Susan West and Jonathan Eberhart report from Washington at the annual meeting of the American Geophysical Union

Lightening the earth

From 1964 to 1975 a series of measurements by different techniques led to lighter and lighter values for the mass of the earth. Now a combination of three independent methods has confirmed that the planet is indeed lighter than was formerly believed—by 41.34 million billion tons. According to Pasquale B. Esposito of Jet Propulsion Laboratory in Pasadena, the latest value for the mass of the earth, including the atmosphere, is 6.586 billion trillion tons.

This latest figure has emerged from calculations of the geocentric gravitational constant—the product of earth's mass and Newton's gravitational constant — which has now been refined to a value of 398,600.453±0.03 kilometers cubed per second per second. This number, Esposito says, is accurate to within eight one-millionths of one percent. Oddly enough, the number for earth's mass is accurate only to within 0.06 percent.

The reason, says Esposito, is that Newton's gravitational constant (G) is "one of the most poorly known of all the fundamental constants." The 0.06 percent limitation is that of the precision to which G is known. The reason the measurements of earth's mass (M) suffer the same fate is that the product of G and M is measured as a single quantity, leaving the same uncertainty in values of M that are calculated from it.

Three kinds of data analysis contributed to the latest GM value: Doppler tracking of radio signals from spacecraft (Mariners 9 and 10, Vikings 1 and 2, Voyagers 1 and 2) sent beyond earth's gravitational influence; laser-ranging between the earth and the laser reflectors left on the moon by Apollo astronauts (yielding a value for the total mass of the earth and moon, from which the moon can then be subtracted by other means); and similar laser techniques with the reflector-equipped LAGEOS geodetic satellite now orbiting the earth.

Even for G times M as measured together, however, Esposito cautions that one imminent limitation will need to be considered by researchers in the future. A few years ago, he says, the National Bureau of Standards remeasured the velocity of light, a key factor in such studies because it affects the timing of laser pulses and radio signals. The difference between the NBS result and the previous value was small (the new number was lower by less than 0.05 km/sec out of about 300,000), but the precision in measurements of GM has gotten so great that even such tiny uncertainties in the velocity of light can now make a difference.

Whither the lightning?

Although pinpointing lightning flashes in advance often ranges from difficult to impossible, a general global idea of where and when lightning strikes can be relevant to topics such as communications, meteorology and the earth's magnetic field. Using flashes photographed by two satellites in the Defense Meteorological Satellite Program, a pair of researchers have made some calculations about the world's lightning patterns.

At dusk, according to Richard E. Orville and Daniel W. Spencer of the State University of New York at Albany, the annual number of lightning flashes over land ranges from 8 to as many as 20 times the number at sea (depending upon the category to which near-coastal flashes are assigned). At midnight, the ratio drops to a range of 4 to 8. The dusk flashes peak at 10°N to 20°N during the northern summer and at 0°-10°N during the southern summer. The midnight flashes concentrate at 10°S-10°N throughout the year, though the peak region broadens to 10°S in the southern summer.

At both dusk and midnight, the scientists report, the frequency of lightning flashes over the whole planet appears to be about 1.4 times higher when it is summer in the northern hemisphere than when it is summer in the south.

Spotty check on solar variability

Solar variability — such as change in the amount of energy leaving the sun or reaching the earth—may be the key thread to unraveling the relationship between the sun and weather (SN: 3/6/76, p. 154). Sunspots have long been suggested as a possible record of that variability, and various weather effects have been linked to the sunspot cycle. Now, the structure of sunspots has been correlated to global temperature changes.

D.V. Hoyt of the National Oceanic and Atmospheric Administration in Boulder, Colo., has found a relationship between the ratio of the two regions of a sunspot (the dark umbra in the center and the lighter penumbra around it) and temperatures on earth. Hoyt compared the record of annual umbral to penumbral ratios, taken between 1881 and 1970 at England's Royal Greenwich Observatory, with annual average northern hemisphere temperatures for the same period. He found a gradual increase in both the ratio and the temperatures between 1881 and 1932, and a decrease in both between 1932 and 1970. Going one step further, R.A. Siquig of the National Center for Atmospheric Research in Boulder checked Hoyt's results against computer model-derived annual temperatures for the entire globe. The global temperatures show the same response to the umbral-penumbral ratio as the northern hemisphere temperatures. Hoyt and Siquig suggest that, if solar variability is indeed the key to sun-weather relationships, the umbral-penumbral ratio might be a reliable means of tracking it.

Watered down quakes and volcanoes

Violent protests of the earth — active volcanoes and near-constant earthquakes—circle the Pacific Ocean, creating what is known as the Pacific "Ring of Fire." They are manifestations of the swallowing of the Pacific oceanic plate beneath the continents. But the nature of the earthquakes and volcanoes, including their cause, distribution and the source of magma, has long been debated. Now, Roger N. Anderson of Lamont-Doherty Geological Observatory and S.E. DeLong of State University of New York in Albany offer data indicating that the release of water from the downward moving oceanic slab is the controlling factor in the Ring of Fire activity.

Using a computer model of the subducting oceanic slab that includes the appropriate water content, Anderson and DeLong calculated the points at which water would be released. They found it is released at two places: From the point of subduction to 30 kilometers beneath the continental plate, free water is squeezed out. And at 70 km to 90 km below the surface, water is "cooked out" of the hydrous minerals in the slab. When these points are compared with the distribution of earthquake and volcano activity in the Tohoku area of northern Honshu in Japan, they match quite well. The calculated point of release of free water correlates with the multiple shallow earthquakes that occur offshore, and the second point of release corresponds exactly with the location of the island arc volcanoes. Anderson and DeLong suggest that initial release of water triggers the shallow offshore quakes, and, more important, that the second release of water produces the magma that spews from the volcanic chains. This second point may resolve a long-standing debate. Though it has been acknowledged that the downgoing Pacific plate never gets hot enough to melt, it was believed to be the only possible source of upwelling magma because the lava is more similar in composition to the oceanic plate than to the continental mantle. Anderson and DeLong suggest that the water, which also carries minerals from the ocean plate, lowers the melting point of the much warmer mantle and, mixing with it, rises as magma. Their solution, says Anderson, seems to satisfy the seismologists and "make the petrologists happy."