GEODETIC LETTER

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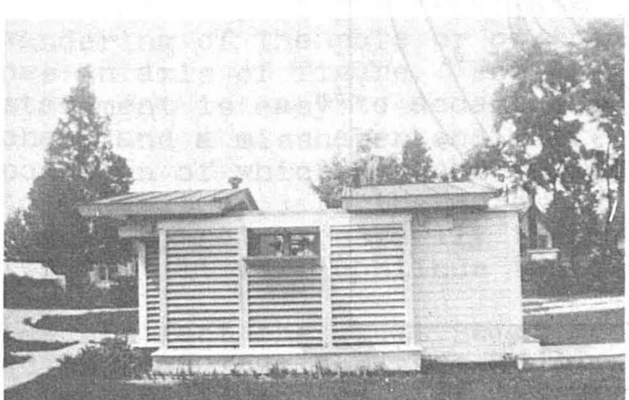
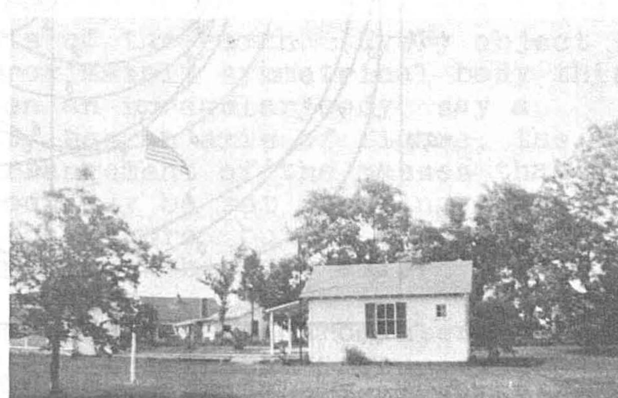
WHO SHOT THOSE PEAS?

W. D. Lambert

The traveler, who from the present city of Washington follows westward the road taken by George Washington and General Braddock before the latter's disastrous defeat by the Indians, may notice just after he enters the town of Gaithersburg, Maryland, a cinder side road coming into the main road from the left. This side road soon becomes a lane leading through a gate to the grounds of the Federal Latitude Observatory at Gaithersburg. The pictures show views of the observatory and surroundings, including the observer's house. There is certainly nothing pretentious or grandiose about them.





In the fancy of the layman -- or the comic strip artist -- the astronomer figures perhaps as an elderly man with long whiskers who spends his nights, eye glued to his telescope, watching the stars go through evolutions like dancers in a ballet. As a matter of cold fact, the astronomer usually spends more time in laborious numerical calculation than in observation and he may indeed look at the stars just enough to orient correctly the photographic apparatus that takes a picture as it follows the stars. He may thus work at second hand from the images on the photographic plate rather than from a direct view of the stars themselves.

The latitude observer at Gaithersburg -- except for the age and the whiskers -- comes nearer than the average astronomer to the figures of the comic strips, for he spends most of the night in observing visually, not photographically, and has comparatively little calculation to do. However, his facilities for viewing the celestial ballet are limited, for his instrument does not range all over the heavens but is narrowly confined to the meridian and his program of observation is made up with a single purpose in view, the study of the vagaries of the earth's axis, or as we generally say, of the wanderings of the pole of the earth.

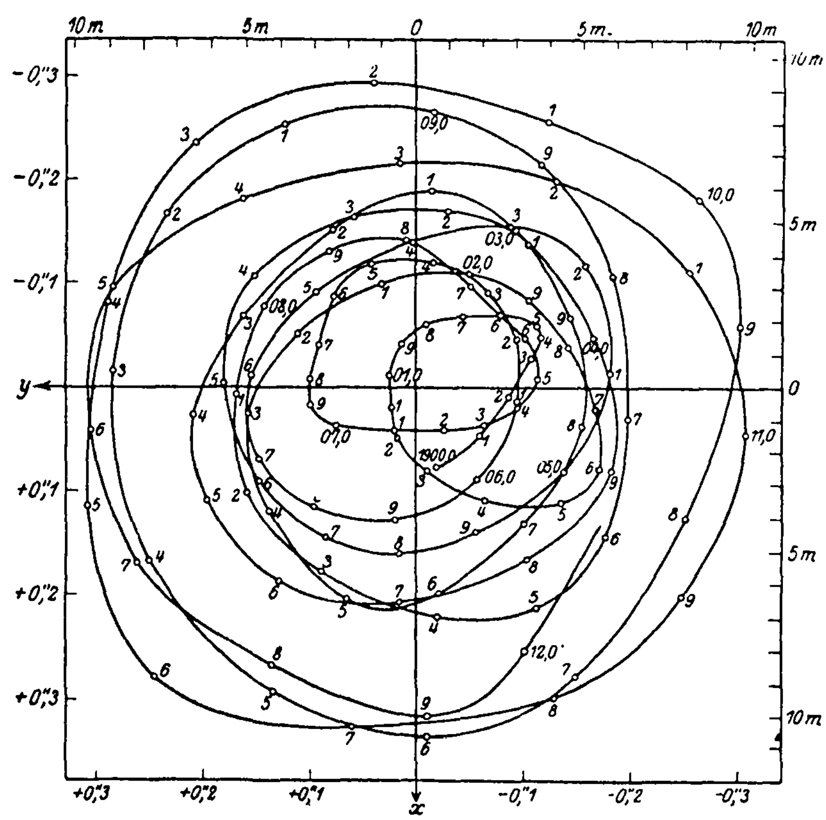


FIG. 1—Observed path of the Pole, 1900-1912. (Taken from Wanach.)

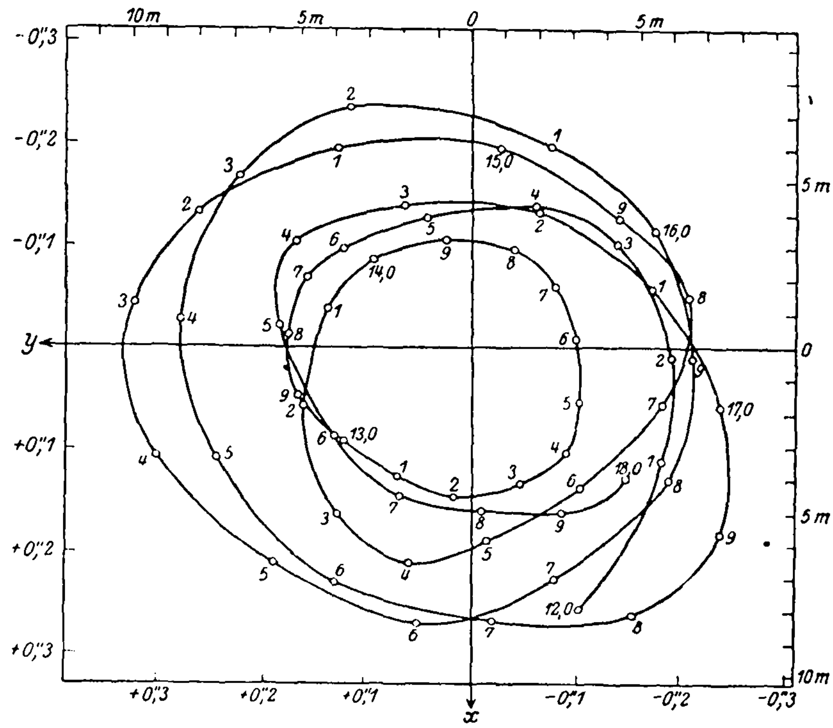


FIG. 2.—Observed path of the Pole, 1912-1918. (Taken from Wanach.)

The wandering of the pole is something that was discovered in theory long before it was actually observed; almost discovered that is; for one part of the theory was incomplete in failing to take account of the physical properties of the earth and this incompleteness confused astronomers by leading them to look for something that did not exist. Often indeed, they really were watching the actual wandering of the pole but when the observed motion failed to conform to the theoretical type, they gave up in disgust.

One very simple remark is necessary before we talk about the wandering of the pole or of the axis of the earth. Every object has an axis of figure. For an approximately symmetrical body this statement is easy to accept but even an irregular body, say a chair and a misshapen chair at that, has an axis of figure, the position of which depends on the arrangement of the masses that go to make it up. Furthermore, any body may be set rotating about any axis, not necessarily the axis of figure, but it does not follow that it will continue to rotate about the same axis.

In fact, the great Swiss mathematician, Leonhard Euler, showed in 1765 that the axis of figure and the instantaneous axis of rotation, if not coincident, will not maintain the same relation to one another. The mathematical problem involved is allied to those of spinning tops and gyroscopes, which have exercised the ingenuity of the greatest mathematicians from Euler's day to the present time. In the case of the motion of the pole, where the two axes are not far apart, it can be said that the axis of instantaneous rotation keeps its direction approximately constant in space but not constant in relation to the rotating body, while describing in the body a conical surface enveloping the axis of figure. That is, if one considers directions in the body, the pole of rotation moves around the pole of figure, whereas in space the pole of figure moves around the almost stationary pole of rotation. Just to give the mathematicians something to think about, there are other axes and their corresponding poles that must be considered in any complete treatment of the problem.

Euler was treating the question of rotating bodies in general, but he specially mentioned the earth and predicted a 10-month period for the motion of one pole about the other and a corresponding variation of latitude, for the latitude of a place depends on the position in the body of the instantaneous pole.

Astronomers started to look for a variation of latitude with a period of 10 months and several times seemed on the point of detecting it but each time it eluded them. They expected an annual variation too, for the pole of figures is not absolutely constant because of changes in the distribution of mass having an annual period, such as changes in the seasonal load of ice and snow, seasonal barometric changes, etc. But so many things with which the astronomer has to deal have an annual period too and have not been determined with absolute precision that the astronomer was much more interested in changes of latitude in a period of 10 months than in possibly spurious changes with a period of a year.

Finally, in 1888, Küstner of Berlin, discussing observations he had made, concluded that there must be a real variation of latitude. The matter was clinched by simultaneous observations for latitude in 1891 at Berlin and other places in Europe and in Hawaii. In these latter, the Coast and Geodetic Survey participated. The longitude of Hawaii differs almost 180° from that of central Europe. It was found that when latitudes in Europe increased those in Hawaii decreased by about an equal amount and vice versa. The obvious indeed, the almost inevitable, explanation was that the latitude had changed because the pole had shifted in the body of the earth; as it shifted towards Europe the latitudes there increased and those in Hawaii decreased.

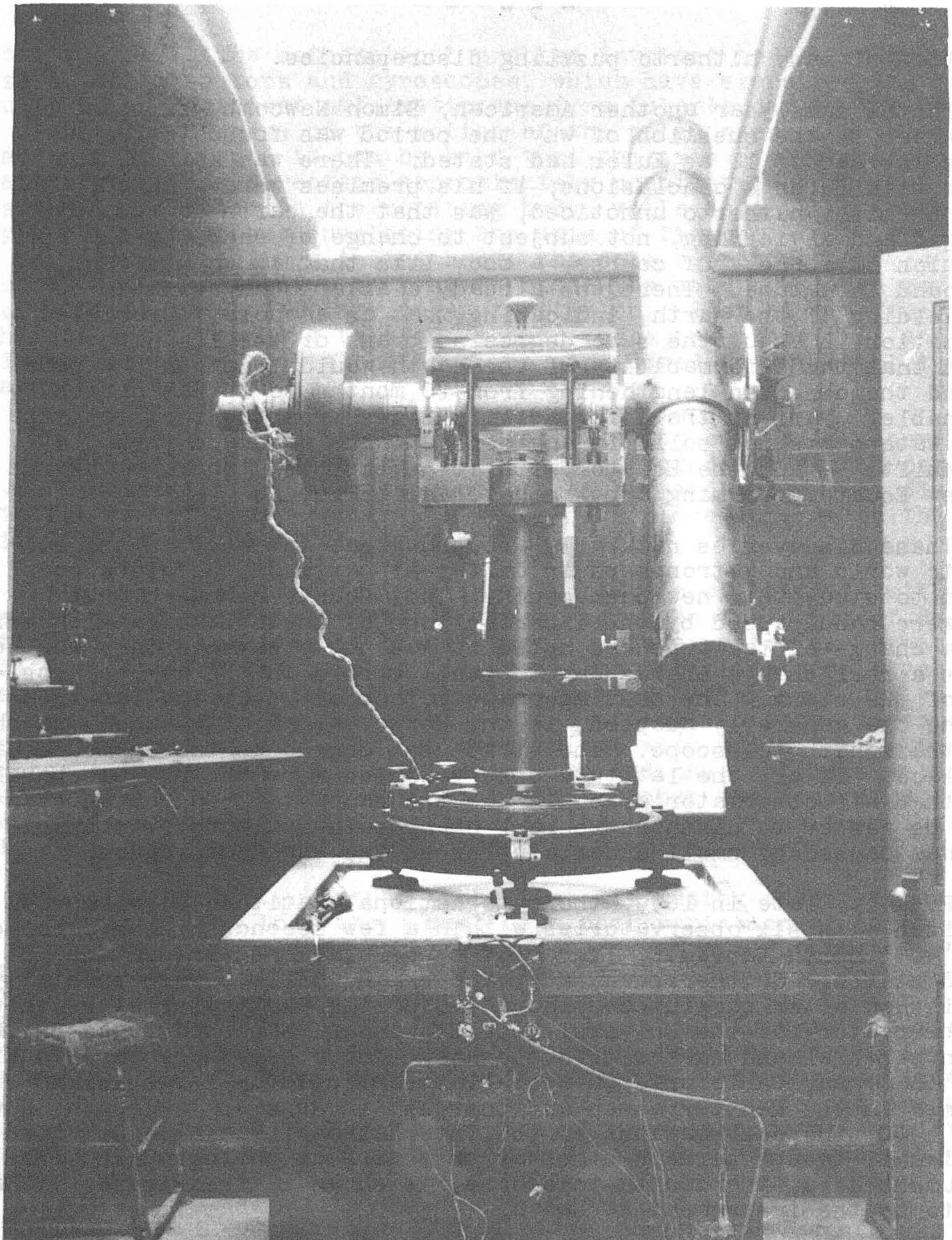
Meanwhile, S. C. Chandler of Cambridge, Mass., had been pursuing his investigations, rediscussing old observations as far back as the eighteenth century, with a view to detecting a variation of latitude, but without any preconceived idea as to possible periods of the phenomena. The next year (1892) he announced his discovery. A variation of latitude with two principal constituents, one having the year for its period and the other 14 months, was found to be the explanation of many hitherto puzzling discrepancies.

In the same year another American, Simon Newcomb, supplied the answer to the question of why the period was found to be 14 months instead of 10 as Euler had stated. There was nothing the matter with Euler's conclusions, if his premises were granted. A tacit premise, hitherto unnoticed, was that the earth is absolutely rigid and unyielding, not subject to change of shape by the application of force. Of course, a body like that is an abstraction, not found in nature. There was already available an estimate of the yielding of the earth, indicating that as a whole it resisted deformation in about the same degree as brass or steel. Newcomb showed that the deformability of the earth would lengthen the period and the observed lengthening from 10 months to 14 was perfectly reasonable. Part of the deformability comes from the fact that the ocean waters are not solid in any sense of the word and when the pole shifts -- and the Equator with it -- they tend to flow towards the new Equator, forming a new equatorial bulge.

These discoveries naturally aroused great interest in the scientific world and astronomers in different parts of the globe cooperated to study this new phenomenon. They found, however, that they were handicapped by the imperfections of their star catalogues. When a change of latitude was noted it was not always certain whether it was a real change or was due to small errors in the assumed position of the stars. The most accurate method of observing latitude and the one generally adopted, is the Horrebow-Talcott method, which uses the zenith telescope. The stars used depend on the latitude of the place. If all the latitude observatories were on the same parallel, then all observatories could use the same star program and it would be easier to disentangle real changes in latitude from spurious ones caused by small uncertainties in the star catalogues.

Finally, late in 1899, the International Latitude Service was organized with six observatories within a few seconds of the parallel of 39° 08' north latitude. Three of these stations were in the United States. Gaithersburg, Md., and Ukiah, Calif., were specially established after careful consideration of the particular sites chosen. The observatory of the University of Cincinnati happened to be on the chosen parallel and agreed to cooperate. The other three were in Mizusawa in Japan, Carloforte on a small island off the large island of Sardinia in the Mediterranean and Charjui* in Russian Turkestan. Now, as in 1900, the observations of the International Latitude Service are visual, though perhaps some day they will be photographic. The instrument used, the zenith telescope, is shown in the figure. It happens to be the instrument at Ukiah.

Note: * Spelled Tschardjui, in German, which needs the extra letters to transliterate the sounds of Russian characters according to the German pronunciation of the Roman alphabet.



Zenith telescope in use at observatory, Ukiah., Calif. Pier is protected from accidental disturbance by a wooden casing.

Of the six original observatories, Ukiah, Carloforte and Mizusawa, constituting a bare minimum of stations necessary to determine the displacement of the pole, have continued to function through all vicissitudes. As a measure of economy, Cincinnati and Gaithersburg were discontinued in 1914 and 1915. During the World War all trace was lost of Charjui but it was found that it had functioned until 1919. Once the station had to be moved a few miles because a river which was formerly several miles off, changed its course and threatened to undermine the observatory. Kitab, near Samarkand, was finally substituted for Charjui and in 1932 the Gaithersburg station was reopened, so now there are five stations on the parallel of 39° 08'.

There are also two stations on the same parallel in the Southern Hemisphere, La Plata in Argentina and Adelaide in Australia. Greenwich Observatory in England, the Naval Observatory in Washington and an observatory near Batavia in Java, though of course, not on the same parallel with any of the other stations nor with each other, are making special studies of the variation of latitude. Some of these use photographic instruments.

Observations from all these stations are sent into a central office to be reduced and discussed so that the observers, contrary to the practice of their brother astronomers, have comparatively little calculation to do. The first central office was at Potsdam, Germany, and was connected with the Prussian Geodetic Institute. After the World War it was moved to the latitude observatory at Mizusawa and since January of this year (1936), to a special organization with headquarters at the Observatory of Capodimonte, near Naples in Italy.

After hearing of all the trouble taken to determine the variation of latitude, the reader will probably suppose that the variation is large, large enough to "hit the observer in the eye", but it is not. The figure (page 2) shows the wandering of the pole from 1900 to 1912 and (page 3) for 1912 to 1918.* The entire wanderings of the

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Note *--The single figures like 1, 2, 3 indicate the positions for tenths of a year. What year it is must be determined by following backward or forward the continuous line representing the path of the pole till the last two figures of the year followed by the decimal zero are found. The general direction of motion is counterclockwise. For example, take the numbers 1, 2, 3 at the top of Figure 1 and follow backwards (clockwise); we come to the number 10,0 in the upper left hand corner of the figure. This means the beginning of 1910. Follow the line counterclockwise, taking care not to be diverted to adjacent lines representing the path for other years and we pass through 4, 5, 6, etc., till we come to 11,0 in the middle right hand edge of the figure. This represents the position for the beginning of 1911.

pole are contained in a square 20 meters (66 feet) on a side, as shown on the figure. In angular measure the extreme change of latitude ranges between -0".3 and +0".3 and is often much less. Why then all this fuss, and what have we found out by our thirty-five years of systematic study?

Chandler announced an annual period, which surprised no one, and a 14-month period, which Newcomb explained. That announcement had stood the test of time, but superposed on these regular motions are unaccountable irregularities. It is like the weather. In these latitudes, April is usually warmer than March, but not always. We can count on July as a whole being very much warmer than January, but by picking and choosing we may find a July day and a January day that are about alike in temperature. All attempts at long-range forecasting of the weather have failed and no more can we tell in advance just what the pole will do. The irregularities, the unexpected changes of amplitude and phase of the annual and 14-month motions, are such that we do not even yet know the exact length of the 14-month period, although it has repeated itself -- after a fashion -- some 30 times since 1900.

The 14-month oscillation is the free oscillation or oscillation in the natural period of the system. A swinging pendulum has its own natural period. Though the pendulum may be subject to transient disturbances, nevertheless, between disturbances it takes on its natural period. The pendulum or any oscillating system may be forced to move by external compulsion in any other period. This is called the period of forced oscillation. The annual part of the motion of the pole -- as far as the seasons of one year resemble those of another -- corresponds to a forced oscillation. The motion of the pole has been compared to the motion of a pendulum subjected to a forced oscillation but always tending, except as it may be disturbed, to oscillate in its natural period. These disturbances of the motion of the pole have been likened to the effect of peas shot at a pendulum by mischievous boys armed with pea shooters. We want to know: Who shoots those peas and when and how and why? The Elephant's Child which Kipling told of, was afflicted with a "'satiable curiosity", and so are we.

The unpredictability of the motion of the pole has been compared to the unpredictability of the weather. It is not pretended that the motion of the pole has the immediate and personal interest for each and every dweller on this terrestrial ball that the weather has. But the problem of the motion of the pole has many and various ramifications and is certainly of enough interest to warrant the small sum spent in studying it. Mention has already been made of the determination of the elastic properties of the earth from the prolongation of Euler's theoretical 10-month period into the observed 14-month period discovered by Chandler.

We can get a hold -- not so accurate -- on these same elastic properties by subjecting the observed latitudes to the same harmonic analysis that is used for the tides, for the latitude is affected by the tide-producing forces of the moon and sun and by the elastic properties of the earth as a whole.

Is the earth tri-axial? That is, is it more nearly an ellipsoid of three unequal axes than it is an ellipsoid of revolution, which has two of its axes equal? Some scientists contend for triaxility, both on the basis of gravity observations and on the basis of deflections of the vertical. A study of the variation of latitude may enable us to check their conclusions by different and entirely independent data. The answer to this question, whatever it may be, involves interesting consequences as to the physical properties of the earth.

Are the irregularities in the rotation of the earth, which some astronomers suspect to exist, connected with irregularities in the variation of latitude? Maybe both are caused by the same pea. What is the relation, if any, between frequency or intensity of earthquakes and the variation of latitude? Attempts have been made to trace such a connection. Again, perhaps both phenomena come from the impact of the same pea.

The geodesist observes latitude, longitude and azimuth. The motion of the pole affects all these, and to put all these determinations on a uniform basis it is necessary to reduce to some mean pole. The observations and calculations of the International Latitude Service, to which the observatories of Gaithersburg and Ukiah contribute, have recently put geodesists in a position to reduce their astronomical observations to a common basis.

Is the pole shifting progressively? Some geologists think that a large displacement of the pole would come in very handy in explaining the ice ages of the past and other geological phenomena. For a while it looked as if the average position of the pole were moving progressively towards the continent of North America but at a rate too slow to be of any use whatever in explaining the last ice age. Now even that progressive motion, small as it was, appears to have ceased, though there has been no very recent investigation of this particular point.

The variation of latitude does not concern only those who deal with the earth. The astronomer who is compiling a catalogue of stars must know the changes in his latitude and the International Latitude Service helps to answer this question. Moreover, the International Latitude Service uses stars taken from some recognized catalogue or catalogues. The observations for latitude contribute to the determination of systematic corrections to these catalogues. It is from the proper motions of the stars which are affected by these systematic corrections, that the astronomers try to answer the question, "Whither are we drifting?" This question has for the astronomer a wider import than when it is asked by the political orator. The astronomer means: Whither are the sun and all its attendant planets drifting? The observations of the International Latitude Service help to answer the question.

Thus, though the actual variation of latitude is a small matter, it ties in with many important geophysical questions, most of them not yet answered and contains mysteries enough to excite the curiosity even of those less inquisitive than the Elephant's Child.

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I LIVE AN UPSIDE-DOWN LIFE

Earl L. Williams

I am the variation-of-latitude observer at Gaithersburg, Md. As such it can hardly be said that I lead a normal existence. My outlook on life is largely "uplook" at stars. I work while the rest of the world sleeps, with only the mournful hoot of a distant owl or the incessant call of the whip-poor-will to keep me company. When the world begins to teem with activity I am just starting my slumber. One nice thing though, I can sleep into the day as far as I please. No raucous alarm clock disturbs my slumbers, calling me unwillingly to a workaday world. But I must begin my labors at the end of the day when others have given themselves to lighter things. Others work and then play; I violate this well-advocated precept by playing first and then working. Then, too, my meals are topsy-turvy, for I eat my breakfast at noon and often wind up the day by eating at three or four o'clock in the morning.

Although thousands of miles from it, I help keep track of the wanderings of the pole. But on a cold windy night in winter, I can tell you, I feel as if I were watching Mr. Pole's activities in person on the spot. In summer, though, it is quite pleasant, as I work during the coolest part of the day. Yet even at this season too, my equilibrium is often disturbed by some bounding insect bent on reaching his destination by the shortest possible path wholly regardless of the position of my nose.