Geodesy in Japan : Legends and highlights

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In this talk, I briefly review early histories of geodesy and geodynamics in Japan, and introduce a few highlights during the last two centuries.

(1) Dawn of geodesy: Meridional arc length measurement in 1801

The samurai government of Japan closed the country in 1639 and only allowed contacts with the western world through Dutch traders using a tiny window at Nagasaki, Kyushu. Even in this period, the Dutch version of the French book *Astronomie* (Lalande, 1764) was imported to Japan as *Astronomia of Sterrekunde* (1773), and it drew attention of samurai scientists in the astronomical bureau of the government. In the middle of the 18^{th} century, geodetic expeditions by the French academy of science revealed the difference between the arc lengths between Ecuador and Finland, and confirmed the Earth's ellipticity. In Japan, Tadataka Ino (1745-1818), a wealthy retired merchant in Kanto, studied modern geodesy to accurately map the Japanese Islands. He was also keen in measuring the meridional arc length in Japan, and determined it as 110.75 km by numbers of surveying campaigns early in 19^{th} century in NE Japan. This is marginally different from the modern value 110.95 km, and the overall accuracy of the maps made by his surveys amazed Europeans who entered Japan 50 years later.

(2) Polar motion and the International Latitude Service: Z-term in 1900

Japan opened the country again in 1854, and the new government vigorously imported up-to-date science at that time from Europe and America. The first international geodetic observation campaign started in 1899 soon after Mizusawa, NE Japan, was selected as one of the latitude observatories along 39°08'. After analyzing the data in 1900, the ILS central bureau at Potsdam, Germany, suggested to reduce the weight of the Japanese data due to its abnormally large residuals derived using the equation relating the latitude change $\Delta\theta$ with the polar motion (X, Y), i.e. $\Delta\theta = X\cos\phi + Y\sin\phi$. The young director of the observatory, Hisashi Kimura (1870-1943), found that a new longitude-independent annually-changing term could largely reduce the residual (Kimura, 1902 *Astron. J.*). The new term (*Z*-term) was officially adopted by ILS, and this became one of the earliest world-class achievements by a Japanese scientist. The Z-term is also the first signature of the fluid core of the Earth, detected earlier than the seismological discovery of the shadow zone of the S wave in 1906.

(3) Geodetic campaigns to detect continental drift during 1920-1930s

Torahiko Terada (1878-1935), a professor of physics (also a member of the Earthquake Research Institute) in University of Tokyo, was a supporter of the continental drift hypothesis by Alfred Wegener. He hypothesized that the Japanese Islands came apart from the continent and have been drifting away (similar to the modern back-arc opening concept). To verify this idea, Japanese national committee of geodesy conducted the first campaign in 1928 to detect the drift of the Tobishima Island off the coast of the Japan Sea (Tobishima means “flying island”, just like *Laputa* in *Gulliver's Travels*) using both astronomical positioning and terrestrial triangulation. Re-occupations in 1934 and in 1954 did not yield consistent coordinate changes for different intervals and techniques. After all, the attempt was not successful (opening of the Japan Sea is not currently active anyway), but the practice of such an ambitious project 90 years ago still impresses us.

(4) Last 70 years

Advance of geodesy after the World-War II in Japan and the world is so rapid, as recognized in various papers presented in this meeting, and I will just mention a few milestones. Yoshihide Kozai (1928-) formulated how the orbital elements of satellites change in time (e.g. 1959 *Astron. J.*), which paved way to the accurate measurement of J_2 and the discovery of J_3 of the Earth by periodic changes of the perigee height of the Vanguard satellite. In 1987, a long history of earth rotation observations based on optical telescopes ended, and Int. Polar Motion Service (central bureau at Mizusawa, Japan) was replaced by IERS. Space geodesy in Japan started in 1980s at Simosato (SLR) and Kashima (VLBI), with the Japanese participation in NASA/Crustal Dynamics Project. Deployment of the dense GNSS array started in the middle of 1990s, and resulted in many new discoveries such as slow fault movements. Newly launched Japanese satellites for geodesy include Ajisai (SLR), ALOS-1&2 (SAR), and QZSS (GNSS). The current frontier seems to lie in the ocean floor positioning with the GNSS-Acoustic technique.