and poles. Also, frost may form on the skin of an aircraft when a cold aircraft flies into warm and moist air or when it passes through air that is supersaturated with water vapor. Hoarfrost is formed similarly to the way dew is formed except that the temperature of the frosted object must be below freezing. Frost forms when air with a dew point below freezing is brought to saturation by cooling. In addition to its formation on freely exposed objects (air hoar), hoarfrost also forms inside unheated buildings and vehicles, in caves, in crevasses (crevasse hoar), on snow surfaces (surface hoar), and in air spaces within snow, especially below a snow crust (depth hoar). Hoarfrost is more fluffy and feathery than rime, which in turn is lighter than glaze. Hoarfrost is designated light or heavy (frost) depending upon the amount and uniformity of deposition. See also dew and dew point.

humidity - a moderate degree of wetness, especially of the atmosphere; dampness.

hurricane - a severe tropical cyclone in the North Atlantic Ocean, Caribbean Sea, Gulf of Mexico, or in the eastern North Pacific off the west coast of Mexico with winds of 75 miles per hour or greater accompanied by rain, lightning, and thunder that sometimes moves into temperate latitudes. Variant names given to the same type of storm in other areas of the world include typhoon (eastern Asia), cyclone (India), winy winy (Australia), and baguio (China Sea).

hydrolysis - process of an agent reacting with water. It does not materially affect the agent cloud in tactical use, because the rate of hydrolysis is too slow.

hygrometer - consists of two similar thermometers with the bulb of one being kept wet. This is so that the cooling that results from the evaporation makes the wet bulb register a lower temperature than the dry one. The difference between the readings constitutes a measure of the dryness (humidity) of the atmosphere.

hygroscopic - readily takes up and retains water, such as water in clay.

infrared radiation - thermal electromagnetic radiation lying outside the visible spectrum at the red end with wavelengths longer than those of visible light.

inversion - an increase of air temperature with increase in altitude (the ground being colder than the surrounding air). When an inversion exists, there are no convection currents and wind speeds are below 5 knots. The atmosphere is stable and normally is considered the most favorable state for ground release of chemical agents.

ionosphere - the part of the earth's atmosphere beginning at an altitude of about 50 kilometers (30 miles) and extending outward 500 kilometers (300 miles) or more.

isobar - a line drawn on a map or chart connecting places of equal or constant pressure. In meteorology, it most often refers to a line drawn through all points of equal atmospheric pressure along a given reference surface, such as a constant height surface (notably mean-sea-level on surface charts); the vertical plane of a synoptic cross section, or a map of the air unaffected by surface heating or cooling. The pattern of isobars has always been a main feature of surface chart analysis. Until recently it was standard procedure to draw isobars at 3-millibar intervals. However, the advent of constant pressure charts for upper-air analysis has brought about the use of 4-millibar intervals to simplify the conversion from surface isobars to 1,000-millibar contour lines.

isothermal - of equal or constant temperature with respect to space, volume, or pressure.

joules (abbreviated J) - international system unit of energy, equal to the work done when the point of application of a force of 1 newton is displaced 1 meter in the direction of the force.

katabatic wind - any wind blowing down an incline; the opposite of anabatic wind. If the wind is warm, it is called a foehn; if cold, it may be a fall wind (such as the bora) or a gravity wind (such as a mountain wind).

kg - kilogram(s).

kmph - kilometer(s) per hour.

lapse - a marked decrease in air temperature with increasing altitude because the ground is warmer than the surrounding air. This condition usually occurs when skies are clear and between 1100 and 1600 hours, local time. Strong convection currents exist during lapse conditions. For chemical operations, the state is defined as unstable. This condition is normally considered the most unfavorable for the release of chemical agents.

lapse rate - the rate of change in atmospheric temperature with increase of height. The variable normally is temperature unless specified otherwise. This is a vertical direction of travel (up or down) and the temperature may rise or fall suddenly.

leeward - the side the wind is blowing away from. Used most often in this manual in reference to a slope facing away from the wind.

M - meter(s).

mechanical turbulence - irregular motion of air resulting from surface roughness and wind speed.

met message - gives wind direction in different increments. May be artillery, ballistic, fallout, computer, or NATO in origin.

meteorology - the science that deals with the study of the atmosphere (or weather) and its phenomena, especially with weather and weather forecasting.

mg - milligram.

micrometeorology - the portion of meteorology dealing with the observation and explanation of small-scale weather and weather forecasting for a local area up to several kilometers in diameter.

min - minute(s).

mistral - a northwesterly or northerly wind which blows offshore along- the north coast of the Mediterranean from Ebra to Genoa. It is characterized by its frequency, strength, and dry coldness.

mixing height - the height to which atmospheric pollutants can be distributed by convective mixing in unstable conditions.

mph - miles per hour.

NBC - nuclear, biological, and chemical.

neutral - when the temperature of the ground is approximately the same as the temperature of the lower air up to 4 meters above it. This condition has light to moderate winds and slight turbulence, and is considered average for the release of chemical agents.

nimbostratus (abbreviated Ns) - a low-level, principal cloud type, gray colored and often dark, rendered diffuse by more or less continuously falling rain, snow, or sleet of the ordinary varieties and not accompanied by lightning, thunder, or hail. In most cases the precipitation reaches the ground, but not necessarily. Nimbostratus is composed of suspended water droplets, sometimes supercooled, and of falling raindrops and/or snow and ice crystals or flakes. It occupies a layer of large horizontal and vertical extent. The great density and thickness (usually many thousands of feet) of this cloud prevent observation of the sun. This, plus the absence of small droplets in its lower portion, gives nimbostratus the appearance of dim and uniform lighting from within. It also follows that nimbostratus has no well-defined base, but rather a deep zone of visibility weakness. A false base may frequently appear at the level where snow melts into rain.

pibal - see pilot-balloon observation.

pillaring - rapid rising of smoke clouds due to heat generated by burning munitions and/or existing convection currents.

pilot balloon - a small unmanned balloon whose ascent is followed by a theodolite (instrument) to obtain data for the computation of the speed and direction of winds in the upper air.

pilot-balloon observation (abbreviated

pibal) - a method of winds-aloft observation, that is, the determination of wind speeds and directions in the atmosphere above a station. This is done by reading the elevation and azimuth angles of a theodolite (instrument) while visually tracking a pilot balloon. The ascension rate of the balloon is approximately determined by careful inflation to a given total lift. After release from the ground, periodic readings (usually at one-minute intervals) of elevation and azimuth angles of the balloon are recorded. These data are transferred to a winds-aloft plotting board, and wind speed and direction at selected levels are calculated by trigonometric methods.

planetary boundary layer (also called the friction layer or atmospheric boundary layer) - that layer of the atmosphere from the earth's surface to the geostrophic wind level.

precipitation - any or all of the forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the ground. It is a major class of hydrometeor, but it is distinguished from cloud, fog, dew, rime, and frost in that it must fall. It is distinguished from cloud and virga in that it must reach the ground.

pressure gradient (also, in meteorology, called barometric gradient) - the rate of decrease (gradient) of pressure in space at a fixed time. The term is sometimes used to denote simply the magnitude of the gradient of the pressure field.

psychrometer - a hygrometer (which consists of two similar bulb thermometers with one bulb kept wet and the other one dry). The psychrometer has a sling attached to the mounted bulb thermometers. A handle is on the free end of the sling. The operator can whirl the bulb thermometers in a circular pattern and speed up the evaporation of water from the wet bulb thermometer. The difference between the two readings constitutes the measure of the dryness of the air—or humidity of the atmosphere—at your location.

QSTAG - quadripartite standardization agreement.

radiation inversion - a stable condition caused by heat released from the earth. See also inversion.

radiosonde - a miniature radio carried aloft by an unmanned balloon to broadcast the pressure, temperature, and relative humidity of the upper air and to automatically transmit that information to the ground.

raob - an abbreviation for radiosonde observation.

rate of dosage - see dose rate.

rawin - a winds-aloft observation made by balloon and radio methods (rawinsonde observation).

relative humidity (popularly called humidity) - the ratio of the actual amount of water vapor present in the air to the saturation point at the same temperature. The corresponding ratios of specific humidity or of mixing ratio give approximations of sufficient accuracy for many purposes in meteorology. The relative humidity is usually expressed in percent and can be computed from psychometric (wet bulb-dry bulb temperature) data.

rime - a rough, white icy covering deposited on trees, or other exposed objects, somewhat resembling white frost, but formed only from fog- or vapor-bearing air.

RP - red phosphorus.

screening length - distance from the source of a smoke screen to the point downwind where the background begins to become recognizable.

sferics - a phonetic contraction of the word "atmospherics."

SGF2 - standard grade fuel number 2.

smoke - a particulate of solid or liquid particles dispersed into the air on the battlefield to degrade enemy ground and aerial observation. Smoke has many uses—screening smoke, signaling smoke, smoke curtain, smoke haze, and smoke deception. Thus it is an artificial aerosol.

solstice - one of the two points on the sun's apparent annual path where it is displaced farthest north or south from the earth's equator. In the northern hemisphere, the summer solstice is reached about 22 June. In the southern hemisphere, the winter solstice is reached about 22 December.

STANAG - standardization agreement.

storm - any disturbed state of the atmosphere, especially as affecting the earth's surface, and strongly implying destructive or unpleasant weather.

stratocumulus (abbreviated Sc) - a principal low-level cloud type, predominantly stratiform, in the form of a gray and/or whitish layer or patch, which nearly always has dark parts and is nonfibrous.

stratosphere - the region of the upper atmosphere characterized by little or no temperature change with altitude. The stratosphere extends from the tropopause (13 kilometers) to approximately 80 kilometers.

stratus (abbreviated St) - a principal low-level cloud type in the form of a gray layer with a rather uniform base. Stratus does not usually produce precipitation, but when it does occur, it is in the form of minute particles, such as drizzle, ice crystals, or snow grains. Stratus often occurs in the form of ragged patches or cloud fragments in which case rapid transformation is a common characteristic. When the sun is seen through the cloud, its outline is clearly discernible, and it may be accompanied by corona phenomena. In the immediate area of the solar disk, stratus may appear very white. Away from the sun, and at times when the cloud is sufficiently thick to obscure it, stratus gives off a weak, uniform luminance.

sublimation - the transition of a substance from the solid phase directly to the vapor state, or vice versa, without passing through the intermediate liquid phase.

superadiabatic lapse rate - an environmental lapse rate greater than the adiabatic lapse rate such that potential temperature decreases with height.

surface boundary layer - the portion of the atmosphere lying next to the surface of the earth and extending up to between 50 and 100 meters.

SWO - staff weather officer.

synoptic - in general, pertaining to or affording an overall view. In meteorology, this term has become somewhat specialized in referring to the use of meteorological data obtained simultaneously over a wide area for presenting a comprehensive and nearly instantaneous picture of the state of the atmosphere. Thus, to a meteorologist, synoptic takes the additional connotation of simultaneity.

thermal turbulence - irregular motion of air caused by convection currents rising from heated surfaces. See also mechanical turbulence.

tornado (sometimes called cyclone or twister) - a violently rotating column of air, pendant from a cumulonimbus cloud, and nearly always observable as a funnel cloud or tuba. On a local scale, it is the most destructive of all atmospheric phenomena. Its vortex, commonly several hundred yards in diameter, whirls usually counterclockwise with wind speeds of 100 to more than 300 miles per hour (161 to 483 kmph). Its general direction of travel is governed by the motion of its parent cloud.

TOT - time on target.

toxicity - relating to a poison or toxin; poisonous.

toxin - a colloidal poisonous substance that is a specific product of the metabolic activities of a living organism and is notably toxic when introduced into living tissue.

tropopause - the zone of transition between the troposphere and the stratosphere (approximately 13 kilometers). The tropopause normally occurs at an altitude of between 25,000 and 45,000 feet in polar and temperate zones. It occurs at 55,000 feet in the tropics.

troposphere - the lower levels of the atmosphere extending from the earth's surface up to the tropopause. It is characterized by convective air movements and a large vertical temperature change.

turbulence - irregular motion of air. See also mechanical turbulence and thermal turbulence.

unstable condition - see lapse.

venturi effect - constricting a passageway, so that the air (or fluid) moving through the constriction is greatly accelerated.

virga - rain or snow that is dissipated in falling and does not reach the ground, commonly appearing in trails descending from a cloud layer.

virulent agents - agents that produce rapid, severe, and malignant results in victims.

volatile - pertaining to a readily vaporizable liquid that evaporates at a relatively low ambient temperature.

weather - the state of the atmosphere, mainly with respect to its effects upon life and human activities. As distinguished from climate, weather consists of the short-term (minutes to months) variations of the atmosphere. Popularly, weather is thought of in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, and wind.

weather forecast - a prediction of weather conditions expected at a place, within an area, or along a route for a specified time or during a specified period.

weather summary - a description of weather along a route or within an area during a specific period; used in analyzing the effects of weather on recent operations and estimating effects on future operations.

wind - air in motion, usually parallel to the earth's surface.

wind direction - the compass point, degree, or roils (see Figure C-4) from which the wind blows.

wind shear - a change of wind speed, direction, and magnitude.

wind velocity - the horizontal direction and speed of air motion.

windward - the side receiving the wind's force. Used most often in this manual in reference to a slope facing into the wind.

woods - for chemical behavior purposes, trees in full leaf (coniferous or medium-dense deciduous forests). See, also, heavily wooded, coniferous, and deciduous.

WP - white phosphorus.

References

All references with information on the subjects listed in this publication may not be listed here. New material is constantly being published and present references may become obsolete. Consult the applicable directory of publications and instructional material catalogues to keep updated.

Required Publications

Required publications are sources that users must read in order to understand or to comply with this publication.

Field Manual (FM)

100-5 Operations

Joint Chiefs of Staff (JCS) Publication

1 Dictionary of Military and Associated Terms

Related Publications

Related publications are sources of additional information. Users do not have to read them to understand this publication.

Air Force Regulation (AFR)

105-3 Meteorological Support for US Army

Army Regulations (ARs)

115-10 Meteorological Support for US Army
115-12 US Army Requirements for Weather Service Support
316-25 Dictionary of US Army terms
310-50 Authorized Abbreviations and Brevity Codes

Department of Army Pamphlet (DA Pam)

115-1 Requests for Climatology to Army Activities

Field Manuals (FMs)

3-3 NBC Contamination Avoidance
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3-9 Military Chemistry and Chemical Compounds
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22-1 The Amphibious Task Force Plan
22-2 Supporting Arms in Amphibious Operations
28 Nuclear Warfare Operations
28-2 The Nuclear Explosion Environment
28-3 Vulnerability and Survivability of Navy Systems
36 Armed Forces Doctrine for Chemical Warfare and Biological Defense (to be renumbered NWP 18)
36-2 Employment of Chemical Agents (to be renumbered NWP 18-1)
36-4 Employment of Chemical Agents (to be renumbered NWP 18-2)

Allied Tactical Publications (ATP)

ATP-1 Vol 1 Allied Maritime Tactical Instructions and Procedures
ATP-25 Nuclear Fall-Out Forecasting and Warning Organization
ATP-31 NATO Above Water Warfare Manual
ATP-45 Reporting Nuclear Detonations, Biological and Chemical Attacks

Instructions

OPNAVINST S3400.10C Offensive Chemical Warfare and Chemical, Biological, and Radiological Defense
NAVOCEANCOMINST 3140.1 DON Meteorological and Oceanographic Support Manual
SECNAVINST 3403.1 Riot Control Agents and Chemical Herbicides in War (rules governing use)

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