3

The Earth's Synoptic Activities

The term synoptic activity (scale) refers to large-scale processes that have a horizontal length scale on the order of 1000 kilometers (about 620 miles) or more. This corresponds to a horizontal scale typically found in mid-latitude atmospheric depressions, e.g., extratropical cyclones. Most high and low meteorological areas seen on weather maps, such as surface weather analyses, are synoptic-scale systems, driven by air pressure in their respective hemisphere. The word *synoptic* is derived from the Greek word συνοπτικός, *synoptikos*, meaning *seen together*.

Greenhouse Effect Adiabatic Theory

The *greenhouse effect* adiabatic theory referred to in Chapter 2 can be defined as a unidimensional model. The planet would be represented as a dimensionless point and the only dimension is the elevation, *h*, above this point (sea level). Such a model is an accurate determination of the global tropospheric parameters, such as its: (1) *greenhouse effect* (average surface temperature), (2) average value of the radiation or (3) humidity-condensational component of the tropospheric heat release.

Lambert's law can be used to describe the illumination of a sphere and converted into a multi-dimensional model. Addition of the longitudinal component and the seasonal fluctuations of the planet's illumination converts this model into a three-dimensional model. A four-dimensional model is created if one adds time. These additions, however, could decrease the model's accuracy in expressing the *greenhouse effect* correlation with the composition of the planetary atmosphere.

Around 1729, Lambert stated that the absorbance of a material is directly proportional to the thickness (path length) it passes through. In 1852, Beer recognized another attribute of this formula, that the absorbance is proportional to the concentrations of the attenuating species. Today, the Beer–Lambert law combines the two laws and correlates absorbance to both the concentrations of the attenuating species as well as the thickness of the material sample. This law is often referred to as Lambert's Law.

Lambert's Law can be stated as, the absorbance of light is directly proportional to the thickness of the media through which that light is being transmitted, multiplied by the concentration of absorbing chromophore:

$$A = ebc \qquad \text{(Eq. 3.1)}$$

where A is the absorbance, e is the molar extinction coefficient, b is the thickness of the solution, and c is the concentration. This law tends to break down at higher concentrations, because at higher concentrations, the molecules are closer to each other and begin to interact with each other. This interaction between the molecules alters several properties of the molecules, thus changing the attenuation. In the case of intense radiation, nonlinear optical processes can cause variance. Lambert's law can be further modified to include the latitude, ψ, which controls the concentration of the incoming light.

Model of Heat Transfer in the Troposphere

It is fundamental to recognize that most heat within the troposphere is exchanged by convection and not radiation (see Chapter 2). Lambert's law enables us to model the transfer of heat in the atmosphere. Included in the proposed model is the latitude, φ. The physical definition of the temperature of an *absolutely-black-body* must be replaced by the concept of temperature for a *gray-body*, T_{gb}:

$$T_{gb}^4 = \frac{S}{4\sigma}\cos\varphi \qquad \text{(Eq. 3.2)}$$

where φ is the location's latitude.

Considering the convective heat transfer in the Earth's troposphere, the Earth-imitating *gray-body* temperature may be expressed as follows:

$$T_{gb}^4 = \left(\frac{S}{4\sigma}\cos\,\psi + \frac{\dot{Q}}{\sigma}\right)^{\frac{1}{4}} \qquad \text{(Eq. 3.3)}$$

where $\dot{Q}$ is the rate of heat transfer by the air masses (erg/cm^2 · s), e.g., cyclones. The tropospheric temperature, accounting for consideration of the Sun and the Earth's precession, under the accepted approximation as determined in Chapter 2 will be:

$$T = b^{\alpha}\left[\frac{S(1-A)}{\sigma\left(4\frac{\left(\frac{\pi}{2}-\psi\right)}{\frac{\pi}{2}} + 4\left(\frac{\psi}{\frac{\pi}{2}}\right)\left(\frac{1-\cos\psi}{(\sin\psi)^2}\right)\right)}\cos\varphi_{\psi} + \frac{\dot{Q}}{\sigma}\right]^{\frac{1}{4}}\left(\frac{p}{p_o}\right)^{\alpha}$$

(Eq. 2.25)

where $\varphi_{\psi} = (1-\psi\delta)$ is the effective latitude of the location, in consideration of the fact that the Earth's polar areas are illuminated by the Sun only half a year and are in the dark the other half; δ is the delta function ($\delta = 1$ in summer for a given hemisphere, whereas $\delta = 0$ in the winter for the same hemisphere). Determination of the average annual values is $j\psi$ $\delta = ½$.

Eq. 2.26 enables the determination of a latitudinal zoning of the near-surface temperatures, T_s. If, however, a latitudinal distribution of empirically measured average annual temperature is available, then it is possible to determine the average specific rate of heat input for an air mass, $\dot{Q}$, at a given latitude!

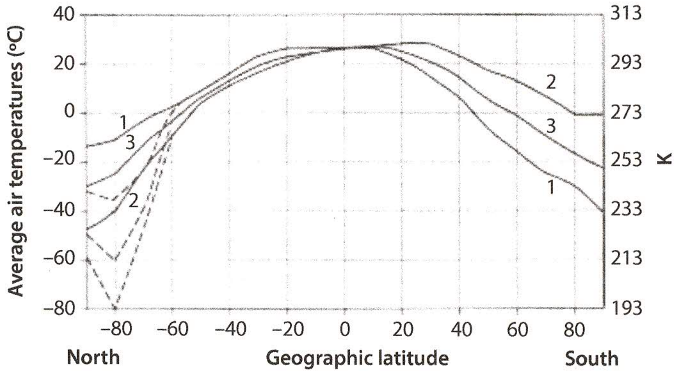

Figure 3.1 Near-surface average air temperature versus latitude. Solid lines, after Khromova and Petrosyants (2001). *Curve 1* – January; *Curve 2* – July; and *Curve 3* – annual average temperatures. Dashed lines (Antarctic data) are average temperatures (obtained from "The Atlas of Antarctic", 1966), for the ice cover dome at the Antarctic pole (80 °S). This data was from well observations in 1964 of the annual average temperature (−60 °C) by Sorokhtin and A. Kapitsa. (After Sorokhtin *et al.*, 2011, figure 13.10, p. 490.)

Eq. 2.26 enables the calculation of the synoptic processes evaluation rate of $\dot{Q}$ if the near-surface temperature, T_s, latitudinal distributions are available. If however, a latitudinal distribution of empirically measured annual temperature is available, then it is possible to determine average specific speed of the heat input with the air mass $\dot{Q}$ at a given latitude. Figure 3.1 displays the average near-surface air temperature vs. geographic latitude (Khromov and Pertosyants, 2001). This figure shows the surface temperature, T_s, theoretical distribution for various $\dot{Q}$ values. These $\dot{Q}$ values are selected on condition of the best T_s theoretical distribution match with empirical data. Figure 3.2 includes the diagrams of the Earth's troposphere synoptic activity vs. latitude. This correlation was determined by variations of the average specific rate of heat input for an air mass, $\dot{Q}$, parameter in Eq. 2.26 on condition of the best match between the Earth near-surface temperature values (as determined from the same equation at $p = p_0$) and its empirical values provided in Figure 3.1.

Figures 3.1 and 3.2 show that the energy release-rate by the trade winds is slightly approximant to 4 to 4.5 × 10^4 erg/cm^2 · s. In the Northern Hemisphere, the average energy release-rate by the air mass cyclonic activity gradually increases toward the high latitudes. It appears that the air mass motion energy is transmitted from the tropical belt to the northern boreal and polar areas. For instance, the local maximum in the rate of synoptic

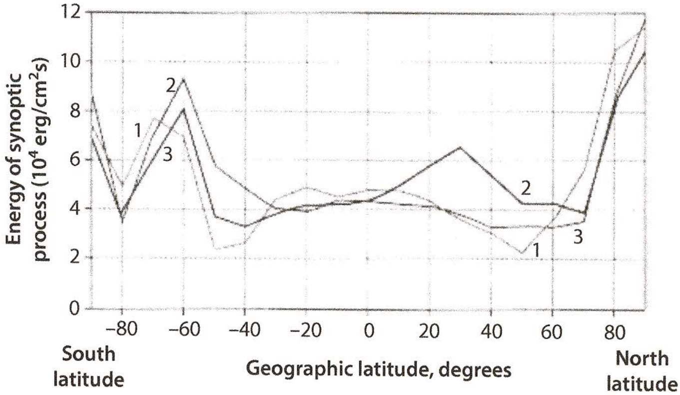

Figure 3.2 Synoptic process activity vs. latitude calculated using Eq. 2-25: *Curve 1* – January; *Curve 2* – July; *Curve 3* – annual average. (After Sorokhtin *et al.*, 2011, Figure 11.10, p. 497.)

energy release in July at 30° N latitude (see Figure 3.2) indicates the emergence of the summer tropical storms and hurricanes. They all occur at that time, for instance, in the northern areas of the Caribbean Basin, and in the Pacific: in the Philippines, in the South Japanese Islands and southern China. It is possible that New Orleans' destruction by Katrina in 2005 was exactly due to such hurricanes. Reflected in the diagrams, significant synoptic activity growth in the Northern Hemisphere polar areas is in good correlations with conclusions of many climatologists. As an example, Khromov and Pertosyants (2001) indicated that in the Arctic basin, in all seasons, intense cyclonic activity is observed. Cyclones emerge on Arctic fronts and slide in the Arctic from lower latitudes where they develop on polar fronts.

Substantial increase in the synoptic activity in the polar areas of the Northern Hemisphere is shown on these diagrams, which also agrees with the views of the leading climatologists. For instance, Khromov and Petrosyants (2001) indicated that intense cyclonic activity is observed in the Arctic basins in all seasons. The cyclones emerge on the Arctic fronts and penetrate the Arctic from the lower latitudes where they develop on the polar fronts.

The Antarctic synoptic activity was measured at the South Pole, Antarctica, approximately along the meridian 90°E along a profile from the Mirny Station through the continent's highest elevation (the ice sheet dome at 80°S and at an elevation of 4000 m above sea level). The Antarctic is almost continuously dominated by anti-cyclonic conditions with clear and quiet weather. Usually cyclones can penetrate only the nearshore areas; however, synoptic activity distribution in central Antarctica turned out very peculiar. Minimum activity was observed over the dome and a drastic increase in the energy of the synoptic process activity was observed southward, toward the pole, and northward. The question is, "Why do observed bursts of synoptic activity emerge over the continents?"

An explanation of this paradox is that there is a very strong katabatic wind continuously blowing from the Antarctic continental high dome toward the shores. In Antarctica, these winds are especially strong in winter (in July), as observed by Dr. O. Sorokhtin. These strong (up to 45 mph) cold winds become warmer adiabatically as they descend from the continental dome on the ice-covered slopes. The air mass descending from the continental dome carries a substantial amount of energy. The maximum release-rate occurs at the continental shores around a circle about the 60° South latitude. Outside of the continent, the katabatic winds disperse over the expanses of the Southern Ocean and gradually die out. The katabatic winds that cause a *bicephalous* (double-headed) shape of the synoptic activity over the Antarctic.

Figure 3.3 shows the latitudinal correlations of average semi-annual Sun radiation energy flows and the synoptic processes. Average value of the solar insolation was 2×10^5 erg/cm$^2 \cdot$ s, whereas the average synoptic process energy is equal to 0.39×10^5 erg/cm$^2 \cdot$ s. The total amount of solar energy reaching the Earth is about 10^{24} erg/s, whereas the total

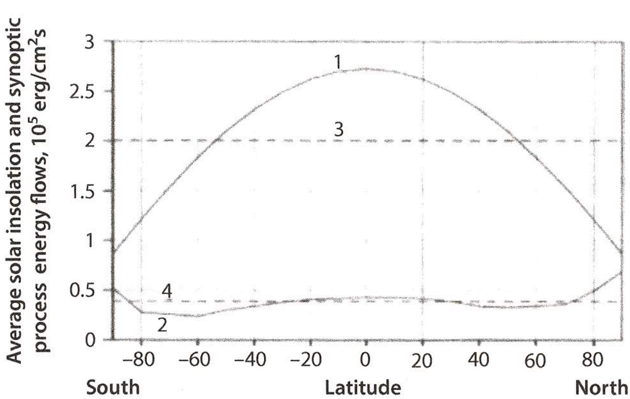

Figure 3.3 Average solar insolation energy and synoptic processes energy flow (105 erg/cm^2/sec) in the Earth's troposphere vs. latitude. *Curve 1* – intensity of the insulation at the Earth's surface. *Curve 2* – intensity of synoptic processes in the troposphere. *Curve 3* – average solar insolation intensity. *Curve 4* – average intensity of the synoptic processes.

energy of synoptic processes is only 0.2×10^{24} erg/s. Obviously, against this synoptic process energy background, the total energy generation by mankind is negligibly low, 1.3×10^{20} erg/s. *Consequentially, this is another reason why the anthropogenic energy effect on the Earth's climate should be disregarded.*

For an Earth with a greater snow covering, the albedo (A_s) increases. Under these conditions, the Earth's near-surface temperature may be estimated using Eq. 3.4 for the planet's average albedo $A \approx 0.3$, replaced by a higher value of $A_s \approx 0.7$. This explains such phenomena as, for instance, the chilling of near-surface air layers in clear nights under anticyclones, when $S \approx 0$ and the heat input $\dot{Q}$ is low. Indeed, for anticyclonic areas the rate of convective air mass exchange usually slows down. As a result, the convective heat input declines; however, the heat radiation from the Earth's surface heats up during the day. As a result, the $\dot{Q}$ factor in Eq. 2.26 declines and at night time, at $S \approx 0$, the near-surface temperature substantially declines. In winter, in high latitudes where the Earth's surface is covered by the snow with a higher albedo, heating by the solar radiation is insignificant, and results in air overcooling and bitter cold. For stable anticyclones, $\dot{Q} \approx 0$, in snow-covered regions a general troposphere overcooling occurs with the atmospheric tropopause descending almost to the Earth's surface. Clear examples of such air overcooling are conditions arising in the Central Antarctic and in winter in the Yakutia and Verkhoyansk areas of Russia. When the anticyclonic regime in the troposphere is replaced by cyclonic activity, there is an immediate resumption of the input of synoptic energy and convective air mass mixing. Warming occurs, and on the average reviewed adiabatic temperature distribution approximately is restored.

Generalizing the model as a 4-D version, it is necessary to introduce the longitude angle and identify the oceanic and continental areas. A 4-D model requires the introduction of seasonal and daily variations in the Earth's illumination, etc. Thus, the proposed model allows a derivation of the local climatic features of the planet. Earth's surface albedo, heat introduction by cyclones, and atmospheric humidity must be included in this model. In areas of high-snow-cover reflectance but devoid of the heat input from cyclones, the Earth's surface temperature declines almost to the tropopause (lower stratospheric stratum) temperature, which is defined by the atmosphere's radiation balance for a given latitude (Figure 3.4). In summer, in such anticyclonic areas with a dry air, the other way around, overheating of the near-surface tropospheric strata it occurs approximately by 4 to 5 °C and higher, with all indications of a drought, e.g., Russia's Trans-Volga steppes (see Figure 3.4). The temperature gradient calculation for a dry

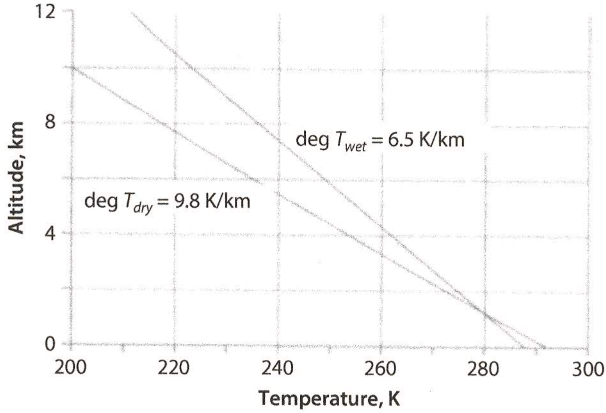

Figure 3.4 Comparison of temperature distributions plotted using Eq. 2.25 for a dry, transparent (grad T_{dry}) and humid, IR radiation--absorbing the Earth's troposphere (T_{wet}). For all other conditions being equal, the near-surface temperature of a humid, absorbing troposphere is always somewhat lower than the near-surface temperature of a dry transparent atmosphere (in this particular example the temperature difference reaches 4.7 °C).

(anticyclonic) and humid (cyclonic) troposphere is usually performed using a simple equation:

$$\text{Grandient } T = \frac{g}{c_p} \qquad \text{(Eq. 3.5)}$$

where g is the gravitational acceleration and c_p is the specific heat.