

COURSE CODE:	WMA 316
COURSE TITLE:	Agrometeorology II
NUMBER OF UNITS:	2 Units
COURSE DURATION:	Two hours per week

COURSE DETAILS:

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Other Lecturers:	Prof. N.J. Bello and Dr. Adejuwon

COURSE CONTENT:

A general survey of climate-agriculture relationships classification of agrometeorological induces. The concepts of plant environment are the relationship between climate and plants biophysical environment.

Geomorphic, Edaphic and Biotic factors. Major climate attributes in plant and animal distribution. General climate aspect of pests and diseases of plants and animal. Forestry, fisheries. Water and energy budget of the plant environment. Modification of plants microclimatic environment modification of soil temperature regime, rain making, evaporation suppression and wind speed checks.

COURSE REQUIREMENTS:

This is a compulsory course for all students of the department of water resources management and Agrometeorology and elective course for students from other departments of the College of Environmental Resources Management in the University. In view of this, students are expected to participate in all course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

1. Ayoade, J.O. Tropical hydrology and water resources
2. Duru, L .1984. Climate, Water and Agriculture in the tropics. Longman publishers. London, UK
3. Gordon, W.1981. Tropical Agriculture the Development of Production, 4th edn., Longmans, London, UK.
4. Shaw, M. 1994. Hydrology in practice. Van Nostrand Reinhold. Berkshire, UK.
5. Yayock, J.Y., Lombin, G., Owonubi, J.J. 1988. Crop science and production in warm climates. MacMillan publishers. London USA.

LECTURE NOTES

INTRODUCTION

Man is simply (or greatly) dependent on climate for the adequacy of his food supplies. The production of food depends on understanding the interrelationship of the total environment which includes climate, soil genetic materials of plants and animals, insects and diseases and man himself. Of all these important environmental variables weather or climate is the only uncontrollable variable which needs special attention.

Understanding the physical principles of climatic parameters such as radiation, temperature, precipitation, evapotranspiration and others together with the understanding of the life process of plants and animals in relation to climate variables is of primary importance in the struggles to supply food. Man struggles with the nature constantly through a connective ability to optimized food production through appropriate land use and at the same time to minimize the weather hazards on plants and animals and man himself.

Yields and productivities analysis is one of the final goal of an agricultural meteorological studies. By understanding the relationship between weather and crop yield through statistical models or other methods the agricultural meteorologist may best predict crop yield in advance. He may also provide information about the climate potential of an area and how it can be used to maximize his potential.

CLIMATE FACTORS AFFECTING AGRICULTURE

The Climate factors affecting agriculture have been generally grouped into three major categories such as.

- (i) The Thermal agro- meteorological induces.
- (ii) The Moisture agro- meteorological indices.
- (iii) The Aerodynamic agro- meteorological indices.

Thermal Agrometeorological Indices

The moisture agro meteorological indices are radiation, temperature of both air and soil.

Moisture Agrometeorology Indices

The moisture agro meteorological indices are different forms of precipitation, the most important in the tropics of which is rainfall; others are evaporation and evapo-transpiration and also relative humidity.

Aerodynamic Agrometeorological Indices

The aerodynamic agricultural indices are made up of wind, hurricanes, thunderstorm, tornadoes and other turbulent motions.

RADIATION AND AGRICULTURAL PRODUCTION

Radiant energy from the sun is the major source of energy for terrestrial life, practically all the energy for all the physical and biological processes occurring on the earth arise in the form of solar radiation. Radiation is the ultimate of all the changes and motion of the atmosphere and it is the single most important control of climate. It is a meteorological element of highest important. Radiation from the sun comes in forms of short-wave electromagnetic radiation. The shortwave radiation are refers to as short-wave incoming radiation. The outgoing radiation from the soil is called the long-wave terrestrial radiation from the soil is called the long-wave terrestrial radiation.

At the outer limits of the atmosphere measures on the surface normal to the incident radiation and at distance from the sun, the energy value at this outer limit is equal to $0.136 \text{ Watts Cm}^{-2} \text{ Mins}^{-1}$ this is equivalent to $1.95 \text{ Calories cm}^{-2} \text{ mins}^{-1}$ (this is called the solar constant).

INCOMING SOLAR RADIATION

As it passes through the atmosphere, solar radiation is depleted by molecules and particles. As the remaining energy reaches the earth surface, part of it is further reduce by reflection generally refers to as SURFACE ALBEDO. The surface albedo is defined as the ratio of the amount of radiation reflected to the incident amount and it is commonly expressed as a percentage (%). In addition to the direct sunlight the earth surface will seems diffuse sky-light cause by scattering. The intensity of the diffuse radiation depends on the solar elevation,

height, cloudiness and atmospheric turbidity. The radiation adsorbed by the earth surface is re-emitted as long-wave radiation in a space, the intensity of the terrestrial radiation may be expressed by the following equation.

$$R = E\sigma T^4$$

Where R= Terrestrial outgoing radiation.

E= Emissivity of the earth surface.

σ = Steffan's Boltzman constant which is given as 7.92×10^{-11} $\text{W m}^{-2} \text{K}^{-4}$.

T= Absolute temperature in $^{\circ}\text{K}$.

Terrestrial radiation is refers to as black body radiation, the black body radiation is the maximum amount of radii energy which can be emitted by body at a given temperature. The surface of the earth can be considered as the black body. Emissivity Varies with wavelength, the emissivity of the soil ranges from 0.95-0.98 and the emissivity of plant surface range from 0.90-0.95. Carbon dioxide, water vapour and ozone in the atmosphere control the exchange of the radiation between the earth surface and the sky. These gases (such as CO_2 water vapour) absorb much of the outgoing radiation from the atmosphere and re-radiation the portion back in the ground producing the green house effect which effectively prevent excessive cooling at night. Water vapour absorbs strongly in the vicinity of 6.0 and beyond 22μ (micron) while carbon dioxide (CO_2) Captures energy in the $4-16\mu$ region. The atmosphere windows through which the terrestrial radiation fully are located in the vicinity of 5.0 and again between 8 and 12.0μ (microns).

NET RADIATION

The net radiation is the difference between total upward and downward radiation flux. It is the energy available on the earth surface and it can be expressed in several forms. One the commons forms of the equation of the radiation balance is stated below.

$$R_n = R_{s\downarrow} - R_{s\uparrow} + R_{L\downarrow} - R_{L\uparrow}$$

Where R_n = Net radiation

$R_{s\downarrow}$ = Incoming shortwave solar radiation (\downarrow + q i.e direct and diffuse radiation)

$R_s\uparrow$ = the shortwave radiation reflected from the surface.(Albedo)

$R_s\downarrow$ = Incoming long wave radiation which is re-radiated principally by water vapour carbon dioxide.

$R_s\uparrow$ = the upward long wave radiation emitted by the surface according to its temperature.

RADIATION OR ENERGY BALANCE

Energy balance is the equilibrium condition which exists in average terms between radiations received from the sun i.e isolation and that re-radiated or reflected. The net radiation may be expressed or represented as below.

$$R_n = LE + H + S_g + P + M \quad (R_m = LE + H + G + P)$$

Where R_n = Net radiation

LE = Flux of latent heat i.e heat used in evaporation and condensation.

H = Flux of sensible heat i.e heat transferred by convection.

S_g = Ground heat storage i.e heat flow into or out of the ground by conduction.

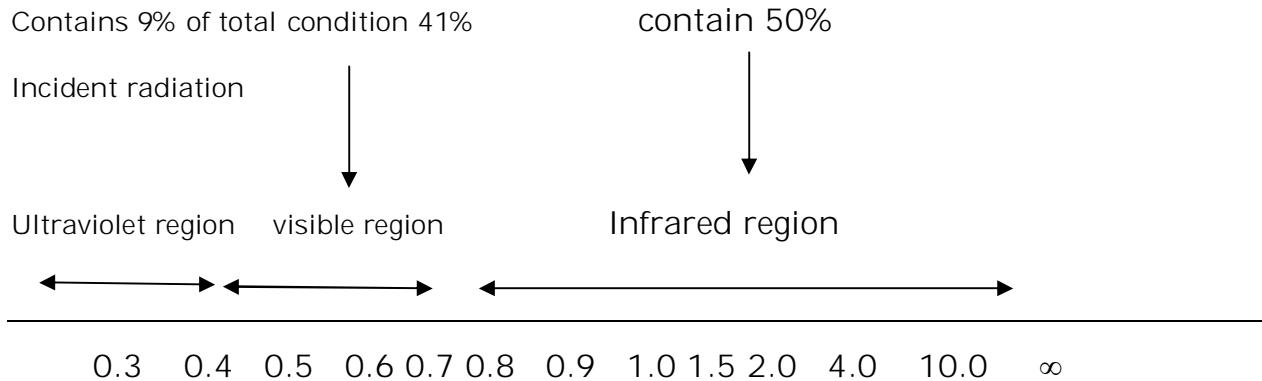
P and M = are small amount of energy utilized by plant for photosynthesis as well as other exchanges' such heat storage in the crop if the ground is covered by vegetation.

Radiation balance is positive by day, negative by night, highest in low latitude i.e between 0 and 30° North and South and greater over the sea than land. An annual positive balance is obtained over the globe as a whole but a negative balance the same amount in the atmosphere. This results in an overall equilibrium in the earth atmosphere system.

SPECTRAL DISTRIBUTION OF SOLAR RADIATION

The spectral distribution of the sunlight i.e, direct radiation at the top of the earth atmosphere and at the earth surface is such that most of the ultraviolet

radiation from the sun absorbed by oxygen high in the atmosphere and by ozone at a height of 25km above the land water surface. The energy in the ultra-violet below the wave length of 0.4μ comprises about 9% of the total incident radiation while the energy in the infrared region beyond 0.74μ contains about 50%. The spectral distribution of radiation changes with altitude and cloudiness- ultraviolet and infrared radiation is reduced much more on the cloud day than on the sunny day.



RADIATION AND LIGHT DISTRIBUTION WITHIN THE PLANT CANOPY

The radiation distribution within the plant canopy is affected by the following factors.

- (1) Plant leaf area
- (2) Plant density
- (3) Plant height
- (4) Leaf arrangement
- (5) The Sun angle
- (6) The inclination and transmissivity of the leaves.

The light distribution in the canopy may be expressed according to Beer's law as

$$I = I_0 e^{-kF}$$

Where I = is the light intensity at a given height within the plant canopy

I_0 = is the light intensity at the top of the plant canopy

e = the base of natural logarithm

i.e $e = 2.71828$

F = Leaf area index. Leaf area index is defined as the leaf area subtended per unit area of land.

K = coefficient determined primarily by leaf inclination and arrangement and secondarily by leaf transmissivity.

Another equation dealing with light distribution within a light canopy is presented Montenth.

$$I = [S + (1-S) \tau F I_0]$$

Where

S= fraction of light passing through a unit leaf layer without interception in f.

τ = is the leaf transmission coefficient

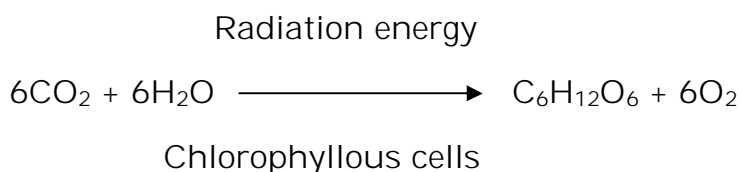
F= leaf area index i.e the leaf area substandard per unit area of land

I= is the light intensity at a given height within the plant canopy as previously defined.

Both equations indicate that leaf area is an important factor but also of secondary important in the transmissivity of the leaf while leaf arrangement plays an important role in the light interception within the plant canopy.

PHOTOSYNTHESIS AND CLIMATE

Photosynthesis is the process by which certain carbohydrate is formed by chlorophyll in cells from carbondioxide, water and light energy from solar radiation. Photosynthesis occurs only in chlorophyllous plants and mainly in the leaves. The process of photosynthesis can be illustrated by the following chemical equation.



This process above is essentially oxidation-reduction process or reaction between carbondioxide and water. Water is oxidized; carbon dioxide is reduced

to carbon dioxide. Light in the visible region i.e the spectral region between 0.4-0.74 μ is used as energy for this process. There are three major important process of photosynthesis and these are;

- (i) Diffusion process
- (ii) Photochemical process
- (iii) Biochemical process

The diffusion process

The diffusion process is first movement of carbondioxide from external air near the leaf towards the reaction centre in the chloroplast.

The photochemical process

The photochemical process is formed in the conversion of light energy into chemical energy which can be used for the reduction of carbondioxide to carbohydrate. This process is influenced by light only.

The biochemical process

The biochemical process is the energy produced by light conversion and used for the reduction-oxidation reaction between water and carbon dioxide. Carbon dioxide in the air is just about 0.03% but this small amount plays an extremely important role in the biosphere. Most of the higher plants make use of carbondioxide continuously from the atmosphere and the carbondioxide removed is normally replenished from respiration and decomposition of plants and animals or normally replenished by the following

- (1) Respiration and decomposition of plants animals and micro-organism.
- (2) Volcanic activity
- (3) Combustion of organic fuel
- (4) The ocean is an important reservoir of carbondioxide.

LIGHT INTENSITY AND PLANT PHOTOSYNTHESIS

Only a portion of the narrow bad of the shortwave in the visible region 0.4-0.74 μ of the solar spectrum is absorbed by plant leaves to photosynthesis. The ability of plant leaves to adsorb the visible spectrum of light varies according to the kind of leaf and intensity of the light. Generally the rate of photosynthesis

in most plant leaves increases almost linearly with light saturated. Beyond this point photosynthesis or photosynthesis rate becomes independent of light intensity. However the saturated light intensity varies from plant to another plant.

TEMPERATURE AND PHOTOSYNTHESIS

Air temperature plays an active role in photosynthesis at saturation light intensity and normal carbondioxide concentration. The rate of photosynthesis is closely related to temperature in conjunction with CO₂ and light. For instance, the rate of photosynthesis in maize crop as a function of temperature and carbon dioxide showed that at low temperature of 14°C, the activities of maize are very low. The activities increase as the temperature is raised at 30°C (this is optimum temperature required). Rate of respiration also increase temp up to a maximum which varies from plant to plant. Dry matter accumulation in plants depends upon both photosynthesis and respiration. This interaction of these two process i.e photosynthesis and respiration may be expressed by the equation below.

$$N_p = P - R_{sp}$$

N_p = Net photosynthesis or net assimilation of dry matter.

P = photosynthetic rate

R_{sp} = Respective rate or rate of respiration.

Note that photosynthesis occur in the leaves when light is available but respiration is a continuous process day and night through the plant provided temperature is not limiting.

WATER TURBULENCE AND PHOTOSYNTHESIS

Less than 10% of water absorbed by plants is used in photosynthesis however water plays a prominent role in photosynthesis. Experiment shows that reduction of water context of leaves could significantly decrease the rate of photosynthesis. For instance when there is reduction of water into the plant environment either as a result of low rainfall or withdrawal of irrigation allocation for a certain period of time then moisture stress in leaves causes the

stomata to close and when this happens carbondioxide diffusion into plant leaves will be inhibited and consequently affect the rate of photosynthesis. When leaf stomata closes under a condition of moisture stress something can be done to check the closure of stomata. For instance this closure could be prevented by circulating moist over and around the leaf thereby maintaining a higher rate of photosynthesis.

TURBULENCE

In still air CO₂ gets to the leaves by diffusion. This is a relatively slow process. For instance, CO₂ concentration within crop canopy is very low during calm day time period when photosynthesis is high during the day time and also CO₂ near the leaf is depleted while at some distance away from the leaf the concentration remains at about 0.03% which is the normal concentration in the atmosphere. All these are influence by turbulence in the plant photosynthesis.

PHOTOPERIOD, PHOTOPERIODISM AND PLANT DEVELOPMENT

Photoperiod in the length (hour) of daily exposure to light and photoperiodism is the response of plant to photoperiod. The relationship between the length of day and night and the development of plant has been extensively investigated and base on this investigation plant has been classified into three groups based in their response to photoperiod and in other word base on their photoperiodism. The three major groups of photoperiodism classification of plants are as follows;

- (1) The daylong plant
- (2) The short-day plant
- (3) Day-neutral plant

Long day plant

The long day plants are plant that could only flower under day length that is not longer than 14hrs e.g small grass and orchard grass

Short day plant

The short plants are plant that could flower under the day length of less the 10hrs of day length e.g soya beans, millet, sweet potatoes and some variety of tobacco.

Day- neutral plant

The day neutral plants are the plants that could form their flowers under any period of day length e.g cotton, tomatoes, carrot and may kind of beans.

Intermediate day plant

An additional group suggested is known as intermediate day plant. These are plant that flowers at a day length of 12-14 hours but these plants are inhibited in reproduction by day length either above or below this duration.

Generally plants which are generated from the tropic requires relatively short day and long night for flowering while plant that are native of the high latitude are long-day short-night type.

Apart from light, temperature probably the most important factor affecting photoperiodism responses. Many plant do not response to critical photoperiodic condition provided then thermal requirements are met. Some plants species can alter then day length requirement in different stages of development for instance a long day plant for vegetative growth limitation can be a short day for fruiting and vice-versa. This phenomenon is refers to as **photoperiodic induction**, Apart from stages of crop development, photoperiod response can also be altered by artificial arrangement of light exposure. For example young seedling of tobacco were started and grown to the 5-6 leaf stage under long warm days which favoured flora induction for 2-3 weeks, they were then returned to long warm days flora induction and initiation hasten growth and development of flower. This effect of changing day length and temperature in different stages of development is known as PHOTOPERIOD INDUCTION.

AIR TEMPERATURE

Temperature is one of the primary factor affecting plant growth and its geographical distribution. Tropical plant have problems of completing their life cycle in cold environment while cold region plants finding it difficult to adapt to the warm climate. There are limits of temperature beyond which plants cannot survive. These are refers to as **lethal temperature or supra-ultimate-temperature**. There is another set of temperature limits beyond which plants growth ceases. Between this limits, there exist a point or a narrow range of

temperature within which plant growth is most favoured. In summary we are referring to maximum, optimum and minimum temperature and these three temperatures are referred to as **CARDINAL TEMPERATURES**. The Cardinal temperature varies with plant species and also varies with different stages of growth of plant. For instance, the minimum temperature required for cotton during the stage of sprouting is 14-18°C while during the stage of fruiting is 15-20°C for warm season crops such as Melloon, Sorghum, Rice, Soya bean and corn. The cardinal temperatures are 15-18°C at the minimum and 31-37°C at the optimum and 44-50°C at the maximum respectively.

For cool season crop like wheat and barley the cardinal temperature i.e for minimum 0-5°C, the optimum 25-31°C and for the maximum 31-37°C (In comparison).

Plant seeds can be treated in various ways to enhance high harvest, for instance a cold treatment of the germinated seed before sowing or seedling before transplanting can hasten time of flowering and result in an early harvest. This process of cold treatment is known as **Vernalization**. Vernalization can be applied to some warm climate crops usually in the tropics heat treatment is common.

METHODS OF RATING PLANT GROWTH

Temperature, radiation and moisture can be used for rating plant growth. Brain 1960, grew soya bean under control condition and find that the average range of development shows that of the linear processing. The threshold or base minimum temperature occurs near 10°C and optimum temperature 30°C. also during the daytime hour according to Brown (1964), 10°C is usually considered to be the lowest temperature at which crop will grow. The growth fastest at 30°C as long as there is no moisture stress. Above 33°C, the growth rate drops. finding like this is also possible through field experiment with careful observation. Another method of creating plant growth is that reported by Caprio 1971, this method is based on solar thermal unit (STU). The equation of STU is expressed as

$$STU = \sum_{T_e}^{B B} Rad \left[\left(\frac{1}{2} T_{max} - T_{min} \right) - X \right]$$

When STU = solar thermal unit

Rad = global radiation (0.3-4 μm) in lagley per day.

T_{max} = Daily minimum temperature

T_{min} = daily minimum temperature

X = Base of temperature and this varies according to different crops.

$T_c = \frac{1}{2} (Max - Min) - X$ = effective temperature

BB= Time plant begin to bloom.

Capino included that STU concept provides the best model available for estimating the rate of development of many plant species. For warm season crops such as corn and beans. 10° C is often used as the base temperature. For some other crops that are sensitive to low temperature such as tomatoes or orange the base temperature between 13- 15.5°C is used.

PLANT AND SOIL TEMPERATURE

Soil temperature is a primary control of plant growth and development or many instances soil temperature has greater ecological significance in plant life than air temperature. Soil temperature first affect the germination of seed and later influences the root development and the growth of the entire plant.

It is found that the optimum root temperature for dry matter production in sugar beet decreases from 26°C at 6 weeks after planting to 23°C at 13 weeks after emergence. Also it was found that high sucrose yield were obtained between 18° and 32°C but outside this range, there is decrease in sucrose yield. Generally physical, chemical and biological process in the soil are strongly affected by soil temperature. For instance the chemical weathering of the parent material of soil, the rate of organic matter decomposition and the mineralization of organic from of nitrogen all increase with increasing temperature furthermore the rate of growth multiplication and activity of soil micro-organisms can be influenced by soil temperature.

PHYSICAL PROPERTIES CONTROLLING THERMAL BEHAVIOUR OF OF SOILS.

There are two independent parameters which control the thermal behavior of soils. These are;

- (i) Thermal conductivities
- (ii) Thermal capacity

Thermal conductivity

Thermal conductivity is generally defined as the quantity of heat which flows through a unit area of unit thickness in a unit time under a unit temperature gradient. The thermal conductivity of soil depends upon its composition and its water and air contents.

Soils have much lower heat conductivity however when the soil is wetted the heat conductivity is increased. Soil temperature and organic matter content of the soil also affect heat conductivity when wet. The heat conductivity of the soil in sand > loam > clay → peat under a wet condition.

Thermal capacity

The thermal capacity or the amount of heat required to raise the temperature of 1g by weight or 1cm³ by volume of some materials by 1°C. The thermal capacity of the soil depends on the mineral composition, texture, moisture and air content. Water has a much higher thermal capacity than mineral soils. The heat capacity of soil varies greatly according to its moisture content. Dry peat has a lower heat capacity than sandy or clay soil but in the wet state the reverse is the case because the peats greater porosity can hold more water. Thermal capacity of the soil is higher in the clay than sandy soil. The quotient of thermal conductivity and thermal capacity is referred to as THERMAL DIFFUSIVITY. Thermal diffusivity is the quotient of thermal conductivity and thermal capacity. It is used to measure temperature changes of any given substance. The thermal diffusivity of a given soil depends on its moisture and generally thermal diffusivity increases with moisture content. It increases to the maximum and then decreases. The thermal diffusivity is usually low in the surface soil layer especially during summer when evaporation is high and surface of soil is dry. Organic matter has a low value of thermal diffusivity because of its low density. When the soil is compacted the value of its thermal diffusivity is increased. Most of the common soils have a range of thermal diffusivity from 0.01-0.001cm² sec⁻¹.

FACTORS AFFECTING SOIL TEMPERATURE

The external factors affecting soil temperature include meteorological elements such as solar radiation, air temperature, rainfall, humidity, evaporation, snow and others. Among these elements direct Q and diffuse q solar radiation (Q+q) is the most impact element. The soil type itself has significant impact. For instance, sandy soil warms up faster than textured loam and clay soils. The daily maximum soil temperature usually occur in the following order sand > loam> peat> clay especially in the upper layer of the soil. Soil temperature is also affected by its moisture contents i.e thermal conductivity and thermal capacity of the soil changes with the soil moisture content. When a soil is irrigated or when rainfalls water percolated through the soil profile, it carries heat with it. Evaporation from the soil creates chilling effect. Dark soils are warmer during warm season and has a wider diurnal change than white coloured soil. The angle of incidence of isolation varies according to direction of slope and this also have significant effect on soil temperature. The effect of exposure of slope is generally small the tropic or in the low latitude but higher in the middle or higher latitude or in the temperate region.

Generally daily and seasonal changes of soil temperature are due largely to concurrent changes in solar and terrestrial radiation, the heat cycle in the soil profile is delayed and decreases or weakened depth, the time lag of the maximum and minimum heat cycle in homogeneous soil can be expressed as

$$t_2 - t_1 = \frac{Z_2 - Z_1 T}{2\pi} \sqrt{\frac{\pi C_s}{TK}}$$

When t_2 and t_1 = true required to reach the maximum or minimum temperature at the depth of $Z_2 - Z_1$, respectively.

T= oscillation period of each cycle

σ = density of the soil

C_s = specific heat

K= heat conductivity

The temperature range in the soil profile at any point ' ΔT ' can be computed by the following equation.

$$\Delta T = \Delta T_i e^{-(Z_1 - Z_2) \sqrt{\pi C_s / TK}}$$

k/C_s = thermal diffusivity σC_s = thermal capacity K = thermal conductivity