UNITED STATES

COAST AND GEODETIC SURVEY

CARLILE P. PATTERSON

SUPERINTENDENT

METHODS AND RESULTS

THE CURRENTS AND TEMPERATURES

OF

BERING SEA

Dall, William Healey

APPENDIX No. 16—REPORT FOR 1880

WASHINGTON
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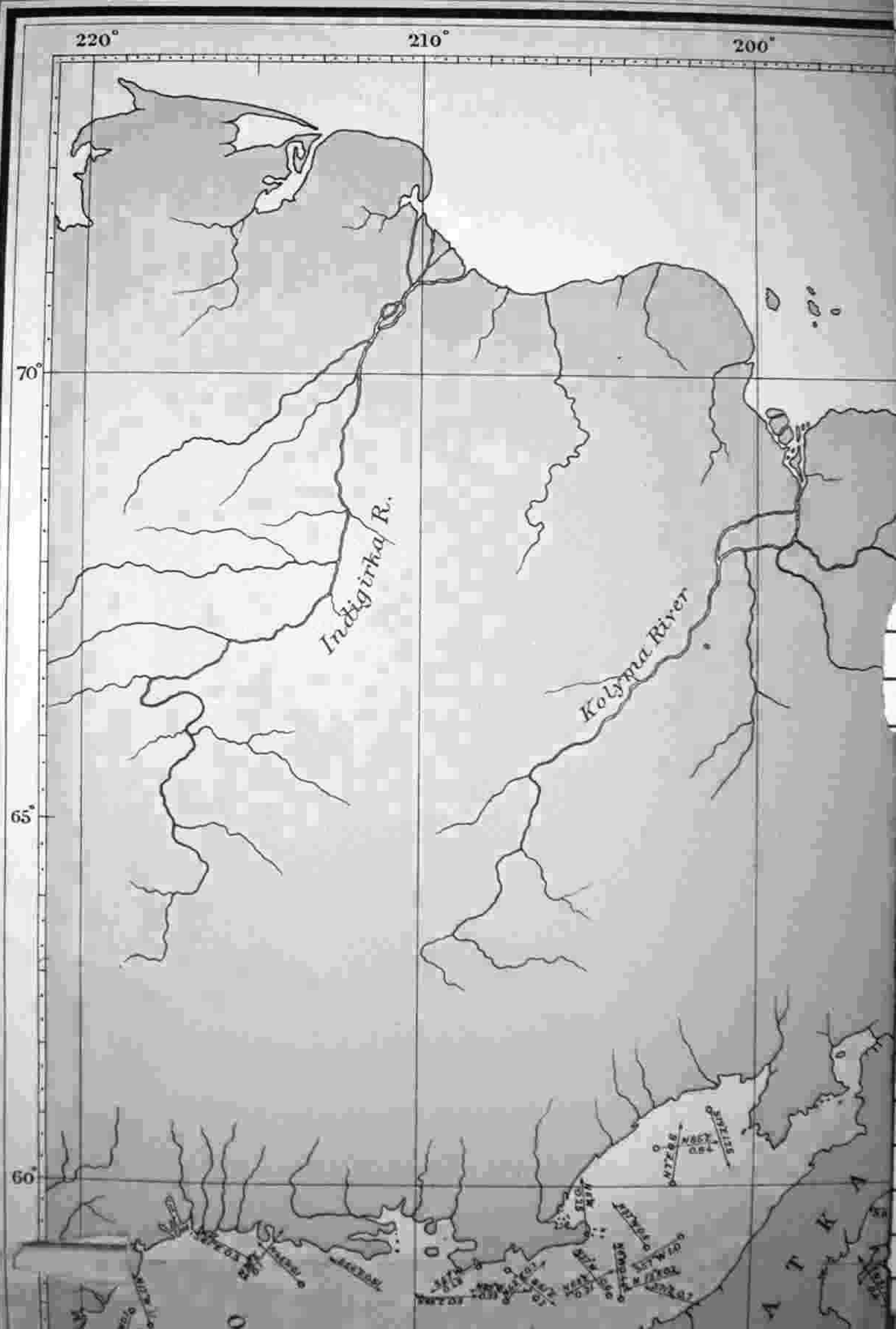
1882


220°
210°
200°
70°
65°
60°
Indigirka R.
Kolyma River


130°
70°
Mackenzie River
65°
60°
Sitka

Sitka
Queen Charlotte Is.
Vancouver I.
FUCA STRAIT
COLUMBIA R.
San Francisco
60°
55°
50°
45°
40°
35°
130°


160°
150°
140°
R
S
E
Point Barrow
Icy Cape
Cape Lisburne
Point Hope
ALASKA
Prince of Wales
St. Michaels
YUKON RIVER
Kuskokwim R.


Kadiak I.
Shumagin Ids.
N D S
A
S87°W 1.0
N83°E 1.29
N76°E 0.6
N82°E 0.88
S84°E 1.14
S73°E 0.5
S38°W 0.95
N83°E 0.66
W 0.35
N72°W 0.64
E 0.9
S60°W 0.8
N82°W 1.17
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W 0.62
S87°W 0.46
N67°W 0.19
N3°W 0.37
N46°W 0.38
N86°E 0.50
W 0.2
S60°W 0.8
S64°W 0.37
S.0.25
160°
150°
140°

U. S. COAST AND GEODETIC SURVEY

CARLILE P. PATTERSON, SUPT.

CHART OF
CURRENTS IN BERING SE
AND ADJACENT WATERS
1881

Compiled from various sources by W^m H. DALL, Assist. U.S.C.&

Symbols for Authorities

Bailey on U.S.S. Rush

Onatsevich on I.R.M.S. Vostok & Vsadnik

Belknap on U.S.S. Tuscarora

Kellett on H.M.S. Herald

Beechey on H.M.S. Blossom

Rodgers on U.S.S. Vincennes

Lütke on I.R.M.S. Seniavine

Krusenstern on I.R.M.S. Nadeshda

Dupetithouars on the Venus

Owen on various whaleships

Dall on U.S.S. Humboldt and Yukon

Hooper on U.S.S. Corwin

Bendel on the Lizzie Sha

Archimandritoff on the John Brigh

Wrangell on the ice

Miscellaneous


190°
180°
170°
P O L A
Wrangell I.
Herald I.
EASTERN SIBERIA
East Cape
Anadyr R.
St. Lawrence I.
St. Mathew I.
S.W. Limits of Pack Ice
S.W. Limits of Ice
Pribilof Ids


U. S. COAST AND GEODETIC SURVEY
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BERING SEA
ALEUTIAN ISLANDS
Commander Ids.
St. Mathew I.
Nunivak I.
Kuskokwim R.
Pribiloff Ids.
Unalashka
Shumagin Ids.
Kadiak I.
S.W. Limits of Ice
S.W. Limits of Pack Ice
190°
180°
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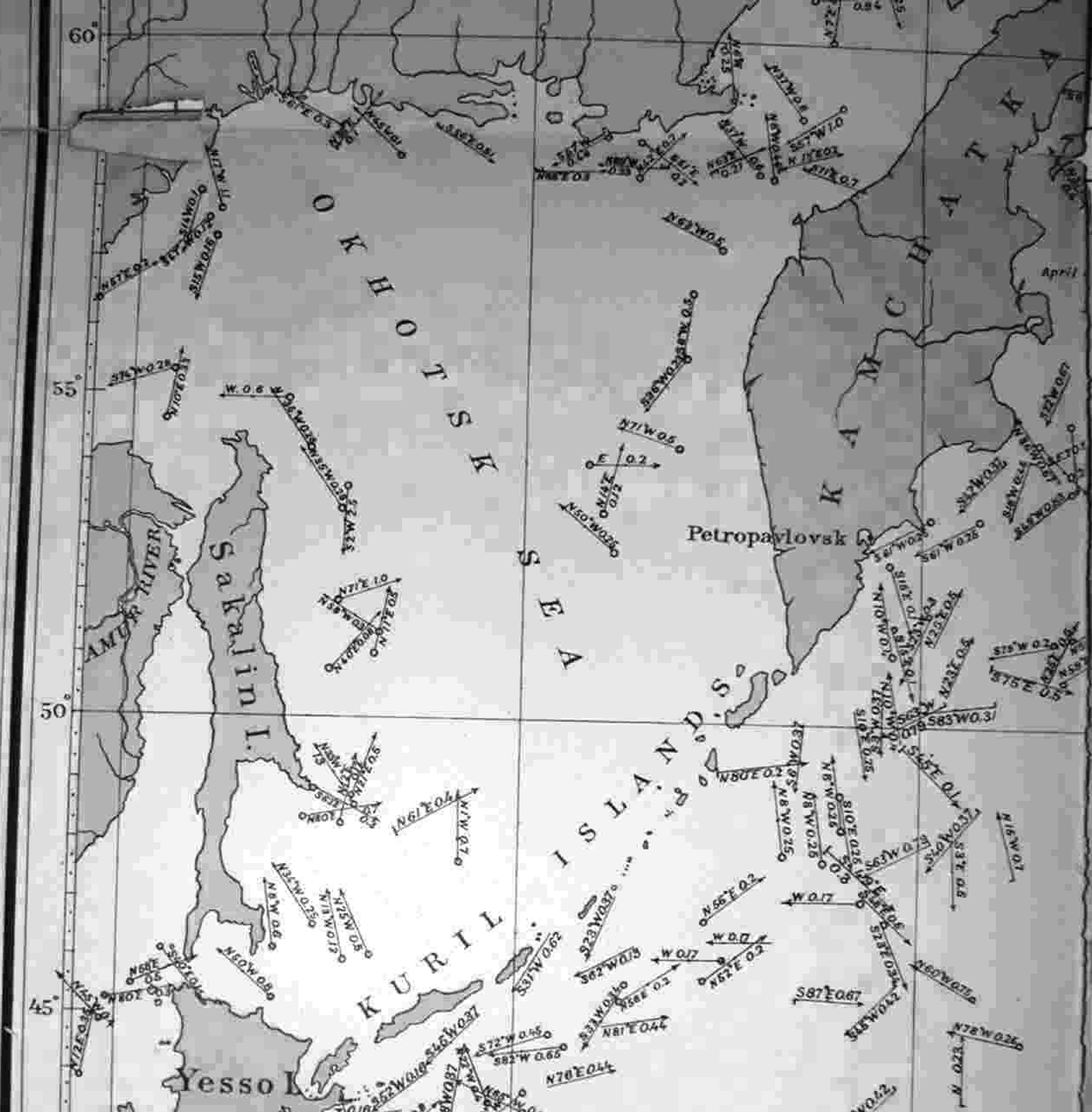
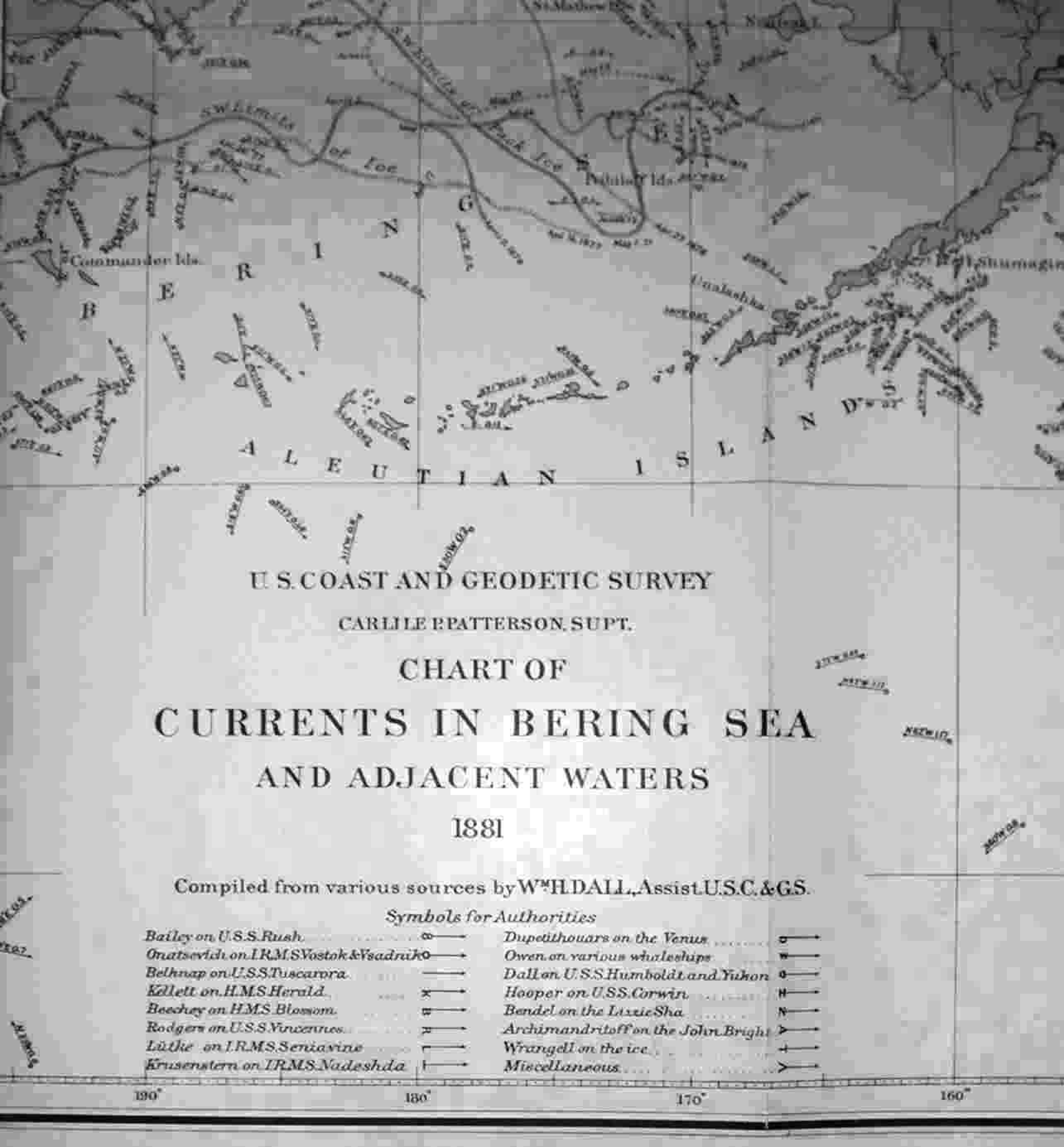
140°



OKHOTSK SEA
KAMCHATKA
Petropavlovsk
Sakalin I.
AMUR RIVER
KURIL ISLANDS
Yesso I.
Hakodadi
April
60°
55°
50°
45°
40°
35°
220°
210°
200°
E 0.62
N87°E 0.46
S87°E 0.67
E 1.0
E 2.13


190°
180°
170°
160°
150°
P O L A R S E A
Herald I.
Wrangell I.
Point Barrow
Icy Cape
Cape Lisburne
Point Hope
EASTERN SIBERIA
ALASKA
East Cape
Cape Prince of Wales
Anadyr R.
BERING STRAIT
St. Lawrence I.
St. Michaels
YUKON RIVER
Kuskokwim R.
St. Mathew I.
Nunivak I.
S.W. Limits of Pack Ice
S.W. Limits of Ice
Pribiloff Ids.
Commander Ids.
Kadiak I.
Shumagin Ids.
B E R I N G S E A


St. Matthew I.
Nunivak I.
S.W. Limits of Pack Ice
Pribilof Ids.
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B E R I N G
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Miscellaneous
190°
180°
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REPORT ON THE CURRENTS AND TEMPERATURES OF BERING SEA AND THE ADJACENT WATERS.

By WM. H. DALL,

ASSISTANT U. S. C. AND G. SURVEY.

(APPENDIX No. 16, COAST AND GEODETIC SURVEY REPORT FOR 1880.)

Since 1871, when I began to carry on the work of the Survey in Alaskan waters, every opportunity has been used for adding to the knowledge of the currents of the sea in that and adjacent regions, both by directing constant observations by the party under my charge, and also by obtaining a record of observations made by others, either from the logs of vessels employed in the waters of Alaska or from other sources. Only very recently has the accumulation of facts been sufficient to form a sound foundation for any theory of the currents which was entitled to consideration, and even now much remains to be done; but the material available has seemed sufficient to clear away much uncertainty, and to indicate with some probability the chief hydrological characteristics of the region.

The observations made by our party in 1880, taken in connection with the previously published data obtained by Onatsevich, in the western part of Bering Sea, for the first time brought into a clear light sundry marked discrepancies between the commonly received theory of the currents and the facts observed.[1] With a view of digesting all accessible material, the literature has been carefully examined and the results of previous observations collated with more modern data.

It has been generally held that a branch of the Japanese stream or Kuro Siwo passed north, between the western end of the Aleutian chain and the coast of Kamchatka, extending northward and eastward through Bering Strait into the Arctic Ocean. A polar current was supposed to extend from the Arctic Ocean, in a southwesterly direction, between the above-mentioned branch of the Kuro Siwo and the Asiatic shore. Another polar stream has been stated to extend from the strait southward, east of Saint Lawrence and Saint Mathew Islands, and then southwest, toward the Aleutians. This has been called the Bering current,[2] while the former was termed the Kamchatka current.[3] Such are in brief the views expressed in most works on the navigation of the Pacific and Bering Sea; such as "Pilots" and "Directories," as well as more pretentious treatises on general hydrology.

Before proceding to discuss the observations, it may be well to state the chief sources from which information has been derived. They are as follows: The voyages of King and Clerke (of Cook's expedition), in 1778–'79[4]; of Krusenstern, in 1803–1806[5], and Kotzebue, in 1816–'18 and 1824[6]

[1] See Coast Pilot of Alaska, Appendix I, Meteorology, p. 21, ¶ 3, 1879.

[2] Labrosse appears to have derived from Becher his authority for this supposed current, though he gives no references. Cf. The navigation of the Pacific Ocean (etc.), translated from the French of F. Labrosse, by Lieut. J. W. Miller, U. S. N., 8°, pp. xii, 360, Washington, United States Hydrographic Office, 1875 (p. 61). Also Becher, Navigation of the Pacific, 8°, London, 1860, p. 75.

[3] Cf. China Sea Directory, p. 25, *et seq.* Also Labrosse (original edition) pp. 65–68; North Pacific Pilot (W. Rosser, 1870), pp. 85–91; Onatsevich, Nabliudenie etc. (summary of various opinions on the subject), pp. 83–100, etc.; *also*, Becher's Navigation of the Pacific Ocean, 1860, p. 73, *et seq.*, etc.

[4] Cook (James), and King (James). A voyage to the Pacific Ocean [etc.] in the years 1776–1780, 3 vols., 4° Atlas, folio. London, 1784–1785; original edition.

[5] Krusenstern (Adam Johann von). Reise um die welt in den jahren 1803–1806, auf befehl Alexander's I. kaisers von Russland auf den Schiffen Nadeshda und Neva. Originalausg. 3 bde., 4°. St. Petersburg, Schnoor, 1810–'12.

[6] Kotzebue (Otto von). A voyage of discovery into the South Sea and Beering's Straits * * * in 1815–'18, &c., 3 v., 8°. London, Longmans, 1821. *Also*, A new voyage round the world in the years 1823–'26. 2 v., 12°. London, 1830.

of Beechey, in the Blossom, 1825-'28[1]; of Lütké, in the Seniavine, in 1828-'29[2]; Du Petit Thouars, in the Venus, 1837[3]; Moore, in the Plover, in 1849[4]; Kellett (and Trollope), in the Herald, 1850[5]; Lieut. (now Admiral) John Rodgers, U. S. N., in the Vincennes, in 1855[6]; Lieutenant Bullock, R. N., in the Dove, in 1861[7]; Capt. George E. Belknap, U. S. N., in the Tuscarora, in 1873[8]; Lieutenant Onatsevich, I. R. N., in the Vostok, in 1875; and the Vsadnik, 1876[9]; Nares, in the Challenger, in 1875[10]; Bailey in the U. S. R. S. Rush, in 1879[11]; and Hooper, in the Corwin, in 1880[12]. All these are published data, but of unpublished material there has been accessible the log-books (or transcripts from them) with temperature and current observations of the United States Coast and Geodetic Survey parties under my charge, on the Humboldt, in 1871 and 1872[13], and the Yukon, in 1873[14], 1874, and 1880; the "Remark books" of vessels commanded by Capt. L. C. Owen, in the whaling business, as follows: Ship Contest, in 1871; ship Jireh Perry, 1872, 1873, and 1874; bark Three Brothers, 1876 and 1877; bark Coral, in 1878 and 1879; all voyages from San Francisco or the Sandwich Islands to the Arctic Ocean during the season and returning.

Other logs affording material are those of the China steamers between San Francisco, Yokohama, and Hong Kong; abstracts of twenty-two voyages, during which temperatures were taken six or eight times a day, having been obtained by Prof. T. Antisell and most kindly placed at my disposal by him.[15] In addition to the above may be mentioned numerous isolated observations obtained from various navigators and recorded in the field books of the United States Coast Survey parties in Alaska, as well as the indications of currents derived from the navigators of the Russian-American Company, and recorded by Tebenkoff on the charts of Alaska, of which his atlas is composed.

The data obtained from these various sources relate both to currents and to sea temperatures, and, of course, in many instances, can be regarded as of merely an approximate character. In using these materials, therefore, it must be understood that in many cases there is an uncertainty of, perhaps, several degrees Fahrenheit in temperature, and that the rates of current in particular, from their very nature, are subject to rather large probable errors except when observed from a fixed point, such as a vessel at anchor, or a piece of grounded ice, and in many cases are only mere estimates. Some of the temperature observations have appeared in the Coast Pilot of Alaska, Appendix I[16], where they are summarized.

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[1] Beechey (Capt. F. W.). Narrative of a voyage to the Pacific and Beering's Strait (etc.), 1825-'28. 4°. London, 1831.

[2] Lütké (Capt. F. P.) Voyage autour du monde (etc.). Partie nautique, 4°. St. Pétersbourg, 1836. *Also in* Zapiski Hydr. Depart., 8°, St. Peterbourg, 1842-1852; 10 vols. (various articles). Cf. vol. ii, pp. 353-376.

[3] Du Petit Thouars (A. A.). Voyage autour du monde sur la frégate la Vénus, pendant les années, 1836-'39, 10 vols., 8°. Atlas, 4 vols., folio. Paris, Gide, 1840-'55. Cf. vol. vi., 1842, pp. 230, 280, et vol. ix, 1844, pp. 297-298. Best of the early voyages.

[4] Moore (T. E. L.). Nautical Magazine, 8°, London, 1850. Proceedings of H. M. S. Plover, pp. 176-184.

[5] Trollope (Com. H.) in Seemann (B.), Narrative of a voyage of H. M. S. Herald, 1845-'51 (etc.). 2 v., 8°. London, 1853; Nautical Remarks, vol. ii, pp. 290, *et seq.* Cf. *also* Nautical Magazine, 1850.

[6] Track chart published by the United States Hydrographic Office. No account of this expedition has appeared from official sources.

[7] Cf. China Pilot (various editions). London. Admiralty, 1864; pp. 449, *et seq.*

[8] Deep sea soundings in the North Pacific Ocean (etc.). United States Hydrographic Office No. 54. Washington, 1874, pp. 52. Illustrated.

[9] Sobranie nabliudenie (etc.), 1874-1877, 4°. St. Peterbourg, Admiralty, 1878; pp. 112. Many illustrations and maps. This work is referred to in note 3 of the preceding page.

[10] Thalassa, an essay on the depth, temperature, and currents of the ocean, by John James Wild, etc.; 8°, pp 140. London, Marcus, Ward & Co., 1877. Maps and plates.

[11] Report upon Alaska (etc.), by Capt. George W. Bailey, U. S. R. M., 8°, pp. 52. Washington, Government Printing Office, 1880. Map and illustration.

[12] Report of the cruise of the U. S. R. S. Corwin (etc.), by Capt. C. L. Hooper, U. S. R. M., November 1, 1880; 8°, pp. 72, and tables. Washington, Government Printing Office, 1881. Map and plates.

[13] Cf. Report United States Coast Survey, 1872. Appendix No. 10, by W. H. Dall; pp. 36, with sketch. [1875.]

[14] Cf. Report United States Coast Survey, 1873. Appendix No. 11, by W. H. Dall; pp. 12, with map. [1875.]

[15] These abstracts formed the basis of his valuable paper read before the Philosophical Society of Washington, April 13, 1878, "On the temperatures of the Pacific Ocean," and which we may hope yet to see published in full.

[16] Pacific Coast Pilot. Coast and Islands of Alaska. Second series. Appendix I, Meteorology. 4°; pp. 376. Washington, Government Printing Office, 1879. Maps and illustrations. Prepared by W. H. Dall and Marcus Baker.

ON THE TEMPERATURE OF THE SURFACE OF THE SEA.[1]

As the motion of oceanic waters is partly determined by their temperature, so their paths may often be traced out by isothermal curves of the surface of the sea. As the motion is usually less measurable with accuracy, when normal, than the temperature, and is much more rapidly lost, it often happens that the distribution of current-water can be much more accurately determined by study of its temperature than in any other way, and that the effects of a special current may be determined with certainty to exist over an area far exceeding that in which it can be proved to have a perceptible constant motion in any given direction.

Conversely, if a large body of water be shown to have a nearly uniform summer temperature, corresponding in general with the normal of the latitude and with the local circumstances in its particular portions, this is, of itself, evidence that no large body of water intrudes within its borders from a region of a different normal temperature. In other words, in the general oceanic circulation a stream of water with a temperature normal to one latitude cannot move to a region where another temperature is normal without exhibiting its presence by deflection of the isotherms.

A study of the sea temperatures of the Okhotsk and Bering Sea basins develops the following facts: In shallow waters, that is in depths of ten fathoms or less, during the long days and under the scorching sun of the Arctic summer, a higher degree of temperature is found than that which obtains in adjacent deeper water. Consequently, in the sounds, gulfs, and bays, especially on the eastern or shoaler side of Bering Sea, we find a midsummer temperature which would only be normal to a much more southern latitude.

The same is true of the Arctic basin, and when, moved by wind, tide, and other influences, this warm water (as in the vicinity of Bering Strait) is transported into the midst of bodies of water of a lower temperature, it, for the time and area within which the change takes place, has an influence as great and of the same nature as that which might be exercised by a similar body of water which, in the course of oceanic circulation, had been brought to the same locality from China or Japan.

These bodies of warm water are necessarily rather small, and from their superficial character yield to the changes of the season and weather much more rapidly than the constantly re-enforced supply of a great ocean current. Hence the time of their maximum of temperature always accords with that of the aerial maximum of their local region, while the corresponding maximum of current-water frequently occurs in cold regions some time after the local seasonal maximum has passed.

The presence of ice after the warm season commences in the seas mentioned has less influence in keeping down the surface temperature than might be expected. It is surprising, in many cases, to note how the water retains nearly its normal temperature up to within a very short distance from a large field of ice. The use of the thermometer in dense fogs is a widely-extended practice among those navigators who have reason to think themselves in the vicinity of ice, and desire to guard against collisions. However, in searching for currents, etc., by the sea temperatures, especially in the Arctic, where ice is abundant, the neighborhood of the ice must be taken into account, or the conclusions will be untrustworthy. For the same reasons observations taken in Bering Sea after the ice is wholly gone are more satisfactory as a basis of discussion, and have in this paper alone been used, except where otherwise stated.

Another factor contributes to the condition of the shallows. When the large rivers which enter Bering Sea and the Arctic first break up in the spring, they carry with them large quantities of fresh-water ice, and hence for a few days are not much warmer than the sea into which they fall. Very rapidly, however, their temperature rises, and under the continuous beams of the hot Arctic sun their waters become much warmer than the adjacent sea, which is yet, in most cases, hardly free from its bonds of ice. In opening passages between the ice and the shore, the important influence of the large rivers has been recognized by most students of the Arctic regions, and in cases of large rivers heading far to the southward of their mouths, such as the Lena, the Mac-

[1] In this report all bearings are *true*; all rates in knots and tenths per hour; all distances in nautical miles; all depths in six-foot fathoms; all temperatures in the text are Fahrenheit scale, those in parentheses or tabulated in broad-faced type are of centigrade scale; all latitudes are north; all longitudes west of Greenwich; except where otherwise stated.

kenzie, the Yukon, and the Amur, during the summer season, the outpouring of water, unless otherwise counteracted, is known to give rise to definite, though local, currents in the adjacent sea. These currents are generally of higher temperature than the average of their vicinity would normally be.

The diurnal variation of temperature of the surface amounts, in extreme cases, to six or eight degrees Fahrenheit, but is generally about three or four degrees, and in the case of uniform conditions, as during calm, densely-cloudy weather, there may be less than one degree difference between the maximum and minimum. The maximum usually occurs between 2 and 6 p. m., and the minimum from 2 to 4 a. m.

The following table indicates the changes of the surface temperature with the vessel at anchor, or in nearly the same position, for every two hours during the day:

No.	Date.		2 a. m.	4 a. m.	6 a. m.	8 a. m.	10 a. m.	Noon.	2 p. m.	4 p. m.	6 p. m.	8 p. m.	10 p. m.	12 m.
			°	°	°	°	°	°	°	°	°	°	°	°
1	July 7, 1880	C..	6.7	6.7	7.2	8.9	9.4	10.0	10.6	11.7	12.2	12.2	11.1	11.1
		F..	44	44	45	48	49	50	51	53	54	54	52	52
2	July 9, 1880	C..	11.1	11.1	11.1	13.9	13.9	13.9	13.9	14.4	14.4	12.8	12.8	12.2
		F..	52	52	52	57	57	57	57	58	58	55	55	54
3	July 16, 1880	C..	6.7	6.7	6.7	6.7	7.2	7.2	7.2	7.2	8.9	7.8	7.8	7.8
		F..	44	44	44	44	45	45	45	45	48	46	46	46
4	July 26, 1880	C..	1.1	1.1	2.2	1.1	0.0	0.6	3.3	3.9	3.3	3.3	2.2	1.1
		F..	34	34	36	34	32	33	38	39	38	38	36	34
5	August 1, 1880	C..	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
		F..	36	36	36	36	36	36	36	36	36	36	36	36
6	June 10, 1880	C..	0.6	0.0	0.0	0.0	1.1	1.1	3.3	2.2	2.2	1.7	1.1	1.1
		F..	33	32	32	32	34	34	38	36	36	35	34	34
7	September 10, 1880	C..	....	6.1	6.1	6.7	6.7	7.1	7.1	7.2	6.9	6.1	....	....
		F..	....	43	43	44	44	44.7	44.7	45	44.5	43	....	....

Nos. 1 and 2 are series from the log of the Corwin, in Norton Sound, at anchor, half clear weather and light airs. No. 3 from the same, in Kotzebue Sound, weather half clear, wind light, except from 2 to 8 a. m., when it blew fresh from southeast. No. 4 from the same, near the pack, in the vicinity of Herald Island, wind moderate, sky wholly cloudy; some anomalies in the forenoon are due to the influence of fragments of ice. No. 5 from the same, at anchor off Cape Sabine, heavy gale blowing, sky wholly cloudy. No. 6 same, northward from Saint Paul Island, sky wholly cloudy, weather calm. No. 7 from log United States Schooner Yukon, at the Diomedes, at anchor, fresh breeze blowing, sky cloudy, with a few glimpses of the sun. The table also illustrates the difference between the temperature of the shallow waters of Norton and Kotzebue Sounds, Bering Strait, and that of the open sea, as well as the effect produced by cutting off the sun's rays and stirring up the cold bottom water, as in the case of No. 5. The following table of hourly temperatures, taken by the Corwin while running into or out of Norton Sound, after the ice had gone out, indicates very well the increased temperature due chiefly to the action of the sun on the shallow and quiet water, and to the warm river flow:

Hourly temperatures from east to west.

		°	°	°	°	°	°	°	°	°	°	°	°	
July 7	C.	6.1	6.7	6.7	7.2	8.3	8.9	9.4	10.0	10.6	11.1	11.7	12.2	Norton Sound.
	F.	43	44	44	45	47	48	49	50	51	52	53	54	
July 10	C.	7.2	8.9	8.9	9.4	10.0	10.6	9.4	10.6	11.1	12.2	12.2	12.8	Do.
	F.	45	48	48	49	50	51	49	51	52	54	54	55	
September 14	C.	3.3	4.4	5.6	4.4	3.3	4.4	5.6	5.6	6.7	6.7	6.7	6.7	Do.
	F.	38	40	42	40	38	40	42	42	44	44	44	44	
September 17	C.	4.4	5.6	5.6	5.6	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	Do.
	F.	40	42	42	42	44	44	44	44	44	44	44	44	
July 15	C.	3.3	3.3	6.7	5.6	5.6	5.6	6.1	7.8	7.8	7.2	7.8	7.8	Kotzebue Sound.
	F.	38	38	44	42	42	42	43	46	46	45	46	46	

The course of September 17 was run from the south and west, the others from the northwest. The temperature in Norton Sound, July 7 to 10, varied from 52° to 58° (11°.1 to 14°.4) later in the season, September 14 to 17, it was nearly uniformly 44° (6°.7). The temperature at Chamisso Island, Kotzebue Sound, July 16, 17, varied from 44° to 48° (6°.7 to 8°.9). Having seen that the diurnal variation in the same locality may amount to eight or more degrees of Fahrenl eit, the variation in any one place during the year may be considered. This may be due to either of two causes, or to a combination of both of them. The first cause is the normal change of the seasons. The second is the intrusion of a current, with a temperature not normal to the sea-basin which it enters, and which temperature may fluctuate from the operation of causes existing in the region whence the current comes, but not existing in that region which it enters. The sea-temperature record of any locality not affected by currents as above should agree in general as to range and times of maxima and minima with the thermal characters of the adjacent terrestrial climate, and the differences should be chiefly differences of retardation and more limited range. This follows from the obvious fact that the sea water receives and parts with its heat more slowly than the air, and seldom to the same extent.

The following table shows the annual range of sea-temperature in a few localities about Bering Sea, and indicates in a general way the fluctuations and times of maximum and minimum temperature. Except when marked with an asterisk the figures are from continuous daily observations with standard instruments.

Locality.		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Saint Paul Island	C..	2.7	3.2	1.2	0.9	1.9	4.4	7.1	8.7	8.8	6.6	5.1	2.3
	F..	36.9	37.7	34.1	33.7	35.5	40.0	44.8	47.7	47.8	43.9	41.1	36.1
Saint Michaels	C..	0.0	0.0	0.0	-0.0	0.5	1.9	13.3	13.4	9.8	1.7	0.6	0.0
	F..	32.0*	32.0*	32.0*	32.0*	32.5*	35.5*	56.0	56.1	49.6	35.0*	33.0*	32.0*
Unalashka	C..	1.8	1.8	1.4	3.3	4.9	5.6	10.8	11.1	9.1	6.2	1.3	1.2
	F..	35.3	35.3	34.6*	38.0*	40.8	42.0	51.5*	51.9*	48.3	43.1	34.3	34.1
Aleutian Islands	C..	1.9	1.8	1.4	3.1	5.9	7.1	7.7	10.2	9.2	7.2	1.3	1.1
	F..	35.4	35.3	34.6	37.6	42.7	44.7	45.8	50.3	48.5	45.0	34.3	34.0

The means marked with an asterisk are approximate only, but are probably not far from the truth. In some seasons Saint Paul would exhibit a considerably higher temperature, as one of the winters included was much colder than usual and ice remained around the island until late in May—a thing hardly known before. The means for Unalashka are made up of parts of several years, Saint Paul of a year and eleven months, the islands of the Aleutian chain of parts of several years. Saint Michaels, Norton Sound, of parts of two summers only.[1] Parallel observations among the Aleutian Islands were taken for some time at five fathoms below the surface. The temperature averaged three or four degrees higher, except in very cold weather, and the changes were retarded from twenty-four to forty-eight hours in reaching that depth. These observations were all taken in quiet, well-sheltered harbors, and the series was necessarily fragmentary. Attention may be called to the fact that in bodies of water having a nearly equal temperature throughout, the long lines of temperatures which may be taken by a party on a steam-vessel have the advantage that a larger number of nearly simultaneous observations are obtained. But in bodies of water which are not homogeneous shorter lines are better, as there is less difficulty in eliminating the diurnal variation.

In the study of the Bering Sea temperatures, the various observations were platted in their proper position on a base-chart, and an endeavor was made to approximate to the normal average summer temperature, by applying the corrections of the following table to the several observations and thus reducing them to one common standard of comparison and obtain a basis for isothermal lines.

[1] Comprising one consecutive series for July, August, and September, and scattered observations during another summer.

Correction table for Bering Sea temperatures to reduce them to a mean summer temperature.

[Degrees centigrade in black.]

Date.	Corr.	Date.	Corr.	Date.	Corr.	Date.	Corr.
January 15	**+5.0** + 9.0	May 9	**+3.3** + 6.0	July 4	**−1.7** − 3.0	October 2	**0.0** 0.0
February 11	**+5.6** +10.0	May 14	**+2.8** + 5.0	July 12	**−2.2** − 4.0	October 7	**+0.6** + 1.0
February 25	**+6.1** +11.0	May 20	**+2.2** + 4.0	July 21	**−2.8** − 5.0	October 11	**+1.1** + 2.0
March 1	**+6.2** +11.2	May 27	**+1.7** + 3.0	August 1	**−3.3** − 6.0	October 16	**+1.7** + 3.0
March 10	**+6.1** +11.0	June 2	**+1.1** + 2.0	August 16	**−2.8** − 5.0	October 22	**+2.2** + 4.0
April 6	**+5.6** +10.0	June 8	**+0.6** + 1.0	September 1	**−2.2** − 4.0	October 26	**+2.8** + 5.0
April 16	**+5.0** + 9.0	June 14	**0.0** 0.0	September 10	**−1.7** − 3.0	November 2	**+3.3** + 6.0
April 25	**+4.4** + 8.0	June 20	**−0.6** − 1.0	September 19	**−1.1** − 2.0	November 7	**+3.9** + 7.0
May 4	**+3.9** + 7.0	June 28	**−1.1** − 2.0	September 25	**−0.6** − 1.0	November 19	**+4.4** + 8.0

This table was derived from the above-mentioned annual means and parts of other broken series, and has necessarily a merely approximate character. The corrections often reduced to agreeable unison, observations taken on different voyages in adjacent spots, and the table especially for the open sea, was of much use; it was evident, however, that it did not take into account sufficiently the differences which give a different summer temperature to the shallows and deeper portions of the sea, and that one table could not be applied over latitudes extending from 45° to 65° without verging into extremes in the higher and lower latitudes, which did not agree with the facts. Some general ideas were gained from the attempt, however, and the discrepancies between various seasons which had before been noticed were more clearly brought out. It is evident from the following examples that different seasons differ widely in their aqueous as well as in their aerial temperatures, if such expressions may be permitted. In running from Unalashka to Saint Paul Island, in 1874 (July 21, 22), the temperatures varied from 48° to 54° (8°.9 to 12°.2). In 1880 (August 3–5), over the same line, they varied from 44° to 48° (6°.7 to 8°.9), when by theory they should have been warmer than the first series. But 1880 was a cold and cloudy season, everywhere a month late, while 1874 was a warm and sunny season.

Again, in making the passage from the coast of Kamchatka toward the western end of the Aleutian chain in July, 1873, Captain Belknap obtained temperatures varying from 42°.6 (5°.9) to 47°.2 (8°.4). These observations agree with those of Onatsevich a year or two later. On the other hand, the observations of Du Petit Thouars on the Venus, in September, 1837, a little more southerly but in the same general region, varied from 51° (10°.6) to 53° (11°.7), agreeing with those made earlier by Beechey. These observers all worked with standard instruments, and the difference is explained when, on referring to their logs, we find that the Venus and Blossom had fine sunny weather, while Belknap and Onatsevich, for the most part, had very cloudy or foggy weather.

It is evident, therefore, that no system except one based upon a much larger series of local and other observations can represent the summer temperature of this region within a range of several degrees Fahrenheit. Nevertheless, the mass of observations accumulated is sufficient to give us a good general idea of the temperatures, subject to the uncertainty above mentioned.

Winter temperatures.—The minimum sea-temperatures of the year seem to occur toward the end of March. At that time the ice attains its greatest extension, and exercises its maximum effect upon the temperature of the sea. The general oceanic circulation is then at its minimum. The Okhotsk Sea, from the best evidence we can obtain, seems ordinarily at this time everywhere incommoded by ice, either in extensive solid fields, or more or less moving smaller floes drifted by the wind.

In my discussion of this subject in the Meteorological Appendix to the Coast Pilot of Alaska (pp. 43–46), I showed that navigation opens on the northern shore about June 5 and closes about October 17, there being an unnavigable period of some 230 days; on the southern and western shores it opens about June 11 and closes about November 30, and for the eastern shore no data are obtainable. The rivers usually break up in May, and close in November, river navigation being practicable for a somewhat longer period than that of the sea.

The ice in Bering Sea varies in different years in its extent, depending much upon the direction and force of the winds, and upon the temperature of the particular winter season. The latter itself depends greatly upon the winds, being much lower in those seasons when the winds prevail from the north for long periods and bring loose floe ice from the north, which is prevented (by the formation of new ice north of it) from returning to its original station when the winds change to the south.

It is noteworthy that a study of the remark-books of various whalers shows that the ice breaks up and disappears much more rapidly when the wind and current pass from it than it does when they tend toward it, if the temperature be above that required for the formation of new ice.

Since the first work of the whalers on arriving in Bering Sea is to cruise along the edge of the pack, seeking to get to the northward, I have been able to determine for each of six or seven years, from 1870 to 1878, the average southern limits of the pack in April and May, between the meridians of 169° and 190° west of Greenwich. The remainder is tolerably well understood from reports of winter cruises by the fur-traders of the region, and from reports as to the opening and closing of navigation at various ports on this sea. From these sources we learn that the edge of the ice extends from a point in about latitude 57° on Aliaska Peninsula, curving to the northward and westward toward the Pribiloff Islands, and generally passing at least a degree to the north from them, then curving again to the southward it generally presents a broad tongue in longitude about 174°, often reaching south to the vicinity of latitude 56°, and then extending in an irregular line westward, usually between latitudes 56° and 58°, toward the coast of Kamchatka, off which it forms a belt 15 to 30 miles in width, which is often entirely dissipated for short periods by westerly winds. This ice disappears for the season usually about the middle or end of May, and begins to form anywhere from the end of October to the middle of December, according to the season.

The following notes, taken from the whalers' remark books, will illustrate the rate of decay in the ice, and progress in opening to navigation the waters of Bering Sea and Strait and the Arctic.

Apropos of this, attention may be called to the fact, elsewhere shown by me, that the sea opens to the westward of Saint Lawrence Island first, it frequently being navigable there and north of the island into Norton Sound, at a time in the season when the passage between Nunivak Island and Saint Lawrence is still blocked with decaying ice. It is noticeable that the water opens first where the southerly cold set away from the ice is strongest, according to all authorities, and where Onatsevich declares his conviction that no warm current exists.

Ship Contest, June 9, 1871, reached Cape Chaplin; June 14, was abreast of the Diomedes; June 16, passed East Cape; August 6, passed Icy Cape; September 14, beset off Wainwright Inlet without any chance of escape and was abandoned.

Ship Jireh Perry, June 12, 1872, entered Bering Strait, but heard that other vessels had entered as early as June 1. Entered the Arctic in loose ice June 19[1]; saw ice aground in 14 fathoms between Cape Lisburne and Icy Cape July 27. Reached Point Barrow August 15; left the Arctic October 11, 1872.

Ship Jireh Perry, August 15, 1872, on reaching Point Barrow found large floes grounded along shore and open water 8 to 10 miles off shore.

Ship Jireh Perry, 1873; June 3, met the ice in latitude 56° 30′, longitude 173° 30′, water 33°; June 15, reached Cape Chaplin, found very little ice anywhere; June 19, passed East Cape; June 21, made the pack in latitude 67° 30′; July 8, passed Icy Cape; July 20, reached Point Belcher; July 26, got around Point Barrow finding a lane of open water about ten miles wide, but the shallows and lagoons were still ice-bound. October 14, left the Arctic.

[1] "Entering the Arctic" here means passing north of the Arctic Circle in the sea of that name.

Ship Java, June 29, 1873, reached latitude 71° 10′ and longitude 165° 35′. "All say a very open season." Bark Helen Mar, July 16, reached Herald Island.

Bark Three Brothers, May 14, 1876, off Cape Chaplin; May 23, reached East Cape; much loose ice in Bering Strait; weather mostly cold and stormy. June 13, entered the Arctic. July 12, reached Wainwright Inlet; ice 15 miles off shore here, but fast to the land at the Seahorse Islands. July 27, reached Point Barrow. On the 17th of September escaped from the pack with bark Rainbow, leaving ten vessels beset to total loss; and on the 19th left the Arctic.

Bark Three Brothers came up with the ice May 29; latitude 58° 31′, longitude 189°; on June 16, 1877, reached Plover Bay; June 20, East Cape; entered the Arctic June 23; up to the time when the record ends, July 13, had not been able to get north of latitude 69° on account of the ice.

Bark Coral, in 1878, May 1, found ice in latitude 58°, longitude 179°; May 13, fast in the ice in latitude 60° 40′, longitude 182°; reached Plover Bay June 10, entered the strait June 12, passed East Cape June 21, and entered the Arctic June 22; in 1879 had a similar experience, but did not get into the Arctic until June 27. Reached Point Barrow August 5 and got as far east as Return Reef, in longitude 149°, August 15; leaving the Arctic October 15, 1878. In 1879 he reached Icy Cape only by August 23, and got no farther north on that shore that season; such ships as got to the north side of the cape were beset and barely escaped by a favorable gale. To the westward they reached nearly to Herald Island by October 7, and left the Arctic October 20, after the hardest season Captain Owen had ever experienced.

In 1880 the bark Pacific entered the Arctic, May 22, but the Corwin reached Plover Bay June 27 and entered the Arctic on the following day, then found the ice solid near Point Hope; reached Cape Lisburne July 23; August 20 he was within a few miles of Herald Island, and on the 25th reached Point Barrow through a narrow lane of water.

In nearly all these cases it is to be understood that the vessels were following up the open water and advanced as fast as the breaking up of the ice would allow.

The time of breaking up of the ice between Cape Navarin and Plover Bay varies so much with the season that no general rule can be laid down. Vessels have reached Cape Thaddeus in April; on other occasions they have not gotten east of longitude 180° in that vicinity until nearly the end of June. The whalers never pass to the eastward of Saint Mathew and Saint Lawrence Islands, as the ice stays there later; in 1880 the Corwin found a narrow lane along the mainland shore by which she reached Norton Sound June 18. The earliest time at which Norton Sound has been known to be accessible to vessels is May 25 (in 1874), the latest, June 22. The average is about June 10. The Yukon breaks up in freshets lasting two weeks, beginning from May 15 to June 5, the average being about May 23. The high water arising from the melting snows lasts many weeks after the freshet which carries away the river ice. The northwesterly current thus generated carries away the rotten field ice toward Bering Strait when it has not previously disappeared. Captain Hooper of the Corwin saw a field of it drifting into the strait July 5 which he had to go to the west side to avoid; but this was a very unusually late season in all respects.

The southern portion of Bering Sea along the Aleutians is rarely if ever troubled by ice, and the northern border of the Pacific is practically always free from ice except possibly a rare fragment formed in some narrow passage or drifted south by some severe winter gale. The sea temperature is probably about 40° (4°.4) in winter, varying from 36° to 44° (2°.2 to 6°.7) according to weather. None lower than 36° (2°.2) has actually been observed so far as is known.

Summer temperatures.—The remarks previously made in connection with the correction table for summer temperatures indicate its merely approximate character; it will, however, be interesting to compare an actual reduction of observations taken with the mean resulting from a computation of the theoretically corrected figures.

The Okhotsk Sea is practically a closed basin partaking of a continental climate, and consequently might be expected to present us with a higher summer and lower winter temperature than an equal area of open sea in the same latitude, which being unconfined would be operated upon by the general oceanic circulation.

Again, the temperatures taken being mostly on soundings of less than 100 fathoms, the factors which determine a greater summer temperature for shallow waters might be expected to result in a more than normal warmth for the localities tested; winter observations when the sea is ice bound being, of course, yet to be made.

The fact agrees with the hypothesis, whether the latter be or be not correct, since the observations of one hundred and twenty different localities (due to Erman[1] and Onatsevich), ranging over nearly the whole summer season (July to September), theoretically corrected, give us a mean maximum summer temperature for this sea 50°.56 (10°.31). The mean of the observations as they were taken is 49°.26 (9°.59), a difference of less than a degree and a half. Localizing the observations, those of the east shore, uncorrected, taken in the early part of July, average 46°.1 (7°.8), those of the north shore, July and August, 48°.88 (9°.38), and those of the west shore, taken in September mostly on the shallows east from Sakalin Island, 50°.45 (10°.23). If the temperatures of the deeper central and southern parts of the sea had been as thoroughly tested we should probably find that the theoretical mean summer sea-surface temperature of about 45°.0 (7°.2) was not far from the truth.

It is true that some current passes through La Perouse Strait into the Okhotsk, especially toward the end of summer; but, from Onatsevich's observations, the resulting effect on the temperature of the sea near the strait would seem to be of a very insignificant character.

If, then, a sea free from great oceanic warm currents reaches a summer maximum of about 50°.0 (10°.0), should we not expect greater things from one in the same latitude into which a great warm current is said to bring borrowed heat in addition to its normal temperature?

Bering Sea may be divided for consideration of its temperature into three divisions: 1. The shallows, such as Bristol Bay and vicinity, Norton Sound, and the region off the coast of the mainland where the depth is less than twenty-five fathoms. 2. The moderate depths extending from the southern entrance of Bering Strait west of the line bounding the shallows and extending south to a line drawn from Cape Thaddeus toward Saint Mathew, the Pribiloff Islands, and the peninsula of Aliaska, following as nearly as we may the seventy-five-fathom curve. Lastly, the deep waters south and west from this line to Kamchatka and the Aleutian Islands.

Taking up these regions successively, we find the shallows of Bristol Bay and vicinity having a theoretical mean summer maximum of 54°.0 (12°.2), and an observed maximum of 56°.2 (13°.4), during the unusually warm season of 1874.

The shallows of Norton Sound from actual observations, by Riedell, have for July and August an average temperature of 56°.05 (13°.36), with a maximum of 62°.0 (16°.7), and, including September, have a mean temperature for the three summer months of 53°.9 (12°.2), at least for 1872. These observations were made with a standard instrument, furnished by the United States Coast Survey. Captain Hooper's observations made in a less favorable season, and covering only a few days, indicate a similar relation between the deeper waters and those of the sound.

The temperature of the area of moderate depths is considerably less. Taken as a whole, they present a theoretical mean summer maximum of 46°.2 (7°.9), and an average summer temperature of 40°.2 (4°.6). This is somewhat too high for the northern portion and too low for the southern portion, but agrees very fairly with the mean of actual observations 46°.8 (8°.2) and 42°.1 (5°.6) respectively, and the conclusions from more meager evidence, published in Appendix I to the Alaska Coast Pilot. These means are derived from observations taken in the open sea and appear low when compared with the observations taken at Unalashka, with a summer mean of 51°.1 (10°.6), and at Saint Paul Island 47°.3 Fahr. or 8°.5 C.; but it must be remembered that these were taken in shallow water, near the shore, and do not adequately represent the off-shore temperatures. The high temperatures of Norton Sound are only comparable for the three months open-water period, with temperature taken farther south, for if the ice-bound months of May and June, and the cold October were included (as they might be at Unalashka), the temperature would be reduced to 44°.8 (7°.1 C.) for the season. For these reasons I have only considered the three months of July, August, and September in these comparisons. The deep area of Bering Sea is also a southern area, and might therefore be expected to have a higher temperature than the rest, even if it were not the part which by popular hypothesis should receive a body of warm water from the Japan Stream. A reduction of the actual observations from one hundred and twenty-two different localities, each representing, in general, the mean of a day's observations, shows that the maximum and mean summer temperatures are but little higher than those of the area of moderate depths,

[1]Journey in Siberia, vol. ii, Phys. Obs.

which covers in part a more northern region. The figures for the observations are 47°.1 (8°.4) and 45°.2 (7°.3), and for the theoretically corrected observations 47°.0 (8°.3) and 41°.0 (5°.0), respectively. Since the former represent only small portions of different seasons, it is by no means certain that the corrected means deduced from continuous series do not more nearly indicate true averages.

The region is of course warmer on the south and colder on the north, but warmest in the local shallows, along the Kamchatka coast, such as the Bay of Avatcha.

It is obvious that the mean temperature over a region partly cold and partly warm would fail to indicate its real character and its want of uniformity. Were such a distribution indicated by the facts in this region, its discussion would have been the first thing in order; since that is not the case, a discussion of that part of the problem will appear later, in connection with a review of the facts known in regard to the Japanese Stream and its extension north and west.

Since the Arctic basin is constantly more or less obstructed by ice, it is impracticable to apply any theoretical corrections to non-synchronous observations, and I have therefore attempted to obtain a mean summer temperature on the basis of the observations as they stand. Kotzebue Sound, when free from ice, bears the same relation to the rest of the basin as does Norton Sound or Bristol Bay to the basin of Bering Sea. I find from the mean of all accessible observations (reduced according to their weights), that the mean temperature of Kotzebue Sound for July and August is 49°.8 (9°.9); for July, August, and September (including one very cold September), the mean temperature is 44°.8 (7°.1).

The mean temperature for the Arctic basin from July to September (being the time when the sea is more or less open or free from ice), reduced in the same way, for the regions between Wrangell Island and America, exclusive of Kotzebue Sound and Bering Strait, is 40°.25 (4°.58). This hardly differs from the July temperature of the sea, west from Novaia Zemlia, according to Petermann, or the Polar basin, east from the Lena, along the Siberian coast, according to Nordenskiold.

The general temperature figures may, therefore, be summarized as follows: the column "max." indicating the greatest mean temperature for the warmest month of summer; the column "mean" indicating the average temperature of the period of open water (July, August, and September[1]) in the north. Except when marked by an asterisk these figures are from actual observations reduced according to their weights.

[Centigrade degrees in black.]

Sea.	Deeps.		Moderate depths.		Shallows.		Area of—
	Max.	Mean.	Max.	Mean.	Max.	Mean.	
	°	°	°	°	°	°	
Arctic	....	....	**5.6** 42.0	**4.58** 40.25	**11.7** 53.0	**7.1** 44.8	Kotzebue Sound.
Bering	**8.4** 47.1	**7.3** 45.2	**8.2** 46.8	**5.6** 42.1	**11.1** 51.9	**10.3** 50.5	Captain's Bay.
Do	....	....	....	....	**13.4** 56.1	**12.2** 53.9	Norton Sound.
Do	....	....	....	....	**13.4** 56.2	**12.2** 54.0*	Bristol Bay.
Okhotsk	....	....	**9.59** 49.26	**7.4** 45.3*	**12.7** 54.9*	**9.9** 49.8	West border.
North Sea[1] [July]	....	**13.9** 57.0	....	**15.0** 59.0	....	**16.7** 62.0	Baltic, &c.

THE KURO SIWO AND ITS EXTENSIONS.

The question of distribution of temperature in the sea is so intimately united with that of the character of its currents, that it is impracticable to separate them entirely. Consequently, as soon as one leaves the general question of mean temperature of a given area, and desires to decide whether that temperature is normal, and if not, from whence and how it is derived, the features of oceanic circulation must at once make part of the discussion.

To reach the root of the matter it is necessary to inquire into the origin, duration, and extent of the Kuro Siwo, outside of the Bering Sea region. The data furnished by Dr. Antisell enable me to do this in a more satisfactory manner than would otherwise be possible. It is true they relate

[1] Petermann, Gulf Stream Memoir Plate I.

almost wholly to its temperature, but, owing to the fogs which cover much of its course, determinations of its motion must long remain few in number and more or less inexact in character.

While other observers have noticed grave irregularities and connected them casually with the changes of the monsoons, Dr. Antisell, in his paper referred to, was the first to draw attention to the marked periodicity of the Kuro Siwo and the great extent to which it depends upon the southwest monsoon for its propagation.

Since his data were derived from the records and experience of those best fitted to judge (the commanders of the China, Japan, and California mail steamships), and cover a great number of voyages, his conclusions must be considered as of great weight.

The Kuro Siwo is produced by the impinging of the Pacific north equatorial current on the eastern shores of Formosa and adjacent islands. While the larger part of the equatorial current passes into the China Sea, a portion of it is deflected northward, along the eastern coast of Formosa, until reaching the parallel of 26°, it bears off to the northward and eastward, washing the whole southeastern coasts of Japan, and increasing in strength as it advances to a limit which appears to be variable.[1] Its average maximum temperature is 86°.0 (30°.0), which differs about twelve degrees from that of the ocean normal to the latitude. The northwestern edge of the stream is strongly marked by a sudden thermal change in the water of from 10°.0 to 20°.0 (5°.6 to 11°.2), but the southern and eastern limit is less distinctly defined, there being a gradual thermal approximation of the air and water.

A branch of the Kuro Siwo passes northward into the Yellow Sea, and another through the straits of Korea, into the Japan Sea, after entering which it becomes variable and irregular, but is believed to issue under favorable circumstances from Sangar and La Perouse straits. These branches for the purposes we have in view may be regarded as of little consequence.

The Kuro Siwo has its origin in almost exactly the same relative part of the Pacific as the Gulf Stream does in the Atlantic, but the parallel is otherwise far from complete. The differences of volume and of temperature between this and the Gulf Stream will be discussed later; assuming an equality in these respects there are still other important discrepancies.

The latter enters a deep ocean without obstructions and about seventy degrees of longitude in width. The Kuro Siwo, at its very outset, is obliged to force its way through the barrier of the Loochoo Islands, and a little later through that chain of rocks, shoals, and islets extending from Yokohama to the Bonin Islands. It then has nearly one hundred degrees of longitude to traverse before reaching the opposite shore of the Pacific. When to these barriers is added the strength of the northeast monsoon from the end of September to the end of February, blowing right in the teeth of the current (which is not, like the Gulf Stream, prevented by an unbroken line of coast from escaping in a westerly direction), it is not a matter of surprise that its force should be checked, and its continuity as an eastward current be for the time almost obliterated. The reports of the British naval officers who have examined it show that this "current is much influenced, both in direction and velocity, by local causes." "It is sometimes entirely checked for a day by a northeast wind." "In June, 1861, the current ran steadily at the rate of seventy miles a day toward the Gulf of Yedo, but, on approaching the great chain of islands south of the Gulf, it diminished in velocity and curved to the southward. During July and August it was not noticed off the gulf."[2] This, it may be noted, was in the period of *favorable* (southwest) *monsoons*. The remark is made in the China Pilot that the current appears to attain its greatest velocity (72 to 80 miles) between Van Diemen Strait and the Gulf of Yedo, but was on one occasion recorded for three successive days at only 24 to 27 miles. "It is sometimes deflected to the south by the chain of islands south off the gulf, or before reaching them. Changes of the stream will probably be found dependent on the seasons." It is hardly necessary to observe that in the Gulf Stream, during the equivalent part of its course, such violent fluctuations have not yet been recorded by scientific observers.[3]

[1] China Pilot, 4th ed., p. 449.

[2] Report by Lieut. Bullock, R. N., H. M. S. Dove, 1861.

[3] It is likely that the Gulf Stream, also, when more fully investigated, will show important fluctuations, especially in the winter months. Such have already been referred to by several writers, especially Com. J. R. Bartlett, U. S. N. If they were as marked and important as those indicated by Antisell's documents for the Kuro Siwo, it would seem that widespread knowledge of them would long since have been attained by the navigators directing the enormous commerce which crosses the Gulf Stream continually. This matter is under investigation by the United States Coast and Geodetic Survey.

The course of the Kuro Siwo, as indicated by various authorities, when in its greatest strength, is from the vicinity of Yokohama in an easterly and northerly direction toward the northwest coast of America, which it reaches in about latitude 50°. For our purposes, the character of that part of the stream between the meridians of 220° and 185° west from Greenwich is of more importance. Lütké observes* that, in six voyages between Kamchatka and the south, while between latitude 30° and 42° and longitude 214° and 198°, a steady current, flowing eastward, even with easterly winds, was noted. In one southward voyage, it was first met with in latitude 38°, on a second at 40°. "North from the parallel of 42° in the western part of the Pacific Ocean, we chanced to have almost constant easterly winds, and with them westerly currents which, when the winds were very strong, amounted sometimes to 20 miles a day, and which, when it became calm, disappeared entirely. In some cases, on the contrary, when the wind blew from the northwest the current then turned to the southeast, the direct influence of the wind herein being evident" (Lütké, l. c., p. 190). Though Lütké reports that Mertens took observations of sea temperatures, it does not appear that they have anywhere been published, and the observations of Beechey are so much generalized in his appendix as to be untrustworthy for close comparisons. Du Petit Thouars, during the voyage of the Venus, took hourly temperatures, which have been admirably worked up in the published records of the voyage. In latitude 30° longitude 180°, he found the temperature of the axis of the Kuro Siwo to be 81° (27°.5). The normal temperature of the Pacific Ocean about latitude 40° to 45° is about 60°.0 (15°.6). He found that the temperatures rapidly decreased northward, falling from 75° (23.9) to 53° (11°.7) in only three degrees of latitude; but of this change twelve degrees (71° to 59° Fahr.) occurred upon one day (August 17, 1837), between latitude 40° and 41°, which would place the northern edge of the Kuro Siwo at the period of its greatest strength about latitude 41° in longitude 197°. The observations of Belknap, taken in June, show that the isotherm of 60°.0 (15°.6) does not pass much north of 42° north latitude, and that the temperature then very rapidly decreases northward, falling 15° Fahrenheit in 150 miles. The observations of Onatsevich in the same region, taken at different periods of the year, agree with those of Belknap.

With regard to the propagation of temperature (and inferentially of motion) in the waters, forming the supposed bed of the Kuro Siwo, the data obtained by Antisell are of high importance, and go far toward sustaining the view that the current is dependent for its existence, east of Yokohama, upon the southwest monsoon. In other words, that it is turned in a southeast direction or obliterated by the northeast monsoon.

The track of the Pacific Mail Steamships, in the voyages referred to (leaving out of consideration a few degrees at the San Francisco end) lies almost wholly between the parallels of 30° and 35°. Between the meridians of 220° and 190°, it cuts obliquely across the current, and if it be true, as there is reason to suspect, that the current has, in general, a considerably more southern course than has been supposed, the track would lie in its trough for a much greater distance.

The northeast monsoon begins to disappear in February. In March the North Pacific appears to be in its most homogeneous condition. The means of six or eight daily observations continued throughout the voyage (4,750 miles), the diurnal fluctuations being eliminated, show extreme differences of only four degrees Fahrenheit. From longitude 217° to 136°, in the mean latitude 33° 03′, the sea only varied from 60° to 64° (15°.6 to 17°.8). It is quite evident there is no warm current here. In April, over a course averaging a degree and a half further north, the temperature was somewhat lower and the variation a little larger (57° to 63° Fahr.), but still remarkably homogeneous.

In May the warm water begins to creep north, along the Japanese coast. In records of three voyages, amid some seasonal differences this change is clear. From longitude 217° to 208°, in these three years the temperature has risen in the last week in May to between 64° and 68° (17°.8 and 20°.0). Thence eastward it still retains a lower and pretty uniform temperature, which is in the mean latitude 36° 12′, from 57° to 63°; fifteen days later, in mean latitude 38° 29′, 53° to 60°, and in mean latitude 36° 16′, from 58° to 64° Fahrenheit.

In June the Kuro Siwo is putting forth its strength. From Yokohama eastward to longitude

* Voy. Séniavine, Partie naut., p. 189 *et seq.*

169° the temperature (except a cooler band ten degrees wide, between the meridians of 198° and 208°) has risen to between 70° and 73°[1] (21°.1 and 22°.8). This cool band, indicative of the Kamchatka stream, is also shown in the Challenger section.

In July (two voyages) we have still indications of the "cool band," but the temperature as far east as 205° W. has risen to between 75° and 81° (23°.9 and 27°.3), and thence during the first half of the month to longitude 180°, and in the latter half to longitude 172° (mean latitude 36° 20′), the surface does not fall below 70° (21°.1).

In August the temperature seems to reach its maximum. The locality of the "cool band" has 79° (26°.1) at the surface and the temperature appears to decrease very gradually from 84° (meridian of 218°) to 75°, (at 169°) and 70° (at 138°). In a voyage by the so-called "northern route," mean latitude (44° 48′), made in this month, the temperature of 70° (21°.1) proper to the Kuro Siwo, was lost in latitude 40° 30′, longitude 207°, and the temperature fell below 60° (15°.6) about 100 miles further north, in the very axis of the hypothetical northern branch, and did not rise above 60° (15°.6) again until the northern edge of the Japan Stream was reached, in latitude 47° and longitude 166°. The "cool band" on this line extended between the meridians of 180° and 202°, with a temperature of between 50° and 59°. In September, toward the end of the month, the southwest monsoon begins to fail and in the record the change is clearly revealed by the changing temperatures. Off the Japanese coast, for fifteen degrees of longitude, the temperatures which had been 78° to 82° (25°.6 to 27°.6) have fallen to 75° (23°.9), with bands 2° to 5° cooler. There is a trace of the "cold band" on the surface, in the region of 205°, with a temperature of 73°, but the water eastward, which in August varied from 72° to 77° (22°.2 to 25°.0), now shows temperatures of 69° to 73° (20°.6 to 22°.8), between longitude 158° and 188°. Other voyages in this month are taken on the "southern route" and show warmer temperatures but are of course not properly comparable with those herein considered.

Throughout the month of October water with a temperature of 70° is found stretching across the Pacific as far east as 140° with intervening narrow bands of slightly cooler water.

In November the southwest monsoon is at an end; the temperatures immediately off the Japan coast have fallen to from 66° to 64°; east of 182° (mean latitude 35° 20′) they vary from 62° to 67° (16°.7 to 19°.4) with a distinctly cooler band between 152° and 170°. Two "southern-route" voyages in this month in the mean latitude 30° 42′ show nothing warmer than 73° (22°.8) in the path of the Kuro Siwo, except a single temperature of 74°. The narrow bands of cooler water become a conspicuous feature.

In December, with the anti-monsoon blowing from the northeast, the temperatures have fallen to 62° (16°.7) on the coast of Japan and nothing warmer than 71° (21°.7) east from it even on the "southern route." The Kamchatka stream is indicated in 198° by a temperature of 64°.

In January and the early part of February for sixteen degrees east from the coast of Japan (mean latitude 35° 05′) the water varies from 64° to 66° (17°.8 to 18°.9), and later in February from 61° to 65° (16°.1 to 18°.3) (in mean latitude 33° 03′), while the eastern half of the Pacific in the same latitude during March is wholly below 60° (15°.6), indicating very clearly that the strong warm current of August has suffered a material change. By the following month, as already indicated, the ocean is almost homogeneous in temperature from Japan to California.

The following table is the result of a recomputation and reference to every *second* meridian of the original data, copied from the logs by Dr. Antisell, and from which he prepared his profiles which were referred to every *third* meridian.

It was thought advisable to do this, not only in order to eliminate any accidental errors of computation in the first instance (though none were found), but also to obtain a more extended, and therefore, more thoroughly representative, table. The result has been a slight modification of some of the minor details of the original, but nothing in any way changing the general tenor of the conclusions heretofore announced on the basis of these observations.

The temperatures of the table are to the nearest Fahrenheit degree, the variation from the

[1] Yet in this month also, Belknap passed the surface isotherm of 65° (18°.3) in lat. 39°, and after escaping from the influence of the warmer current from Sangar Straits, he found (from lat. 42°.30) nothing warmer than 50°.0 (10°.0), while the great gap between the Aleutians and Kamchatka varied on the surface from 40° to 47° (4°.4 to 8°.3), and below the immediate surface hardly rose above 35° (1°.7).

Yokohama. Date.		Bay temp.	Mean sea-surface temperatures for every second meridian of																										
			220	218	216	214	212	210	208	206	204	202	200	198	196	194	192	190	188	186	184	182	180	178	176	174	172	170	168
Feb. 6, '72	Ar.	43	62	62	62	62	64	64	65	65	66	67	64	62	65	66	65	66	68	67	67	65	64	64	63	62	63	63	63
Feb. 5, '75	Ar.	50	62	65	63	63	64	65	64	64	66	66	66	65	65	66	67	68	67	67	66	65	65	66	66	65	64	64	64
Feb. 24, '74	Sld.	....	63	66	65	63	62	62	62	62	62	62	62	62	62	61	60	58	60	61	62	63	62	61	60	59	59	59	60
Feb. 28, '72	Sld.	42	58	59	60	61	60	60	61	61	63	65	63	62	61	61	61	61	61	62	62	62	62	62	62	62	62	61	61
Mar. 11, '75	Sld.	50	67	64	62	62	62	62	62	62	63	62	62	62	61	60	60	61	61	61	61	60	62	63	62	61	61	62	63
Apr. 27, '74	Ar.	63	65	64	64	64	63	63	63	63	63	62	62	62	61	60	61	61	62	61	60	59	57	57	57	57	57	57	58
May 1, '72	Ar.	62	69	66	66	65	65	65	65	65	64	64	65	65	65	64	64	64	64	64	63	63	63	64	65	62	62	64	59
May 28, '75	Ar.	68	68	68	69	67	68	69	66	63	62	61	61	60	60	60	60	60	60	60	60	60	60	60	60	60	60	59	59
May 23, '74	Sld.	*63	70	68	66	66	66	66	66	66	61	61	61	60	60	59	58	57	58	58	58	58	58	58	57	56	56	56	56
May 25, '72	Sld.	67	68	66	66	66	66	65	64	64	63	62	63	63	64	62	62	62	61	61	62	62	59	59	58	58	58	58	58
June 24, '75	Sld.	....	71	73	72	72	71	70	69	69	69	68	68	68	70	71	71	72	72	73	73	72	72	70	70	70	69	69	68
June, July	Sld.	....	72	71	70	70	70	68	66	66	66	69	68	69	70	71	71	70	70	70	71	72	73	70	69	66	66	65	65
July 22, '74	Ar.	79	73	79	80	78	77	75	75	76	76	75	74	73	71	71	71	71	71	71	71	70	70	69	69	68	68	67	67
July 25, '72	Ar.	81	80	81	79	79	79	78	76	75	75	75	75	74	74	75	75	74	73	73	73	73	72	72	71	71	70	68	68
Aug. 27, '75	Ar.	80	80	84	82	80	80	80	80	81	80	80	80	79	78	78	78	78	77	77	77	77	76	76	75	75	75	75	73
Aug. 14, '74	Ar.	(*)	81	82	81	82	78	75	75	(59)	61	59	59	58	57	54	(50)	54	52	53	53	54	56	56	56	55	56	57	57
Aug. 22, '72	Sld.	83	79	82	81	80	80	79	78	76	75	75	75	77	76	76	76	75	77	78	75	73	72	71	71	74	73	73	73
Oct. 9, '73	Ar.	68	71	76	76	74	74	75	75	(73)	76	76	78	77	80	76	75	75	75	73	72	71	70	70	69	70	70	69	69
Oct. 25, '71	Ar.	....	74	75	75	74	75	76	76	(76)	77	77	77	78	78	79	79	79	79	77	76	76	75	76	77	76	76	74	74
Oct. 28, '74	Ar.	62	70	72	72	74	73	77	75	(73)	75	75	76	76	77	76	(73)	77	77	76	77	76	75	74	74	74	74	72	72
Nov. 2, '73	Sld.	50	(64)	70	69	70	72	71	72	71	73	72	72	(68)	72	72	72	71	69	69	68	67	66	68	67	65	64	63	62
Nov. 23, '71	Sld.	59	66	72	68	69	70	73	74	73	70	72	72	71	71	71	70	70	69	69	69	68	68	67	67	64	64	65	65
Nov. 23, '74	Sld.	51	67	73	70	71	72	71	71	72	(70)	73	74	72	73	73	73	72	72	72	71	69	70	69	68	68	68	68	69
Dec. 29, '73	Ar.	50	62	68	66	66	67	69	70	70	69	69	70	(64)	70	70	71	72	69	71	71	70	69	69	69	69	69	69	69
Mean		61.6	68.7	70.7	69.9	69.5	69.7	69.9	69.5	69.1	69.2	69.4	69.4	68.6	69.3	69.0	68.9	68.9	68.8	68.8	68.5	67.9	67.4	67.1	66.8	66.2	66.0	65.6	65.5
		....	72.2	75.7	74.5	74.2	74.4	74.4	74.0	73.4	73.5	73.9	74.1	73.6	73.6	73.4	73.3	73.1	72.8	72.5	72.3	71.7	70.9	70.4	70.0	69.7	69.4	68.4	68.1
		....	64.4	64.8	64.3	63.9	64.1	64.4	64.2	63.9	64.1	64.0	63.8	63.5	64.9	64.7	64.7	64.8	64.8	65.0	64.7	64.0	63.8	63.8	63.5	62.6	62.6	62.8	62.7

actual being less than the usual errors of observation and instruments in work not done by trained observers and with standard instruments. The employment of Celsius' scale, as I had at first intended, with its cumbersome and inevitable fractions of degrees, would have increased the size of the table (already too large for convenient printing) nearly one-third. The date of arrival or departure from Yokohama and San Francisco is given under its appropriate head at either end of the table, with a column showing the temperature of the water in the harbor at the time of arrival or departure. It will be observed that this is almost invariably colder than the sea water outside of the harbor, except under the influence of an August sun at Yokohama.

The columns of mean temperatures follow under their appropriate meridians. A few peculiar single observations (denoting, perhaps, cool bands of surface water) are inclosed in parentheses, as worthy of attention, instead of being swamped in the general means. A heavy line separates the observations of the last day of any month from those of the following day, so that the data relating to particular months may be singled out if desired.

The mean latitude of the principal part of the course, given at the right of the table, is that between meridians 140° and 210°. This was usually run on a nearly east and west line, and the means show the relative latitude of the several voyages. Two voyages by the "northern route" are marked with an asterisk, and are not included in the mean for the year or the other general means. The means for the year and for "June–Nov." and "Dec.–May" show the average annual temperature of the North Pacific in the mean latitude for every second meridian, as far as it can be deduced from the material in hand; also the same for the periods when the favorable (southwest) monsoon and the (northeast) anti-monsoon winds are blowing.

sea temperatures.

West longitude between San Francisco and Yokohama.																						Bay temp.	San Francisco.		Mean lat. between meridians 140° and 210° W.	Mean temp. for the latitude of voy.	No. of voyage.
166	164	162	160	158	156	154	152	150	148	146	144	142	140	138	136	134	132	130	128	126	124		Date.		° ′		
64	64	64	63	63	63	64	63	63	63	62	61	61	61	60	58	57	56	55	56	54	52	52	Jan. 5, '72	Sld.	29 51	62.5	1
64	65	65	65	66	67	67	68	68	68	68	67	66	64	64	64	62	61	60	56	55	54	52	Jan. 2, '75	Sld.	30 30	64.5	2
59	59	59	58	58	57	57	56	56	56	56	56	56	57	57	56	55	55	54	54	54	51	50	Mar. 19, '74	Ar.	35 05	59.1	3
62	62	62	62	61	61	61	61	60	59	59	59	58	58	58	58	57	56	55	54	54	52	53	Mar. 23, '72	Ar.	30 52	60.1	4
62	62	62	62	63	63	63	63	63	62	62	61	61	61	60	60	59	59	58	54	54	52	50	Apr. 4, '75	Ar.	33 03	61.1	5
58	59	59	59	59	58	59	60	59	59	59	60	60	60	60	60	59	58	57	56	54	....	....	Apr. 1, '74	Sld.	34 36	59.9	6
58	57	57	62	63	64	64	64	63	63	63	63	63	63	63	62	61	61	60	59	54	52	47	Apr. 5, '72	Sld.	31 54	62.7	7
58	57	57	56	56	56	57	58	58	58	59	60	61	60	60	60	60	60	60	59	56	53	53	May 1, '75	Sld.	36 12	60.4	8
56	56	55	54	53	54	54	55	55	55	55	55	55	56	58	58	60	59	59	59	56	55	°57	June 15, '74	Ar.	38 29	58.6	9
59	59	60	60	62	64	64	64	64	64	63	63	61	60	60	59	58	58	56	55	55	55	56	June 17, '72	Ar.	36 16	61.3	10
67	67	67	67	68	68	69	69	69	69	68	67	66	66	64	64	63	61	60	59	55	56	55	July 15, '75	Ar.	36 03	68.0	11
65	65	65	66	68	68	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Challenger	......	35 30	(68.5)	12
67	67	69	68	67	67	66	66	65	64	63	63	63	62	62	62	62	61	60	60	58	56	52	June 27, '74	Sld.	36 29	68.4	13
67	66	66	66	66	66	67	67	67	66	66	66	65	65	65	64	63	62	61	58	56	56	54	July 1, '72	Sld.	36 10	69.8	14
72	72	71	71	72	72	72	72	71	71	71	71	71	70	70	66	66	64	62	61	60	56	55	Aug. 2, '75	Sld.	36 05	73.8	15
58	59	59	59	60	61	61	61	61	62	62	62	62	62	63	63	63	63	65	64	63	59	(*)	Sept. 3, '74	Sld.	44 48	61.7	16
73	73	73	73	74	75	73	74	73	74	73	72	71	71	69	67	66	64	62	60	57	57	....	Sept. 12, '72	Ar.	36 06	72.9	17
69	70	71	71	(68)	74	74	75	75	74	74	74	74	73	72	71	70	70	68	67	64	55	57	Sept. 16, '73	Sld.	36 28	72.2	18
77	78	78	77	77	77	76	75	75	73	72	71	70	69	69	68	68	66	65	65	62	58	....	Oct. 1, '71	Sld.	30 45	74.0	19
72	72	71	71	70	70	70	70	71	71	69	71	70	69	69	68	68	67	65	65	62	59	57	Oct. 3, '74	Sld.	33 44	71.9	20
62	62	62	61	61	61	61	59	64	64	64	65	66	66	66	65	65	65	60	59	58	53	....	Nov. 23, '73	Ar.	35 20	65.9	21
65	66	65	65	66	67	68	68	67	67	67	65	64	63	62	62	60	59	58	57	54	52	52	Dec. 17, '71	Ar.	30 20	66.4	22
68	68	69	68	67	67	67	66	66	66	66	65	65	65	63	64	64	63	62	62	59	56	52	Dec. 18, '74	Ar.	31 05	68.1	23
69	69	69	70	70	70	69	69	70	71	70	69	70	70	69	68	66	65	64	62	60	53	....	Dec. 1, '73	Sld.	30 06	68.1	24
65.5	65.6	65.7	65.5	65.8	66.1	66.1	66.0	66.0	65.8	65.4	65.2	64.8	64.4	63.9	63.1	62.3	61.5	60.1	59.0	56.9	54.4	53.2	Year		33 45	66.3	
68.2	68.3	68.4	68.3	68.4	69.3	69.2	69.1	69.4	69.0	68.3	68.3	67.7	67.1	66.6	65.4	64.9	63.8	61.9	60.9	58.7	56.1	....	June-Nov		36.14	69.7	
62.4	62.5	62.5	62.7	62.9	63.0	63.3	63.3	63.0	62.9	62.8	62.4	62.3	62.0	61.4	61.1	60.0	59.4	58.4	57.2	55.3	52.7	....	Dec.-May		32.08	62.7	

The last column in the table shows the mean temperature of the north Pacific for the mean latitude and season of each voyage.

It must be borne in mind, in considering the table and the subject to which it relates, that the Pacific, like Bering Sea and other bodies of water, as well as the atmosphere at any locality on land, varies in different years, so that in a relatively small series like the present there may be, and probably are, some anomalies due to this cause. A very much larger series would be required to eliminate these and other sources of error; but, notwithstanding all this, the general conclusions afforded may be safely taken as relatively correct, though the "bench-mark" of the series might be changed in absolute level by the discussion of a greater amount of material.

The general accuracy of the observations is attested by their agreement with those taken by the Challenger in the same region and at the same time of the year.

It is hardly necessary to point out that the anomalies of temperature due to current in any particular voyage are almost lost in the general means for the year or half year. Information on these points must be sought in the records of single voyages.

The cooler area about the meridian of 170° I take to be due, perhaps, not entirely to cold water from the north, but also in part to the fact that here in the given latitude the axis of the Kuro Siwo passes north of the usual track of the steamers. This, however, requires further observation. The fact that in the two most northern voyages, the cooler area occurs further to the westward (188°) tends rather to show that it is due to the Kamchatka stream, and that that has a more or less easterly tendency as it progresses southward.

In this connection the only data in the North Pacific for submarine temperatures, except those of Captain Belknap (and corroborating his in every respect), are those of the Challenger. There are, fortunately, sections taken by the Challenger party in the two oceans almost exactly comparable. In the Atlantic their section extends between Cape May and Madeira, covering about fifty-two degrees of longitude and in nearly the same latitude as the voyages of the China steamers just described. This section was taken from April to July.[1] The corresponding Pacific section is that from Yokohama to station No. 253, in longitude 156° 25′, covering some sixty degrees of longitude, beyond which some thirty degrees more intervene between station 253 and the California coast in the same latitude. This section was made during June and July. By redrawing the isotherm profiles, and taking off the values for every two and a half degrees, the sections have been made more comparable, and are presented in the following table.

Comparison of sea temperatures between latitudes 33° and 38° north in the Atlantic and Pacific Oceans, arranged from observations by H. M. S. Challenger, 1873 *and* 1875.

Meridian W.		Surface temperature.				Depth in fathoms, of the isotherm of—					
		Centigrade.		Fahrenheit.		10° C. = 50° F.		15° C. = 59° F.		20° C. = 68° F.	
Atlantic.	Pacific.	Atlantic.	Pacific.	Atlantic.	Pacific.	Atlantic.	Pacific.	Atlantic.	Pacific.	Atlantic.	Pacific.
° ′ [72. 10]	° ′ [220. 30]	° 10. 0	° 19. 2	° 50. 0	° 66. 6	0	185	—	70	—	0
70. 00	220. 00	18. 3	22. 2	64. 9	72. 0	465	206	355	100	—	50
67. 30	217. 30	18. 3	21. 7	64. 9	71. 0	475	240	360	137	0	30
65. 00	215. 00	22. 8	21. 4	73. 0	70. 5	455	250	330	137	40	20
62. 30	212. 30	23. 0	21. 2	73. 5	70. 2	445	250	330	147	35	25
60. 00	210. 00	22. 3	19. 9	72. 2	67. 8	430	212	300	100	25	5
57. 30	207. 30	21. 8	18. 7	71. 2	65. 6	440	115	320	50	20	—
55. 00	205. 00	21. 3	18. 8	70. 4	65. 8	440	70	295	25	20	—
52. 30	202. 30	21. 1	20. 7	70. 0	69. 3	430	200	275	100	15	10
50. 00	200. 00	23. 8	20. 3	74. 9	68. 5	440	190	305	80	30	15
47. 30	197. 30	22. 2	20. 6	72. 0	69. 0	530	185	355	60	25	10
45. 00	195. 00	21. 2	21. 1	70. 2	70. 0	515	230	340	75	20	10
42. 30	192. 30	21. 1	21. 7	70. 0	71. 0	470	240	335	70	35	20
40. 00	190. 00	21. 1	21. 4	70. 0	70. 5	450	200	292	50	35	10
37. 30	187. 30	21. 7	20. 9	71. 0	69. 7	440	195	120	27	20	5
35. 00	185. 00	21. 7	20. 8	71. 1	69. 4	315	190	100	27	15	5
32. 30	182. 30	21. 7	22. 3	71. 1	72. 2	345	235	150	40	17	8
30. 00	180. 00	20. 7	22. 8	69. 2	73. 1	380	210	92	45	25	20
27. 30	177. 30	21. 1	20. 9	70. 0	69. 6	370	150	60	25	20	5
25. 00	175. 00	21. 7	19. 4	71. 1	67. 0	345	145	60	25	20	0
22. 30	172. 30	21. 9	18. 6	71. 4	65. 5	412	160	55	25	15	—
20. 00	170. 00	21. 6	18. 1	70. 8	64. 6	448	170	70	20	15	—
[19. 17]	167. 30	21. 5	18. 3	70. 7	64. 9	440	175	80	20	15	—
....	165. 00	....	18. 3	....	64. 9	....	160	....	20	....	—
....	162. 30	....	18. 3	....	64. 9	....	150	....	20	....	—
....	160. 00	....	18. 8	....	65. 8	....	130	....	20	....	—
....	157. 30	....	19. 8	....	67. 6	....	110	....	20	....	—
....	[156. 25]	....	19. 8	....	67. 6	....	100	....	20	....	—

[1] I am indebted for the data to Wild's "Thalassa," Table III, p. 70, Table XII, p. 114, plates 8 and 18.

It should be noticed that the differences of observation about counterbalance one another, the Atlantic section being partly taken in a colder period of the year, while its eastern end is turned somewhat southward into presumably warmer water. On the other hand, the Atlantic section begins two hundred miles further away from the starting point of the Gulf Stream than does the Pacific section from the inception of the Kuro Siwo. On the whole, everything else being equal, it would seem as if the effect of the differences of observation would be to make the Pacific section somewhat the warmer of the two.

For a comparison between the average temperatures of the two masses of water, I have taken the fifty degrees of longitude between 20° and 70° W. in the Atlantic and 170° and 220° W. in the Pacific as comparable parts of the two sections.

One noticeable difference in the two profiles is the manner in which, in the Gulf Stream, its western edge forms an almost perpendicular wall of water at 50° (10°.0) or warmer, with colder water between it and the shore, and continues eastward for some 35° of longitude a nearly solid, unbroken mass; while, on the other hand, with the Japan Stream its warmest water is at the coast, 15° east of which the Kamchatka stream heaves the isotherm of 50° (10°.0) within 60 fathoms of the surface, while the whole mass of the water at 50° (10°.0) or more is hardly more than half as much in sectional area as in the Gulf Stream. The lower boundary of the mass of water at 50° (10°.0) reaches in the Atlantic a depth of 430½ fathoms. The following table shows a comparison of the two oceans to this depth within the boundaries assigned:

Pacific.			Atlantic.		
Fahr.	Cent.	Depth.	Fahr.	Cent.	Depth.
°	°	*Feet.*	°	°	*Feet.*
70.2	21.2	70.8	71.2	21.8	127.7
63.5	17.5	319.2	63.5	17.5	1,272.1
54.5	12.5	765.1	54.5	12.5	1,183.2
45.5	7.5	900.6	....	....	....
40.0	4.4	527.4	....	....	....
49.94	9.97	2,583.0	59.76	15.42	2,583.0

The temperatures are mean temperatures for a stratum of water extending 50° of longitude east from the point of beginning in each ocean, having the mean depth indicated.

It is evident that the average heat of the mass of Atlantic water is nearly 10° Fahr. greater than the average heat of the Pacific mass. When we bear in mind that the Pacific stream has to move over 90° of longitude, while the Atlantic stream has but 52° to cross, and that the Atlantic stream is supposed to be constant, while we may assume that for at least one-third of the time the Pacific stream is checked or diverted by the anti-monsoon, it will be evident that the proportional effect on the coasts finally reached of the two streams will be greatly in favor of the Gulf Stream. The ratio between the latter and the Kuro Siwo, considering only temperature and duration, would be as 1.0 to 0.558—not far from the inverse ratio of the distances traversed by them; that is to say, 0.578 to 1.0.

I believe that the comparative weakness and inefficiency of the Kuro Siwo, as compared with the Gulf Stream, has never before attracted the attention of hydrographers, and would suggest that, so far as the currents of the open sea are concerned, it is not improbable that the Kuro Siwo may be a type of the Pacific currents generally, as compared with those of the Atlantic. The Pacific is open to the influx of Antarctic cold water without stint, and in it, probably, goes on a great system of true oceanic circulation, such as might occur were there no continents. The more superficial currents, like the Gulf Stream, while not independent of the general circulation, do, as they actually exist, form no necessary part of it, except as it is augmented, guided, or controlled by continental shore-lines, trade winds, tides, and other cosmic phenomena less powerful. Consequently, it is conceivable that such currents will be less marked and constant (considering the effect of winds) in proportion to the size of the oceans they traverse, other things being equal.

It is not a matter of surprise, after the preceding review of the character of the Kuro Siwo, to learn that, after reaching the northwest coast of America, that branch which turns southward along the coast, by the time it has reached the latitude of San Francisco, has become rather a cold current than a warm one, while that one which turns to the north and west, and finally loses itself along the Aleutian chain, is warm only because it intrudes on a normally cold area. The fact that these two branches exist and have the above general course is determined beyond all controversy, and it is not necessary to go over that ground again. It may be observed, however, that to the westward march of the tide which prevails along the Aleutian chain is added whatever of impetus this current may have to give, so that the flood northward and westward through the passes of the Aleutian chain is much stronger than the ebb, and, when not interfered with by wind, tends to give the water immediately north of the chain a westerly set, especially in summer and autumn.

Currents of Bering Sea.—I have already pointed out that Belknap, in crossing the gap between Kamchatka and the Aleutians, found only comparatively cold water, and no indications of any warm stream setting through this wide opening. I may recall here that he not only found no northerly set of warm water, but that the only places where northeasterly surface currents were experienced while crossing this passage were observed to be, if anything, rather colder than the rest. The currents observed were probably due to wind and tide. Their general tendency was to the ENE., but in two places where submarine currents were observed for, it was found the greater the depth at which the observations were made, the more nearly south was the direction of the current, and the stronger its flow. Thus, in longitude 195° (approximate), while the surface current ran half a knot a little to the N. of E., at 80 fathoms it ran SE. by E. $1\frac{1}{8}$ knots, and at 100 fathoms SE. $1\frac{1}{4}$ knots. Again, in longitude 192°, it ran at the surface a little S. of E., at 25 fathoms three-quarters of a knot SE., and at 30 fathoms seven-eighths of a knot S. 5° W.

It is to be observed that the lines run by Captain Belknap and by the Venus are not exact sections of the narrowest part, extending in a northwesterly direction from Attu Island, but that the first extends from about longitude 200° and latitude 50° to Agattu Island, and the second in a slightly irregular line extending from Avatcha Bay to the intersection of the meridian of 185° with the parallel of 50°.

In the same region, all the currents observed by Onatsevich were southerly, with a westerly deviation; those observed on the voyage of the Venus were southerly, generally with an easterly but sometimes with a westerly deviation, with one exception of a weak current in a direction N. 59° E., of three-tenths of a knot. Between Saint Paul Island and Attu, Bailey, in the Rush, observed almost continuous S. by E. currents varying from half to nine-tenths of a knot per hour. The currents along the coast of Kamchatka observed by Lütké and Onatsevich ran in almost all conceivable directions, often, in nearly the same spot, in opposite directions at different times, showing clearly the influence of tides.

The following table shows the observations for current and temperature taken by the two expeditions above noted, Belknap's observations[1] extending from July 7 to 14, and those of the Venus from September 16 to 29; the latter, from the time of year, should show higher temperatures as a whole than the former, as is in fact the case.

[1] Deep-Sea Soundings, p. 46.

Comparison of the observations of the Tuscarora and the Venus.

Belknap's W. meridian ° ′	200 20	198 52	197 40	196 37	195 30	194 35	193 34	192 38	191 50	191 0	190 18	189 32	188 45	187 58	187 19	186 46
Surface Temp. Fahr.	42°.6	43°.8	43°.1	42°.6	45°.0	46°.3	46°.1	45°.0	46°.4	47°.2	47°.2	46°.7	46°.4	41°.0	46°.2	45°.9
Surface Temp. Cent.	5.9	6°.7	6.2	5°.9	7.2	7°.9	7°.8	7.2	7°.8	8.4	8.4	8.2	8.0	7.8	7.9	7.7
Dir. of current	S.	N. 25 E.	....	N. 25 E.	....	S. 40 E.	E. 25 N.	....	E. 18 N. to S. 5 W.	......	......	....	......	......	......	....
Rate per hour	0.37	0.5	....	0.5	....	1.25	0.5	....	0.5 to 0.87	......	......	....	......	......	......	....
Rate per hour	......	....	0.2	....	0.3	0.3	....	......	0.6	......	......	0.8	......	......	......	0.6
Dir. of current	......	....	S. 79° W.	....	N. 59° E.	S. 77° E.	....	......	S. 17° W.	......	......	S. 53° W.	......	......	......	S. 16° W.
Surface Temp. Cent.	10°.8	11°.5	11°.6	11°.6	11°.6	10°.8	10°.0	9°.8	10°.0	9°.7	9°.3	9°.4	9°.4	9°.2	8°.8	9°.0
Surface Temp. Fahr.	51.4	52.7	52.9	52.9	52.9	51.4	50.0	49.6	50.0	49.5	48.7	48.9	48.9	48.6	47.8	48.2
Venus W. meridian ° ′	199 12	198 4	197 17	[196 30]	195 37	194 18	[193 30]	[192 30]	191 23	[191 0]	[190 30]	189 29	[188 45]	[188 0]	[187 15]	186 38

The positions in brackets are interpolated (by means of the hourly observations) between the noon positions given in the original. Belknap's interpolated positions appear in the original table.

At the time when Captain Belknap was getting temperatures from 42° to 47° (5°.6 to 8°.3) in the path of the hypothetical warm branch of the Kuro Siwo, the United States Coast Survey were finding between Unalashka and Saint Paul Island (where nobody has ever imagined any warm current to exist), in the eastern part of Bering Sea, temperatures from 49° to 54° (9°.4 to 12°.2), while the mean for the same month, in Norton Sound, some seven hundred miles further north, already reached 56° (13°.3), with a maximum of 60° (15°.6).

On a track chart issued by the United States Hydrographic Office (at an unknown date), of the United States North Pacific Exploring Expedition, under Captain (now Admiral) John Rodgers, in 1854–'56, on the track of the Fenimore Cooper, from Avatcha to Attu Island, arrows are marked pointing in a NW. and NNW. direction. Although no explanation is appended, I take these to indicate the currents observed, though they are without any figures indicating direction or rate. A little further south is the track of the John Hancock, from Paramushir Island of the Kuril group, toward San Francisco. On this track the current arrows for the same meridians point southward without exception. The first series were taken in July, the second in September. It is much to be regretted that the records of this expedition have never been made public. The uncertainty, indicated by the two series above mentioned, in the direction of the currents observed here, strongly recalls the words of Lütké, before quoted, in regard to the same locality.

The accompanying chart, showing the various currents observed in Bering Sea, will give an idea of their variety, which could not be attained by any mere verbal description; it will be noticed, however, that the majority of them tend southward.

My own conclusion, from a study of the data, is that the general tendency of the water in Bering Sea is to the southward, and where deep enough, as in the western part of the sea, it forms a tolerably well defined current (which I shall call the Kamchatka[1] current), whose outline is clearly perceivable in the Challenger section, whose influence is traceable in many of the Pacific Mail voyages before mentioned, and whose character and motion are probably very constant, if not especially pronounced. While a certain amount of water enters Bering Sea through the strait, under favorable circumstances, this amount is relatively insignificant, and the Kamchatka current can hardly be properly termed a polar current. It is a current proper to the cold, deep basin of that part of Bering Sea west of the shoal waters, and to a great extent re-enforced by precipitation and the river supply from the two continents.

[1] Though not the Kamchatka current of most hydrographers, which forms only a very small part of the one under consideration.

Over this, and forming a thin and entirely superficial stratum, the waters from the north edge of the Pacific and the southern border of Bering Sea, warmed by the heat of the summer season, have a general motion of translation northward wherever unimpeded, but this motion is not that of a persistent current, strictly speaking, and is liable to be at any time reversed by winds, and near the shore by tides. Moreover, this water does not appear from the evidence to attain a temperature sufficiently above the normal for it to have any exceptional effect on the climate, and it is unquestionably much cooler than the waters of the shallows in the eastern part of the same sea during the summer. There is not a particle of evidence to show that any mass of warm water constituting a warm current, as distinguished from a superficial stratum as above described, is given off in the direction of Bering Sea by the Kuro Siwo, or enters that sea from any source whatever. The merely superficial character of the water above 40°.0 between the meridians of 185° and 200°, is clearly shown by Belknap's section (Profile C), which, however, requires to be platted on a map, in order that its relations may be clearly understood.

Beechey remarks that, in June, after passing latitude 40°, on his voyage from the Sandwich Islands to Avatcha Bay, he had no current of consequence. Between Avatcha and Saint Lawrence Island, in all, the current only amounted to 31 miles, in a S. 54° W. direction. Lütké has already been quoted so far as his remarks relate to this locality.

Trollope, in writing up the nautical observations for the Herald's voyage (Kellett commanding), observes that going and returning they found, between Avatcha and Saint Lawrence Island, a current of about 9 miles a day in a direction S. 60° W.

The report of Brossal on the sea temperatures of the voyage of the Venus assumes the existence of a warm current from the fact that they found the temperature falling from 10° and 12° C. in longitude 194° W. to 8° and 9° C. But an examination of the log shows this change to be simultaneous with a change in the wind from southerly to northerly, and a record of the currents for that special locality shows that the lower temperature was coincident with both northwesterly and southerly currents, while the higher temperatures accompanied weak drifts, both easterly and westerly in direction.

The voyage of Krusenstern (1804–1806) in the Nadeshda[1] affords a few current observations in the region under discussion. The thorough scientific method of this author renders the observations worthy of preservation, though in most cases others, especially Lütké and Onatsevich, have more lately traversed the same seas.

On his way to Kamchatka from the Washington Islands, in July, 1804, in latitude 38° 44′, longitude 195° 05′, he encountered the Kuro Siwo running N. 46° E., with a rate of half a knot an hour. Thence to latitude 49° and longitude 199° 34′ he encountered moderate southerly and easterly currents. Subsequently the following observations were made:

Date.	Lat. N.	Lon. W.	Current.	Strength.
	° ′	° ′	°	
July, 1804	50 39	199 12	S. 65 W.	0.20
	51 53	199 30	N. 53 E.	0.20
	52 27	200 07	S. 36 E.	0.24
September, 1804	50 28	201 12	S. 46 W.	0.5
	47 37	202 00	S. 49 E.	0.3
April, 1805	48 24	215 53	None.	0.0
	47 39	215 16	S. 45 W.	0.5
	48 18	214 08	N. 83 E.	0.7
	48 37	212 01	N. 61 E.	0.4
	48 02	207 07	S. 57 E.	0.2
	49 34	205 22	S. 73 E.	0.9
	49 19	204 11	N. 83 E.	0.2
	50 38	202 03	South.	0.5
October, 1805	50 46	197 11	S. 75 E.	0.5
	51 34	199 13	S. 52 E.	0.7

From latitude 47° 37′, longitude 202°, in September, 1804, sailing toward Japan, to latitude 40°, when the northern edge of the Kuro Siwo was reached, Krusenstern encountered no currents

[1] Original German edition, vol. iii, various tables.

or only light northerly drifts not exceeding three miles a day, or less than the ordinary uncertainties of a sea position. In October, 1805, sailing from Kamchatka to China, from latitude 50° 46′ and longitude 197° 11′, southward to the Kuro Siwo, similar currents of four miles a day or thereabouts were experienced running in a northerly, northwesterly, or easterly direction, very much as the prevailing winds indicated.

On the same subject, Onatsevich[1] (l. c., p. 102) says that the surface water along the east coast of Kamchatka in spring and early summer may have, from melting snow, river freshets, and the cold outflow from Holy Cross Bay, a slight southerly set, with a temperature of 41° (5°.0), but later in the summer or early autumn this becomes imperceptible, or is replaced by a northerly drift of warmer water; that, nevertheless, whatever conclusions be drawn from the observations yet taken, there remains a certain number which are contradictory of the others.

The following notes by whalers are of interest, and worth recording:

Ship Jireh Perry, May 19, 1874: Ship 10 miles off Cape Navarin, becalmed, found a two knot current setting westward; this continued three days, with light westerly winds.

Ship Jireh Perry, May 25, 1874: latitude 63°, longitude 177°, between Cape Thaddeus and Saint Lawrence Island. "Breezed up from the southward, current set ENE., at close of daylight hove to in loose ice." May 26: "Ice closed tight all day, wind shifted to E. and NE.; found that current changed to the westward; very little of it any way."

Bark Three Brothers, April 29, 1877: latitude 59° 45′, longitude 185° 57′, off Cape Olintorsk; on this and the two succeeding days drifted 30 miles to westward, while making every endeavor to keep to the eastward. The wind was northeasterly.

Bark Three Brothers, May 29, 1877: latitude 58° 31′, longitude 188° 56′, near Cape Olintorsk, came up with the ice; have a westerly set of one-half knot per hour. Wind very light.

Bark Three Brothers, June 5, 1877: latitude 59° 24′, longitude 183° 54′, found a strong current setting southwest, with fresh SE. wind.

Bark Coral, May 13 and 14, 1878: latitude 60° 50′ to 60° 36′, longitude 181° 40′ to 182° 10′ (near Cape Navarin); ship fast in the ice; barks Pacific and Helen Mar in company, all fast in the ice; wind fresh to moderate, from ENE. and NE.; drifted 23 miles SW. in twenty-four hours.

Bark Coral, June 5, 1879: latitude 63° 20′, longitude 179° (near Cape Thaddeus); wind light NNE. "Much current, setting SSW."

On the eastern side of Bering Sea, numerous large rivers pour the annual precipitation of an immense area into the sea, and, in addition to the westwardly and northwardly marching tide, create a distinct set in the vicinity of their mouths. This will be more or less directed by the local winds. Thus the current from the Yukon, noted by Bailey and Hooper, in a calm would proceed in a northwesterly direction, and with southerly winds, rising tide, or both, would be thrown into the gap between Saint Lawrence Island and Cape Rodney. In times of northerly winds or ebb tide, or both, part of it (perhaps, in extreme cases, all) would pass to the southward of Saint Lawrence Island, and be spent in adding to the general SW. set of the Bering Sea waters. The Kuskokwim and Bristol Bay rivers discharge more to the southward, the result being a SW. or SE. set of the waters near them, according to the prevailing wind and tide. This general southerly set of the SE. part of Bering Sea, observed by various navigators, is the basis of the "Behring Current" of Becher, Labrosse, and other hydrographers, which they (wrongly in my opinion) derive from Bering Strait. It occupies the region to which some have transferred the northerly "branch of the Kuro Siwo," when the western passage between Saint Lawrence Island and Asia, having been investigated and found to be cold water, no longer afforded an area for the expansion of that hypothesis.

In evidence of the existence of this tendency, the following notes have been brought together:

Captain Bailey, of the Rush (Report, p. 36, 1880), says that, on passing north from Unalashka toward the Arctic, eastward of the islands (except Nunivak), "We found the general set of the

[1] In 1878 (Coast Pilot of Alaska, App. 1, Meteorology, pp. 20, 21, 23), before receiving the confirmatory observations of Onatsevich, I called attention to the need of proof, before the existence of the supposed northwardly branch of the Kuro Siwo could be safely assumed. I recall this at the present time in view of some premature criticisms published by persons who have not investigated the history of the subject, and who have assumed (without waiting for the promised data, or, apparently, even reading what had already been printed on the subject) that the sole reason for the views advocated here was my limited experience in Bering Strait during the season of 1880.

current to the westward growing stronger from Nunivak to Saint Lawrence Island, and turning more to the northward after passing the latter." "We found on our return * * * about the same current, or, if anything, a little stronger." "Here, as well as in other parts of Bering Sea (away from the influence of the rivers), the current is influenced a great deal by the direction and force of the wind."

Schooner John Bright, June, 1872, cruising north of Saint Paul Island about 80 miles to the edge of the pack. Captain Archimandritoff reports a south current in this vicinity amounting to 15 miles a day. He thinks that the currents in Bering Sea vary with the winds, but in spring usually tend to the SW., rarely toward the E.

Schooner Lizzie Sha, becalmed off Cape Newenham, July, 1870; in twelve hours drifted 35 miles in a southeasterly direction, owing to the current from the Kuskokwim River.

U. S. S. Corwin, June 10, 1880, latitude 59°.03, longitude 169°.07. From Saint Paul Island northerly to noon, as above, experienced a current of one-third of a knot S. ¾ E.

June 13, noon, latitude 60° 41′ longitude 166° 04′. The vessel north of Nunivak Island working N. and E. through ice; Cook Strait, bearing SE. At 11 p. m. anchored to wait for day light; remarked an easterly current of 3 knots. The following day, being kept by the ice in about the same position, noticed that the ice moved with the tide from three-quarters to two knots per hour, NW. in the morning and SE. in the afternoon. On the following day, drifting with the ice, in about the same position, about half a knot per hour S. and E. in the morning, N. and W. in the afternoon; on the 16th and 17th, much the same.

U. S. S. Yukon, while running toward Plover Bay from Saint Paul Island, with strong easterly winds, experienced between latitude 63° and 65°, and in about longitude 175°, a set which amounted to about 50 miles in two days in a direction N. 70° W.

The U. S. S. Yukon, September 20 to 23, 1880, while sailing from Saint Lawrence Island (Southeast Cape) to Saint Mathew Island, experienced on the first day with a fresh SE. to SW. wind a SW. current of three-quarters of a knot per hour, with a temperature of 41° to 43° (5°.0 to 6°.1). In the same locality the U. S. S. Rush, Captain Bailey, had experienced a SW by W. current of a third of a knot on the previous year. On the second and third days with a strong westerly wind the current averaged two-thirds of a knot per hour in a S. 46° E. direction. In this vicinity Lütké had observed a quarter knot S. 48° E. current many years before. The temperature averaged 41° to 42° (5°.0 to 5°.6). The following day, September 23, on leaving Saint Mathew for Unalashka, a current of S. 44° E. of more than a knot an hour was experienced, water 41°.5 to 43°.5, the wind being strong NW. In about the same locality the Rush had had a strong southerly and easterly current the previous year, and on another occasion a southerly and westerly current of about a third of a knot. Variable as they are when acted on by wind, it would seem evident that there is a southerly tendency in this part of Bering Sea, which some hydrographers have indicated under the name of the Bering current. In the same region, and nearly at the same time, the Corwin was running from near Cape Nome in Norton Sound to Saint Paul Island and also experienced an easterly set, though she was not able to get observations to exactly determine its amount or direction, and found the water varying from 38° to 44° (3°.3 to 6°.7), the latter near Saint Paul. Knowing that September is the midsummer of the Pacific, and especially of the Kuro Siwo, if any such branch as has been asserted passed east of Saint Lawrence Island it is incredible that these temperatures should be so low. The entire practicable path of any such branch or warm current has been crossed by the Corwin, the Rush, or the Yukon, in every summer month, and the presence of water warmer than 45° (7°.2) in either of the passages separating Saint Lawrence Island from America and Asia has not been detected, while it has been demonstrated that in Norton Sound the water exceeds 55° (12°.8) for months at a time (even reaching 60° (15°.6) on occasions), while the temperature of Kotzebue Sound and the vicinity of the shore between the two sounds ranges hardly 5° less. The hypothesis of a submarine warm current can hardly be seriously held when it is known that the total depth of water does not exceed twenty-five nor average over fifteen fathoms on that side of Saint Lawrence Island.

Leaving the region of the straits for further discussion, we may refer to the general observations on the currents of Bering Sea by Lütké, who remarks (p. 192): "We had very few currents in this sea independent of the prevailing winds. The few exceptions to this rule seem to show that south of the parallel of latitude 60° the current has more tendency to the westward than to any other direction, for we remarked that although east winds always produced westerly currents, westerly winds did not always produce easterly currents. On the Asiatic shore the tendency is to the S. and SW. parallel with the land. But these exceptions, confirmed also by observations by some of the colonial navigators, were, nevertheless, too rare and indefinite to serve as a basis for any well-founded deductions; in general the currents correspond to the winds both in direction and in strength.

"At Saint George Island, however, a steady current of one or two knots from the west is sometimes observed for several days. In the Gulf of Anadyr we found no current, or only a very feeble one, which followed no particular direction. We experienced only once the action of that northerly current which some navigators have found in Bering Strait, on which occasion it took us 22 miles N. 26° E. in forty-eight hours against feeble northeasterly winds. We then found our; selves in the latitude of the entrance of Saint Lawrence Bay, and nearly in the middle of the strait, but during several preceding days we had had in the same place a feeble southeasterly current. In coming from the southeast toward the bay of Saint Lawrence, we also experienced a half-knot easterly current, which may be attributed to the freshets produced by the snows then melting on the mountains about this bay."

Onatsevich also declares that between Cape Chaplin and Saint Lawrence Island there is no warm current, and between Cape Thaddeus and Anadyr Gulf there is no northerly current (l. c.,

The remarks of these various navigators with regard to the westerly currents are especially applicable to the southern border of the sea along the Aleutians, where the westerly set, due to the stronger flood-tide in its march, has been noticed by nearly every navigator who has published on these regions. It also applies to the eastern part of Bering Sea near the great rivers. Beechey remarks (l. c., p. 639) that from Bering Strait to the Aleutians (Unimak Pass) going eastward of Saint Lawrence, Saint Mathew, and the Pribiloff group, westerly currents prevailed, and near the islands ran strong.

Bailey observes in his report (pp. 36, 37), "Here, as well as in other parts of the Bering Sea (away from the influence of the rivers), the current is influenced a great deal by the direction and force of the wind."

It is unnecessary to enlarge further on this subject. It will be seen that every navigator bears about the same testimony, and that, while some of them accept the theory of a warm current from the Kuro Siwo, these do it, not as established by their own observations, but as a supposed fact, which they try to make their observations agree with. The only exception to this is the deduction from the sea temperatures of the Venus's voyage, by Brossal, which, as I have shown, is not supported by the current observations of the same expedition.

It now remains before entering the Arctic basin to review the observations taken on either side south of Bering Strait, and to explain them, if possible, by a rational hypothesis. The first thing which will attract the attention of the careful reader is the testimony of numerous witnesses to a current southward through the strait in the very place where the warm northerly current should by hypothesis exist. Secondly, that in the absence of disturbing influences there is a tidal flow either way, but stronger to the northward, as usual in this region.

My own suggestions in solution of the problem will follow the evidence now quoted or recorded from the observations of my own party.

Commander Trollope, R. N., in his nautical remarks on the voyage of the Herald, Captain Kellett, (Seemann Nar., App., l. c., p. 290), recounts that between the NW. end of Saint Lawrence Island, and Sledge Island, on the American coast, near Cape Rodney, the Herald was set 37 miles S.76° E., in forty-eight hours. Between Cape Darby, Norton Sound, and Bering Strait, the whole amount of current experienced was to 37 miles S.58° W. "Captains King and Beechey both mention a strong northerly current, particularly the former, * * * through the strait. In our own case, both going and returning, we found it the reverse, particularly when leaving Kotzebue Sound for the southward. On each day the effect was so regular that it could hardly have been the effect of accident or error. It would seem from its direction to have *come from the American shore toward the coast of Asia*,[1] where, finding itself checked, it, with increased velocity, found vent between the

[1] The italics are my own.

Diomede Isles and East Cape; it was here we found it in its greatest strength. The daily set is seen in the table,[1] the whole amounting to S. 60° W. 160 miles, or 9 miles a day; the going and returning passage giving somewhat similar results." "When off Saint Lawrence Island, returning from Kotzebue Sound, in October, the current amounted to 22 miles S. 82° E., and, as mentioned before, in August S. 76° E. 37 miles, a sufficient resemblance at different times and under different circumstances to render it remarkable. A discrepancy appears, according to general report, in the currents we met with in the entrance to Bering Strait, and also in one respect in what we ourselves experienced. Captains Cook, King, and Beechey all speak of a northerly current; Sir John Barrow mentions it as a well-known and undoubted fact, but does not state his authority; the one instance in our case was in the boat off Tchukotsky (August 30), where its direction was ENE., true, one to two knots an hour." Beechey says (Voy. App., pp. 637, 638), off Saint Lawrence Island the current ran SSE. seven-eighths of a knot an hour, and on another trial, seven hours afterward, NE. five-eighths of a knot an hour, but between this island and Bering Strait it ran to the northwestward about three-quarters of a knot an hour. To the northward of the strait it takes a more northerly direction, and near the land runs first to the NE. (toward Kotzebue Sound), and then NW. (toward Port Hope).

According to Captain Cook (ii, p. 521), "Between Norton Sound and Cape Prince of Wales we found a current setting to the northwest, particularly off the cape and within Sledge Island. But this current extended only a little way from the coast, nor was it consistent or uniform."

H. M. S. Discovery and Resolution, at anchor in the NW. part of Norton Sound, August 4, 1778, 9 miles E. by S. from Sledge Island, "found that the flood-tide came from the east and set to the west." The ebb set to the eastward. "The flood ran both stronger and longer than the ebb, from whence I concluded that besides the tide there was a westerly current (Cook Voy. ii, p. 440). Billings in 1791, S. 75° E., 9 miles from Cape Rodney, encountered, according to Sauer (l. c., p. 243), an east current of half a knot per hour.

United States steamer Corwin, June 19, 1880, steaming into Norton Sound, off the delta of the Yukon, experienced a current in a N. by E. direction. On the 23d, going out of Norton Sound, from 8 a. m. to 12 m., observed a half-knot northerly set. On the following day, being under steam going west, off the mouth of the Yukon River, from 6 a. m. to 8 p. m., "found a strong NW. set or current, with dark-colored water," "surface 38° (3°.3) (Hooper, l. c., p. 9),[2] after which the following successive currents were experienced: 6 to 8 a. m., half knot easterly; 8 a. m. to noon, a three-quarter knot set to WNW.; noon to 8 p. m., NW. current, one to one and a half knots per hour. Thence observations were impeded by the thick fog, but on the 25th, at noon, it was found that the vessel (as a resultant of the various currents she had experienced) had been set N. 70° W. 39 miles since leaving Saint Michaels—the general trend of the Yukon mouths being about N. 60° W., while the tide floods to the N. and W.

July 5 the Corwin passed south through Bering Strait, on the Asiatic side, being compelled to cross over to avoid a floe of ice coming through the strait from Norton Sound, on the east side.

United States schooner Yukon, September 18, 1880, while running from Cape Chukotski, along the north shore of Saint Lawrence Island, with light southerly winds, experienced a current in the direction of N. 60° E. of nearly a knot per hour.

Ship Contest, June 15, 1871, 12 miles NW. (true) from the Diomedes: Vessel in a water-hole, surrounded by ice; drifted NE. 12 miles in three hours, with light SSE. wind.

Ship Jireh Perry, June 2, 1874: Vessel off Plover Bay, the Heads about 10 miles northward; laying off and on under easy sail; much ice in sight; part of the time experienced a two-knot current to ESE; later in day it sets along shore into the strait. Following day much the same; light airs and calms continue. During this forty-eight hours the vessel drifts 50 miles to the eastward in the midst of loose pack-ice. June 4 and 5, vessel in the straits, wind to the eastward, current setting northward. June 7, passed East Cape.

Bark Coral, July 15 and 16, 1878: East Cape bearing SSE. 15 to 20 miles; four other vessels in company, carrying all sail they could bear, working southward against a strong S. wind; could

[1] Unfortunately not published.

[2] N. B.—There is an error in the June table for this and succeeding dates, in "Remarks" column of Hooper's Report.

make no headway, the northerly current running apparently 2 or 3 knots; this current lasted several days, until, on the 19th, a northerly wind sprang up, after twenty-four hours of calms.

Bark Coral, June 17 and 18, 1878: Latitude 64° 50′, longitude 171° 39′; calm or light winds, current setting SW. Same date, 1879: Ship in nearly same position; wind light and variable, current setting NNE. so strong that vessels can make no headway against it southward. June 20, 1878: Ship trying to work to northward abreast of Saint Lawrence Bay, North Head, but making hardly any progress on account of SW. current. June 19, 1879: The same vessel, in the same locality, after strong SW. breeze, worked two days against northerly current, trying in vain to get to SW. That the current away from the ice opens it more than that toward the ice is shown by the fact that, under nearly similar conditions otherwise, in 1878, with SW. current strongest, the vessels entered the Arctic on the 22d of June; while with the NE. current strongest, in 1879, they were unable to enter the Arctic until June 27.

United States schooner Yukon: At anchor SE. from the S. end of the Big Diomede Island, in 23 fathoms, with 75 fathoms of hawser paid out; September 10, 1880, at 7 a. m., wind fresh from NNE. to N. (true), growing stronger later in the day. At 7 a. m. the tide was running to the ENE., and holding the vessel broadside-on to the wind, the current making a nasty short, choppy sea. At 7.50 a. m. the tide slackened, and the vessel swung to the wind. At 8.10 the tide began running to the WSW., and held the port side to the wind as before it had held the starboard; the sea smoothed down almost immediately. At noon the current was running W. by N. at the surface, with a rate of 1 foot per second, or about 1.6 knots per hour. In running hence to Cape Chaplin, no marked currents were experienced, or, if there were any, they neutralized each other. From the Diomedes to Cape Chaplin, the surface temperature decreased 8° or 9°, and through the passage between Saint Lawrence Island and Cape Chukotski the surface did not rise above 40° (4°.4), being 5° or 6° cooler than the waters of Norton Sound, Port Clarence, and the east side of Bering Strait. In August (14th to 16th), when running from Plover Bay toward the Diomedes, a similar difference was experienced.

U. S. S. Yukon, August 15, 1880: Entered Bering Strait; when off Cape Chaplin it fell dead calm; fine weather, and so remained. During a part of the day drifted to the NE. about half a knot an hour for six hours; later, lost this, and remained nearly stationary. Found surface of water 38°.5 and bottom 38°; air, 45°; weather, half clear. During four days of extremely light weather, made only one mile northing above our reckoning. On the latter part of the 18th, during the afternoon, being about 12 miles west of Cape Prince of Wales, a strong tide made from the south, which, against a moderate northerly breeze, produced quite a choppy sea. The temperature of this water was from 48°.5 to 50° (9°.2 to 10°), about 8 p. m. By noon of the 19th we had been set 22 miles north and 2 miles east by this current, which ran about 2 knots while it lasted.

H. M. S. Resolution and Discovery, beating through Bering Strait August 9, 1778, against a fresh NE. breeze, from 10 a. m. to 2 p. m., were unable, even with the assistance of the current, to make northing, and so stood to the westward, beyond the Diomedes. On the 11th, 12 miles from the American coast, N. 16° E. from Cape Prince of Wales, being at the northern entrance to Bering Strait, while anchored, from 6 to 9 p. m., "found little or no current"; wind light, or none.

Captain Clerke, July 4 and 5, 1779, in Bering Strait, was set twenty miles northward during that time, and notes that the same current had been experienced the year before.

U. S. S. Corwin in Bering Strait, south of the Diomedes, August 9, 1880, hove to in fog, with gentle SE. breeze. From 4 to 8 a. m. vessel drifted WSW. half a knot an hour in the strait. At 12.45 p. m. anchored, found the current setting NE. by N., about a knot and a quarter per hour, which continued for six or eight hours. These data, taken from the transcript of the log, clearly indicate tidal action. On the 11th of August left Plover Bay for the strait toward evening, in thick fog. From 8 p. m. until midnight, and from midnight to noon of the 12th, a northerly set of two-thirds to three-quarters of a knot was observed. Afternoon (lat. 65° 15′), although still some thirty-five miles south of the Diomedes, it was not noted. The wind was southerly and easterly, very light.

By noon of August 13, having reached about 100 miles north of the Diomedes, the log states that at noon, with light SE. wind, the ice was drifting to the southward. In the evening a sight was had of the high mountains, back of Point Hope 45 miles distant, and by noon of the fourteenth of August a northerly current is recorded of over a knot an hour for the preceding forty-eight hours; but it is probably estimated, since no observations for position at noon were obtained.

U. S. S. Yukon running from Kotzebue Sound to East Cape, owing to bad weather could not accurately determine current experienced, but arrived at the edge of the ice, near East Cape, about 7 a. m. September 5, 1880, the cape itself being clearly visible about four or five miles distant surrounded by rather closely packed drift ice, in large and small pieces. The party then proceeded to take observations for a hydrothermal section of the strait. There was a fresh northwesterly wind blowing, which increased in strength gradually, and during the latter half of the observations produced a rather short, choppy sea. The depths being all small, an ordinary hand lead and line was used in sounding, tested for correction of shrinkage or strain before and after using. The water bottles used for obtaining water from the several depths were of the ordinary pattern and held about a gallon and a half. Instantly after being hauled up this water was allowed to flow into and over a specific-gravity cup of very thin copper, containing a fixed thermometer. This instrument was by Tagliabue, N. Y., metal scale graduated to 110° Fahr., with mercury column, and having a minus correction of 1°.5 (0°.8), the values as read off being too great by that amount, when compared with standard instruments used by the United States Signal Service at San Francisco. The cup held about a pint and a half, and was read at once, the whole thermometer being covered with the water to be tested. This method, by actual test, when the depths are not great, and the time is short and the temperature of the air not greatly differing from that of the water, is far more accurate than any which involves the use of the protected thermometers of Miller-Casella pattern, which necessarily must be used in deep-sea work. They take at least fifteen minutes to come to the temperature of the water, while the naked-bulb thermometer responds instantly.

The temperatures of the surface were taken every ten minutes. Every four or five miles, as determined by patent log, the vessel was luffed to the wind, the log read, the position determined by compass bearings, with standard spirit-compass, on the Diomedes, East Cape, and Cape Prince of Wales, and other visible objects of known position. The water bottle was then sent first to the bottom and then to every succeeding five fathoms less, and finally the surface water and air were tested, and the vessel filled away on her course. Individual soundings were taken from time to time. The air averaged from 38° to 43° (3°.3 to 6°.1), the sky was cloudy, the atmosphere pretty clear, except for an occasional spurt of fine rain.

Eight serial temperature stations were occupied, seven in a nearly direct line across the strait, when it became necessary on account of shoal water to run to the southward and obtain the last as near the American shore as the depth of water would permit.

Table of temperatures.

Depth of serial temperature.		Serial temperatures at stations and of intervening surface.															
		I.	Surf.	II.	Surf.	III.	Surf.	IV.	Surf.	V.	Surf.	VI.	Surf.	VII.	Surf.	VIII.	Surf.
		°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Top	C..	3.1	......	3.0	......	5.1	......	6.2	......	8.1	......	8.6	......	8.9	8.6	8.3	8.3
	F..	37.5	......	37.37	......	41.25	......	43.25	......	46.5	......	47.5	......	48.0	47.5	46.87	47.0
5 fathoms	C..	3.1	3.3	2.9	3.1	5.1	5.2	6.1	6.7	8.1	8.4	8.7	8.6	8.9	8.7	8.3	8.4
	F..	37.5	38.0	37.25	37.5	41.25	41.37	43.0	44.12	46.5	47.25	47.75	47.5	48.0	47.75	46.87	47.12
10 fathoms	C..	3.1	2.8	2.8	3.6	4.8	5.6	5.7	7.2	7.6	8.4	8.6	8.6	8.6	8.7	8.1	8.5
	F..	37.5	37.0	37.12	38.5	40.75	42.0	42.25	45.0	45.75	47.25	47.5	47.5	47.5	47.75	46.5	47.25
15 fathoms	C..	2.8	2.5	2.8	4.3	4.7	5.6	4.3	7.6	7.6	8.4	7.9	8.7	8.6	8.6	8.1	8.6
	F..	37.0	36.5	37.12	39.7	40.5	42.0	39.75	45.62	45.75	47.25	46.25	47.7	47.5	47.5	46.5	47.5
20 fathoms	C..	2.6	......	2.8	......	4.6	5.3	4.7	7.6	7.4	8.4	8.2	8.7	8.4	8.2	......	8.5
	F..	36.75	......	37.0	......	40.25	41.5	40.5	45.75	45.25	47.25	46.75	47.7	47.12	46.75	......	47.25
25 fathoms	C..	2.8	......	......	......	......	6.1	......	......	......	......	......	......	......	8.3	......	8.3
	F..	37.12	......	......	......	......	42.87	......	......	......	......	......	......	......	46.87	......	47.0
Bottom	C..	3.1	......	2.6	......	4.2	......	5.4	......	7.4	......	8.0	......	8.2	8.0	8.0	......
	F..	37.5	......	36.75	......	39.5	......	41.75	......	45.25	......	46.5	......	46.75	46.37	46.37	......
Depth of sounding		28 f.		26 f.		5 f.		26 f.		26.5 f.		28 f.		25 f.		23 f.	
Minutes of interval			10		10		10		10		10		10		10		15

The serial temperatures at each station (I–VIII) were taken in one spot, beginning with the bottom temperature and working as rapidly as possible; the time employed for each full station being about 11m.3. The surface temperatures were taken every even ten minutes between the stations; the intercalary columns of surface temperatures above begin at the top. Those taken after leaving Station VIII were taken every quarter of an hour, running for Port Clarence, and terminate at its entrance.

The following table exhibits the currents experienced as shown by the vessel's drift:

From station.—	By reckoning.		By observation.		Time of run.	Hour of luffing. h. m.	Current.		
	Course.	Dist.	Course.	Dist.			Dir.	Dist.	Rate.
	°		°		m.	a. m.	°		
I	E. 21.8 S.	......	......	......	......	7.05	......	......	......
To II	E. 21.8 S.	4	E. 21.8 S.	10.50	40	8.00 }	E. 21.8 S.	6.7	3.4
II to III	E. 21.8 S.	4	E. 21.8 S.	4.20	38	8.50 }			
III to IV	E. 21.8 S.	6.5	E. 10.7 S.	5.50	50	9.50	N. 24.3 W.	1.53	1.5
IV to V {	E. 21.8 S. E. 33.1 S.	2 } 4.5 }	E. 44.4 S.	5.75	40	10.50	W. 28.3 S.	1.72	1.7
V to VI	E. 33.1 S.	6.75	E. 3.6 S.	7.75	50	11.50	N. 33.3 E.	3.82	3.8
VI to VII	E. 44.4 S.	6.0	E. 57.1 S.	8.00	50	12.50	S. 1.3 E.	2.52	2.5
VII to VIII	S. 0.6 E.	12.0	S. 9.2 W.	11.00	71	2.15 p. m.	W. 31.0 N.	2.20	2.2
Total	S. 45° 41′ E.	40.75	S. 49° 32′ E.	44.011	7 h. 10 m.	......	E. 1.35 S.	4.35	0.6

The directions in degrees and tenths corrected for variation of the compass; the distances in nautical miles and tenths. The particular soundings will appear on the accompanying sketch map of the strait; the details of the temperatures in the section and in the preceding table. The totals above are the resultants of the whole run.

It will be observed that the drift, except that preceding Station III, is in alternate directions, and the several drifts so compensate each other that only the easterly current is left. I believe that we met the falling Asiatic tide at its greatest strength at East Cape; that opposite the Diomedes we encountered an eddy (Station IV); that we then encountered the falling tide (nearly done running) from the American side (Station V); that at Station VI, or thereabouts, the rising tide drifted us northeastward; while, on approaching the shoal water near Station VII, we encountered another eddy; and that the set encountered between VII and VIII was due to the rising tide coming around Cape Prince of Wales.

Too much stress must not be laid on these observations, for it is evident, considering the short distances run and the strong breeze, that they are liable to error both in amount and direction, and consequently in rate. Their general tendency, however, may justly be considered as having some weight.

Much more extended observations must be taken and continued over the summer months, to which must be added a better knowledge of the tides, before we can be said to have a sufficient fund of information upon the complicated currents of the strait.[1] Observations from a fixed point are alone satisfactory. The preceding notes and quotations show, however, that opposing currents exist in the strait at different times; that there is a gradual decrease in warmth of water from near the American side over toward Asia; that the verticality of the isotherms, as shown in the section, apart from other concurring circumstances, indicate there is no reason to suspect any submarine current of cold water; the strong northerly and southerly currents have been experienced on both sides of the strait by various navigators; and therefore, without further proof, it is unsafe to assume, in opposition to the present evidence, that a cold current runs south on one side while a warm one runs north on the other. What, then, is the explanation of these facts? My own opinion

[1] It should be noted that in the sketch maps engraved for the article in Petermann's Mittheilungen and that in the Am. Journal of Science, the meridians are laid down from the original computations based on one chronometer. This proves, on the final revision and application of seven chronometers (not then available), to be one minute (approximate) too far east. The true meridian of the boundary line bisecting the strait between the Diomedes is 168° 58′ 05″ W. ± 39″, and the discussion of the data will be found in the Supplementary Note to this article.

of them, subject to modification with greater knowledge, is about as follows: A glance at the chart shows that the eastern coast of Asia, bordering on the strait, is deeply indented by bays, the headlands of which are bold and projecting. The American coast, on the contrary, is smooth, and the action of the current has nearly closed the single indentation at Port Clarence by the formation of a long and narrow gravel spit, along which the tides run as if the coast were continuous. The opening would doubtless long since have been closed were it not that a considerable river discharges itself into Grantley Harbor at the head of Port Clarence. There are no rivers of any consequence on the Asiatic shore, and the rocks are of a much harder nature, and the currents are much weaker; hence the spits formed on that side are small and insignificant.

The still water between the headlands of the Asiatic side remains ice-bound long after the center and American side of the straits are clear, as there is no current to carry away the ice, and it is sheltered from heavy winds. Even after the ice has melted, if any is brought into the strait from north of East Cape by northerly winds and by the tide, it is carried into these bays, and may remain there during the remainder of the season. The water in these bays and their vicinity is thus kept cool; the air from the ice cools the immediately adjacent shore; the warm water from the American side, being (as I suppose) moved chiefly by the tides, rarely has persistence enough in motion westward to reach these recesses, and is repelled and limited (as Weyprecht has shown to be the case elsewhere) by the stagnant ice; the great freshets of the Yukon and other American rivers (these lasting about three weeks), which strew all these coasts with drift-wood, are in most cases long past before the ice barrier is melted, so that on this Asiatic coast, as compared with the American coast ninety miles away, the climate is colder, the vegetation less luxuriant (this also partly on account of difference in soil), and the drift-wood is prevented from landing, and carried farther north or south—being found abundantly in either direction.

We have seen that the tides on the American side march north and west; that the current of the Yukon, observed by Hooper and others, runs in a N. 70° W. direction; we know that the form of the earth and the prevalent southerly winds of summer combine to make the northerly tendency stronger than that in the reverse direction; we know that on certain occasions the tidal flow has been distinctly noted in the strait, and that currents in opposite directions have been there observed by different navigators. I conclude from this that the current through the strait is a resultant from these forces, and that its temperature in its warmest part is due to the movement of the warm waters of the Yukon, of Norton and of Kotzebue Sounds oscillating back and forth with the tide. We have shown definitely that the warm water cannot be traced into the bed of Bering Sea, but exists only in the shallows, and that it grows rapidly cooler as we pass northward, so that at Point Belcher we have, under ordinary circumstances, only the ordinary Arctic Ocean temperatures for the particular season of the year.

I consider, therefore, that this temperature of the water (like the high midsummer temperature of the lower Yukon Valley) is a strictly local phenomenon, though it has, as was observed in the Appendix I to the Alaska Coast Pilot, as much effect upon the vicinity of its location while it lasts as if it had been gathered in the China Seas and transported thither.

To descend to details, it is supposable that the rising tide and Yukon current, when not otherwise disturbed, would strike the Asiatic coast after passing Saint Lawrence Island, south and west of Cape Chaplin, and as far as Chukotskoi Noss, and would be by that land turned to the northeastward, thus producing the notable current so often observed just off Cape Chaplin, but whose force, as we ourselves observed, does not extend very far from that cape. The main part of the current northerly through the strait is produced by that part of the tide which hugs the shore of the peninsula north of Norton Sound, as has been so many times observed. This runs very strong off Cape Prince of Wales, and follows the shore around into Kotzebue Sound, and reappears for a short distance with a strong set off nearly every prominent headland on the American side, such as Cape Krusenstern, Point Hope, Cape Lisburne, etc., at each of which a spit formation drifted two ways (by the flux and reflux) is observable, either above or below water.

On the Asiatic side the falling tide rushes with great force SE., past East Cape.

As has been pointed out, the form of the land interferes with the existence of much current SW. from that promontory.

The ratio of the two currents around Cape Prince of Wales is probably pretty well measured by the length of the submarine spit-shoals due to their respective action. The ratio of the flood spit to the ebb spit is as 45 to 34, or 7½ to 5⅔ miles.

They are about equal at Point Hope, with a tendency to preponderance of the ebb. At Cape Lisburne the flood spit is much shorter than at Cape Prince of Wales, but there is no ebb spit indicated on the charts. At Icy Cape they are about equal, while at Point Belcher and Point Barrow the ebb spit is almost lost sight of. These are indeed but rough approximations, since neither the surveys nor the conclusions from them have claims to much precision; still they agree, for the most part, with the deductions from other data.

We will now consider observations bearing first on the region north of the strait on either coast, then on the Arctic in general and the Point Barrow region in particular, before summing up the conclusions from the investigations as a whole.

U. S. S. Corwin, August 30, 1880, off Cape Krusenstern, Kotzebue Sound, at 8 p. m., anchored and observed NW. ½ W. current of 1¼ to 1½ knots per hour. Wind fresh from ESE. On the following day, a few miles east of the cape, observed a similar current.

U. S. S. Corwin, July 29, near Cape Blossom, Kotzebue Sound, current in a. m. setting to the northward along shore about 1 knot per hour; wind moderate from S. and W. Following day running to the eastward, against a fresh SE. gale, along south shore of Kotzebue Sound, etc.; during first twelve hours a three-quarter knot current NNE. was experienced. On the 31st, having run in a nearly northerly direction from lat. 65° 30′ to Point Hope, find that in running this 100 miles they had experienced about nine miles current in a northeasterly direction, a strong SSE. gale blowing at the time.

Bark Vigilant, Captain Smithers, in July, 1879, off Cape Thompson, experienced a strong SE. current for ten hours; with a fresh NW. wind to beat with, could make no headway against it.

U. S. S. Corwin, July 28, 1880: On arriving at Cape Thompson the difference of reckoning showed considerable northerly current, but the amount and exact direction are uncertain, as the steamer had twice crossed a large part of the Arctic Sea between Herald Island and Point Hope within a week and had had no satisfactory observations for several days.

Observations off the coast of Asia.—Ship Jireh Perry, July 3, 1874: latitude 68°, longitude 176°; light airs and calms; ship among the loose ice off Koliuchin Bay, and cannot get out on account of the strong westerly current.

U. S. S. Corwin, latitude 68° 18′, longitude 171° 28′. August 7, 80 miles north of the Asiatic shore, near Serdze Kamen. This day having been passed working to the eastward in thick fog, an E. by N. current, somewhat less than a knot per hour, is recorded, probably an estimate, since no observations for position had been had since leaving Herald Island. Eighteen miles south of this locality Rodgers, in 1855, experienced a half-knot current in a W. by N. direction. Large quantities of drift-wood were seen hereabouts by the Corwin and by Onatsevich, which is worthy of notice, as it is frequently asserted that no drift-wood is found on the Asiatic side. On the 8th the Corwin steamed through the strait, finding a strong northerly set between the Diomedes. Before reaching the strait, by bearings on the land, an E. by N. set of 44 miles was found to be the difference between the reckoning and position by bearings during the preceding 48 hours. As no position had been obtained since leaving Herald Island, and the course had been irregular along the edge of the pack, both distance and direction of the set are subject to more or less error, and, in any case, only represent the resultant of currents over a distance of 240 miles.

Observations in the Arctic in general.—Captain Clerke, July 12, 1779, in latitude 68° 41′, longitude 170° 39′, with moderate southerly breeze, found current setting NW. half a knot per hour. A W. one-half S. current is recorded by Rodgers in 1855 in about the same locality, having about the same strength.

Bark Coral, September 5, 1879, latitude 70° 35′, longitude 175° 30′. "Fine whole-sail breeze from NNE., and clear weather. Ship working to the north between two packs of ice" in a water-lane 15 to 20 miles wide, "five or six ships in company. Saw Herald Island bearing N. 45 miles distant at 4 p. m. Lay by over night under easy sail." September 6: "Fresh breeze from NNE. and NE.; ship under easy sail working to the northward and eastward in the leads of water, as yesterday." "Herald Island in sight, about 30 miles distant. Find a current setting to the northward. Twenty vessels in sight. Heard that Bennett's steamer (the Jeannette) was seen by the Sea

Breeze three or four days ago steering to the northward. Had some fog to-day, but not continuous. Lat. 70° 45′ at noon." The weather of the 2d and 3d is reported as "foggy with snow squalls, light and baffling airs, the fleet working to the westward and SW." along the pack ice.

U. S. S. Corwin, latitude 70° 39′, longitude 175°: Near Herald Island, July 26, 1880, wind fresh, southerly and westerly, experienced a half-knot current to southward.

U. S. S. Corwin, latitude 69° 58′, longitude 173° 47′, July 25. No time observations, but a southerly current indicated by the difference between the observed latitude and the reckoning.

U. S. S. Corwin lying-to in thick fog about 35 miles southward from Herald Island. July 27 experienced from 1 to 4 a. m. half-knot current to SW., then shifted, and from 4 to 8 a. m. ran to NW.; wind light, variable.

U. S. S. Corwin, August 4, 1880, latitude 71°, longitude 174° 40′. In a. m., 40 miles SE. from Herald Island, experienced a strong current setting to S. and E. Wind fresh from S. and W.

U. S. S. Corwin, from 15th to 20th of August, east from Herald Island, working toward it through the pack. On the 16th, 4 a. m. to 7.45 a. m., wind light NE., vessel hove to in the fog, drifting to the SE., passing through heavy drift ice. On the 17th, 10.20 a. m., sent an officer with a boat to examine drift of ice along the edge of heavy pack; returned at 10.30, reporting the ice to be drifting SSE. three-quarters of a knot per hour. At 10.45 Herald Island bore SSW. 10 miles distant; wind NE., light. In the evening came to anchor about 7 miles east of Herald Island and tested the current, which proved to be about SW. half a knot, the wind as before, but lighter. On the 19th, at 1.25 p. m., got out the boat and found the current setting south three-quarters of a knot per hour; wind northerly, light. On the 20th, at 10 a. m., found same current, with light NW. wind. The general drift of the ice in this vicinity, according to Captain Hooper, is to the southward, from one-quarter to three-quarters of a knot per hour, but it is to a certain extent controlled by the wind (l. c., p. 36).[1]

U. S. S. Corwin, from 42 miles NW. of Point Hope, September 9, 1880, steering NW., noted a current setting NW. one-third of a knot; this continued until noon of the 10th, 180 miles NW. from Point Hope.

U. S. S. Corwin, 40 miles SW. by S. half S. from Herald Island. September 11, "found a strong easterly set for the first time" (Hooper, l. c., p. 49). Running thence direct to Point Hope in the afternoon, and on the following day made the point at 9.10 p. m., the landfall showing an E. by N. one-half N. current of 47 miles during the last thirty-three hours as the resultant of the currents, etc., experienced in running from Point Hope toward Herald Island, some 250 miles and return.

Captain Cook, August 21, 1778, when 12 or 15 miles north of Cape Sabine "sent the master in a boat to try if there was any current; but he found none." The weather was nearly calm.

Captain Cook (ii, p. 521) has the following remarks on the tides and currents of this region south of Icy Cape, which was his farthest north in 1778:

"The flood comes from the S. or SE., everywhere following the direction of the coast to the northwestward." "To the north of Cape Prince of Wales we found neither tide nor current either on the American or on the Asiatic coast, though several times looked for."

Captain Clerke, on the 20th of July, 1779, 15 or 20 miles N. of the coast near Cape Lisburne, with an ESE. wind, experienced a current of a knot an hour to the ENE., which seems to have come on suddenly with "the wind lessening." He further remarks, in regard to the currents of this part of the Arctic Sea, in general, "we found them unequal, but never to exceed one mile an hour. By comparing the reckoning with the observations we also found the current to set different ways, yet more from the SW. than any other quarter; but whatever their directions might be, their effect was so trifling that no conclusions respecting the existence of any passage to the northward could be drawn from them" (l. c. iii, p. 276).

U. S. S. Yukon, at anchor N. of the shore some 10 miles eastward from Cape Lisburne, August 21 and 22, 1880. During the twenty-four hours passed at anchor here, the current ran steadily to the W. and S., holding the vessel broadside to fresh SSW. and SSE. breezes. Toward evening an eddy ran in the opposite direction close in shore near the beach.

U. S. S. Yukon, at anchor 20 miles eastward of Cape Lisburne, during a calm on the afternoon

[1] See Supplementary Note.

of August 22, 1880. While at anchor the vessel tailed to the W. and S., but the current seemed very moderate.

U. S. S. Yukon, at anchor 5 miles SW. from Icy Cape, from 10 a. m. to 4 p. m., during which time we experienced a northeasterly set of about three-quarters of a knot an hour.

U. S. S. Yukon, at anchor off Point Belcher, August 26 to 28, 1880, experienced a strong northerly current here, especially with the tide flowing. During the ebb the vessel swung to the wind, which was fresh NE.; but during the flood the current held her broadside to the wind. The rate of the current seemed to be about three-quarters of a knot during the flood tide.

U. S. S. Corwin: August 22, 1880, 45 miles NW. from Icy Cape, set of current half a knot to the northward and eastward. Wind variable, easterly. On the 23d, near Wainwright Inlet, observed an E. by N. current of three-quarters of a knot.

Ship Contest, August 5, 1871, 3 miles SW. from Icy Cape. Ice drifting SW. about one and a half knots per hour; strong breeze from N. and E.

U. S. S. Corwin, between Point Belcher and Icy Cape, August 27, 1880, standing to the westward along shore, encountered an easterly current of about a knot an hour; wind light, easterly.

Bark Coral, September 11, 1879, latitude 69°, longitude 173° 15′, near Cape Lisburne. "Airs light and baffling, with falling barometer and SE. swell, find current setting to W. and NW."

U. S. S. Corwin, near Cape Lisburne, July 31, 1880. Off the coal mine at anchor; experienced a NE. ½ N. current, of three-quarters of a knot an hour in the morning. The following day, in same locality, strong SSE. and S. gale, the current ran two knots to northward and eastward, and so continued until the afternoon of August 2, when the wind abated, and the Corwin sailed for Herald Island.

U. S. S. Corwin, near Cape Lisburne, at the coal mine, July 23, 1880, experienced strong N. and W. current; wind mostly southerly, variable.

U. S. S. Yukon, near Cape Lisburne, August 21, 1880, at 9.30 a. m., anchored in six fathoms; found the surface temperature 49°.1 (9°.5), and the bottom 48°.1 (8°.9); wind light, NE.; sky, overcast; air, 50°.0 (10°.0).

U. S. S. Yukon, off Point Belcher, August 28, 1880, at 8 a. m., anchored in 9 fathoms; found the surface temperature 42°.7 (5°.9), the bottom 41°.7 (5°.4); the air 40°.0 (4°.4); sky, overcast; wind, fresh NE.

U. S. S. Yukon, from 9 a. m. August 28 to 11 a. m. August 29, 1880, in making a straight run from Point Belcher to Cape Lisburne, with a fresh NE. wind, experienced a SW. set of 9 miles during that run. From Cape Lisburne to Point Hope, a distance of 40 miles as run, which took five hours, a set of 7 miles to the SSW. was experienced. The Yukon met the flood tide near Point Hope, where, against the NE. wind, it created white water and a smart choppy sea. Southward of Point Hope the U. S. S. Corwin and schooner Loleta, at anchor, were tailing with the wind, showing that the current was not very strong there. On the 20th of August, running toward Cape Lisburne, we were set 18 miles northward of our reckoning, most of which seemed due to a strong current setting round Point Hope to the northward. Between Bering Strait and Point Hope no indications of current were noticed.

U. S. S. Corwin, at Point Hope, July 21, 1880. Fresh gale from the SSE. starts the ice off the shore, and it passes northward in a current estimated at two knots an hour. On the following forenoon heavy gales continued. Drift-ice passing eastward north of Point Hope, along shore.

Rosser and others quote some rather extended remarks by Surgeon Simpson, of H. M. S. Plover, in 1852, on the currents of Bering Strait and the Arctic. As the author acknowledges "the absence of actual observations for determining the currents of these seas," and proceeds to argue upon suppositions, natural in themselves, but which later investigation and experience have shown to be largely erroneous, the paper does not require extensive criticism. Dr. Simpson supposes "an almost imperceptible set" to proceed between Saint Lawrence Island and the Asiatic coast into Norton Sound, thence to be reflected through the strait "with lessened speed," receiving "a further tribute from Kotzebue Sound, which is very palpable off Point Hope," and then extending in a NE. direction along the coast of America to Point Barrow, whence it proceeds NE. into the Arctic. Through all this course it is subject to retardations and accelerations from favorable and unfavorable winds. He notes that the current in the strait between Saint Lawrence Island and

NE. current in the Arctic, southwest of Icy Cape, is less than that sweeping thence to Point Barrow, and there is reason to believe the increase is derived from the waters on the NE. coast of Asia "is variable, and the passage seldom entirely free from ice until July"; also, that the coast Asia." Much of the preceding agrees with later observations, while it is not necessary to follow this author in his suppositions that the coal, the gravel beaches of the Arctic coast, and the Arctic shells of Icy Cape, "have a southern origin." (Short notes on the wind, weather, and currents of the N. and S. Pacific, by W. H. Rosser, 8°, pp. 120: London, Imray, 1868, pp. 85–88.)

• • • Captain Owen, of the Mary and Helen, and Captain Jerningham, of the Tropic Bird, stated, as the result of their experience, that there were three general sets or tendencies of the water in the Arctic—one from Cape Lisburne along the coast toward Point Barrow, another NW. from Kotzebue Sound by Point Hope to the vicinity of Herald Island, the last along the NE. coast of Asia, from East Cape, north and west. These currents are largely affected by the wind and tides, chiefly by the latter, while the motion of the ice depends more especially, though not wholly, on the winds.

Captain Hooper (l. c., p. 41) observes in regard to the ice: "The ice pack seldom moves more than a few miles off shore, between Icy Cape and Point Barrow, and is likely to close in at any time. A northeast wind, although it blows directly along shore, keeps the ice clear and allows the current to set up past Point Barrow (1). The heavy ice when close in shore stops the surface current entirely (2), and lowers the temperature to 36° (2°.2) or less, so that a vessel working up this shore may readily tell if the ice is on the Point by watching the set of the current and the temperature of the water. If the ice is clear of the shore the current will be setting to northward from one to three knots an hour, with a temperature of 40° (4°.4)."

With all deference to Captain Hooper, whose views are entitled to great weight, it must be conceded that these generalizations are not invariably borne out by the experience of others. 1. The observations of Owen and others recorded here show clearly that at times a strong northeaster reverses the current at Point Barrow instead of letting it set up by the point. 2. Exceptions to this general rule are found in the observations of Pullen in the Plover's boats, and those of Captain Hamill in 1870; the current has been observed by these navigators to run strong up to and under the very margin of the ice. Lastly, in 1880, when the surface water was at 40° at Point Belcher, and running with a good rate toward the NE., the ice was reported to us as on the shore both at the Sea-horse Islands near by and at Point Barrow, forcing the schooner Alaska aground between these places, and coming near to wrecking her.

Observations in the vicinity of Point Barrow.—Ship Contest, August 16, 1871, off Point Collie, one mile of water between the ice and land. Wind light SW., current running NE. 1½ knots. August 19, same place and current, with a light NE. wind.

Ship Jireh Perry, August 2, 1872, latitude 70° 30′, longitude 160° 30′, at anchor at the head of open water. Found current setting to the northward one knot, and off shore loose ice passing with it. Wind, light southerly. August 6, 1872, 10 miles west from Wainwright Inlet, wind strong SW., current strong NE.

Ship Jireh Perry, August 16, 1872, 15 miles NNE. from Point Barrow, at anchor in 22 fathoms. Light airs and calm. Current setting NE. 2½ knots, much loose ice with it; August 17, latitude 71° 40′, longitude 155°, attempted with light easterly winds to work out of the loose ice into clearer water, but current ran so strong that could make little headway southward against it, as the wind was in puffs and otherwise calm. Had to make fast to the grounded ice. Six or seven other vessels were seen in the same predicament August 19, beset in same situation and unable to get out of the pack. Wind westerly and southerly, moderate, ice drifting rapidly to the eastward. August 23 westerly winds, succeeded by light airs and calms. Easterly current nearly ceased and began in shore to run to the westward. Later in the day had fresh easterly winds and the ship worked out of the ice. September 4, beginning 4 miles WSW. from Point Barrow and continuing during the two following days, thence to the Sea-horse Islands, with SSW. and NW. winds had strong ENE. current along shore.

Ship Jireh Perry, July 20, 1873, at anchor off Point Belcher, strong southerly wind and NE. current, which continued strong on the following day, the wind hauling to the westward. July 22, anchored close into Sea-horse Islands, wind W., same current; July 24, light airs from S., and, later, strong breeze from SW., current running 2 knots to NE.

Ship Jireh Perry, July 31, 1873, latitude 71° 20′, longitude 155°, winds from fresh SE. and E. to NE. and N., light, and then calms. There seemed to be very little current at all.

Ship Jireh Perry, August 7, 1873, anchored off Point Tangent in 5 fathoms; sent boats off shore into the loose ice for whales; found on the ice the main hatch combings of Bark Roman, with official tonnage mark and number cut into it. She was lost two years previously in the pack, off shore from the Sea-horse Islands. The distance between the two points is only 120 miles.

Ship Jireh Perry, September 2, 1873, latitude 71° 15′, longitude 154°, wind strong NW., this and previous day gradually moderating. Current running to WNW., ship standing off and on shore in about this longitude all day amongst loose ice.

Ship Jireh Perry, September 8, 1873, working to the eastward, in about longitude 153°, 2 to 20 miles off shore, with fresh ESE. wind, which had blown for thirty-six hours and gradually moderated, encountered strong westerly current and finally anchored in longitude 153° 08′ to hold her ground.

Ship Jireh Perry, September 14, 1873, latitude 71° 30′, longitude 157°, strong S. wind continuing September 15, and then calm; encountered a NE. current of a knot and a half an hour. September 17, 15 miles NW. from Point Barrow, wind S. and SW., current running strong to NE. September 18, same vicinity, Point Barrow W. by S., 8 miles distant, wind shifts to W. and current runs E. September 19, same vicinity, west wind moderated and hauled to NW., current changed to SE., one and a half knots; ship at anchor. September 20, wind W. again; got under way to work to the westward of Point Barrow, and could barely get around the point on account of the head current.

Ship Jireh Perry, September 24, 1873, latitude 69° 48′, longitude 169°. Having been steering W. by S. (true) for forty-eight hours with moderate easterly winds, from vicinity of Point Barrow was carried some 60 miles southward by current during that time.

Ship Jireh Perry, July 13, 1874, NE. breeze, light airs and calm; ship near Point Belcher; a large floe along shore; outside, a strong current was running to the NE. "Saw one of the old wrecks of a whaler lost in 1871." July 14: "Foggy, light NE. wind; at 1 p. m., about 3 miles off Sea-horse Islands, current setting to NE. and E.; ship aback on both tacks, drifting; at 1 p. m., July 15, weather cleared up and found the ship half-way from Sea-horse Islands to Point Barrow, making a NE. drift of some 30 miles for the twenty-four hours." July 25, anchored off Smith Bay, E. from Point Barrow. This and following day "found it difficult to work the ship in a 3 or 4 knot breeze, on account of conflicting currents." July 29, latitude 71°, longitude 152° 40′; calm. Ship fast to the ice and drifting SW. August 3, latitude 71° 10′, longitude 152° 40′; worked to the N. and E. and anchored off shore in loose ice. A variety of winds and strong conflicting tides; later, fell calm, with little current.

Ship Jireh Perry, August 23, 1874, Point Barrow SSE., 14 miles distant; laid the ship aback. Drifted 15 miles SW. during the night; wind NE.; vessel continued in this vicinity; wind shifted to WNW. and NW., but the SW. current continued until the 28th.

Bark Three Brothers, July 12, 1876, anchored SW. from Point Belcher, near the land; wind had been strong from W. and S. for two days, and now died out. Found strong easterly current. July 14, strong easterly wind set in, continuing until the 16th, when the current was observed setting to the WSW. 1½ knots. July 22, at anchor under cover of grounded ice, off Refuge Inlet, 8 miles SW. from Cape Smyth. Strong NW. wind, and current setting along the land 2 knots to the eastward. July 29, at anchor to the eastward from Point Barrow; wind set in from NE., and the loose ice commenced to drift with current to the westward very fast. Same continued to August 3. August 4, the wind moderated, and the current changed and commenced to run "to the NE. very slow." Wind freshened the following day, and the current apparently ceased. On the 9th it is noted, "wind finally settled at SW. The current changed to-day, running to the eastward, having had it running SW. longer than I ever saw it before, no doubt on account of prevailing easterly and NE. winds." August 11, after moderate NW. winds, "wind worked round to the NE. and eastward." Ships were at anchor a little to the eastward of Point Barrow, or cruising east and west of it in open water 3 or 4 miles wide, to the northward. Ice plenty, current running to the NE. along the ice; but running to the westward south of the ice. August 17, "wind hauled to NE.," "current running 3 knots to the westward." August 23, "wind freshened to almost a gale from the westward, and started a strong current to the eastward." August 24, wind "still to the westward"; died out later in the day; "current running fast to the eastward." Next day, light airs; most of the fleet fast in the ice, drifting to the eastward with it very slowly. On the 27th, most of them had drifted past Point Barrow, and on the 28th it breezed up from the SW. and started the fleet and ice drifting quite fast to the eastward, the ships being in great peril. September 1, 1876, the wind changed to the NE., but light and baffling. On the 5th, the loose ice began drifting to the W. and SW., under the influence of light NE. winds, which, on the 6th, backed round to NW. and then fell calm, but started the current again to the eastward. On the 7th, the bark got round Point Barrow to the westward, and anchored in the bend west of the point, close to the shore. On the 9th, ten ships were abandoned in the ice, about 50 miles eastward from Point Barrow, and the men in boats passed Point Barrow, and on the 13th got out of the ice to the bark Florence, leaving the Three Brothers still hemmed in. A fresh gale from ESE., September 15, did not release her, the ice being aground outside of her, but they saw the Acors Barnes (one of the abandoned ships) in the ice 25 miles northward and drifting westward. On the 16th, they were still beset, but saw the abandoned Java drifting to the westward in the ice, 10 or 12 miles north of them. September 17, the Three Brothers and her companion, the Rainbow, got out into clear water, and by this time the wreck of the Acors Barnes had drifted SW. toward them, so that it was only 6 or 7 miles off, but in impenetrable pack. The bark Clara Bell was beset and abandoned about the same time off Refuge Inlet. Sixty men, mostly Kanakas, remained on board these vessels, of whom, since that time, nothing has ever been heard. On the 19th, the Three Brothers sailed for Saint Lawrence Bay, and left the Arctic.

Bark Coral, August 8, 1878, a few miles eastward from Point Barrow, experienced light W. and S. winds which were accompanied with some NE. current; it then fell calm and breezed up from NE., whereupon the current changed to WNW.

Bark Coral, August 21, 1878, at anchor under lee of Point Barrow, to west of it; a strong NE. wind blowing. Boats off looking for whales were unable to return on account of the current, and had to board vessels lying near Cape Smyth, 4 or 5 miles to the SW. The same conditions noted until the 24th (with the remark that the 23d was the 12th day), when the wind died out, the current slackened up; on the 25th, with light SE. breezes, the current changed to northerly and the vessels shifted to the east side of Point Barrow to get out of it; on the 28th the SE. wind died out and the current changed, running to the westward, on account of which the vessels shifted again to the lee side west of the point. August 29, wind from westward and WNW. Ship at anchor west of Point Barrow; "current setting to the eastward and ice passing the point all day." This continued unchanged until September 7, during which time the ship was on the lee (east) side of Point Barrow. It then fell calm, and, after midnight, "light airs sprang up from the eastward and increased slowly, and at 7 a. m. the current changed to the westward; got under way and went around to the westward of Point Barrow and anchored." All the fleet, which had been in some peril of being beset, worked out with this favorable chance and got to the southward.

U. S. S. Corwin, off Point Barrow, August 25, 1880, 7.20 a. m., found current setting northward and eastward two knots.

Bark Coral, August 15, 1878. Three miles SW. from Return Reef at anchor latitude 70° 30′, longitude 149° under the lee of the reef to escape a two-knot westerly current, which accompanied fresh NE. wind; got three boat-loads of spruce logs from the beach for firewood; there were many logs much decayed at this place.

Capt. Charles Hamill, in the Providence Journal (quoted in the New York Herald of April 30, 1881), states that in latitude 73° 28′, longitude 164°, he came up with a huge body of unbroken ice and found "a three-knot current setting N. under the ice," with no bottom at 90 fathoms. "A short distance to the SW. we found little or no current." In 1867 he found the current in the vicinity of Herald Island "very irregular and influenced by the winds, but hardly ever exceeding two knots, setting northwest."

The following notes by Parry, in regard to temporary currents in the Arctic regions, kindly communicated by Mr. George Kennan, are of interest in this connection. These observations were made on the southwest coast of Melville Island in August, 1820:

"Although the holes had certainly increased in size and extent, there was still not sufficient room for one of our boats to have worked to windward, and the impossibility of the ship's doing so was rendered more apparent on account of the current which is always produced in these seas soon after the springing up of a breeze, and which was now running to the eastward at the rate of at least one mile per hour." (Parry's Voyage, 1819–'20, p. 243. London, John Murray, 1821.)

"We found the current at the extreme point running at the rate of 2 or 2½ miles an hour, so as to require great caution in laying out our warps to prevent the ship being carried back to the eastward; and this not three hours after it first began to make. The frequent experience we had of the quickness with which currents are thus formed in consequence merely of the wind naturally leads to this useful caution, that one or two trials of the set of the stream in icy seas must not be too hastily assumed in drawing any conclusion as to its constant or periodical direction." (Parry, l. c., p. 248.)

In the foregoing series, most of which is now for the first time published, and has been derived from the log or "remark books" of the whaling vessels, I have given *all* reference to currents which occurred in those books I have examined.

I have taken especial pains in this matter, since the "opinions of whalers" have been largely referred to in several vague dissertations on this subject. We now have, not the opinions, but the facts observed by these hardy navigators, as they were taken down at the time of observation.

With regard to Point Barrow, it would seem clear to an unprejudiced mind that, while there is a tendency to a northerly set off that point, which, under favorable circumstances, develops into a temporary current of great rapidity, this is reversible totally, and frequently is totally reversed by the wind, and has a temperature not greater than the average of coast-waters not actually ice-encumbered, in most parts of the Arctic region, being in no sense a warm current. With regard to the general currents and their direction in this part of the Arctic region, the opinions previously quoted from Captain Owen seem to fairly represent the facts. The plausibility of Simpson's suggestion that part of the current near Point Barrow may come from north of the Asiatic coast may be doubted, yet this is worth considering, since the strength of the currents on the American coast south of Icy Cape does not seem sufficient to account for the phenomena observed occasionally at Point Barrow. There are indications that the basin north of Point Barrow and east from Wrangell Island is a closed basin—whether closed by land or by heavy ice cannot be now decided. That there is no well-marked current through Long Strait, and that the occasion of the usual ice blockade there is the meeting of two contrary currents, either one of which may for a time be subordinated to the other, is also indicated by the slender data we have on that subject. That the currents in this part of the Arctic have no necessary connection with any movements of the waters south of Saint Lawrence Island seems clearly established, and to this we may ascribe the fact that in no other part of the Arctic regions unobstructed by land (except the belt occupied by the polar current of the east coast of Greenland) does the permanent pack-ice retain such a low latitude.

Before summarizing the general conclusions, it may be desirable, for the further clearing up of this subject in the popular mind, to examine the capacity of Bering Strait for supplying warm water to the Arctic basin, were there an opportunity for it to fulfil that office.

The average depth of the strait near the line of our section, about the narrowest part (49.33 nautical miles), except that line passing through the Diomedes, is 23½ fathoms. The highest rate observed while at anchor by our party was 1 foot per second for the current. The highest temperature observed was 48° (8°.9), as will appear by a glance at the section.

These figures allow nothing for the space obstructed by the Diomedes, or occupied by stationary ice on the Asiatic side.

The area of the section thus taken, reduced to a rectangle, is 42,289,425 English square feet, and the rate being taken as 1 foot per second, this number represents the number of cubic feet of water which can pass into the Arctic Ocean through the strait at any one second of time. The amount per day is therefore 3,653,806,320,000 cubic feet, assuming the flow to be constant and in that single direction.

The basin of the Arctic immediately north of the strait, between Asia, America, and Wrangell Island, occupies an area considerably exceeding 150,000 square geographical miles, with a depth averaging rather less than 28 fathoms, so far as the data go. This contains 931,553 billions of cubic feet of ice and water, which, at the opening of the season, is doubtless at a lower temperature than 32° (0°.0). Assuming that half of it consists of ice at 32° (0°.0), which is a liberal estimate, we have about 466 trillions of cubic feet of ice.[1]

If the basin were empty, it would take eight months and a half to fill it by the flow through the strait.

The period of unobstructed flow of water through the strait does not usually exceed ninety days, and, when it does, the excess is at seasons when the water is cold. Assuming the flow to be continuous, and to be at its highest temperature (48° Fahr. or 8°.9 C.), and its highest observed rate (1 foot per second), heat enough would be carried in by the supposed current to reduce thirty-six and a half trillions of cubic feet of ice at 32° Fahr. to water at the same temperature, leaving the inflowing water also at 32°. It is true that other factors are at work, but what we wish to find out is the value as an ice-melter of this particular factor. The amount of ice which would be melted by the above process is a little less than eight per cent. But the weighted mean temperature of the water observed to flow through the strait is not 48° (8°.9), as assumed, but 42°.5 (5°.8). This would, therefore, reduce only five and two-tenths per cent. of the ice to water at 32° (0°.0).

But we know also that while the tendency of the flow is greater northward, it does not flow through uniformly in one direction, nor always with the highest rate observed; hence if we allow two-thirds of the time for the northerly flow, and assume that this is all at the highest rate, and that none of the warm water flows back with the tide and that it loses no heat by radiation into the atmosphere, we get as the probable maximum of ice melted a percentage of three and four-tenths, equal to an area of 5,100 square geographical miles, or a square 71.4 miles on each side, or, roughly, an area somewhat less than half that of Kotzebue Sound.[2] This is, of course, when the other circumstances are considered, almost inappreciable, and leaves us to conclude that, under any circumstances at all probable, the amount of warm water which could pass the throat of the strait is so small that it would have practically no effect on the Arctic basin into which it might enter. It seems somewhat singular that no one has hitherto computed the capabilities of the strait with assumed data; for the publication of the figures would seem of itself to be sufficient to quench most of the theories based upon the supposed influx of warm water by this entrance. We may sum up the results of the investigation as follows:

The Kuro Siwo compared with the Gulf Stream is cooler, has a much smaller volume, and is subject to serious fluctuations, which appear to be due to the monsoons.

The Kuro Siwo sends no recognizable branch northward, between the Aleutians and Kamchatka, nor from any other direction into Bering Sea.

The chief current of Bering Sea is a motion of cold water southward. This has a superficial stratum above it, which has, in summer when not interrupted by winds, a northerly motion of translation, but is not sufficient, either in mass, motion, or consistency of direction, to be entitled to take rank as an ocean current.

The surface currents of Bering Sea are formed by or chiefly dependent on tides, winds, river flows, the southerly motion of cold water, the distribution of floating ice, and the northerly motion of slightly warmer surface water, which are effective about in the order named.

No warm current from Bering Sea enters Bering Strait, with the exception of water from the neighboring rivers or the adjacent sounds. This water owes its heat directly to the local action of the sun's rays.

The strait is incapable of carrying a current of warm water of sufficient magnitude to have any marked effect on the condition of the Polar basin just north of it.

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[1] Ice has been frequently reported ashore in fourteen fathoms water. It is always aground on Herald Shoal, where there are not less than seven fathoms. The average height of the pack above the sea-level is from six to thirty feet, which is usually estimated as equal to one-seventh of its submerged mass, but is really somewhat less. See subsequent foot-note.

[2] If the thickness here assumed for the ice be considered excessive, let it be assumed to be only one-half that thickness, or seven fathoms thick, or one-quarter of the contents of the basin, which can hardly be taken exception to. The area which might then be melted by the influence of this water alone would be about 10,000 square miles, or less than seven per cent., which is still an insignificant proportion of the whole. Of course a much larger area than this is actually melted every season, but this is due to the direct action of the sun and various other causes quite independent of any warm current through the straits.

The currents through the strait are cool and chiefly tidal, but with a preponderating tendency northward, as before fully set forth.

The currents in the Arctic, north of the straits, are largely dependent on the winds, but have tendencies in certain recognized directions. Nothing in our knowledge of them offers any hope of an easier passage toward the pole, or, in general, northward through their agency. Nothing yet revealed in the investigation of the subject in the least tends to support the widely spread but unphilosophical notion that in any part of the Polar Sea we may look for large areas free from ice.

I have to thank Capt. L. C. Owen, of Vineyard Haven; Dr. Thomas Antisell, of the United States Patent Office; Mr. Marcus Baker, and other members of the United States Coast Survey, for data and assistance of various and most important kinds.

WASHINGTON, *June* 17, 1881.

SUPPLEMENTARY NOTE.

Before the return of the Yukon party to headquarters, the Superintendent of the United States Coast and Geodetic Survey thought best to publish[1] a portion of my preliminary report containing some of the generalizations drawn from the facts herein enumerated.

As some time must necessarily elapse after our return before the data could be published in due official course, it was thought best to publish a portion of the data before that time for the information of hydrographers, the subject being of considerable interest.

By the authority of the Superintendent, and the kind concurrence of the distinguished editor, Dr. E. Behm, a large part of the foregoing matter was made public in the chief geographical journal of Europe, Petermann's Mittheilungen, in a German translation, accompanied by a map and section.[2] Since this was published, a number of interesting data have come to hand, a few of which have been incorporated in the preceding text, while some of quite recent date find a place in this note.

It is believed that whether the conclusions reached by me are considered worthy of adoption or not, at least the facts collected show a sufficient deviation from the commonly received hypothesis to render the latter no longer acceptable without question by scientific hydrographers. To the complacent ignorance which declines to be moved by any accession of knowledge this document is not addressed, nor is it expected to find favor among the few remaining enthusiasts who still cherish a belief in an open polar sea.

Additional observations in the Arctic Sea.—On October 10, 1879, the whaleships Mount Wollaston, Captain Nye, and Vigilant, Captain Smithers, were last seen by Captain Bauldry, of the Helen Mar, in latitude 71° 50′, longitude 173° 45′, in a narrow channel of open water. The Helen Mar barely escaped being frozen in by crowding all sail and forcing her way through the rapidly forming new ice. In all human probability the two vessels which did not escape were frozen in then and there and never got out of the pack.

More than a month earlier the exploring steamer Jeannette, Lieutenant De Long commanding, was last seen (September 2, 1879) by Captain Barnes, of the whaler Sea Breeze, about 80 miles south of Herald Island. The next day her smoke is reported to have been seen 50 or 60 miles farther north, but the accuracy of this observation remains to be established.

In November, 1880, one of the whaleships came ashore on the northern Siberian coast in the vicinity of Cape North (Svernoi), stove, and only prevented from sinking by the ice which still encircled her. Her crew had disappeared, except a few who lay where they had perished, and it is probable that the wreck was that of the Vigilant. Another wreck was reported by natives to have come ashore farther west on the same coast, but this report does not appear to have been definitely confirmed.

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[1] American Journal of Science and Arts, 3d series, XXI, February, 1881, pp. 104–111, with a map. Reprinted as an extract, with cover and title, "Notes on Alaska and the vicinity of Bering Strait."

[2] Hydrologie des Bering-Meeres und der benachbarten Gewässer. Petermann's Geographische Mittheilungen 1881; Heft X, October, pp. 362–380, mit Karte, Taf. 17, und Tabelle; Heft XI, November, pp. 443–448.

We do not know, of course, what had been the wanderings of this hulk before she was stranded, but the resultant of her drift for one year was about 200 miles in a southwest (true) direction. This is in accordance with the direction of the prevalent winds (NE.) of this region, which, as has been previously pointed out, govern the motion of the ice much more than the currents; but it is also evident that no such overmastering northerly current as has been claimed for this region could have been experienced by this vessel.

The Jeannette appears, from the few words yet transmitted from Irkutsk, to have gone into the ice in the vicinity of Wrangell Island soon after she was last seen, and to have drifted at the mercy of wind and tide, solidly beset, until the middle of June, 1881, when, in latitude 77° and longitude 203°, she was crushed and abandoned.[1]

It is uncertain whether she passed north or south of Wrangell Island; the resultant of the whole drift in either case would have been about northwest 500 miles in twenty-one months—the rate not greatly differing from that of the Vigilant, and the direction partly according with the more easterly winds prevailing in the higher latitude traversed by the Jeannette. This would also be in accordance with data as to currents about Herald Island, which are hereinbefore made public. The probability is that, as in the case of the Tegethoff, of the Polaris ice-party, and the floe-party of the second German Polar expedition, the rate and direction of her course varied considerably from time to time, and her track, if platted, would show an extremely irregular line.

A few additional observations have come to hand at the last moment, confirmatory of the position herein taken that the influence of the tides is the most important factor in determining the direction of the current in this part of the Arctic Sea, and showing the evil of too hasty generalizations.

"A long lane of open water, extending at least 100 miles northward from Herald Island, looking like an open river between the banks of ice, which was frozen to the shallow bottom. This stream sets northerly at about two knots." (John Muir, in New York Herald, October 22, 1881).

"Mr. Muir says that off the eastern side of Wrangell Land, and evidently lying between it and another undiscovered shore, is, during the open season, an open lane of water leading to the north as far as the eye can reach, through which a current flows steadily north at the rate of 20 or 25 miles a day. This current flows like a river between two ice-bound banks, the shore-ice on either side appearing not to have been disturbed for years, and possibly for ages. The coast-line of Wrangell Land was visible as far as the eye could reach." (San Francisco Bulletin, October 21, 1881).

"The floe outside of us (the Corwin, when at Wrangell Land) was drifting along shore to the northeast with a powerful current, at a speed of 50 miles a day, the majestic movement being made strikingly manifest by large bergs that were aground in water 60 feet deep, standing like islands, while the main mass of the pack went grating past them." (John Muir, letter of August 17, 1881, in San Francisco Weekly Bulletin of October 26, 1881). In the same letter, the writer speaks of ice a hundred feet thick near Wrangell Island. "The ice (near Point Barrow) is of tremendous thickness, 100 feet or more." (Same, in letter of August 18, 1881, same paper.)

The preceding observations were made and published before it was known that Wrangell Land was a comparatively small island, and the danger of drawing generalizations from too limited experience is illustrated by a comparison of them with the following notes of investigations by Lieut. Robt. Berry, U. S. N., commanding the U. S. S. Rodgers, a little later in the same season:

"Ensign Hunt's party were * * * instructed to encircle the island if possible, for he (Lieutenant Berry) felt pretty certain of its insular character since making our observations from Herald Island of the variable changes of currents and ice," &c. "Your correspondent says it was surprising to see the ice moving constantly to westward along the shore. * * * These rapid changes are most confusing to navigators," &c. (New York Herald, November 8, 1881. Also repeated by Doctor Rosse in letter of September 12, New York Herald of November 18, 1881).

"After cruising along the pack * * * we steamed toward Herald Island for the purpose of making observations upon the current reported to flow in a northwesterly direction * * *. As the fog continued we dropped anchor in 15 fathoms * * * on the afternoon of the 20th (September). During the following twenty-four hours the observations of the current were continued, which indicate a tidal current setting toward the northwest as the water is deepening

[1] Later dispatches, while this is passing through the press, confirm this supposition.

(flood), and toward the southeast when shoaling (ebb), while at high and low water there was no current perceptible. The measurements were made at the surface and at a depth of 10 fathoms." (Report in New York Herald of November 18, 1881).

Of the 6-knot northwesterly current discovered (according to statement of Captain Jacobson, published in New York Herald of November 5, 1881), by Lieutenant Berry, near Wrangell Land, nothing is said (of any such current) in his official report, and the statement doubtless arose from some misapprehension.

As an instance of anomalies of temperature met with in the shallows of the seas of this region, the following extract from a letter of the Herald correspondent on the Corwin, dated September 7, 1881, and published in the Herald of November 21, 1881, is of interest, "Some anomalies in the temperature of the water were noticed; for instance, near Herald Island, on July 30 it was 48° (at the surface) and 49° at the bottom. A few days later, off the Siberian coast, 100 miles southward, it measured 37°, while later, in Bering Sea, over 600 miles to the southward, it fell to 35°. Similar observations have been made by several navigators.

The following remarks by Captain Fisher, of the Sea Breeze (Daily Alta California, San Francisco, September 28, 1881), have had a somewhat extended publication, and may be compared with the previously mentioned details extracted from the "remark-books" of several whale ships, which relate to observations made and recorded at the time of occurrence, and with the conclusions of Lütké and Kellett. "All summer long a strong current sweeps northward through this (Bering) Strait, and it is only in September or October that strong northerly winds affect it. I, myself, have been swept many miles northward in October. * * * Off Point Barrow a 3 or 4 knot current sets regularly along the land northeastward, which does not extend 50 miles off shore. In 1872 the Sea Breeze, while becalmed, drifted 20 miles off shore, entirely out of sight."

It is needless to observe that Captain Fisher never spent "all summer long" in the strait, nor is it probable that he ever spent twenty-four consecutive hours in the same spot in the strait. Doubtless he has observed on various occasions a current similar to that experienced by many other navigators in the strait and at Point Barrow, but there is no doubt that he has overestimated the rate at the latter point, and that his conclusions as to the regularity at both places are based on insufficient evidence. In this, as in many other cases, when observations are recorded by persons unfamiliar with the need of exactitude in such matters, it is probable that currents were noticed only when they forced themselves on the navigator's attention by interfering materially with his reckoning or progress, while the (for our purposes) equally important, but feebler, counter currents passed without notice. I have called attention to the circumstances of this particular statement, not because it is more remarkable or more erroneous than many others, but because upon it and similar slipshod statements persons unfamiliar with the subject have seen fit to base disquisitions on the currents of Bering Strait, and to call in question the result of observations, which, however limited their scope, were made with care, and are entitled, so far as they go, to the confidence and due consideration of hydrographers.

The following extracts from the report of Mr. Marcus Baker, astronomer of the United States Coast and Geodetic Survey party on the U. S. S. Yukon, under my charge, will give a fair idea of the value of the determination, and the manner in which it was made. The full account, by permission of the Superintendent of the Survey, was published in the Bulletin of the Philosophical Society of Washington, vol. IV, pp. 123–133, 1881, with a map. As noted previously, the longitude of the maps accompanying the article in the American Journal of Science, and that in Petermann's Mittheilungen, was necessarily dependent upon the results by one chronometer, the computations not being finished then, and therefore requires a plus correction of about 1′ westerly:

Boundary line between the territory of the United States and of Russia, passing through Bering Strait.

The present boundaries of the Territory of Alaska were defined in the treaty of March 30, 1867, whereby Russian America was ceded to the United States. In that treaty the western boundary, or rather so much of it as is here considered, was defined as follows:

"The western limit, within which the territories and dominion conveyed are contained, passes through a point in Behring's Straits on the parallel of sixty-five degrees thirty minutes north latitude, at its intersection by the meridian which passes midway between the island of Krusenstern or Ignalook, and the island of Ratmanoff or Noonarbook, and proceeds due north without limitation into the same Frozen Ocean."

The longitude of this meridian was very properly left out of the treaty on account of its uncertainty. In order to show our knowledge of the subject at the time of the framing of the treaty, the following table has been prepared from all known authorities upon the subject down to the present time.

The last three determinations entered in the table, it must be borne in mind, have been made since the treaty was drawn up.

Date.	Longitude.	Authority.
	° ′	
1761	155 00	Map published by the Imp. Acad. of Sciences of St. Petersburg.
1778	169 32	Cook's Atlas.
1802	168 48	Billings.
1822	168 59	Kotzebue.
1827	168 55	Beechey. Br. Adm. Ch. No. 593.
1828	168 54	Lütké's Atlas.
1849	168 57.5	Tebenkoff's Atlas.*
1852	168 54	Russian Hydr. Chart No. 1455.
1855	168 48	Rodgers. U. S. N. Hydr. Chart No. 68.
1874	169 04	Russ. Hydr. Chart.*
1878	168 58	Onatsevich.
1880	168 58	U. S. Coast and Geodetic Survey, 1880.

In the case of the two determinations marked with a * the two Diomede Islands are so represented on the chart that the boundary line is tangent to each island.

During the summer of 1880 an attempt was made by the party on board the United States Coast and Geodetic Survey schooner Yukon to make a more careful determination of the longitude of this meridian than had been attempted hitherto. For longitude purposes the party had one pocket and six box chronometers. For determining time the sextant was used, recourse being had to equal altitudes whenever possible.

Plover Bay in Eastern Siberia is about 150 miles to the southward and westward from the Diomede Islands in Bering Strait. This bay was visited by Prof. Asaph Hall, of the United States Naval Observatory, in 1869, for the purpose of observing the total solar eclipse of that year, and, in connection with the eclipse work, Professor Hall made a careful determination of the longitude of his station. After a careful examination of all the longitude determinations known to exist, and because the facilities for determining the longitude of this place by the Yukon party were not sufficient to improve upon the determination by Professor Hall, his results have been adopted, and the longitude of the boundary meridian made to depend upon his determination. * * *

Previous to 1848, Plover Bay, though an extensive arm of the sea running inland some 20 to 25 miles, appears not to have been known. It is not shown upon any map before 1850. In the period from 1845 to 1848 it seems to have been visited by the whalers. The first information touching it upon which we can lay our hands is the report of Commander Moore to the Admiralty, published in the Nautical Magazine, March, 1850. From this it appears that Commander Moore first anchored in Plover Bay October 17, 1848. Later he moved his vessel, the Plover, farther in, and wintered in the harbor named by him Emma Harbor. He remained in Emma Harbor until June 23, 1849. Concerning the scientific or surveying work accomplished in this period of eight months he says: "At intervals Mr. Martin, assisted by Mr. Hooper, made a survey of the place in which I had secured the ship for the winter; which, connected with Mr. Martin's and my own observations on the coast to the westward, will, I hope, give a tolerably correct representation of these shores, and when associated with magnetic observations on every attainable point, will, I trust, meet their lordships' approbation."

The results foreshadowed by this report have not come to light. No map or plan of Emma Harbor or Plover Bay has been published by the British Admiralty Office, and no statement or account of the observations at Plover Bay, if any were made. General Sabine, in his contributions to Terrestrial Magnetism No. XIII, gives some results which he credits to a MS. in the Magnetic Office by Commander Moore, but no *magnetic declination* or *intensities* are given; whence we conclude that no observations, or at least no satisfactory observations therefor were taken. A few results for *dip* are given. The geographical position of the station where the dip observations were taken is given by General Sabine, and this position, if due to Commander Moore, is the earliest determination on record of a position for Plover Bay. The position given probably refers to some point near the northern shore of Emma Harbor. * * *

A rough sketch of Plover Bay was made in 1866, by the exploring parties of the Western Union Telegraph Company, and this sketch was published in 1869 by the Coast Survey. The observations were made by Lieut. J. Davison, of the United States Revenue Marine Service, and the resulting position is stated to depend upon nine observations, referred by a crude triangulation to the mountain Bald Head. * * *

In 1876 the bay was visited by Lieut. M. L. Onatsevich, of the Russian Navy, in the Vsadnik, and a rough survey made of the bay, with a somewhat detailed survey of the anchorages. At the same time astronomical and magnetic observations were made.

In 1877 the Russian Hydrographic Office published several charts embodying the results of Onatsevich's observations, and among them a chart of Port Providence, or "Plover Bay," as it is usually called by the whalemen. * * *

The station occupied by Lieutenant Onatsevich is clearly marked upon his chart, and as we had this chart with us, the place was quite closely identified, probably within a few feet. The attempt was made to have our station identical with his. * * *

Our adopted value of the geographical position of the astronomical station of the United States Coast and Geodetic Survey at Plover Bay, Eastern Siberia, is

$$\text{Latitude,}\quad 64^\circ\ 22'\ 00''\ \pm 6''\quad \text{N.}$$

$$\text{Longitude,}\left\{\begin{array}{l} 173^\circ\ 21'\ 32''\ \pm 6'' \\ 11^h\ 33^m\ 26.1^s \pm 0.4^s \end{array}\right\}\text{W. Gr.}$$

Our station was marked by driving a piece of whale's rib into the ground and piling rocks around it. Being identical with the station of Lieutenant Onatsevich, any one visiting the place will, by the aid of that chart, readily identify it. * * *

The Yukon arrived at Plover Bay at ten in the evening of August 11, 1880. The following day was cloudy in the morning, afterward rained, and later partially cleared up so that we obtained two pairs of equal altitudes of the sun for time, the interval being about three hours. During the afternoon we succeeded in getting four sets of six each of double altitudes of the sun for time. From the equal altitudes, the time of local mean noon by the chronometer was $11^h\ 18^m\ 13.9^s$, and from the double altitudes it was $11^h\ 18^m\ 14.2^s$, a very satisfactory agreement. By means of the intervals the probable errors of each of these determinations have been made out. For the equal altitudes it is $\pm 1.7^s$, and for the double altitudes it is $\pm 0.30^s$, values which may be taken as fairly representative of the different conditions under which the observations were made. From these observations the corrections of our chronometers to Greenwich mean time on August 12 were determined.

On August 14, we sailed from Plover Bay to the eastward and northward, cruising along the Arctic coast as far as Point Belcher, and returning thence passed through Bering Strait to Port Clarence, and afterwards returning to Bering Strait made a landing on the southeastern shore of Ratmanoff, or the Big Diomede Island, on September 10. We came to anchor at seven in the morning, about a mile off shore, and sailed away about three in the afternoon. During our stay observations were made for latitude and time, and all the magnetic elements, declination, dip, and intensity. Of time observations, three sets of six each of double altitudes of the sun were obtained with sextant and artificial horizon. These three sets give as the correction of our "hack," or observing chronometer, to local mean time

$$+1^h\ 03^m\ 26.9^s \pm 0.35^s,$$

this probable error resulting from computing the eighteen observations singly and treating in the usual way. The sky was nearly covered with cumulus clouds, the wind fresh, raw, and chilly, and thermometer 39° Fahr. Near noon the sun appeared again for a short time, and nine pointings were obtained for latitude, giving the following results, each depending upon a single observation:

°	′	″
65	44	54
		50
		38
		54
		44
		52
		53
		60
		65

Mean latitude, 65 44 51 ± 1″.5 N.

Leaving the Diomedes on the afternoon of September 10, we sailed directly for Plover Bay. That night we were stopped by ice, the next day delayed by calms, but on the following day, September 12, we reached our anchorage in Plover Bay a little before noon, just in time to get a good series—39 observations of circummeridian altitudes of the sun for latitude. In the afternoon we obtained a good series of time observations, but the following morning was cloudy. We succeeded, however, in getting four altitudes corresponding to those of the preceding day, thus enabling our time determination to hang upon four pairs of equal altitudes, the epoch being local mean midnight September 12 and 13. The times of local apparent midnight from these four pairs by our "hack" were

h.	m.	s.
11	09	0.2
		1.2
		0.3
		0.7

from which the probable error is found to be ± 0.15ˢ.

For the longitude of our station upon the Big Diomede Island we have, therefore, as follows:

	s.
Plover Bay, 1880, August 12, noon, chronometer correction determined	± 1.7
Big Diomede Island, 1880, September 10, 8ʰ.9, a. m., chronometer correction determined	± 0.35
Plover Bay, 1880, September 12, midnight, chronometer correction determined	± 0.15

By means of the time determinations of August 12 and September 12, the rates of the chronometers are determined, and then the Greenwich time determination at Big Diomede Island, September 10, is made to depend upon the determination at Plover Bay, September 12, and the rates of all the chronometers carried back to September 10, a period of 2.64 days.

The resulting longitude by each chronometer is shown in the following table:

Chronometer.	h.	m.	s.
214	11	16	18.3
866			17.9
1131			18.0
1713			19.0
2535			14.7
311			16.6

Chronometer No. 2535 was our "hack," and 311 a sidereal chronometer, used in making comparisons. Each had rather large rates, that of 2535 exceeding *nine* seconds, and that of 311 *five* seconds per day. The indiscriminate mean of all is 11ʰ 16ᵐ 17.4ˢ. Assigning only half weight to chronometer 2535, the longitude resulting is

11ʰ 16ᵐ 17.7ˢ

The probable error of the Greenwich time at the Diomedes, based upon the agreement of the chronometers, is ± 0.30ˢ.

For the probable error of the longitude, therefore, we have

Probable error of longitude of Plover Bay	$=\pm 0^s.39$
Probable error local time determination, Plover Bay, September 12	$=\pm 0.15$
Probable error local time determination, Diomedes, September 10	$=\pm 0.35$
Probable error Greenwich time determination, Diomedes, September 10	$=\pm 0.36$

Resulting longitude adopted, $11^h\ 16^m\ 17^s.7 \pm 0^s.65$.

The astronomical station of the United States Coast and Geodetic Survey at the mouth of the ravine, on the southeastern shore of the Big Diomede Island in Bering Strait is, therefore, in

	°	′	″	″	
Latitude,	65	44	51		N.
Longitude,	169	04	25 ±	10	W. Gr.

From bearings and angles taken from the astronomical station and from the schooner at anchor, using the distance of the schooner from the station as a base line, together with other bearings taken while in the vicinity of the islands, a sketch of the two islands has been prepared from which it appears that the meridian tangent to the extreme eastern edge of the larger island is 2.1 nautical miles, and the meridian tangent to the extreme western edge of the smaller island is 3.1 nautical miles, east of the astronomical station. The boundary line is to pass midway between these meridians, *i. e.*, the meridian which forms the boundary is 2.6 nautical miles east of the astronomical station.

In latitude 65° 45′, the latitude of the astronomical station, 2.6 nautical miles is equal to 6′ 20″ of longitude, and, deducting this from the longitude of the astronomical station, the longitude of the boundary line is found to be

168° 58′ 05″ W. Gr.

If we assume an uncertainty of one-quarter of a nautical mile, equal in this latitude to 37″ of longitude, in thus transferring the position of the station to the boundary line, and this seems to be quite large enough, we have finally as the longitude of the boundary line between Alaska and Eastern Siberia

168° 58′ 05″ ± 38″

or, in time,

$11^h\ 15^m\ 52^s.3 \pm 2^s.5$ W. Gr.

WASHINGTON, *January* 25, 1882.

REFERENCES TO THE PLATES.

1. Bering Strait. Surface and Vertical Isotherms.

The line of the vertical section and the locality of the eight stations at which serial temperatures were taken are shown in the upper part of the plate. The soundings from Station VII to the shore are from the chart of Beechey, the shoal water on the bars there represented being unsafe for the purposes of navigation. The other soundings are from observations by the party. The temperatures are in degrees of Fahrenheit scale. In the section the vertical isotherms of 40°, 41°, and 42° are somewhat distorted by the eddy caused by the interruption of the current around the Diomede Islands.

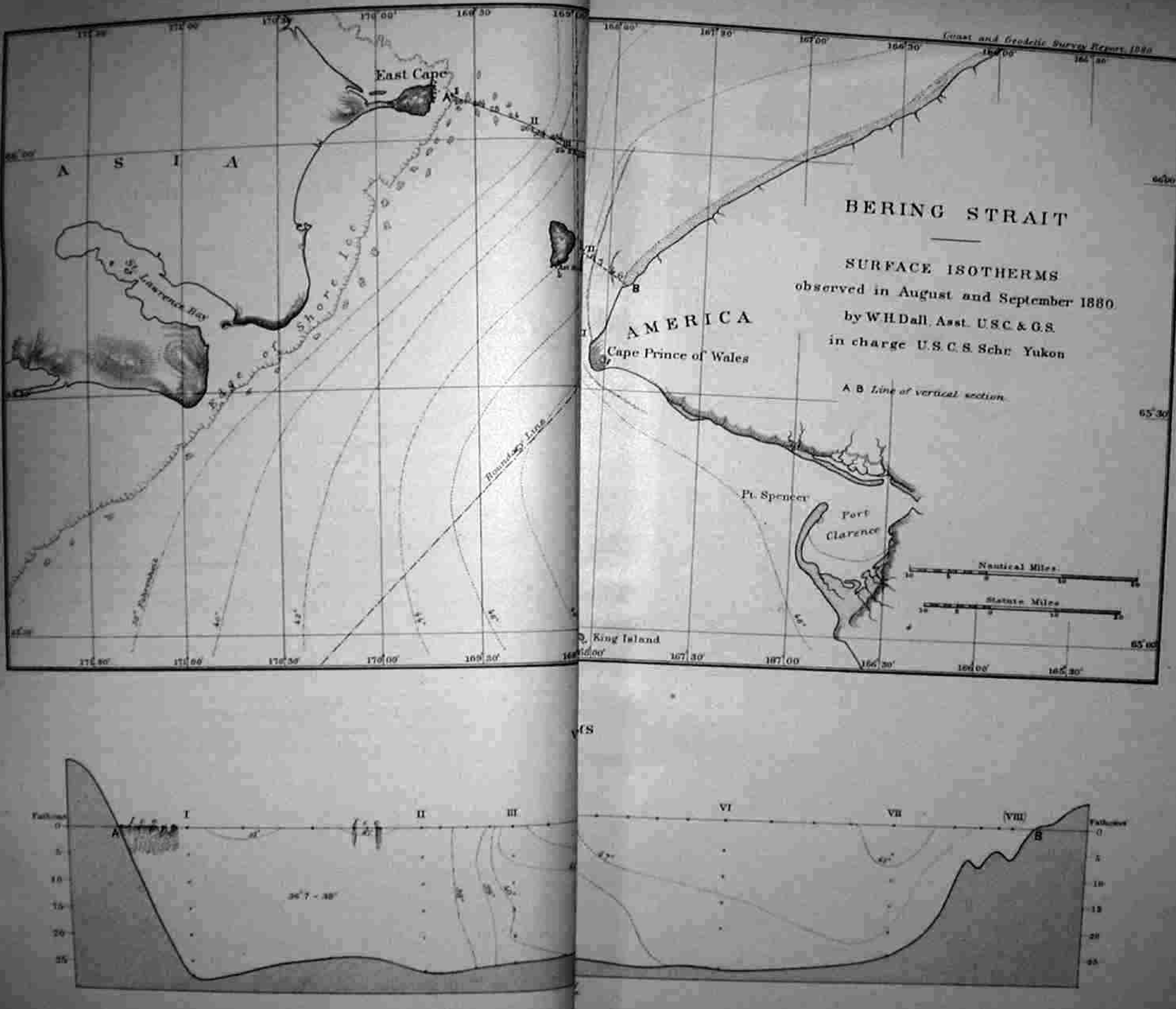
The shorelines of the chart are taken from the charts of Beechey and Tebenkoff, with some corrections resulting from observations by the party on the U. S. S. Yukon.

2. Chart showing direction and strength of currents observed in Bering Sea and adjacent waters by different navigators, and also the approximate borders of the pack ice of Bering Sea in spring for various years.

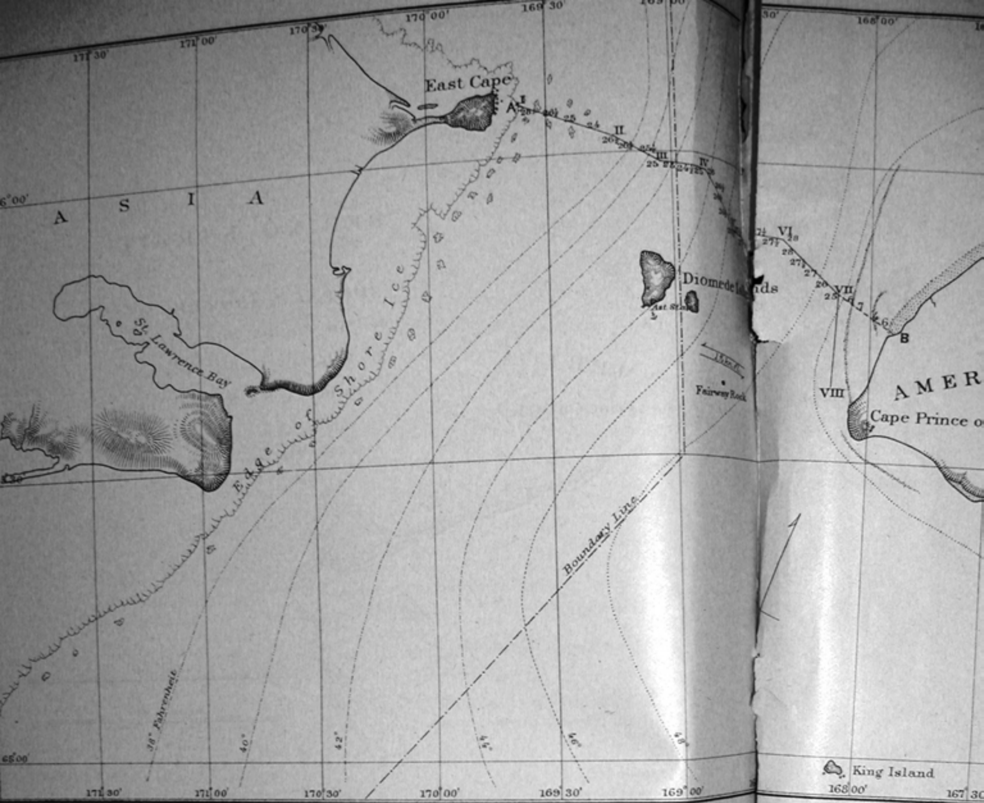
The sources from which this chart has been compiled are referred to in the text. The open water in every case is that part of the sea south and west from the lines indicating the margin of the ice.

The regions usually occupied by ice during the summer in the Arctic Sea, north of Bering Strait, are approximately indicated by the absence of current observations on the map. In cases where the number of observations is too great for them all to be represented on the chart (as in Bering Strait itself), the selection has been determined by attempting to choose characteristic observations which should represent the varying currents reported by different navigators.

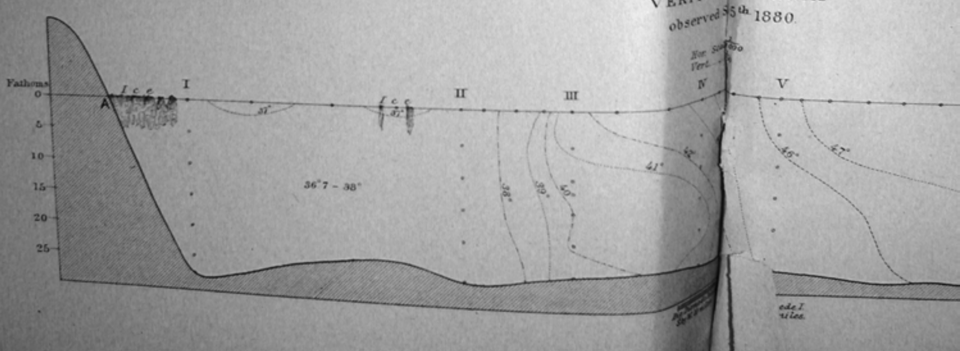
○

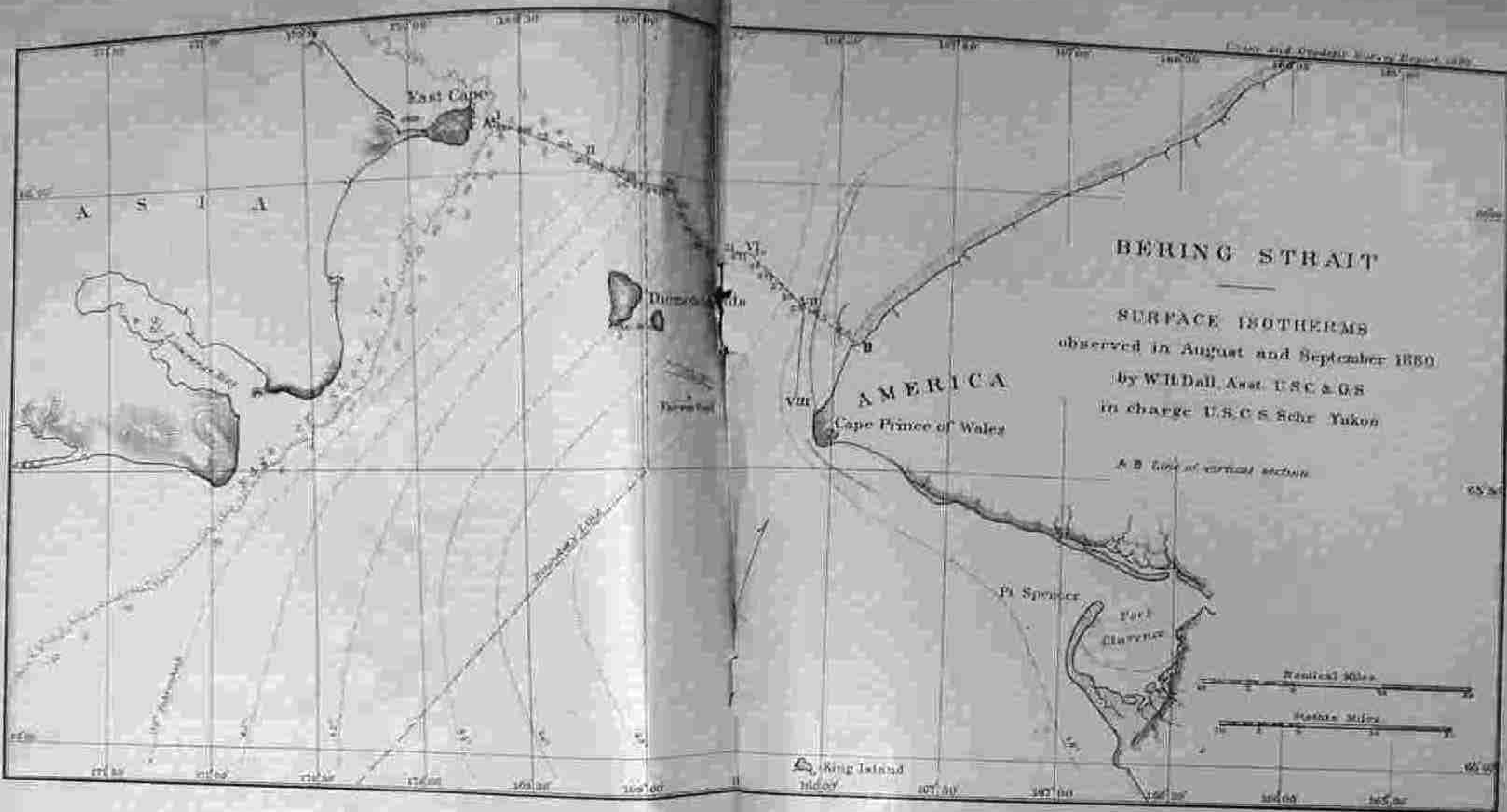

BERING STRAIT
SURFACE ISOTHERMS
observed in August and September 1880
by W.H. Dall. Asst. U.S.C. & G.S.
in charge U.S.C.S. Schr. Yukon
A B Line of vertical section
ASIA
AMERICA
East Cape
St. Lawrence Bay
Edge of Shore Ice
Cape Prince of Wales
Pt. Spencer
Port Clarence
King Island
Boundary Line
Nautical Miles
Statute Miles
66°00'
65°30'
65°00'
170°00'
169°30'
167°30'
167°00'
166°30'
166°00'
165°30'
Fathoms
36°7 - 38°


BERING STRAIT
SURFACE ISOTHERMS
observed in August and September 1880
by W.H. Dall, Asst. U.S.C.& G.S.
in charge U.S.C.S. Schr. Yukon
A B Line of vertical section.
ASIA
AMERICA
East Cape
St. Lawrence Bay
Edge of Shore Ice
Diomede Islands
Fairway Rock
Boundary Line
Cape Prince of Wales
Pt. Spencer
Port Clarence
King Island
Nautical Miles
Statute Miles
66°00'
65°30'
65°00'
171°30'
171°00'
170°30'
170°00'
169°30'
169°00'
168°30'
168°00'
167°30'
167°00'
166°30'
166°00'
165°30'



VERTICAL OTHERMS
observed 5th 1880.




BERING STRAIT
SURFACE ISOTHERMS
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A B Line of vertical section
ASIA
AMERICA
East Cape
Cape Prince of Wales
Pt. Spencer
Port Clarence
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Nautical Miles
Statute Miles


VERTICAL THERMS
1880
Fathoms