CHAPTER 1
GENERAL

1-1. Purpose

This manual contains general criteria and information for considering frost action, permafrost and other factors in the design of military facilities in arctic and subarctic regions.

1-2. Scope

The contents of this manual are applicable to both Army and Air Force construction. This manual provides basic background data for the detailed criteria pertaining to the various elements of arctic and subarctic facility design presented in the other manuals of the Arctic and Subarctic Construction series, TM 5-852-2 through 7, and 9/AFR 88-19, Volume 2, 5 and 6/AFM 88-19, Chap. 3, 4, 7, and 9.

1-3. Need for special approaches

In the design, construction and maintenance of facilities such as roads, utilities and buildings in arctic and subarctic regions, many problems are encountered that (do not exist, or are not present in the same degree, in more temperate regions. These problems arise, for example, from the presence of permafrost over vast areas, with its potential for thaw and thaw settlement; from the special properties of frozen soil, frozen rock and ice; from the effects of frost heave and other phenomena in soil, rock, paving and other materials subject to intense annual cycles of freezing and thawing temperatures; from drainage, water supply and sewerage problems peculiar to those regions; and from such factors as the shortness of the above-freezing summer season, the limited amount of daylight in fall and winter, environmental aspects, and often difficult conditions of transportation, access and communications. Special design, construction and maintenance approaches, and management of construction are often required to cope with such problems and to meet stability and operational requirements for facilities.

1-4. Definitions

Certain specialized terms used in current literature on frost and permafrost and in the Arctic and Subarctic Construction manuals are defined below. Additional terms pertinent to heat transfer calculations are defined in TM 5-852-6/AFR 88-19, Volume 6.

a. Regions.

(1) *Arctic.* The northern region in which the mean temperature for the warmest month is less than 50°F and the mean annual temperature is below 32°F. In general, the arctic land areas coincide approximately with the tundra region north of the limit of trees.

(2) *Subarctic*. The region adjacent to the Arctic in which the mean temperature for the coldest month is below 32°F, the mean temperature for the warmest month is above 50°F, and in which there are less than 4 months having a mean temperature above 50°F. In general, subarctic land areas coincide with the circumpolar belt of dominant coniferous forest.

(3) *Seasonal frost areas*. Those areas of the earth in which there is significant freezing during the .winter but without development of permafrost.

b. Soil and frost terms.

(1) *Active layer*. A commonly used term in permafrost areas for the annual frost zone.

(2) *Aggradation*. Progressive raising of the permafrost table, taking place over a period of years.

(3) *Annual frost zone*. The top layer of ground subject to annual freezing and thawing. In arctic and subarctic regions where annual freezing penetrates to the permafrost table, the active layer, suprapermafrost and the annual frost zone are identical.

(4) *Closed system*. A condition in which no source of free water is available during the freezing process beyond that contained originally in the voids of soil.

(5) *Creep*. Extremely slow, continuing strain deformation of material under stress, at rates so slow as to usually be imperceptible except by observations of high precision or of extended duration.

(6) *Degradation*. Progressive lowering of the permafrost table, occurring over a period of years.

(7) *Excess ice*. Ice in excess of the fraction that would be retained as water in the soil voids upon thawing.

(8) *Frost action*. A general term for freezing and thawing of moisture in materials. It also covers the effects on these materials and on structures of which they are a part or with which they are in contact. The term "frost" is often used to refer to frost action in general.

(9) *Frost boil*. The breaking of a limited section of a highway or airfield pavement under traffic and ejection of soft, semi-liquid subgrade soil. This is caused by the melting of the segregated ice formed by frost action.

(10) *Frost creep*. The ratchet like downslope movement of particles as a result of frost heaving and subsequent ground settling upon thawing. The heaving is predominantly normal to the slope and the settling more nearly vertical.

(11) *Frost heave*. The raising of a surface because of ice formation in the underlying soil.

(12) *Frost slough*. A shallow slide that occurs when the stability of frost-loosened and

moisture-saturated fine-grained soils on slopes is reduced during thaw.

(13) *Frost-susceptible soil*. Soil that will experience significant ice segregation when the requisite moisture and freezing conditions are present. Such soils are further defined in TM 5-818-2/AFM 88-6, Chap. 4.

(14) *Frost table*. The surface, usually irregular, that represents the level, at any time in spring and summer, to which thawing of seasonal frozen ground has penetrated.

(15) *Frost thrust*. A force due to frost action.

(16) *Frozen zone*. A range of depth within which the soil is frozen.

(17) *Ground ice*. A body of more or less soil-free ice within frozen ground.

(18) *Heterogeneously froze. soil.* A soil with part of its water frozen as macroscopic ice occupying space in excess of the original voids in the soil.

(19) *Homogeneously frozen soil.* A soil in which water is frozen within the material voids without macroscopic segregation of ice.

(20) *Ice segregation*. The grow the of ice within soil in excess of the amount that would be produced by the in-place conversion of the original void moisture to ice. Ice segregation occurs most often as distinct lenses, layers, veins and masses, commonly, but not always, oriented normal to the direction of heat loss.

(21) *Ice wedge*. A wedge-shaped ice mass in permafrost, usually associated with fissures on trough type polygons.

(22) *Non frost-susceptible materials*. Cohesionless materials such as crushed rock, gravel, sand, slag and cinders in which there is no significant ice segregation under normal freezing conditions (see TM 5818-2/AFM 886. Chap. 4).

(23) *Normal period*. The time of the year when there is no alteration in strength of foundation materials because of frost action. In seasonal frost areas, it generally extends from mid or late spring to mid or late fall.

(24) *Open system.* A condition where free water in excess of that contained originally in the voids of the soil is available to be moved to the surface of freezing to form segregated ice in frost-susceptible soil.

(25) *Percent heave*. The ratio, expressed as a percentage, of the amount of heave to the depth of frozen soil.

(26) *Permafrost.* Perennially frozen ground. It may be defined more specifically as a thermal condition in soil or rock in which temperatures below 32°F persist over at least two consecutive winters and the intervening summer.

(27) *Permafrost base*. The lower boundary of permafrost.

(28) *Permafrost, continuous*. Permafrost occurring everywhere beneath the exposed land surface throughout a geographic region, with the exception of widely scattered locations.

(29) *Permafrost, discontinuous.* Permafrost occurring in some areas beneath the ground surface throughout a geographic region where other areas are free of permafrost.

(30) *Permafrost table*. An irregular surface within the ground that represents the upper boundary of permafrost.

(31) *Residual thaw layer*. A layer of unfrozen ground between the permafrost and the annual frost zone. This layer does not exist where annual frost (active layer) extends to permafrost.

(32) *Solifluction.* The perceptible slow downslope flow of saturated unfrozen soil over a base of impervious or frozen material. Movement takes place primarily when melting of segregated ice or infiltration of surface runoff concentrates excess water in the surface soil, which then behaves like a viscous fluid.

(33) *Suprapermafrost*. The entire layer of ground above the permafrost table.

(34) *Tangential adfreeze shear.* Tangential shear between frozen ground or ice and another material to which it is bonded by freezing.

(35) *Thaw-stable froze soils*. Frozen soils that do not, on thawing, show loss of strength below normal, long-time thawed values nor produce detrimental settlement.

(36) *Thaw-stable frozen soils*. Frozen soils that show, on thawing, significant loss of strength below normal, long-time thawed values or significant settlement, as a direct result of the melting of excess ice in the soil.

c. Temperature-related terms.

(1) *Average annual temperature.* The average of the average daily temperatures for a particular year.

(2) *Average daily temperature*. The average of the maximum and minimum temperatures for one day or the average of several temperature readings taken at equal time intervals during one day, generally hourly.

(3) *Average monthly temperature*. The average of the average daily temperatures for a particular month.

(4) *Breakup period*. The period of the spring thaw during which the ground surface is excessively wet and soft, and ice is disappearing from streams and lakes. Duration of the breakup period varies usually from 1 to 6 weeks, depending on region or local climatic conditions.

(5) *Degree-days*. The degree-days for any one day equal the difference between the average daily air temperature and 32°F. The degree-days are negative when the average daily temperature is below 32°F (freezing degree-days) and positive when above (thawing degree-days). Degree-days may be computed in either Fahrenheit or Celsius units; in this

manual, Fahrenheit degree-days are used. Figure 1-1 shows a typical curve obtained by plotting cumulative degree-days versus time.

(6) *Design, freezing index*. For design of permanent pavements, the design freezing index should be the average air freezing index of the three coldest winters in the latest 30 years of record. If 30 years of record are not available, the air freezing index for the coldest winter in a 10-year period may be substituted. For design of foundations for average permanent structures, the design freezing index should be computed for the coldest winter in 30 years of record or should be estimated to correspond with this frequency if the number of years of record is limited. Periods of record used should be the latest available. To avoid the necessity for adopting a new and only slightly different freezing index each year, the design index at a site with continuing construction need not be changed more than once in 5 years, unless the more recent temperature records indicate a significant change. A design freezing index for pavements is illustrated in figure 1-1.

(7) *Design thawing index.* The design thawing index is computed on the same frequency and other bases as the design freezing index, except that summer thaw conditions are used.

(8) *Freezeup period.* The period during which the ground surface freezes and an ice cover is forming on streams and lakes. The duration of the freezeup period varies from 1 to 3 months, depending on regional or local climatic conditions.

(9) *Freezing index.* The number of degree-days between the highest and lowest points on a curve of cumulative degree-days versus time for one freezing season. It is used as a measure of the combined duration and magnitude of below-freezing temperatures

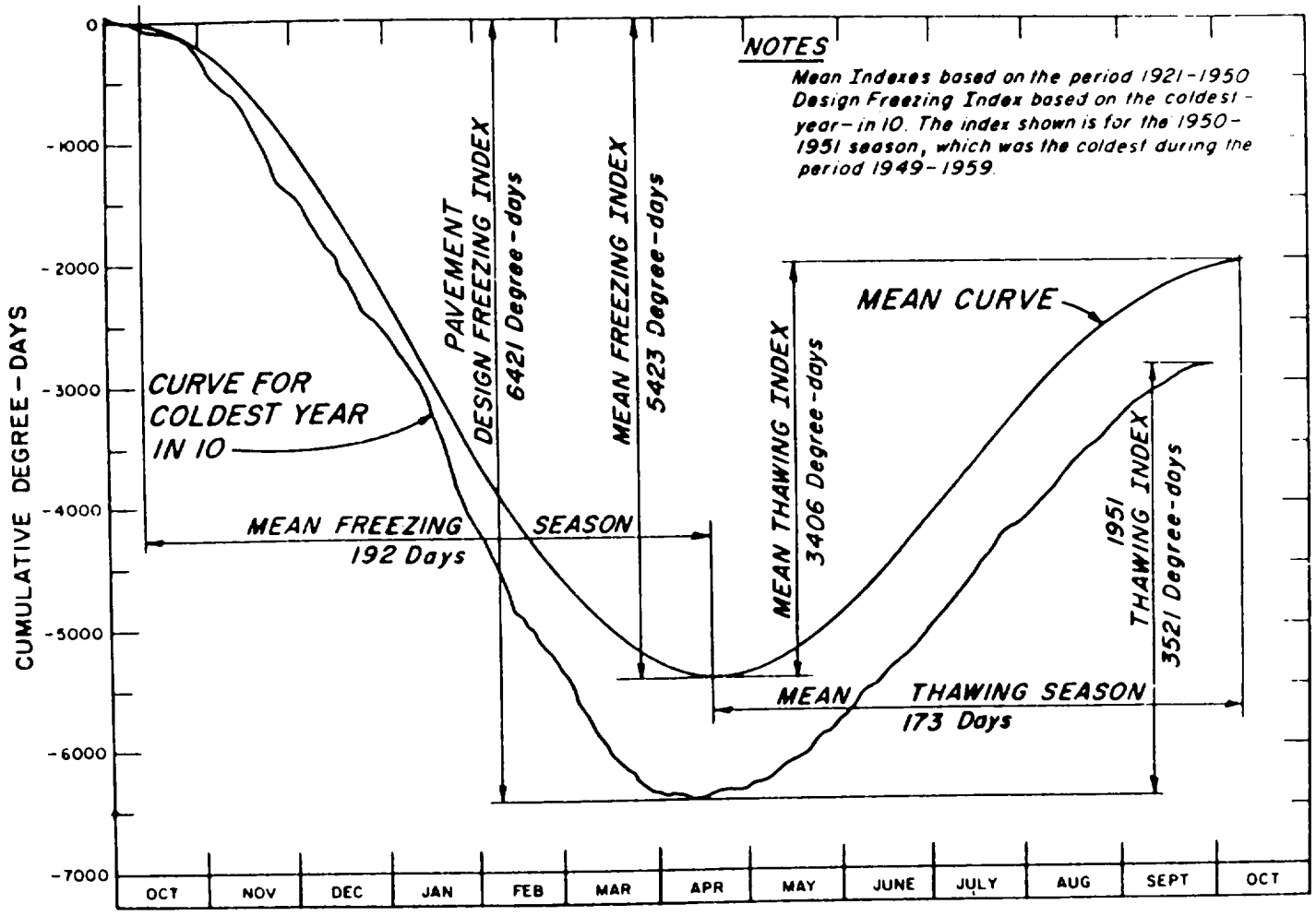

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Figure 1-1. Determination of freezing and thawing indexes.

occurring during any given freezing season. The index determined for air temperatures at approximately 4.5 feet above the ground is commonly designated as the air freezing index, while that determined for temperatures immediately below a surface is known as the surface freezing index.

(10) *Freezing season*. That period of time during which the average daily temperature is generally below 32°F. Figure 1-2 shows mean dates for beginning of the freezing season in the Northern Hemisphere.

(11) *Frost-melting period*. An interval of the year during which ice in the ground is returning to a liquid state. It ends when all of the ice in the ground is melted or when freezing starts again. Although in the generalized case there is only one frost-melting period, beginning during the general rise of air temperatures in the spring, one or more significant frost melting intervals may take place during a winter season.

(12) *Geothermal gradient*. The temperature gradient in the ground below the zone of annual temperature fluctuations, produced by the continuous flow of heat from the Earth's hot interior toward the relatively cool Earth's surface.

(13) *Mean annual temperature*. The average of the average annual temperatures for several years.

(14) *Mean daily temperatures*. The average of the average daily temperatures for a given day for several years.

(15) *Mean freezing index*. The freezing index determined on the basis of mean temperatures. A mean freezing index is illustrated in figure 1-1.

(16) *Mean monthly temperature*. The average of the average monthly temperatures for a given month for several years.

(17) *Mean thawing index*. The thawing index determined on the basis of mean temperatures. A mean thawing index is illustrated in figure 1-1.

(18) *n-factor*. The ratio of surface index to air index for either freezing or thawing. Surface index equals air index multiplied by the n factor.

(19) *Period of weakening*. An interval of the year that starts at the beginning of the frost-melting period and ends when the subgrade strength has returned to normal period values or when freezing starts again. In seasonal frost areas, the period of weakening may be substantially longer than the frost-melting period, but in permafrost areas the periods coincide.

(20) *Thawing index*. The number of degree-days between the lowest and highest points on a curve of cumulative degree-days versus time for one thawing season. It is used as a measure of the combined duration and magnitude of above-freezing temperatures during any given thawing season. The index determined for air temperatures at 4.5 feet above the ground is commonly called the air that determined for temperatures immediately below a surface is known as the surface thawing index. A thawing index is shown in figure 1-1.

(21) *Thawing season.* That period of time (luring which the average daily temperature is generally above 32°F. Figure 1-3 shows mean dates for beginning of the thawing season in the Northern Hemisphere.

(22) *Thermal regime*. The pattern of temperature variations found in the ground with time and with depth from the surface.

(23) *Wind chill*. The excess rate of removal of body heat from exposed skin by moving air compared to still air at low temperatures. It is often expressed as a lower equivalent air temperature that is a function of actual air temperature and wind speed.

d. Terrain terms.

(1) *Frost mound*. A localized upwarp of land surface caused by frost action with or without hydrostatic pressure.

(2) *Icing*. A surface ice mass formed by freezing of successive sheets of water.

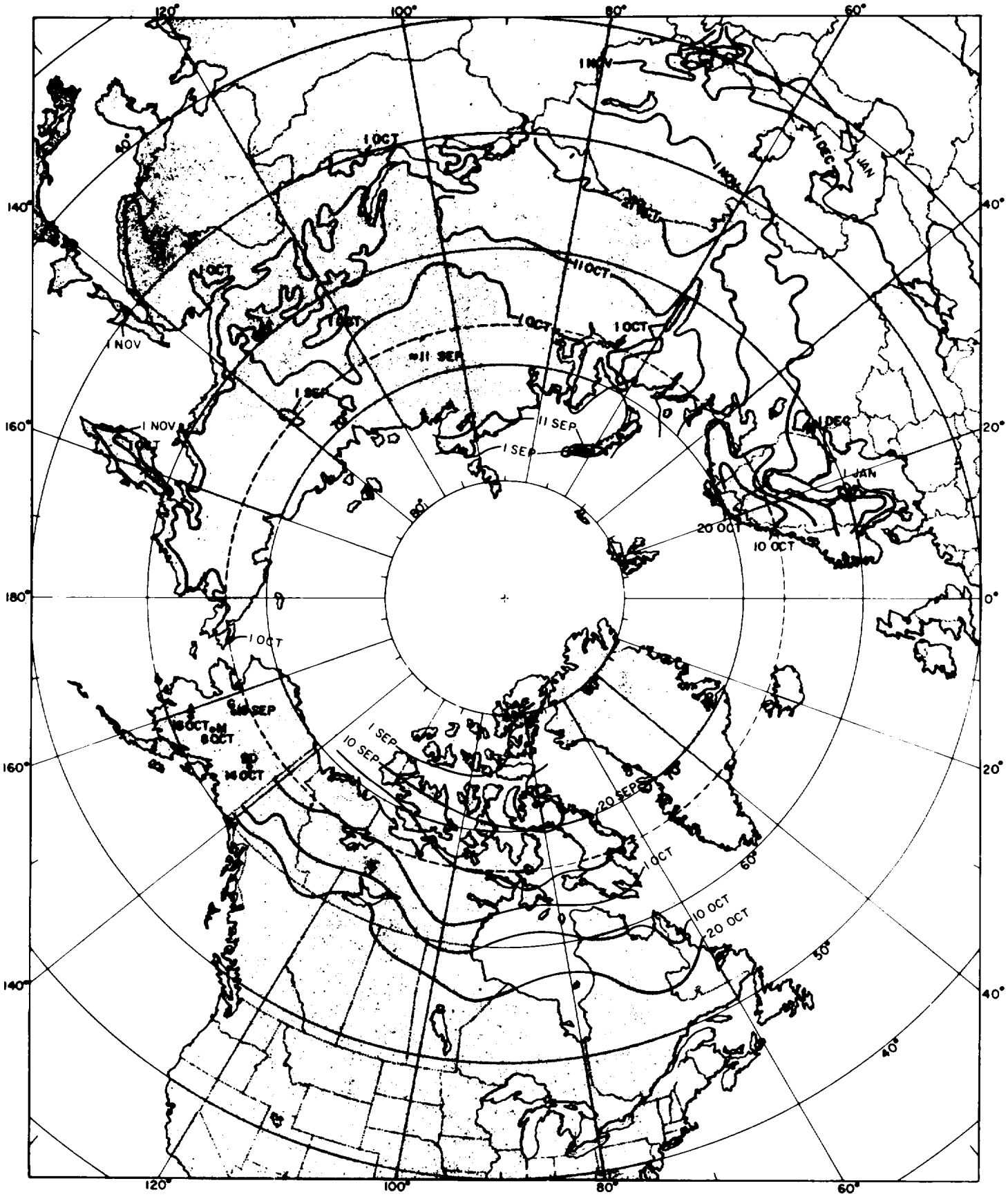
(3) *Muskeg*. Poorly drained organic terrain consisting of a mat of living vegetation overlying an extremely compressible mixture of partially decomposed peat, varying in thickness from a few inches to many feet.

(4) *Patterned ground*. A general term describing ground patterns that result from frost action, such as polygons, circles and nets, stripes, and solifluction features.

(5) *Pingo (hydrolaccolith).* A large ice-cored frost mound, often 100 feet high or more.

(6) *Thermokarst*. The irregular topography resulting from the process of differential thaw settlement or caving of the ground because of the melting of excess ice in thaw-unstable permafrost.

(7) *Tundra*. A treeless region of grasses and shrubs characteristic of the Arctic.



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Note: The earliest date is approximately 10 days before the average for most stations.

Figure 1-2. Mean date of the beginning of the freezing season.

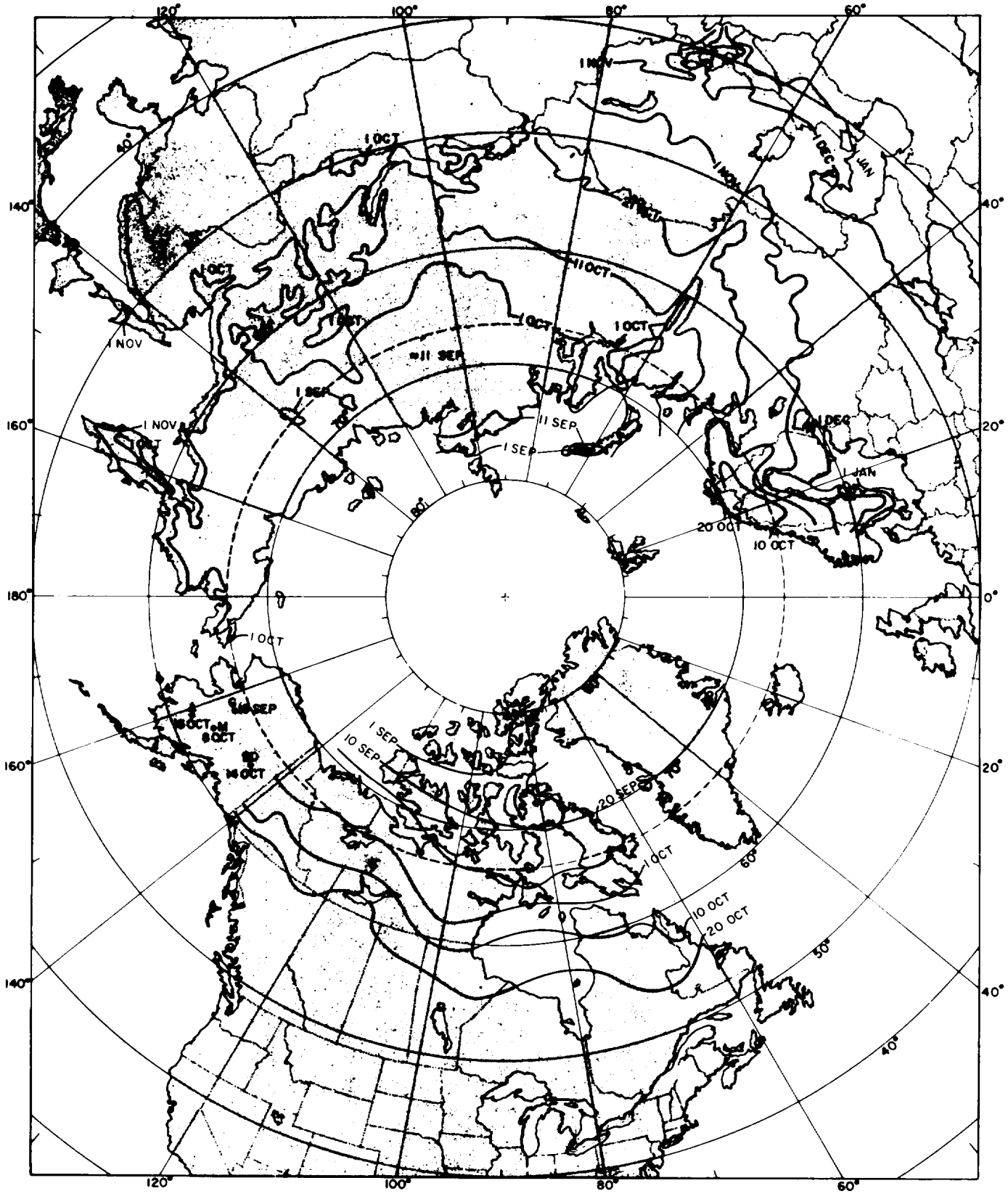

Figure 1-3. Mean date of the beginning of the thawing season.