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Where was Nootka in 1792? An Explanation of Captain Vancouver's Longitude Error

by

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Captain George Vancouver surveyed the west coast of North America and the waters around Vancouver Island in 1792, arriving at Nootka in late August. It was not the first time he had been there; he had sailed with Cook 14 years earlier as midshipman on Cook's third voyage to the Pacific. This experience entitled him to be regarded as the first European to have circumnavigated Vancouver Island, even though frigate captain Alcalá-Galiano, who completed a voyage from Nootka to Nootka arriving only a few days later than the British captain, might not have agreed.

Captain Vancouver was a very meticulous and thorough observer, but most of his longitude determinations were too far east, those at Nootka being no exception. The location of his observatory at Friendly Cove was 49°35.6' N, 126°37.1' W, but by his own calculations he was at 49°34.3' N, 126°28.5' W. This is a latitude error of only 1.3' (2.4 km), but a longitude error of 8.6' (10.3 km). Moreover, as he somewhat ruefully observed in his book, his calculated longitude was a full 20.5' (24.6 km) east of the position for Friendly Cove calculated from many hundreds of observations by Captain Cook. This was, for Vancouver, a worrying and puzzling discrepancy.

The Spanish were no help either. Commandant Bodega y Quadra, with whom Vancouver was negotiating the status of Nootka, placed the observatory slightly west of the usual Spanish position, and, quite fortuitously I am sure, almost exactly half way between Cook's and Vancouver's reckonings. In his journal, Bodega notes that Nootka is 21°23' W of the *Contaduría* at San Blas, i.e. at 126°39.5' W, which is about 2.4' (2.9 km) west of its true position.

The method that the British Navy used to measure longitude is known as the method of lunar distances. What they did was measure the position of the Moon in its monthly orbit around the Earth, and then use pre-calculated tables to determine the predicted time for the Moon to be at that position. This told them the time at Greenwich in England. By comparing this time with the local time as determined by the Sun, and noting that the Earth revolves 360° in 24 (solar) hours, they could calculate how far east or west of Greenwich they were.

The position of the Moon was determined by Vancouver by measuring the angle, or angular distance as it is known, between it and the Sun, using a sextant. At new moon, the angle is very small; but two weeks later, at full moon, it has grown to close to 180°. It is this slowly changing angular distance that 18th-century navigators used to determine Greenwich time, and hence their longitude.

In 1778, Captain Cook spent four weeks at Resolution Cove on Bligh Island, which is 6.6 kilometres ENE of Friendly Cove. While he was there, he and the astronomers on the expedition made over 600 observations of the position of the Moon. The resulting determination of their longitude was 10.8' (12.9 km) west of its true value. This was, by the standards of the day, and considering the accuracy of their sextants, a good estimate; yet it falls short of what might have been expected from such a prodigious amount of work.

Thanks to William Bayly, the astronomer travelling with Cook as a representative of the Board of Longitude, we have a good record of Cook's observations. Recently I completed an analysis of these observations, using data from an ephemeris of the Sun and Moon compiled by the Jet Propulsion Laboratory in Pasadena [1]. This analysis showed that if one neglects the measurements Cook made of the position of the Moon relative to the star Regulus, the longitude of Resolution Cove can be calculated from Cook's observations to an accuracy of 0.6 minutes of arc, or about 700 metres. The principal source of Cook's error was the Nautical Almanac of 1778 which contained the predicted positions of the Moon and Sun for that year.

The movements of the Moon are governed by the gravitational fields of all the other objects in the solar system. The principal fields, those of the Earth and Sun, have been fairly well understood since Isaac Newton's time, but in the late 18th century the influence of the planets on the Moon and the subtleties associated with the Earth's non-perfect shape were yet to be discovered. The tables of Tobias Mayer, which formed the basis of the Nautical Almanac's Ephemeris of the Moon, were derived from algebraic equations containing about 18 groups of terms. The 19th- and 20th-century astronomers Laplace, Hanford and Brown were later to expand this to over a 100 groups of terms, and then eventually to a large book-full of terms.

Algebraic analysis of telescopic observations has nowadays been largely replaced by computer modelling of the solar system. These models, which are many thousands of times more accurate than anything that has gone before, use information gathered from radar, laser ranging, and the movements of artificial satellites and spacecraft to plot the course of the members of the solar system.

Captain Vancouver made 106 sets of observations at Nootka, each involving six measurements of the Moon's position. Unfortunately, the full details of these observations have been lost and it is not possible to make the same detailed analyses of these results as was possible for Cook. Nevertheless, Vancouver's book contains a good summary of his results and it is possible to correct his results for errors in the Nautical Almanac for 1792.

The accompanying table shows the results of this analysis. The columns are the Julian day, the date in Vancouver's book, the observer (Vancouver or Joseph Whidbey), the number of sets of measurements made (each set comprised the result of six observations), the longitude in Vancouver's book in modern notation [2], the correction to be applied, and the corrected longitude. Julian days, for those who do not know, are used by astronomers and historians to label days unambiguously. Calendar reform applied at different times in different countries, and failure to change the date on crossing the international date line, make the more familiar calendar dates unreliable.

This table shows that Vancouver, using the same techniques as Cook, and making the same number of measurements as Cook, did in fact succeed in producing a result that was every bit as accurate as Cook's. Vancouver's corrected longitude for the observatory at Friendly Cove is 126°37.6' W, a mere 0.5' (600 metres) west of its true position.

For the record, and for those who are interested, the five-step correction procedure that I used is described in Appendix 1.

Julian Day 0400 PST	Vancouver's Date 1792	Obs.	No. of sets	Vancouver's Longitude	Correction	Corrected Longitude
2 375 808	Aug. 22	V	5	126°10.9′W	+ 4.6′	126°15.5′W
		W	5	126°23.9′W		126°28.5′W
2 375 810	Aug. 24	V	4	126°23.2′W	0.0′	126°23.2′W
		W	4	126°25.3′W		126°25.3′W
2 375 824	Sept. 7	V	2	126°37.5′W	+14.5′	126°52.0′W
		W	2	126°41.0′W		126°55.5′W
2 375 825	Sept. 8	V	8	126°21.3′W	+15.8′	126°37.1′W
		W	8	126°15.7′W		126°31.5′W
2 375 826	Sept. 9	V	8	126°28.5′W	+16.7′	126°45.2′W
		W	8	126°22.7′W		126°39.4′W
2 375 829	Sept. 12	V	6	126°32.9′W	+11.0′	126°43.9′W
		W	8	126°27.5′W		126°38.5′W
2 375 840	Sept. 23	V	8	126°33.4′W	- 1.9′	126°31.5′W
		W	8	126°46.9′W		126°45.0′W
2 375 840	Sept. 23	V	8	126°47.2′W	- 1.9′	126°45.3′W
		W	8	126°47.3′W		126°45.4′W
2 375 848	Oct. 1	W	6	126°24.6′W		
	collective mean =			126°30.1′W		126°37.6′W
						modern value is 126°37.1′W

Notes: Vancouver's collective mean was 126°28.5′W. This is probably an arithmetic error on his part as it is difficult to replicate by postulating typographical errors.

Oct. 1 results are based on lunar distance from Altair in the constellation of Aquila. All others are based on lunar distance from the Sun.

It is not clear why there are two entries for Sept. 23.

Table 1: Summary of Vancouver's Observations at Nootka,
corrected for errors in the Nautical Almanac for 1792.

Whilst the result of this analysis does show Vancouver to have been an observer of the highest calibre, it is a little disturbing that Vancouver himself seems not to have suspected his Nautical Almanac might have been in error. Yet there was evidence for this in that his observations did not agree with those of the Spanish. Galiano certainly was a very intelligent and competent navigator, well versed in alternative techniques for measuring longitude, and probably aware of the differences between the British and other Almanacs. Galiano even went so far as to tell Vancouver that he had found that tables could lead to longitude errors of up to three-quarters of a degree:

> "So we told Captain Vancouver, to whom our proposition was strange because of the ideas established in England by the best astronomers, who had predetermined, as an exact method of establishing longitude, the mean of many lunar distances." [3]

In general, Vancouver made many of his observations from land, so he was not prevented from using a high powered telescope to observe the moons of Jupiter. The beginnings and ends of the eclipses of these moons make a very good clock, although, to be fair, at the particular time Vancouver was at Nootka, Jupiter was setting only about an hour after the Sun and observations would have been difficult to make.

One of the questions that certainly interests me is whether or not it would have been possible for a late 18th-century astronomer to have corrected Vancouver's results on his return to England, by using observations made at the Royal Greenwich Observatory whilst he was away. The observatory records show observations on Aug. 23 and 27, and Sept. 2, 4, 26 and an incomplete observation (no declination) on Sept. 22.

The method I used to analyze these results was to concentrate on the error in the ecliptic longitude of the Moon. The calculation of the distance between Sun and Moon also involves the ecliptic longitude of the Sun and the ecliptic latitude of the Moon, but the relative contribution of these two quantities to the distance error is small. The Nautical Almanac of 1792 tabulated the Moon's ecliptic longitude every 12 hours.

The exact method of analysis is described in Appendix 2, and the results were as follows:

	ecliptic.long.error	longitude correction
Aug. 23	1.6"	+0.8'
Aug. 27	-5.2"	-2.6'
Sept. 2	20.6"	+10.3'
Sept. 4	23.2"	+11.6'
Sept. 26	-7.9"	-4.0'

The corrections to be applied to the (terrestrial) longitude determinations indicate that it would indeed have been possible for someone in the 18th century to have come close to the point we have, 200 years later. As it turned out, the magnitude of the errors attributable to the Nautical Almanac was not fully appreciated in Britain until the longitudes obtained by Matthew Flinders during his survey of Australia were re-computed in 1811 [4].

Appendix 1

The procedure that was used to correct Vancouver's longitudes was as follows:

1. From the JPL Ephemeris, take the RA (Right Ascension) and Declination of the Sun and Moon at Ephemeris Time 0000 hrs (approximately 1600 hrs PST) and compute the lunar distance.

2. Convert Ephemeris Time 0000 hrs to Universal Time (K8 in the Astronomical Almanac 1991). The difference between these time scales reflects the difference between atomic time and time based on the rotation period of the Earth. The length of our present 24 hour day is increasing at a long-term average rate of one hour every 200 million years because of tidal friction.

3. Convert the Universal Time of Step 2 to Apparent Time using the equation of time. Apparent time is true solar time and differs from mean time because the Earth's orbital speed is not constant throughout the year.

4. By inverse interpolation, from the 1792 Nautical Almanac, compute the Apparent Time at which the Moon was at the lunar distance calculated at Step 1.

5. From the difference between the times calculated in Steps 3 and 4, compute the correction to be made to Vancouver's longitudes.

Appendix 2

The procedure that was used to determine the error in the Nautical Almanac longitude for the Moon based on observations of the Moon's transit at Greenwich was as follows:

1. At the time of transit of the Moon's illuminated limb across the Greenwich meridian, determine the Sun's RA (Right Ascension) and the obliquity of the ecliptic. Neither of these figures is critically dependent on the time of observation. Also, 18th-century values are very similar to those computed from modern ephemerides.

2. Determine the apparent time of the observation by subtracting the RA of the Sun from the RA of the illuminated limb.

3. By interpolation determine the longitude of the Moon at the time of observation from the Nautical Almanac.

4. Calculate the observed longitude using the observed RA of the centre of the Moon's disc, the observed declination (90°-North Polar Distance), and the obliquity of the ecliptic of date.

5. Subtract the longitude obtained at Step 4 from the longitude obtained at Step 3.

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