ART. V.—*Remarks on the Temperature of the two extreme Seasons in the Temperate Zones as affected by the Variations in the Sun's Distance and in its Angular Velocity in the Ecliptic*; abridged from a treatise on Astronomy, (in course of preparation,) by WILLIAM DENNIS, Philadelphia, Pa.

THE eccentricity of the earth's orbit being about $\frac{1}{60}$ th of its mean distance from the sun, the whole variation in its distance, or the difference between its greatest and least distances, must be about $\frac{1}{30}$ th of the mean: and from Kepler's law for the equal description of areas by the radius vector of the earth (or other planet), it follows that the velocity of the earth's motion in its orbit, or the consequent angular motion of the sun in the ecliptic, varies inversely as the square of this distance. Then, since a numerical quantity increased by a small fraction of itself has its square increased by (a little more than) the double of that fraction, it is evident that as the distance varies by about $\frac{1}{30}$ th of its mean value, the variation in the velocity must be about $\frac{1}{15}$ th of its mean.

Again, the amount of light and heat received from the sun in a given time, following the general law of influences emanating as from a centre, also varies inversely as the square of its distance, and therefore follows precisely the same law that governs the variation of the sun's angular motion in the ecliptic. Hence we conclude,

1. That the whole variation in the rate at which light and heat are received from the sun, or in other words, the difference of rate at its greatest and least distances, amounts to about $\frac{1}{15}$ th of the mean rate.

2. That the amount of light and heat received from the sun while passing through a *given arc* of the ecliptic is the same in every part of its annual course; its greater distance in one part being exactly compensated by the longer time occupied in passing through the supposed arc in that part; and *vice versa*. Now the present position of the line of apsides is such that the perihelion or minimum distance of the earth from the sun occurs about the first of January, or near our winter solstice, and the aphelion or maximum distance about the first of July, or near our summer solstice; and as the solstices are the middle points of the northern and southern portions of the ecliptic respectively, it happens that nearly all that part of the ecliptic in which the sun is nearest the earth is passed over while the sun is south of the equator, and that part in which it is most remote, while it is north of that line. But since the ecliptic is divided by the equinoctial into equal portions (or ares) it follows from the second of the conclusions just stated, that the sun communicates to

the earth the same amount of heat while over its north hemisphere or north of the equator, that it does while south of it: for although it is considerably nearer while south yet it is nearly eight days longer at the north, and this additional *time*, according to what has been shown, completely makes up for the greater *distance*. It may be worth while to note in passing that an indication or measure of the actual extent of the loss of heat sustained by the sun's increased distance is furnished by the fact that it requires about $7\frac{3}{4}$ days of the sun's influence for its compensation. The north and south hemispheres may therefore be regarded as receiving equal shares of heat in the period of a *complete year*, and popular writers on astronomy seem to have contented themselves with exhibiting this fact without examining, very carefully at least, how the different seasons of the two hemispheres respectively are affected by the manner in which these shares are distributed;—an inquiry in some respects more interesting perhaps than that concerning the equality of the shares themselves.¹ It is the effects of the variations in the sun's distance and in its angular motion in the ecliptic upon this distribution and consequently upon the extreme seasons in the temperate zones, that are now to be considered.

It will be sufficiently accurate for our present purpose, and will tend to simplicity of statement, to suppose the duration of the summers and winters of the two hemispheres to be determined by the sun's passage through those two quadrants of the ecliptic that have its perigee and apogee for their middle points respectively: these limits will assign to them two periods of which one extends from about the middle of May to the middle of August, and the other from the middle of November to the middle of February, fully including the extremes of both seasons. Now it was remarked in a preceding chapter that the earth is receiving heat from the sun and parting with it by radiation at all seasons, and that when at any given place or latitude the gain by the one process exceeds from day to day the loss by the other, a gradual elevation of the general or average tempe-

¹ "Now the perihelion of the orbit is situated nearly at the place of the northern winter solstice, so that were it not for the compensation just described the effect would be to exaggerate the difference of summer and winter in the southern hemisphere, and to moderate it in the northern. . . . As it is, however, no such inequality subsists, but an equal and impartial distribution of light and heat is accorded to both."—Herschel, *Outlines of Astronomy*, London, 1849. It will presently appear that the exaggeration and moderation here referred to are produced to some extent notwithstanding the compensation.

Arago, (*Pop. Astron.*, London, 1858), illustrating this compensation, remarks: "Thus the two warm seasons of our atmosphere (spring and summer) are certainly somewhat colder than the warm seasons of the southern hemisphere, but they are at the same time of longer duration." Had he employed the cold seasons in the illustration it would have run thus,—they are certainly somewhat milder at the north, "*but they are at the same time shorter*;" which, instead of being a compensation, would of course make them milder still.

perature takes place: when the loss exceeds the gain a gradual reduction must of course result. It is by these two processes respectively that the high heat of summer and the severe cold of winter are produced. As it follows directly from the law of compensation just explained that the same amount of heat is received from the sun during each of the two winters (northern and southern) and also the same amount during each of the two summers, the question of the effects of the variations under consideration turns upon the influence which they shall appear to have upon that gradual elevation, and that gradual reduction of temperature from which, as just stated, the extremes of these two seasons result. It will enable us to estimate more correctly the extent and importance of these effects to observe how they are concentrated, so to speak, upon these two seasons. Thus the sun is not quite $7\frac{1}{2}$ days longer north of the equator than south of it in the tropical year, while it is $4\frac{1}{2}$ days, or more than $\frac{3}{4}$ ths of this whole difference, longer in the north or apogee quadrant than in the south or perigee quadrant of the ecliptic: the northern summer is therefore $4\frac{1}{2}$ days longer than the southern and the northern winter shorter than the southern by the same amount. Again, the whole change in the sun's apparent semidiameter, which is the index of its change of distance, amounts to $32''$, but in the apogee quadrant it varies from its minimum (about July 1) and in the perigee quadrant from its maximum (Jan. 1) only about $5''$: in fact its mean semidiameter while in either of these arcs does not differ from the extreme limit belonging to that arc but about $1''\cdot5$. To this it may be added, as not without a bearing on the same point, that the controlling cause itself of the change of seasons has its influence in like manner concentrated upon these quadrants; for while the maximum declination of the sun is but $23\frac{1}{2}^\circ$ its mean declination while in these two arcs is about $20\frac{3}{8}^\circ$ or its mean distance from the tropics respectively less than 3° . Let us now keep in view the following particulars:—

1. The sun is at its perigee at midwinter and at its apogee at midsummer, using those terms with reference to the north hemisphere.

2. It dispenses the same amount of heat while passing through the apogee quadrant of the ecliptic, (summer, north—winter, south), as while in the perigee quadrant, (winter, north—summer, south) but is $4\frac{1}{2}$ days longer in the former than in the latter.

3. While in these quadrants it varies but little in the one from its maximum, and in the other from its minimum distance; and its declination is on an average near the maximum in both.

4. The high heat of summer and the severe cold of winter are the results of a gradual accumulation of heat in the earth's sur-

face, (including the atmosphere and objects on the surface,) and a gradual reduction of its temperature by loss or waste in those two seasons respectively, and not *direct* results of the gain or loss from day to day. Then, since opposite seasons occur at the same time in the two opposite hemispheres, we evidently have the following results as consequences of the variations in question *with the present position of the line of apsides.*

<i>North Hemisphere.</i>	<i>South Hemisphere.</i>
Summer cooler from the sun's being more distant.	Winter colder from the sun's being more distant.
“ hotter for being longer.	“ “ for being longer.
Winter warmer from the sun's being nearer.	Summer hotter from the sun's being nearer.
“ “ for being shorter.	“ cooler for being shorter.

Directing our attention first to the summers we find in these the two conditions of time and distance opposed in their influence: in the northern summer the sun is more distant but the time longer; in the southern the sun is nearer but the time shorter: but as the same amount of heat is received in each, we have only to consider whether its being received in a longer or shorter time will be most favorable to accumulation. If all the heat were retained there would of course be no difference, but as a large portion is lost each day (at night) by radiation, and this continues in the northern summer for a *longer time*, it seems to follow that the accumulation must be greater in the shorter or southern summer. It is true that the radiation during the night will be more rapid where the days are hotter, as those of the short summer must necessarily be, but the loss by increased radiation does not equal the gain arising from the more rapid reception, for if it did there would be no accumulation in summer. If the supply, supposing its rate constant, were continued indefinitely, a limit would doubtless be reached at which, a very high temperature having been produced, the loss or radiation would become equal to the supply, but that the heat of summer is very far below this limit is clearly shown by the fact that the accumulation continues for about a month after the summer solstice, that is, after the supply has begun to decline. We are justified then in concluding that in the short summer of the south not only are the days hotter and the force of the sun's direct rays considerably greater, but that, other conditions being the same, the accumulation of heat or average temperature will reach a higher point.

Referring again to the statement of results on a preceding page, and turning our attention now to the winters, we at once perceive that in these the conditions of time and distance are not, as in the summers, opposed to each other in their effects but combined, so that instead of one being compensated by the

other they both conspire to produce the same result. The cold of winter not being, like summer heat, produced by the sun but by radiation or loss of heat in spite of the sun's influence, (a point that seems not to have been sufficiently attended to by some writers,) it happens that the two conditions referred to have a different relation to each other in the two opposite seasons, being as just stated opposed to each other in the one case while in the other both contribute towards the same result. Thus in our northern winter not only is the sun near its minimum distance throughout the whole period in which the principal reduction of temperature takes place and during which it is most rapid, but the period itself is materially shortened. For these combined influences there seems to be no effective compensation, and it can hardly be doubted that the present arrangement gives to our northern winters a character very considerably different from that which they would present were the position of the line of apsides reversed. It is remarked by Herschel, in reference to the southern summer, that " $\frac{1}{15}$ th is too considerable a fraction of the whole intensity of sunshine not to aggravate in a serious degree the sufferings of those who are exposed to it." But in this case not only is the winter reduction of temperature counteracted by the addition of this 'considerable fraction' to the supply, but the *time* of rapid reduction is shortened by about $\frac{1}{8}$ th of its whole amount. Under these circumstances it becomes a matter of some interest to know that although the perihelion of the earth's orbit has a progressive motion yet the rate is so extremely slow that it would require about 50,000 years for the perihelion and aphelion to change places, and we may therefore congratulate ourselves that things are as they are, without the least concern as to what a reversed position of these points would produce. Indeed, such changes by their very slowness provide against all the inconveniences that at first sight might be supposed likely to result from their accomplishment.

In the southern winter the two conditions also combine, but their joint effect in this case takes the opposite direction. The cooling process by which the temperature is gradually reduced at this season has its rate increased by the increased distance of the sun, and the time during which this high rate continues is extended. While therefore the effect of the present position of the earth's orbit is to make the winters of the north milder, its tendency to make those of the southern hemisphere more severe is equally decided: and could a comparison of the two be instituted on the basis of actual observation under conditions in any tolerable degree similar the contrast would doubtless be striking. But circumstances of geographical position seem to render such a comparison impracticable. The small portions of the two continents extending into the south temperate zone are

so surrounded by oceans, especially on the cold or polar side, as to render their position in effect insular, and the influence of insular position upon climate, particularly when the surrounding waters are broad oceans, is too well known to be insisted on. The actual difference between a northern and a southern summer, under similar circumstances of situation, would probably be equally striking; for although the more rapid supply of heat at the south is, as we have seen, in some measure counteracted by its shorter continuance, yet $\frac{1}{1\frac{1}{2}}$ th of the sun's heat is a much larger quantity in summer than in winter, and being moreover added when the heat is at its maximum instead of minimum, its direct effect would necessarily be much more marked. It is possible that, owing to the greater stillness of the atmosphere in summer, the influence of geographical position may be less effective at that season than in winter; however that may be, the testimony of travellers and from other sources clearly indicates, not only a hotter sunshine, but hotter days in Southern Australia than are ever observed in the north temperate zone.'