his sincere Friend & Servant
The Author

THERMOMETRICAL NAVIGATION.

BEING

A Series of Experiments and Observations,

TENDING TO PROVE,

THAT BY

ASCERTAINING

The RELATIVE HEAT *of the* SEA-WATER

FROM TIME TO TIME,

The Paſſage of a Ship

THROUGH

THE GULPH STREAM,

AND

FROM DEEP WATER INTO SOUNDINGS,

May be discovered in Time to avoid Danger,

ALTHOUGH (OWING TO TEMPESTUOUS WEATHER,)

IT MAY BE IMPOSSIBLE

To heave the Lead or obſerve the Heavenly Bodies.

Extracted from the American Philoſophical Tranſactions. Vol. 2 & 3.

WITH

ADDITIONS AND IMPROVEMENTS.

" God helps them that help themſelves."

Poor Richard.

PHILADELPHIA:

PRINTED AND SOLD BY R. AITKEN, No. 22, MARKET STREET.

1799.

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TO

THOMAS TRUXTON, *Esq.*

COMMANDER

OF THE

American Frigate

CONSTELLATION.

Dear Sir,

THE experiments which induced me to believe that the thermometer might become a valuable nautical inſtrument to diſcover ſoundings having been firſt made on board of a ſhip under your command, the following performances have a natural claim to your patronage; and if the propoſed method ſhould be practiſed on board of the Conſtellation, your example would doubtleſs ſtimulate other navigators, and bring it into general uſe.

The

The public voice, for obvious reaſons, point you out as a character to whom American Improvements in Navigation ought to be dedicated; and I am prompted by perſonal conſiderations to embrace this opportunity of teſtifying the high ſenſe I entertain of your patriotiſm, ſpirit and talents; as a firm friend to your country, a gallant officer, and ſkilful navigator.

I am with great regard,

Dear Sir,

Your ſincere friend and

Obedient ſervant,

JONATHAN WILLIAMS.

PHILADELPHIA, *August* 1, 1799.

The following corrections, which materially affect the sense, should be made before reading.

Introduction, p. vii, line 1, after the words "*twelve hours safe run*" add, "from the Chesapeak northwards—southwards, the distance of "soundings lessens in proportion as the stream runs nearer to the coast."

Introduction, p. ix, line 1, instead of "the influence of the sun, "&c. *is* limited; *and* as it penetrates, &c." read, "the influence of "the sun, &c. *appears to be* limited; *for* as it penetrates, &c."

Introduction, p. x, line 2, instead of "*at* 32, and *must* not that be "ice? read, "*below* 32, and *may* not that be ice?" See note E.

INTRODUCTION.

THE following memoirs may be little known where they originated, owing perhaps to their appearing among a number of transactions which form a volume too bulky to be in many hands. One of them however has had better success in Europe, having been favorably received in England, and translated at Petersburg and Madrid into the Russian and Spanish languages: The latter publication was preceded by a report made by the Director of the Marine Academies in Spain, a translation of which is hereto subjoined.

The present respectable state of the American Navy, both warlike and commercial, induces the author to publish what he has written on this subject, together with the concurrent testimony of others, in one point

of

of view, in hopes that it will be found, on experience, that our coast may be approached with confidence although soundings cannot be obtained, nor the land be seen; and, consequently, that errors in reckoning, may be corrected before danger is near; when (owing to tempestuous weather) it may be impossible to heave the lead, or observe the heavenly bodies. The use of the thermometer in navigation, becomes doubly important, when it is considered that the course towards America is generally westward; so that the corrections of latitude by observation do not determine the distance a ship has to run; and lunar observations are too difficult to be generally understood, even if the moon could be always seen.

Every mariner, when near the coast, feels the importance of speaking a ship from the place to which he is bound; that he may correct the longitude of a long reckoning; by that of a very short one, which cannot be materially wrong if well kept; by this he is enabled to judge of the bearings and distances of the land, and to shape his course accordingly. This is exactly the office the thermometer performs; for it declares by a sudden fall of the mercury, the time when the ship comes into the water between the Gulph Stream and the coast, and, by a further fall, it declares the time when she comes within soundings. In this situation there is, generally,

twelve

twelve hours ſafe run; ſo that inſtead of ſtanding off for fear of being too near in the night, the navigation may be purſued as ſafely as if the lead could be kept going, with the land in view. In the ſeveral inſtances mentioned, of ſhips being a-head of their reckonings, they ought not to be underſtood as implying any reproach to the Captains; for in ſailing along the eddy of the Gulph Stream, or in any other current, in an eaſt or weſt direction, no navigator can expect to be accurate by dead reckoning; ſince currents can not be aſcertained in the uſual way, unleſs the ſea be ſmooth, and that rarely happens. The Captains mentioned in the courſe of the following obſervations were ſkilful navigators, and prudent men; but the more liable the beſt calculators are to err, the more ought we to value any diſcovery which tends to determine the diſtance of danger, before a ſhip is too near to avoid it.

It has been intimated in one of the following memoirs, that the cauſe of this difference in the heat of ocean and coaſt water, may ariſe from the conducting power of rocks, &c. under water. As the ſubject is now reſumed, it may not be amiſs to add ſome reflections on the ſubſtance of that part of the globe, which forms the bottom of the ſea.

We are only acquainted with the ſhell, the mere ſcarf-ſkin of the earth, and the ſea appears to all human efforts fathomlefs; for it is very probable that after founding to a certain depth, the line floats the lead. This fuppofition may ferve to explain a phenomenon mentioned by Captain Ellis, and related by Don Cipriano Vimercati, in the annexed report. After founding to the depth of 3900 feet, Captain Ellis found his thermometer to mark 53°, and when he had 5346 feet of line out, it marked the fame degree: Is it not likely that 5346 feet of line, (to which the water muft offer fome refiftance in its defcent) would overcome the weight of the lead? Befides, Is it not reafonable to fuppofe that water at a great depth is more denfe than at the furface, and confequently more buoyant? For although water is underftood to be incompreffible by the weak means in our power, it cannot be fo confidered by the natural laws of gravity. In this cafe the fea guage might be carried horizontally, draw out more line, and be always in the fame temperature.

As far as we have gone by digging, and as far as we have been able to penetrate into caverns, the temperature is neither more nor lefs than 52 or 53, varying only as the inftruments may be fuppofed to differ from each other. This is the ftate of the thermometer under the obfervatory at Paris, and in the fubterraneous places that have been examined in this country. This is not the cafe in thofe places at fea, where bottom can be reached with a lead. The water at the furface over the banks

of

of Newfoundland, is known by experiment to be 47° in *summer, and it is also known by experiment in summer, that at the depth of only 46 fathoms the entrails of a Cod fish is at† 37° and 16° colder than the water at the surface.

From analogy, then, it seems, that the banks of Newfoundland, at the bottom, may be considered nearly as cold as ice. But let us suppose a depth many times farther than ever was reached with a lead, and that the banks, descend below their summit, as far as terrestial mountains rise above their base; why may not this bottom be ice? Water in its natural state is ice, and every thing that can be made liquid, by the communication of heat, will return to its state of solidity, by the privation of it; hence it has been found by circumnavigators, that the Poles are inaccessible on account of their perpetual congellation; so it is found at the top of the highest mountains, where heat cannot be generated by the reverberation of the sun's rays, that the earth is in a state of perpetual congellation.

The influence of the sun on the surface of the Globe, as we have already seen, is limited; and as it penetrates into the matter of the Globe, it grows weaker and weaker. May we not then suppose a depth where it

* See the annexed chart.

† See appendix, No. 5.

muſt ceaſe? If ſo, is it unreaſonable to ſuppoſe a depth where the ſea would be at 32°? and muſt not that be ice? why, it may be aſked, is the temperature of the earth and ſea, out of ſoundings, ſo uniform at a certain depth, both being permanently 53°? As to the earth ſuch as the ſurface generally is, it may be anſwered, that it is not a very ready conductor of heat; and therefore, may retain the heat at a certain depth, beyond which human efforts cannot reach, and which is comparatively, only ſkin deep. As to the ſea; heated water is lighter than cold, and heat therefore communicates downwards but ſlowly; though as water is a better conductor than common earth, it may go to a greater depth; but as it grows gradually weaker, it muſt ſomewhere ceaſe in the fathomleſs ocean. This is not the caſe in ſoundings, for on the ſuppoſition that the banks and rocks are ſeated on the central matter of the Globe, which may be ſuppoſed to be at leaſt as cold as ice, we have a complete conductor continually robbing the circumjacent water of its heat. Rocks and ſand, it will be remembered, are powerful conductors of heat; more ſo than water, and much more ſo than earth, commonly ſo called, hence it is always found, that after coming within banks, head lands, capes &c. (where there is generally a muddy bottom,) the water is always warmer than on the outſide of a bar. This does not affect the principle of thermometrical navigation, as the land in ſuch caſes is generally in

ſight,

ſight, and if not, the navigator, by previous obſervation, muſt know where he is: It is on the contrary a corroborating proof of the accuracy of a reckoning; for *this inſide* muddy bottom will be expected after gaining the coaſt.

Much has been written about ſubterraneous fires, which apparently contradict the hypotheſis here attempted; but from all we know of them, they may be ſeated much higher than the banks of the ocean. Theſe fires may be conſidered as the effect of a chemical combination in Nature's laboratory; and until the combination takes place, the combuſtible matter may be cold. It is eaſy to conceive that powder may be made as cold as flint and ſteel can be, though it only requires colliſion to produce a ſpark, and a ſpark to produce an exploſion; and who does not know, that very cold quick lime, mixed with very cold water, would ſoon produce a very hot ſubſtance. Whenever therefore, ſuch combinations happen, an earthquake, or an irruption muſt follow; for fire in an active ſtate cannot be confined; and until it becomes active, the heat will not be generated. May we not therefore conclude, that the exiſtence of ſuch matters as produce ſubterraneous fire, is not incompatible with the conjecture that the bottom of the ſea is ice. Is not Hecla a burning mountain, and is it not in Iceland?

The

The foregoing obſervations have been written with ſentiments of great deference and reſpect for the opinions of many learned men, which they apparently contradict; but as many of theſe opinions are diametrically oppoſite to each other, the field of conjecture is ſtill open: It is a common ſoil, which every one has an equal right to cultivate, and the writer has entered it with diffidence. He aſks the reader's indulgence and candour for whatever he cannot approve, but he makes no claim to his belief, till it ſhall be juſtified by time and experience.

JONATHAN WILLIAMS.

EXTRACT

FROM THE

MARITIME OBSERVATIONS

OF

DOCTOR FRANKLIN,

Relative to the GULPH STREAM—*Publiſhed in the ſecond Volume of the* AMERICAN PHILOSOPHICAL TRANSACTIONS. *Page* 315.

Dated at Sea, on board the London Packet, Capt. Truxton, Auguſt 1795.

THIS ſtream is probably generated by the great accumulation of water on the eaſtern coaſt of America between the tropics, by the trade winds which conſtantly blow there. It is known that a large piece of water ten miles broad and generally only three feet deep, has by a ſtrong wind had its waters driven to one ſide and ſuſtained ſo as to become ſix feet deep, while the windward ſide was laid dry. This may give ſome idea of the quantity heaped up on the American coaſt, and the reaſon of its running down in a ſtrong

ſtrong current through the iſlands into the bay of Mexico, and from thence iſſuing through the gulph of Florida, and proceeding along the coaſt to the banks of Newfoundland, where it turns off towards and runs down through the Weſtern iſlands. Having ſince croſſed this ſtream ſeveral times in paſſing between America and Europe, I have been attentive to ſundry circumſtances relating to it, by which to know when one is in it; and beſides the gulph weed with which it is interſperſed, I find that it is always warmer than the ſea on each ſide of it, and that it does not ſparkle in the night: I annex hereto the obſervations made with the thermometer in two voyages, and poſſibly may add a third.* It will appear from them, that the thermometer may be an uſeful inſtrument to a navigator, ſince currents coming from the northward into ſouthern ſeas, will probably be found colder than the water of thoſe ſeas, as the currents from ſouthern ſeas into northern are found warmer. And it is not to be wondered that ſo vaſt a body of deep warm water, ſeveral leagues wide, coming from between the tropics and iſſuing out of the gulph into the northern ſeas, ſhould retain its warmth longer than the twenty or thirty days required to its paſſing the banks of Newfoundland. The quantity is too great, and it is too deep to be ſuddenly cooled by paſſing under a cooler air. The air immediately over

* This is the Journal of the voyage hereto ſubjoined.

over it, however may receive ſo much warmth from it as to be rarified and riſe, being rendered lighter than the air on each ſide of the ſtream; hence thoſe airs muſt flow in to ſupply the place of the riſing warm air, and meeting with each other, form thoſe tornados and water-ſpouts frequently met with, and ſeen near and over the ſtream; and as the vapour from a cup of tea in a warm room, and the breath of an animal in the ſame room, are hardly viſible, but become ſenſible immediately when out in the cold air, ſo the vapour from the gulph ſtream, in warm latitudes is ſcarcely viſible, but when it comes into the cool air from Newfoundland, it is condenſed into the fogs, for which thoſe parts are ſo remarkable.

The power of wind to raiſe water above its common level in the ſea, is known to us in America, by the high tides occaſioned in all our ſea-ports when a ſtrong north-eaſter blows againſt the gulph ſtream.

The concluſion from theſe remarks is, that a veſſel from Europe to North-America may ſhorten her paſſage by avoiding to ſtem the ſtream, in which the thermometer will be very uſeful; and a veſſel from America to Europe may do the ſame by the ſame means of keeping in it. It may have often happened accidentally, that voyages have been ſhortened by theſe circumſtances. It is well to have the command of them.

Obſervations

Observations of the warmth of the sea-water, &c. by Farenheit's thermometer, in crossing the Gulph Stream; with other remarks made on board the Pennsylvania Packet, Capt. Osborn, bound from London to Philadelphia, in April and May, 1775.

Date.	Hour.	Temp. of Air.	Temp. of Water.	Wind.	Course.	Distance.	Latitude N.	Longitude W.	Remarks.
April 10			62						
11			61						
12			64						
13			65						
14			65				° ′	° ′	
26		60	70		W b S		37 39	60 38	Much gulph weed: saw a whale.
27		60	70	S S E	W b S		37 13	62 29	Colour of water changed.
28	8A.M.	70	64	S W	W N W		37 48	64 35	No gulph weed.
—	6P.M.	67	60			34			Sounded, no bottom.
29	8A.M.	63	71	N	W	44	37 26	66 0	Much light in the water last night.
—	5P.M.	65	72	N E	W b S	57			Water again of the usual deep sea colour, little or no light in it at night.
—	11 dit.	66	66	NWbN					
30	8A.M.	64	70	N E	W b N	69			
—	12	62	70		E b S	24	37 20	68 53	Frequent gulph weed, water continues of sea colour, little light.
—	6 P.M.	64	72	E S E	W b N	43			
—	10 dit.	65	65	S		25			Much light.
May 1	7A.M.	68	63			60			Much light all last night.
—	12	65	56	S S W	W N W	44	38 13	72 23	Colour of water changed.
—	4P.M.	64	56		W b N	21			
—	10 dit.	64	57	S W	W N W	31			Much light.
2	8A M.	62	53			18	38 43	74 3	Much light. Thunder-gust.
—	12	60	53	W S W	N W	18			
—	6P.M.	64	55	N W	W S W	15			
—	10 dit.	65	55	N b W	W b N	10			
3	7A.M.	62	54			30	38 30	75 0	

Observations of the warmth of the sea-water, &c. by Fahrenheit's Thermometer; with other remarks made on board the Reprisal, Captain Wycks, bound from Philadelphia to France, in October and November, 1776.

Date.	Hour A. M.	Hour P. M.	Temp. of Air.	Temp. of Water.	Wind.	Course.	Distance.	Latit. N	Long. W	Remarks.
Octo. 31	10		76	70	S S E	E b S	135	38 12	70 30	Left the capes Thursday night, October 29, 1776.
—		4		71						
Nov. 1	10			78	W S W	E ½ N	109	No ob.	68 12	
—		4	71	81						
2	8		71	75	N					
—	12			78			141	ditto.	65 23	
—		4	67	76						Some sparks in the water these two last nights.
3	8			76	N W	ESE ½ E				
—	12			76		E b S	160	37 0	62 7	
—		4	70	76						
4	9		68	76		N b E				Ditto.
—		1		76			194	36 26	58 8	
—		4	68	76						
—		8		78						
5	8		68	76		N E				Ditto.
—	12		70	75			163	35 21	55 3	
—		4		75						
—		8		75						
6	8			76	E b N	S 50 E				
—	12			77			75	35 33	53 52	
7	8			78	S E b E	N 30 W				
—	12			77			108	36 6	52 46	
—		4		77						
8	9		75	77	S b E	N 49 E				
—	12			77			175	38 2	50 1	
—		4		77						
9	9		75	77						
—	12		75	70	S W	N 33 E	175	39 39	46 55	

(CARRIED OVER.)

Observations of the warmth of the sea-water, &c. by Fahrenheit's Thermometer; with other remarks made on board the Reprisal, Captain Wycks, bound from Philadelphia to France, in October and November, 1776.

(CONTINUED FROM THE PRECEDING PAGE.)

Date.	Hour A. M.	Hour P. M.	Temp. of Air.	Temp. of Water.	Wind.	Course.	Distance.	Latit. N.	Long. W.	Remarks.
Nov. 9		4		71						
10	8		70	68						
—	12			64	E	N 17 E	64	40 39	46 27	
11	8			63						
—	12			61	S E	N 8 E	41	41 19	46 19	
12	8		56	59						
—		4		69	N N W	N 80 E	120	41 39	43 42	
13	all	day		68	E	S 82 E	69	41 29	42 10	
14	8		70	70		N 74 E	111	42 0	39 57	
—		Noon		72	E S E					
—		4		71						
15	8		61	69						
—		Noon		68	W S W	N 70 E	186	43 3	33 51	
—		4		67						
16		Noon	65	67	S W	N 67 W	48	43 22	34 50	
—		4		63						
17	8			63	E S E	N 19 E	56	44 15	.34 25	
18	all	day		65	S b W	N 75 E	210	45 6	29 43	Some gulph weed.
19		Noon	65	64	S W	N 80 E	238	45 46	24 2	
20	8			62	N	S 80 E	155	45 19	20 30	
—		4		60						
21	9			62	S	N 88 E	94	45 22	18 17	
22	10		60	62	S S W	S 89 E	133	45 19	15 19	
23		Noon		61	W S W	S 86 E	194	45 6	10 35	
24		do.		60	N N E	N 78 E	191	45 46	6 10	
25		do.		60	N E	S 76 E	125	45 4	3 23	
26		do.	56	60	E	N 73 E	31	45 13	2 20	
27		do.		58						Soundings off Bellisle.
28		do.	54	56						

Dates.	Latit. N.	Long. W.	Therm. A.M. Air.	Therm. A.M. Water.	Therm. P. M. Air.	Therm. P. M. Water.	Winds.	Course.	Dist.	Variation of the Needle.	Therm. Noon. A.	Therm. Noon. W.
July 29			62	57			*These are taken on an average of 24 hours.*					
30			62	58	63	58						
31			60	58	62	62			Miles.	West.		
Aug. 1	49 15	4 15	63	62	60	64	East	S W ½ W	60	22° 0		
2	48 28	8 58	64	64	64	63	E S E	W b S ½ S	174			
3	47 0	12 13	60	67	omitted.		N E	S W b W	160			
4	45 0	15 43	66	66	do.	66	N WbW	S W ½ W	190			
5	43 5	17 25	67	65	65	68	N E	S W b S	131	20 0		
6	41 3	19 44	70	68	71	69	N E	S W ½ S	166	16 30		
7	38 45	21 34	70	70	68	70	N E	S S W ¾ W	165	11 30		
8	36 42	23 10	72	71	73	72	N E	S S W ¾ W	149	11 15		
9	35 40	25 40	73	73	73	74	N E	W S W ¼ S	137			
10	35 0	27 0	71	73	77	75	N W	W S W ¾ S	76			
11	33 51	28 42	74	74	76	77	North	S W ¾ W	112			
12	33 30	31 30	76	75	76	76	North	W ¾ S	143			
13	33 17	33 32	76	76	78	77	N E	W ½ S	103		77	78
14	33 22	34 31	76	76	81	79	S S E	W ½ N	50		81	79
15	33 45	35 0	78	79	79	78	W N W	S W ¼ W	35		79	79
16	34 14	35 30	79	78	81	80	West	N W ½ N	38		81	80
17	35 37	36 4	80	79	80	78	W S W	N N W	75		80	78
18	36 7	37 16	80	78	omitted.		N WbW	W N W ½ N	65		80	79
19	36 38	38 0	78	77	78	77	W S W	N W ½ W	49		79	77

N. B. Longitude is reckoned from London, and the Thermometer is according to Fahrenheit.

OBSERVATIONS.

(CARRIED OVER.)

1785. *A Journal of a Voyage from the Channel between France and England, towards America.*

(CONTINUED FROM THE PRECEDING PAGE.)

Dates.	Latit. N.		Long. W.		Therm. A.M.		Therm. P.M.		Winds.	Course.	Dist.	Variation of the Needle.			
					Air.	Water.	Air.	Water.							
Aug 20	37	38	38	6	78	76	omitted.		West	N ¼ W	62			77	75
21	36	15	38	26	73	74	78	76	W N W	S b W	82			77	75
22	35	40	38	44	77	76	80	77	W b S	S S W	38			80	77
23	35	35	40	52	79	77	78	75	North	W ¼ S	100			omitted.	
24	35	12	41	31	75	73	75	74	W N W	S W b W	41			75	74
25	35	40	42	33	79	76	79	76	W b N	W N W ¾ N	60			80	76
26	35	30	42	44	79	76	80	76	S W b W	S W ½ S	14			80	76
27	35	14	43	23	79	77	81	79	West	W S W ¼ S	38			81	78
28	34	23	44	0	78	76	78	78	N N E	S W b S	60			78	78
29	34	12	45	52	77	78	78	78	N E	W ¼ S	94	8	0	79	78
30	34	5	48	31	78	78	78	78	East	W ½ S	134			78	78
31	34	20	51	4	80	79	81	79	East	W ¾ S	129			80	80
Sept. 1	34	20	52	47	81	78	omitted.		S S W	W ¼ N	86			83	80
2	34	55	55	12	81	80	83	80	S W	W b N ½ W	125			83	80
3	35	30	57	24	83	80	83	80	S W b S	W b N ¼ N	114	6	0	84	81
4	35	50	59	1	82	80	83	80	S W ½ W	W b N ¼ N	82			83	81
5	35	55	61	0	81	81	82	80	S S W	W ¼ N	96			82	81
6	36	20	62	30	80	80	79	81	N W b N	W b N	75			78	80
7	34	50	63	10	87	81	78	80	N W b W	S S W	86			78	81
8	34	45	64	40	75	79	75	79	North	W ¼ S	74			75	79
9	35	43	66	42	75	79	77	73	N E	W N W	108			78	80
10	37	20	68	40	77	73	77	70	E N E	N W	126			78	72

N. B. Longitude is reckoned from London, and the Thermometer is according to Fahrenheit.

OBSERVATIONS.

July 31. At one P. M. the Start bore WNW diſtant ſix leagues.

Auguſt 1. The water appears luminous in the ſhip's wake.

——2. The temperature of the water is taken at eight in the morning and at eight in the evening.

——6. The water appears leſs luminous.

——7. Formegas SW diſtant 32½ deg. St. Mary's SW¼S 33 leagues.

——8. From this date the temperature of the water is taken at eight in the morning and at ſix in the evening.

——10. Moon light, which prevents the luminous appearance of the water.

——11. A ſtrong ſoutherly current.

——12. Ditto. From this date the temperature of the air and water was taken at noon, as well as morning and evening.

——16. Northerly current.

——19. Firſt ſaw gulph weed.

——21. Southerly current.

——22. Again ſaw gulph weed.

——24. The water appeared luminous in a ſmall degree before the moon roſe.

——29. No moon, yet very little light in the water.

——30. Much gulph weed to-day.

——31. Ditto.

Sept. 1. Ditto.

——2. A little more light in the water.

——4. No gulph weed to-day. More light in the water.

——5. Some gulph weed again.

——6. A little light in the water. A very hard thunder-guſt in the night.

——7. A little gulph weed.

——8. More light in the water. Little gulph weed.

——9. Little gulph weed. Little light in the water laſt evening.

——10. Saw ſome beds of rock-weed; and we were ſurprized to obſerve the water ſix degrees colder by the thermometer than the preceding noon.

This day (10th) the thermometer ſtill kept deſcending, and at five in the morning of the 11th, it was in water as low as 70, when we ſtruck

foundings.

soundings. The same evening the pilot came on board, and we found our ship about five degrees of longitude a-head of the reckoning, which our Captain accounted for by supposing our course to have been near the edge of the gulph stream, and thus an eddy-current always in our favor. By the distance we ran from Sept. 9, in the evening, till we struck soundings, we must have then been at the western edge of the gulph stream, and the change in the temperature of the water was probably owing to our suddenly passing from that current, into the waters of our own climate.

On the 14th of August the following experiment was made. The weather being perfectly calm, an empty bottle, corked very tight, was sent down 20 fathoms, and it was drawn up still empty. It was then sent down again 35 fathoms, when the weight of the water having forced in the cork, it was drawn up full; the water it contained was immediately tried by the thermometer, and found to be 70, which was six degrees colder than at the surface: The lead and bottle were visible, but not very distinctly so, at the depth of 12 fathoms, but when only 7 fathoms deep, they were perfectly seen from the ship. This experiment was thus repeated Sept. 11, when we were in soundings of 18 fathoms. A keg was previously prepared with a valve at each end, one opening inward, the other outward; this was sent to the bottom in expectation that by the being both open when going down, and both shut when coming up, it would keep within it the water received at bottom. The upper valve performed its office well, but the under one did not shut quite close, so that much of the water was lost in hauling it up the ship's side. As the water in the keg's passage upwards could not enter at the top, it was concluded that what water remained in it was of that near the ground, and on trying this by the thermometer, it was found to be at 58, which was 12 degrees colder than at the surface.

This last Journal was obligingly kept for me by Mr. J. Williams, my fellow passenger in the London Packet, who made all the experiments with great exactness.

MEMOIR

MEMOIR *of* JONATHAN WILLIAMS,

On the uſe of the Thermometer, in diſcovering Banks, Soundings, &c.

Read Nov. 19, 1790. I HAVE hitherto delayed making a public communication of my ſea journals, from an apprehenſion of being thought too forward in calling the attention of the Philoſophical Society to the ſubject of them; but being impreſſed with a belief, that by noticing the changes in the heat of the ſea water, a navigator might always know when he is in ſoundings, and thereby be able to eſcape the dangers ariſing from unexpected currents, and erroneous reckoning, I cannot think myſelf juſtifiable in longer heſitating to ſubmit my remarks to their learned and judicious examination.

This ſenſe of duty is ſtrengthened by the recollection of many melancholy inſtances where mariners, in full confidence of being at a diſtance from land, have, with crouded ſails, ruſhed on to deſtruction; and I was once within half an hour's time of being ſhipwrecked on the rocks of Scilly, when the return of day preſented to our view the frightful rocks we had ſo narrowly eſcaped.

If it ſhould be found that the uſe of the thermometer would be an improvement in the art of navigation, I ſhall be abundantly rewarded by the reflection of having contributed to the ſervice of humanity, which is the common cauſe of all men. If it ſhould, on the contrary, appear

appear that I am miſtaken, either in the facts or the concluſions deduced, I truſt that the deſire of doing good, the only motive that actuates me, will meet with indulgence from every candid mind.

In the months of Auguſt and September, 1785. I was a fellow paſſenger with the late Doctor Franklin from Europe to America, and made, under his direction, the experiments mentioned in his deſcription of the courſe of the gulph ſtream, an account of which was annexed to his maritime obſervations, and publiſhed in the Philoſophical Tranſactions Vol. II. page 328, I then determined to repeat theſe experiments in my future voyages. Accordingly on a paſſage from Boſton to Virginia in October 1789, I kept a journal of the heat of the air and water at ſun riſe, noon and ſun ſet; I then noticed that the ſea-water out of ſoundings was about ten degrees warmer than that on the coaſt, and it very naturally occurred to me that the thermometer might become an uſeful nautical inſtrument to indicate an approach to the ſhore. I thought it prudent, however, to keep this idea to myſelf till after I had made a courſe of fair and repeated experiments, which I accordingly did during four paſſages, 1ſt, the one from Boſton to Virginia abovementioned, 2d, from Virginia to England, 3d, from England to Halifax, and 4th, from Halifax to New-York. By conſulting theſe journals and the obſervations made at the dates written, together with

with the tracks of the ſhip's way marked on the chart annexed, it will not only appear that Doctor Franklin's account of the warmth of the gulph ſtream has been amply confirmed, but alſo that banks, coaſts, iſlands of ice, and rocks under water, may be diſcovered when not viſible, and when the weather is too boiſterous to ſound, with no other trouble than dipping the thermometer into the ſea water. It is well known to ſailors, that the water on the banks of Newfoundland is cold, but as they only try this, with the hand, their remarks are contradictory owing to the varied temperature of the hand, and I never heard of any further application of what they think merely a mattter of curioſity. Doctor Franklin's obſervations had the knowledge of currents for their object, and this extenſion of his diſcovery did not occur; but as I am indebted to his inſtructive converſation and example, for my inducement to purſue philoſophical reſearches when in my power to do ſo, he may be conſidered as the original cauſe of what is now preſented for examination.

It will be proper to ſuſpend any concluſions till the journals have been attentively conſidered, but as a guide to the object of them, it may not be amiſs to ſtate ſuch facts as it is preſumed the experiments have a tendency to eſtabliſh.

1. The water over banks is much colder than the water of the main ocean, and it is more cold in proportion as it is lefs deep.

2. The water over fmall banks is lefs cold than that over large ones.

3. The water over banks that are near the coaft is warmer than that over banks far diftant, but it is colder than the adjacent fea.

4. The water over banks of the coaft, *i. e.* thofe immediately connected with the land above water, is warmer than that over thofe which admit deep water between them and the coaft; but ftill it is colder than the adjacent fea.

5. The water within capes and rivers does not follow the above rules; it being lefs agitated, and more expofed to the heat of the fun, and to receive the heat from the circumjacent land, muft be colder or warmer than that in foundings without, according to the feafons, and temperature of the atmofphere.

6. The paffage, therefore, from deep to fhoal water may be difcovered by a regular ufe of the thermometer, before a navigator can fee the land; but as the temperature is relative, no particular degree can be afcertained as a rule and the judgment can only be guided by the difference. Thus in Auguft I found the water off Cape Cod

Cod to be 58°. by Fahrenheit, and at ſea it was 69°; in October the water off Cape Cod was 48°. and at ſea it was 59°. This difference was equally a guide in both caſes, though the heat was different at different ſeaſons.

I do not preſume to ſay what is the cauſe of this difference of heat between the ſea and bank water, but if a navigator were to obſerve it when near an iſland of ice, he would very naturally ſay that the ice conducted the heat from the circumjacent water, and left it colder than that at a diſtance. And as it is well known that ſtones and ſand are great conductors of heat, it ſeems probable that banks alſo conduct the heat from the adjacent water, though not ſo rapidly as ice. The heat of the water may indeed be ſuppoſed to ſeek its equilibrium, but as long as iſlands of ice and banks continue to conduct, there muſt be ſome difference, and this it is, which, by attention, may be made a faithful ſentinel to give an alarm when danger is near.

I have thought it my duty to preſent my journals as they were written at ſea, to avoid the ſuſpicion of having added any thing from the ſuggeſtions of the imagination. While this will be received as a circumſtance favourable to the truth of them, I hope it will alſo operate as an apology for their imperfections.

The

The journal A. from Boston to Virginia, shews that the water on the coast of Massachusetts, was at 48°; at sea between that coast and the stream, 59°; in the gulph stream at its edge, 67°; between that and the coast of Virginia farther southward, 64°; and in soundings on that coast, 56°. At that season (in October, just after the warm weather) the water grew warmer as we approached the land.

The journal B. from Virginia to England, shews that in December, the water in the coast of Virginia was at 47°; between the coast and the stream, 60°; and in the stream, 70°. This current being in our favour, we did not avoid it, and the water continued with little variation, till we came near the banks of Newfoundland, when the thermometer fell from 66 to 54; passing these, it rose again to 60°. and then continued a very gradual descent as we went to the northward, till we struck soundings, when it was at 48°.

It may be here observed, that the decrease in the heat of the water was so gradual as to give but one degree in a day's run, while in going to, or coming from the coast of America, the thermometer will alter 8 or 10 degrees in a few hours run. It is well known, by sounding, that the English coast extends with a very gradual descent to a great distance. It is also known that the American coast does not extend very far, and the water is suddenly deep. Let these facts be compared with the

changes

changes in the thermometer, on the two coafts, and they will agree with each other and confirm what has been faid about the ufefulnefs of that inftrument.

It may be obferved in Doctor Franklin's journal on board of the Reprifal, that in November 1776, when near the banks of Newfoundland, his thermometer fell ten degrees, though confiderably to the Southward of them, and after paffing them, it rofe nearly to its former ftate: the Doctor did not make any obfervation on this circumftance; but it agrees with my journal, in nearly the fame place, made nine years afterwards.

The journal C. from England to Halifax, fhews the changes in the heat of the water as we failed over banks and deep water alternately, with an accuracy that I confefs, exceeded my expectation, the land appearing as the thermometer indicated our approach to it.

The journal D. from Halifax to New-York not only fhews the variety of depths we paffed over, but indicates the inner edge of the gulph ftream. As by the thermometer and foundings it appeared to me that the fhip was a-head of the reckoning, I made allowances for the eddy current of that ftream in our favour, and comparing thefe with the chart, I noted in the journal, the longitude I thought we were in, under that calculated by the fhip's officers: what encouraged this opinion,

was

was the difagreement between the foundings by the lead, and thofe marked on the chart in the places where, by the common reckoning, the fhip was fuppofed to be; while upon the other fuppofition they both agreed. When we made the land this latter reckoning turned out accurate, and I won a fmall bet of the Captain who candidly acknowledged the ufefulnefs of the thermometer, and declared that he would in future, always have one on board.

Finding the coaft of America to grow fuddenly deep as it approaches the gulph ftream, and finding continued foundings from Cape Sable to New-York, I am induced to believe that it has its fhape according to the courfe of that current, and that it is connected in a fweep from the banks of Newfoundland to Florida, the various banks between being only eminences of the coaft. If my apprehenfion of the accuracy of thermometrical obfervation is well founded, it would be an eafy thing to make a general furvey of the coaft under water, more particularly than has hitherto been, or could be done by founding.

On the chart annexed, the tracks of my feveral paffages are marked with the daily heat of the water in degrees according to Fahrenheit, by which the variations on the approach to land may be feen at one view. The edge of the gulph ftream is alfo traced according to the

experiments

experiments as far as the banks of Newfoundland: how far it runs to the eaſtward I do not pretend to ſay, but having found a current in the natural direction of its ſweep among the weſtern iſlands, I am inclined to think it extends ſo far, before it turns off to the ſouthward. It may be obſerved, however, that as this ſtream, like all other currents, muſt be affected by tempeſts on either ſide; it may, as theſe prevail, run ſomewhat nearer or ſomewhat farther diſtant from the coaſt.

In confirmation of what has been ſaid about the eddy current of the gulph ſtream, I have extracted from the journal of an officer belonging to the Britiſh ſhip of war Liverpool, ſome obſervations which deſcribe this eddy on both ſides of the ſtream,* two other extracts from the ſame journal† deſcribe a current among the weſtern Iſles, which is perhaps the gulph ſtream, then turning to the ſouthward. This journal was communicated to me by Capt. Schuyler of the Britiſh packet, on board of which I made my laſt experiments and obſervations.

‡ In addition to my journals, I have ſubjoined an account of ſome experiments on fiſh, which ſhow that their animal heat was 16 degrees colder than the water at the ſurface; from which it may be ſuppoſed that the water at bottom is in proportion colder than that above. It may

* Appendix No. I.

† Appendix No. II. and III.

‡ Appendix No. IV.

may be naturally ſuggeſted, that trying the heat of the water at the ſurface, (the only way in one's power when ſailing rapidly through it,) is too inaccurate to be depended on ſince the ſurface muſt be heated by the atmoſphere. To this it may not be amiſs to anſwer.—1. That by repeated experiments at the depth of 30, 40, and *60 fathoms*, I have found the water below, out of ſoundings, to be no more than ſix degrees colder than that above; and at four or five fathoms deep, when the ſea was agitated, there was no difference worthy notice. 2. When the ſea is not agitated and the ſurface, by being expoſed to a hot ſun, is warmer, the weather being calm, it is eaſy to have water from a conſiderable depth; this I have found to make a difference of one or two degrees only, and it is eaſy to make the allowance. 3. The difference of heat which marks an approach to land is ſufficiently ſenſible at the ſurface for the purpoſe of giving notice of danger. I have generally found it to be 6°. in three hours run, and long before we were near enough to be in danger. Upon the whole, as it is fact, and not argument which ſhould inſpire belief, I wiſh every doubting navigator to endeavour to confute me by making other experiments, and thereby, if he can, detect the fallacy of mine.

JONATHAN WILLIAMS.

These Journals, as they were presented to the society, contained the experiments in detail; but it was thought expedient in the publication of them, to suppress all those, which, by having nearly similar results, may be considered as repetitions of the preceding, or gradual approaches towards the succeeding ones. The reader may depend, however, that nothing is altered, and that the heat of the water was taken at least three times every day during all the voyages, and when passing over banks, or approaching the coast, almost every hour, as well by night as by day. N. B. The Thermometer used was on Fahrenheit's scale.

A. A Thermometrical Journal of the temperature of the atmosphere and the sea, on a passage from Boston towards Virginia, on board of the schooner America, Capt. Brace.
By Jonathan Williams.

Dates.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
1789.					
Oct. 11	Sun set.	42° 5′	69° 40′	58	48
12	Sun rise.			50	54
	Noon.	40 23	68 46	50	52
	Sun set.			52	[illegible]
13	Sun rise.			57	65
	Noon.	38 40	70 35	60	67
	Sun set.			64	66
14	Sun rise.			65	62
	Noon.	38 46	71 58	69	61
	Sun set.			66	64
15	Sun rise.			70	65
	Noon.	38 25	73 10	67	64
	Sun set.				
16	Sun rise.			59	63
	Noon.	37 45	73 40	60	64
	Sun set.			61	64
17	Sun rise.			62	64
	Noon.	37 36	74 1	66	64
	Sun set.			63	64
18	Sun rise.			60	57
	Noon.	37 34	74 45	60	56
	Sun set.			50	57
19	Sun rise.			56	60
	Noon.	37 4	76 4	58	58

NOTES.

October 11—sun set. Sailed at 8 A. M. from Boston; and at sun set, we were off Cape Cod, which is in lat. 42. 5. N and long. 69. 40. W from London. See John Hamilton Moore's practical navigator.

October 12—noon. No fymptom of the gulph ftream in this longitude.

—fun fet. We now probably approach the gulph ftream, the water being 7°. warmer than at noon.

October 13—fun rife. At midnight, we had made nearly SW courfe diftant 80 miles; the water then was at 60.

October 13—noon. We are now probably within the ftream, the water being 15°. warmer than yefterday at this time.

October 13—fun fet. We had a good obfervation at noon; we are probably ftill in the ftream, the water continuing warm.

October 14—fun rife. We have made about a weft courfe during the night, diftant about 52 miles.

October 14—noon. It appears by obfervation, that we are 18 miles north of our reckoning; hitherto our reckoning has appeared accurate.

October 14—fun fet. The water yefterday noon was 6°. warmer than at the fame time to-day, yet the air was 9°. warmer to-day than at the fame time yefterday. By this difference of temperature, and by the lofs of 18 miles diftance, it is probable that we were within the ftream yefterday, and carried to the northward by its current; thus it appears, that in the lat. 38°. 43′. N, the weftern edge of the ftream extends as far as long. 71. 15. W, which is the mean between yefterday and to-day's reckoning.

October 16—noon. I fent a well corked bottle 30 fathoms deep, and drew it up empty. I fent it again 60 fathoms deep, and drew it up full, this water was then taken at a depth fomewhere between 30 and 60 fathoms, and it was by the thermometer at 58°. fix degrees colder than at the furface, 64°.

October 17—noon. Obferve how regular the temperature of the water has been during four days, *i. e.* fince leaving the ftream.

October 18—fun rife. By the fudden change in the heat of the water, I fufpect we are drawing near foundings.

October 18—noon. Sounded, but no bottom, with 60 fathoms of line. No obfervation for the firft time fince we have been out.

October 18. At 8 P. M. got bottom 33 fathoms, heat of water 56°. At midnight 21 fathoms.

October

October 19. At 2 A. M. 18 fathoms, at 4 A. M. 14 fathoms, at 8 A. M. made Cape Charles, WNW, at 9 Cape Henry, W by SW off Willoughby's point, in the mouth of James river. Cape Charles, by John Hamilton Moore's practical navigator, is in lat. 37°. 9'. N long. 75°. 50'. W. We are now about 16 miles within the Cape, thus the reckoning proves to be very accurate.

N. B. The water appears somewhat warmer in shoal than in deep soundings, within the Cape.

B. A Thermometrical Journal of the temperature of the atmosphere and the sea, on a passage from Virginia to England, on board of the brig Mercury, Captain Thompson.

By JONATHAN WILLIAMS.

Dates.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
1789.					
Nov. 30	Noon.	37° 0'	75° 43'	42°	47°
	Sun set.			42	50
Dec. 1	Sun rise.			42	54
	Noon.	36 30	70 12	44	60
	10 P. M.			50	70
2	Sun set.	36 30	68 47	58	67
3	Noon.	36 30	65 39	60	70
	Sun set.			63	72
4	Sun rise.			59	69
	Noon.	37 3	62 13	60	68
	Sun set.			59	67
5	8 A. M.			56	66
7	Sun set.	38 7	54 4	66	68
8	Noon.	38 43	52 12	68	66
9	Sun rise.	39 56	48 52	66	62
10	Sun rise.			46	54
	Noon.	40 10	46 12	54	60
	Sun set.			52	62
11	Noon.	40 44	43 39	56	60
13	Noon.	42 22	39 35	62	59
14	Sun rise.	43 54	36 4	61	58
15	Sun rise.			58	57
	Noon.	44 58	32 27	60	55
16	Noon.	45 58	29 0	56	53
22	Sun rise.	48 22	21 2	48	50
24	Midnight.	49 48	13 54	46	49
25	Noon.	49 40	10 14	48	48
27	Noon.	49 56	3 32	58	49
28	Noon.	50 24	2 22	50	49

NOTES.

NOTES.

Nov. 30. Sailed this morning from Hampton Road; at noon Cape Henry bore West, distant 2 leagues.

Dec. 1. Entered the Gulph stream, at 10 P. M.

December 10—sun rise. I suppose this coldness to be owing to the banks of Newfoundland, which are in this Longitude.

December 22. Since the 16th there has been little or no alteration 'til to-day.

December 25. At 8 P. M. sounded in 75 fathoms.
December 27. At noon sounded in 40 fathoms.
December 28. At noon saw Portland.

C. A Thermometrical Journal of the temperature of the atmosphere and the sea, on a passage from Falmouth in England, to Halifax in Nova Scotia, on board the British packet Chesterfield, Cap. Schuyler.

By JONATHAN WILLIAMS.

Dates. 1790.	Time.	Places in at Noon.				Temper. of	
		Lat. N.		Long. W.		Air.	Water.
June 12	Noon.	49°	57′	5°	14′	61°	55°
	6 P. M.					57	57
14	Noon.	48	11	12	18	61	58
15	8 P. M.	47	25	16	16	60	59
21	Noon.	48	7	25	16	62	57
22	8 A. M.	47	19	26	11	59	58
23	Noon.	46	38	27	55	62	60
24	6 P. M.	45	13	28	29	64	62
25	Noon.	44	46	30	32	67	63
26	7 P. M.	44	53	32	15	66	62
27	Noon.	44	51	33	29	63	61
30	Noon.	44	56	36	21	64	60
July 1	Noon.	44	0	37	4	66	64
2	8 P. M.	44	31	38	25	65	61
3	8 P. M.	44	52	39	56	62	60
4	Noon.	44	23	40	53	66	62
5	6 P. M.	44	20	43	25	66	63
6	6 A. M.					66	62
	Noon.	44	43	46	7	62	57
	1 P. M.					62	55
	4 P. M.					58	53
	5 P. M.					55	51
	6 P. M.					60	56
	7 P. M.					59	57
	Midnight.					59	55

(CARRIED FORWARD.) C.

C. A Thermometrical Journal of the temperature of the atmosphere and sea, on a passage from Falmouth in England, to Halifax in Nova Scotia, on board the British packet Chesterfield, Cap. Schuyler.

By JONATHAN WILLIAMS.

(Continued.)

Dates. 1790.	Time.	Places in at Noon. Lat. N.	Places in at Noon. Long. W.	Temper. of Air.	Temper. of Water.
July 7	4 A. M.			58°	54°
	6 A. M.			56	50
	7 A. M.			56	49
	10 A. M.			56	51
	11 A. M.			55	53
	Noon.	45° 0′	47° 57′	55	51
	6 P. M.			55	49
8	6 P. M.	45 14	49 13	53	47
9	8 A. M.	45 10	51 9	53	47
10	8 A. M.	44 54	53 39	57	51
11	8 A. M.	44 52	54 57	58	53
	6 P. M.			60	54
12	8 P. M.	44 49	56 16	55	55
13	8 A. M.	44 80	58 28	55	53
	8 P. M.			56	54
	10 P. M.			56	53
14	8 A. M.			60	56
	Noon.	44 33	59 54	60	61
	Midnight.			57	57
15	2 P. M.	44 50	61 20	60	57
	5 P. M.			60	53
	8 P. M.			60	56
16	Noon.	44 34	62 17	61	57
	8 P. M.			60	53
17	6 A. M.			59	52
	Noon.			62	57
18	4 A. M.	At the mouth of Halifax H.		54	52

NOTES.

July 1. In the evening, I strained a bucket of water through a towel, and the luminous appearances so common in the sea, remained on the cloth.

July 6—at 5 P. M. I suppose we are on Jacquet's Bank.—7 P. M. I suppose we are between Jacquet's and the Grand bank of Newfoundland.

July 7—at 4 A. M. These irregular degrees of heat indicate eminences in the valley between Jacquet's and the Grand Bank.

July 9—at 8 A. M. Sounded in 40 fathoms.

July 10—at 8 A. M. Sounded in 45 fathoms.

July 11—at 8 A.M. Sounded 56 fathoms.—6 P.M. Sounded 75 fathoms.

July

July 12—at 8 P. M. Sounded, no bottom, in 110 fathoms, over the Grand Bank.

July 13—at 8 A. M. Sounded in 42 fathoms; perhaps on the whale Bank.—8 P. M. Sounded 40 fathoms.—10 P. M. Sounded 35 fathoms.

July 14—at 8 A. M. Sounded in 38 fathoms.—Noon. Sounded 60 fathoms, calm, and bright ſun.

July 15—at 2 P. M. Saw land.—5 P. M. Tacked and ſtood off land, ſounded 13 fathoms.—8 P. M. Land out of ſight.

July 16—noon. Standing in for land.—8 P. M. Tacked and off the land.

July 17—6 A. M. On Jeddore Bank.—Noon. Off the Bank.

Obſervations on a paſſage from Falmouth to Halifax.

By Jonathan Williams.

1790. June 17. The very gradual increaſe in the heat of the water as we leave England indicates a ſmall deſcent of the coaſt, which as far as ſoundings go, is known to be the caſe.

July 6. lat. 44. 43. N lon. 46. 7. W Here we find a ſudden change of 7 degrees in the heat of the water, which indicates our approach to the banks of Newfoundland, though not in ſuch ſoundings as we could obtain.

We tried with 160 fathoms but the lead was only about 12 pounds, and the line was a very thick one: perhaps the line floated the lead. At 5 P. M. the water was ſtill colder 4 degrees; but at 8 A. M. it grew warmer again 6 degrees, this ſeems to indicate a paſſage over a bank, into water, as deep as when we diſcovered the firſt change.

July 7. lat. 45. 0. N lon. 47. 57. W We are now in cold water again (49) 13 degrees colder than the ocean water had regularly been during 12 days previous to the firſt change, except only the ſmall variations of a more northern or more ſouthern courſe, theſe changes ſeem to indicate our entrance on another bank. There is a bank laid down in the charts, by ſome called Jacquet's bank, but by the older charts called Falſe bank, over which we have probably paſſed. In this longitude, but farther

farther ſouth, both by Dr. Franklin's and my own obſervations, the water grew ſuddenly cool. This ſeems to confirm the ſuppoſition of this outer bank, the ſouthernmoſt point of which I ſuppoſe to extend as far as lat. 40. 0. N. We hove too in order to try the ſoundings, but the force of the back ſail carried away the main top maſt head, and brought the top gallant ſail, maſt and rigging down, this confuſion interrupted the ſounding; and we had only 80 fathom of line out, when it was hauled in.

July 8. At 6 P. M. the water was only 2 degrees colder (47°) than when we were interrupted in ſounding, and we got bottom in 40 fathoms.

July 12. From the laſt ſound to this time the thermometer has
lat. 44. 49. N varied, regularly as the ſoundings varied the water being
lon. 56. 16. W warmer when deeper, and cooler when ſhoaler. It is now at 55, which is 8 degrees warmer than when we had 40 fathoms. We now ſounded and could not reach bottom with 110 fathoms of line. This indicates that we are off the Grand bank, and within it. By taking our diſtance from the time the thermometer firſt fell to 54, to the laſt time it ſtood at that degree, we may give an account of the width of the ſoundings on this Grand bank, though it probably extends much farther, but in deeper water. This is noted on the chart. The variations in the thermometer between laſt night and this morning, indicate our paſſage over an eminence of the bank, called the Whale bank, ſituated on its inner edge.

July 13. Thermometer at 8 A. M. was at 53, two degrees
lat. 44. 30. N colder than when we could not reach bottom with 110
lon. 58. 28. W fathoms of line: and we ſounded in 42 fathoms. This indicates our entrance on another bank, which is called in the charts Banquereau. It is obſervable that the water of ſmall banks is not ſo cold as that of large banks, and this ſeems natural, if it is ſuppoſed that the conducting power of the land, taking away part of the heat of the water, is the cauſe of the changes in the thermometer; for

for that power muſt have leſs effect, as the quantity of the ground under water is leſs: and this muſt be ſtill more remarkable when the bank is immediately connected with land above water, for ſuch land conducting heat away from the atmoſphere, and receiving much from the ſun, muſt require leſs from the water. This remark has been uniformly confirmed in all my experiments within Capes, where the water is much warmer than in ſoundings without them. And it is further obſervable, that the water on the coaſt of America on the edge of ſoundings, is not above 6 or 8 degrees colder than deep water; but on the banks of Newfoundland it is from 12 to 15 degrees colder.

July 14. lat. 44. 33. N lon. 59. 54. W Here we have the water 57°. which is 2°. warmer than when we could not get bottom between the banks, yet we have 65 fathoms, at noon it was up to 61. and we had the ſame ſoundings; but as it was calm weather, and as we had a hot ſun, allowance muſt be made for its influence, and therefore no certain concluſion can be drawn. The depth of the water however indicates our going off Banquereau, and the white ſand of the bottom indicates that we are on the edge of the bank which is connected with the Iſle of Sable. This alſo accounts, from the above mentioned principle, for the unexpected warmth of the water.

July 15. lat. 44. 50. N lon. 61. 20. W We ſaw the land at 2 P. M. and now we are in 13 fathoms of water, thermometer 53. This land agrees with the deſcription of that about St. Mary's river, and tracing our courſe back, ſhews us to have been laſt night, and the preceding days, in the very places indicated by our reckoning, thermometer, and ſoundings. We tacked and ſtood off.

July 18. Off Halifax Harbour. The thermometer, when we ſtood off the land, roſe up to 57. and when we came on and made the high lands of Jeddore, it indicated Jeddore banks by falling to 52. when being becalmed we caught fiſh; leaving the bank it roſe to 57. and now we are in ſight of our port it ſtands at 52.

D.

b. A Thermometrical Journal of the temperature of the atmosphere at sea, on a passage from Halifax to New York, on board of the British packet Chesterfield, Captain Schuyler.

By JONATHAN WILLIAMS.

Dates. 1790.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
July 21	9 A. M.	Halifax	Harbour.	56°	53°
	11 A. M.	Without the	Harbour.	55	52
	4 P. M.			64	56
22	6 A. M.			56	50
	Noon.	43° 12′	64° 6′	56	58
	4 P. M.			56	50
	7 P. M.			56	54
24	8 A. M.			56	50
	10 A. M.			58	53
	Noon.	41 57	65 1	68	58
	6 P. M.			62	57
	Midnight.			62	56
25	Noon.	41 53	65 33	64	58
	4 P. M.			64	55
	6 P. M.			62	53
	Midnight.			62	60
26	3 A. M.			62	53
	6 A. M.			60	57
	Noon.	41 8	66 56	64	60
	4 P. M.			64	62
27	3 A. M.			60	54
	7 A. M.			62	60
	Noon.	40 44	67 32	64	56
	4 P. M.		*68 30	64	54
	8 P. M.			65	59
	10 P. M.			64	55
28	1 A. M.			64	56
	6 A. M.			67	61
	Noon.	40 44	68 6	68	60
	8 P. M.		*69 40	69	64
	10 P. M.			69	64
29	4 A. M.			68	63
	Noon.	40 25	68 20	68	63
	10 P. M.		*70 30	65	64
30	Noon.	40 23	69 14	67	66
	4 P. M.		*71 10	69	67
	8 P. M.			69	68
	Midnight.			70	69
31	3 A. M.	40 29	70 51	70	68
Aug. 1	4 A. M.		*72 30	70	68
	9 A. M.			66	66
	4 P. M.	40 29	*73 40	68	66

* N. B. By the soundings and the thermometer, I suppose the true longitude to be as marked under the reckoning.

NOTES.

July 21. Sailed at 8 A. M.—4 P. M. Land out of ſight.

July 22—6 A. M. I ſuppoſe we are on Roſeway bank.—Noon. I ſuppoſe we are between Roſeway and Brown's bank.—4 P. M. I ſuppoſe we are on Brown's bank.—7 P. M. I ſuppoſe we are off do.

July 24—6 P. M. Tried current and found it NE 1 knot, no bottom in 80 fathoms.

July 25—noon. Much Gulph weed, a whale, two ſharks, and many porpoiſes.—6 P. M. Bottom in 42 fathoms, no Gulph weed.—Midnight. Bottom in 32 fathoms, ſtood north.

July 26—3 A. M. Bottom in 32 fathoms, ſtood ſouthward.—4 P. M. Bottom in 50 fathoms, ſtood North.

July 27—3 A. M. Bottom 35 fathoms, ſtood ſouthward.—7 A. M. Stood weſt.—4 P. M. Bottom in 28 fathoms.—8 P. M. Bottom in 40 fathoms.—10 P. M. Bottom in 30 fathoms.

July 28—1 A. M. Bottom 32 fathoms, ſtood SE.—6 A. M. Bottom in 43 fathoms, ſtood SW.—Noon. Bottom 36 fathoms, ſtood ESE.—8 P. M. Bottom in 65 fathoms, wore ſhip, almoſt calm.—10 P. M. No bottom, I ſuppoſe we are within the influence of the Gulph ſtream; in its eddy perhaps.

July 29—4 A. M. Bottom in 57 fathoms, ſtood weſt.—10 P. M. Bottom 45 fathoms, the water being warmer than in the ſame depth when I thought we were near the ſhoals, I am induced to believe that this bottom is that of the coaſt.

July 30—8 P. M. Bottom in 56 fathoms, mud.

July 31—3 A. M. Bottom in 63 fathoms, mud. The muddy bottom ſhews that we are within the ſhoals and banks of the coaſt.

Auguſt 1—9 A. M. Saw the land off Long Iſland, bearing north.—4 P. M. New York Light Houſe in ſight, bearing weſt. N. B. Since 2 A. M. we have been going from 5 to 7 knots, *i. e.* about 50 miles W which makes the longitude by thermometrical reckoning and ſoundings, 73. 40. W at noon, which turns out accurate, the land being in 7. . 0. W.

Obſervations

Observations on a voyage from Halifax towards New-York.

1790. July 21. Sailed this morning from Halifax. The water at the harbour's mouth and just within Chebucta head, was at 53. but without it was at 52.—In land locked places I have generally found the water warmer than in even greater depths, on the borders of the ocean.

22. When we lost sight of land the water was at about 56. but at 6 this morning it having cooled to 50. I suppose we are passing over Roseway bank.

At noon the heat of water had risen to 53. which makes me suppose we are over the ground between Roseway and the other bank called in some charts Brown's bank, and at 4 the water cooling again to 50. I suppose we are on this last mentioned bank.

24. The water at noon yesterday growing as warm as 56. I
Lat. 41. 57. suppose we are on the SE edge of Brown's bank. As we
Long. 65. 1. afterwards hauled up more to the westward, and as the water at 8 this morning cooled to 50. again, I supposed we had returned more on the bank. But at noon the thermometer rose to 58. As it was calm, and the sun hot, I made some allowance for that cause, but supposed we had got off soundings, and as at 6. (the air being 6°. cooler than at noon) it was at 57. I was confirmed in this.—It being still calm, and there appearing some Gulph weed, we hoisted out the boat to try the current which we found to set NE nearly 1 knot. This puzzled me, I could not conceive ourselves to be in the Gulph stream, because the water was not hot enough for that supposition, and as the iron pot by which we anchored the boat, was not at bottom though 80 fathoms of line were out, I thought the heat 57. fully accounted for by the depth of water; but about 7 when we had made a little way through the water, it became again calm, and we then saw and heard the ripple of a current as evidently as we could have expected over a shoal. I could not account for this any otherwise than by supposing it to be the Gulph stream, yet it appeared

appeared impossible that it should come so near the bank. Our Captain resolved to try again if there was a current here, at a distance from this ripple and in a calm. He accordingly hoisted out the boat again, and the current was found to set SE by S about ¾ knot. The evidence of this various current in so short a space, the heat of the water not being raised to the heat of the stream, and our situation to the northward made me conclude this to be the whirlpools of the eddy of the Gulph stream just on the northern edge of it.

July 25. Noon. The water still continuing till noon nearly at the same
Lat. 41. 53. temperature, and our course being to the west southerly,
Long. 65. 33. I concluded that our situation with respect to the stream was nearly the same as last remarked, this was confirmed by the passage of immense quantities of Gulph weed, a deal of scum and mucus, with a whale, two or three sharks, and a school of porpoises in the course of the morning; but in the afternoon we fell off further to the northward, and at six P. M. the water was from 55. to 53. no Gulph weed to be seen, and in soundings of 42 fathoms. We tacked and stood south at 8 P. M. and I was astonished to find at midnight that the water was heated to 60. though the soundings were only 32 fathoms. Here again I could account for this only by the influence of the Gulph stream, which the Capt. seemed to think

26th. probable, and tacked to the northward, the wind being still at about west, and by 3 A. M. the thermometer fell to 53. with the same soundings, when we again tacked and stood to the southward. I then tried the heat of the water by the thermometer, regularly every hour, and by 5 P. M. it was up to 62. The soundings then were 46

27th. fathoms;—We tacked and stood north, and at midnight it was again down to 55. at 3 A. M. to 54. the soundings then about 35 fathoms; we then stood south when it returned to 60. Thus upon three successive tacks each way we cooled or warmed the water as we were standing either northward or southward from 6 to 9 degrees.—I could only

only account for this (the soundings varying but very little) by supposing that when we stood southward we got into the warm influence of the Gulph stream, and as we

July 27. stood northward we got out of it. I do not think we got into the stream itself, because I should in that case have expected the water to have been much warmer, but probably we have been very near, perhaps upon the edge of it: and perhaps we have had a benefit instead of a disadvantage, by an eddy westerly current: that we have been near it, seems pretty clear, for when we warmed the water we saw plenty of Gulph weed, and the weather was clear, when we cooled the water we saw no Gulph weed and the weather was foggy.

Perhaps we may be farther to the westward than we think: time and a good look out will discover.

July 30.
Lat. 40. 25.
Long. 70. 30.

Since the last observation relative to the stream and soundings, I have kept the thermometer going almost every hour except when we were standing off the shore, and by examining the soundings according to those marked in Mr. Des Barres' chart, I have regularly traced them, and if we were to suppose that a current was setting us about one knot per hour to the westward, the soundings would agree very well. When in about lat. 40. 25. we were standing off shore, we warmed the water to 64 and got 45 fathoms, this heat I account for by the influence of the stream, it being greater than the proportion as to soundings, for in 40 fathoms farther toward the shore it was only 60. In looking over my journal from Boston to Virginia in Capt. Brace, I found that in nearly the same latitude the heat increased in about the same time from 52. to 59. but in a somewhat longer run. It was then October, it is now July, and the difference in the number of the degrees is easily accounted for by the season. By going more south and west in Capt. Brace, the water was raised to 67. when we found ourselves within the stream, it would at this season probably be upwards of 70. I therefore

fore conclude that we are within the influence of the heat, but not the current of the ſtream, and I am in hopes to find that we have had that eddy current in our favour.

August 1. 9 A. M. Having the land in ſight, we are confirmed in the ſuppoſition that a favourable current has carried the ſhip faſter than the Captain reckoned.

APPENDIX.

NOTES TO THE MARITIME OBSERVATIONS.

N°. I.

Extract from the Journal of an Officer on board the British ship of war Liverpool, in November and December, 1775, on the coast of Carolina and Virginia.

WHEN Cape Henry bore NW 160 leagues found a current setting to the southward at the rate of 10 or 12 miles per day, which continued so till Cape Henry bore WNW 89 or 90 leagues, then found a current setting to the NE at the rate of 32 or 34 miles per day, this current continued till within 33 or 30 leagues of the land on the above coasts, then it sets to the southward and westward, at the rate of 10 or 15 miles per day, till within 12 or 15 leagues of the land. This current which is only the eddy of the Gulph stream, sets mostly SW or as the land lies.

In lat. 37. 50. sounded, and had 65 fathoms, fine sand, being 25 leagues from the land. In the same latitude and only 26 leagues from the land, had no bottom, with 180 fathoms.

From

From lat. 35. 30. to lat. 37. 0. there are no foundings 20 leagues from the land, but at 19 leagues diftance there are foundings in 60 fathoms, at 18 there are only 35 fathoms, and from thence gradual foundings to the fhore.

From Cape Hatteras to Cape Henry, the ground is fine fand, and to the northward of Cape Henry, coarfe fand with fome fhells among it.

No. II.

Extract from the Journal of an Officer on board the British fhip of war Liverpool, between 26th September and 9th October, 1775.

IN lat. 45. 43. N long. 21. 20. W from Greenwich, found a current fetting to the fouthward 12 to 15 miles per day, which continued till we made the ifland of Corvo, the north part of which is in lat. 39. 56. N and long. 31. 8. W from Greenwich by celeftial obfervation, which agreed within 12 miles of the longitude per account, that being 30. 56. The variation of the compafs off this Ifland is 18°. 19. W and in failing to the fouthward and weftward, it gradually diminifhed, till we arrived in lat. 29. 0. N long. 66. 40. where we had no variation.

N°. III.

N° III.

Extract from the Journal of an Officer on board the British ship of war Liverpool.

ON the 18th of October, 1775, in lat. 42. 4. N long. 10°. 8. W from the island of Corvo, it bearing S 75. E distant 156 leagues; the sea being then very smooth it was suddenly agitated into a short irregular sea (without any shift or increase of wind) such as is generally occasioned by currents, and the next day we found we were 30 miles to the southward of the reckoning. This current continued till the 22d of October, having then arrived in lat. 37. long. 13. 30. W. It set S by W ½ W 1½ miles per hour.

Having a fair wind, and a good observation every day, and also good astronomical observations for determining the longitude, we had the greatest reason to depend on the authenticity of the above.

N° IV.

Extract from the Journal of an Officer on board the British ship of war Liverpool, July, August and September, 1775.

THE bank from Cape Cod extends almost as far as Cape Sable, where it joins the banks of Nova Scotia deepening gradually from 20 to 50 or 55 fathoms, which depth there is in lat. 43. In croſſing the bank between lat. 41. 41. and lat. 43. the bottom is very remarkable; on the outſide it is fine ſand, ſhoaling gradually for ſeveral leagues; on the middle of the bank, it is coarſe ſand or ſhingle with pebble ſtones; on the inſide it is muddy with pieces of ſhells, and deepens ſuddenly from 45 or 48 to 150 or 160 fathoms.

N°. V.

In lat. 44. 54. N long. 53. 19. W on board the Britiſh packet Cheſterfield, Capt. Schuyler. July 10, 1790.

THE Captain caught a cod fiſh, and in a few minutes after it was opened and gutted, I put the thermometer into its belly, the inſtrument marked 39. when in air it was 57. and in water on the ſurface 52. Depth 46 fathoms.

In lat. 44. 52. N long. 54. 57. W. July 11, 1790. The people caught ſeveral cod fiſh and hallabot, the thermometer was put into three cod fiſh and one hallabot ſucceſſively, the inſtant they were hauled up, and the inſtrument marked 37. in every caſe. The air was at 57. and the water at the ſurface was 53. The firſt experiment

experiment was repeated after the fifh was gutted, and it then marked one degree warmer. I thence concluded that the difference between the two experiments was owing to the time the fifh was in the air before the trial, and that in all the inftances the animal heat of the fifh was about 16°. colder than the water at the furface; and as it feems natural, from analogy, to fuppofe that animal heat is at leaft as warm as the fluid in which the animal lives, I conclude that the water at the bottom was as cold as 37. *i. e.* 16°. colder than at the furface. In a former voyage it was found by decifive experiment, that near the coaft in very hot weather the water at the bottom in 18 fathoms was 12 degrees colder* than at the furface.

Another reafon to fuppofe that the water was colder at bottom than the animal heat, was the great diftention of the cods founds when they were opened, although they had fent out innumerable bubbles of air in the paffage up; the air, therefore, within the found, muft have been much more compreffed, (either by cold or the power of the animal) below, than above where it was at 37. Several fifh that had been hauled up to the furface of the water, and then dropped from the hook, fwam light on the furface till they recovered their vivacity,

* See my Journal of a voyage with Doctor Franklin, in the London Packet, Captain Truxton.

city, although they loſt much air in coming up; the ſpecific gravity was therefore much leſs than at bottom, and this was probably owing to the diſtention of the ſound. That fiſh riſe and ſink in the water, by this power of increaſing and diminiſhing their bulk, and conſequently their ſpecific gravity, is well known to naturaliſts, but I was pleaſed to ſee the truth of that fact confirmed by theſe experiments.

JONATHAN WILLIAMS.

REPORT.

By Don Cipriano Vimercati,

Director of the Marine Academies of Spain.

THE memoir of Jonathan Williams, on the ufe of the thermometer in the fea, has been tranfmitted to me, with his Majefty's orders, that I fhould examine it, give my fentiments upon it, and obtain a correct tranflation of it, in cafe I fhould confider it ufeful—This I have faithfully executed, adding thereto an exact copy of the chart containing the route in which the author made his obfervations, leaving fome names of capes, iflands, &c. in the Englifh idiom, which appeared to me in moft general ufe, and giving to others, for a fimilar reafon, thofe which had firft been Spanifh, or permanently fixed or denominated in that language—and from the judgment I have formed on an attentive reading,

I DO REPORT,

That the experiments of Williams are made fo minute, fo progreffive, and regular, and fo analagous to thofe deducible from phyfical principles, univerfally admitted, concerning the continued action of heat and the diftribution of it through all bodies, that they cannot but be

an

an additional ſupport to navigation, and a happy acceſſion to the progreſs of the known hydrography.

That heat ſpreads and paſſes from one body to another contiguous to it, ſeeking as far as poſſible its equilibrium, is a fact aſſerted by the famous Boerhave, and ſince confirmed and acknowledged by all philoſophers.

In this ſenſe it is ſaid, that the coldeſt body imbibes or abſorbs a part of the heat of that which is leſs ſo. This diſtribution is equal, if the bodies are perfectly homogeneous, and they transfer from the one to the other equal quantities of the matter of heat* at regular periods, until the equilibrium is obtained: Or, more ſtrictly ſpeaking, there is a certain acceleration of movement in it when paſſing from one body to another; but this caſe, except in ſmall maſſes, is either rare, or does not in fact exiſt in nature. Yet the effects of this matter and movement, approach nearer to it, in proportion as the bodies in which it acts are homogeneous. With the heterogeneous, this diſtribution is not uniform, and the action of the heat is ſlower, or accelerated in proportion to the impediments which one body oppoſes to another. In ſmall bodies the difference is ſcarcely perceivable. This is proved by the experiments of Muſchenbroek, (Lulof's edition from No. 1597 to 1600;)

* Caloric.

1600;) in very great maſſes upon the earth, for inſtance, mountains, or under the water, ſuch as large banks, the difference is very ſenſible, the progreſs with which this diſtribution is made, being more or leſs ſlow, according to the various denſities, or other local circumſtances, though always drawing towards the equilibrium.

The abovementioned Muſchenbrock, No. 1602, gives the two following obſervations, relative to the heat of the ſea water, of which he treats very lightly, no doubt from the want of the facts to ſupport him. The firſt was taken from Count Marſigli's hiſtory of the ſea, which is, that the water of the ocean at the depth of 720 feet poſſeſſes the ſame degree of heat as the atmoſpheric air. The ſecond is from Captain Henry Ellis, of the royal ſociety of London, who in the *Philoſophical Tranſactions*, Vol. 47, page 213, affirms, that marine water from the ſuperficies to the depth of 3900 feet gradually becomes more cold, more ſalt, and conſequently heavier; but from this depth to that of 5346 (as far as he could extend his experiments) preſerved the ſame degree of heat, that is 53°. of Fahrenheit, being at the ſurface 84. As to the firſt quality of heat, which is the preſent object, let us compare this obſervation with the hypotheſis of Williams, and with the general principle, in order to ſee whether it confirms or contradicts either of them.

But

But before we go into this comparifon, it appears to me proper, that Ellis's obfervation may be feen, with the circumftances at full length, here to give an extract of a letter from him, inferted in thofe *tranfactions*, dated 7th of January, 1751, and addreffed to the celebrated Hales, on board the fhip Count of Halifax; to wit, "In "my voyage, being in latitude 25′. 13″. north and "longitude 25′. 12″. weft. I made feveral experiments "with the bucket fea-guage. I charged it and let it "down in different depths from 360 to 5346 feet, and "by means of a fmall thermometer, modelled by Fah- "renheit's, conftructed by Mr. Bird, which was placed "in it, I difcovered that the cold increafed regularly, "in proportion to the depths, till it defcended to 3900 "feet; from whence the mercury in the thermometer "came up at 53 degrees; and though I afterwards "funk it to the depth of 5346 feet, that is a mile and "66 feet, it came up no lower. The warmth of the "water upon the furface, and that of the air, was at "that time, by the thermometer, 84 degrees. I doubt "not but that the water was a degree or two colder, "when it entered the bucket, at the greateft depth, "but in coming up, had acquired fome warmth, for I "found that the water which came up in the bucket, "having ftood 43 minutes in the air (the time of wind- "ing it up) the mercury rofe above 5 degrees." Thus far the obfervation of Ellis, and he adds: "This ex-

periment

" periment which seemed at first but mere food for cu-
" riosity, because, in the interim, very useful to us.
" By its means we supplied our cold bath, and cooled
" our wines or water at pleasure, which is vastly agree-
" able to us in this burning climate." He concludes:
" I intend in our passage to the West Indies, to sound
" a mile deeper than I have done, having a sufficient
" quantity of line. But I cannot attempt your method
" to find the depth of the sea, for want of apparatus."

To this letter, which Hales communicated to the society, he added one from himself to the president, in which he describes the construction of the sea guage, used in the experiments, and speaks thus: "The bucket
" sea gauge which he (Ellis) mentions, and which I
" provided for him, to find the different degrees of
" coolness and saltness of the sea, at different depths,
" was a common houshold pail or bucket, with two
" heads in it, which heads had each a round hole in
" the middle near four inches diameter, which were
" covered with valves, which open upwards; and that
" they might both open and shut together, there was a
" small iron rod fixed to the upper part of the lower
" valve, and at the other end, to the under part of the
" upper valve: so that, as the bucket descended, with
" its sinking weight into the sea, both the valves open-
" ed by the force of the water which had by that
" means a free passage through the bucket. But

" when the bucket was drawn up, then both the valves
" were ſhut, by the force of the water, at the upper
" part of the bucket: by which means the bucket was
" brought up full of the loweſt water, to which it had
" deſcended. When the bucket was drawn up, the
" hole at the bottom was ſtopped with cork to keep the
" water in, when the valves were opened, to come at
" the thermometer, which being tied to an upright
" ſtick, could readily be unfaſtened, by pulling out a
" looſe nail, which went into the upper end of the
" ſtick, which was faſtened at its lower end in the ſame
" manner. But great care muſt be taken to make an
" obſervation of the degree the mercury ſtands at, be-
" fore the lower part of the thermometer is taken out
" of the water; elſe it would immediately be altered
" by the different temperature of the air. In order to
" keep the bucket in a right poſition there are four
" cords fixed to it, which reach about three feet below
" it, to which the ſinking weight is to be fixed."

Thus far Doctor Hales. I have, out of compliment to the ingenuity and ſimplicity diſcovered in this invention, digreſſed for the purpoſe of introducing theſe extracts.

Having now come to what may be deduced from the above obſervation, on comparing it with thoſe of Williams, as well as with the general principle of the communication

munication of heat, the following are the refult: The experiment recited by Williams (appendix No. V.) is, that the water being at the furface 52 degrees of the fame fcale of Fahrenheit, and the depth, by founding 46 fathoms, the thermometer introduced into the belly of a fifh indicated a heat of 37 degrees, which might probably be confidered as nearly the degree of the warmth of the water at the bottom. The difference between it and that at the furface are 15 degrees, and this was 5°. lower than that of the atmofphere, which was at 57°. So that whether the bottom abforbs the heat, according to the general principle, or whether the air, communicating itfelf more flowly in proportion as the water is deepened, it fucceffively becomes more cool: from one of thefe caufes, or from a combination of both, arofe at 46 fathoms deep, the difference of 15 degrees, with refpect to the furface, and of 20°. with refpect to the air. But in thefe differences arife a notable diverfity, compared with that refulting from Ellis's obfervation. Becaufe,

1. The air and the fuperficies of the water were of equal degrees of warmth.

2. The 3900 feet, which may be fuppofed to be nearly 650 fathoms, the difference of the fuperficies and of the air, and the greateft depth of the water was 31 degrees.

3. From that to 5346 feet, or nearly 890 fathoms, as far as is aſcertained by Ellis, the heat was the ſame.

Notwithſtanding, on examining the circumſtances, of both obſervations, I meet with no great difficulty in reconciling them; and conceive, that the variations may be attributed to the ſame cauſes, diverſely combined.

In that of Williams, the latitude was 44°. 52′. north, and the time, the 11th July, in which the atmoſphere is leſs warm than at the end of ſummer. That of Ellis, was in the middle of the torrid zone, and the time not expreſsly determined; and though the date of his letter is the 7th of January, which, in that latitude is one of the winter months, yet we collect from the uſe made of the cold deep water for bathing and cooling liquors, that the ſeaſon was exceedingly hot. This, together with the frequent equinoxial calms, and the conſiderable part of the year during which the ſun continues perpendicularly over thoſe climates, muſt produce little or no difference in the circumambient air and the ſurface of the water.

And if in July, and in latitude 44°. 52′. north, this difference was only 5 degrees, it is not extraordinary if it ſhould be inſenſible near the line.

Beſides, the difference in the ſuperficies of the deep water, is from 15. to 16. in that of Williams, and 31.

in

in that of Ellis, which is the double of the former, and the depth of the latter fourteen times greater than in the observation of the other. Hence it appears the result ſhould be, that the exceſſes of the cold preſerve a due proportion to that of the depth. In ſuch caſe the exceſs of the heat at the ſurface, beyond that of deep water, muſt be fourteen times greater in one obſervation than in the other. The water under the line, and in the depth of 3900 feet, inſtead of being at 53°. above the naught of Fahrenheit, would be 126°. under this limit, which is 126°. colder than that produced by the mixture of *ſnow and ſal amoniac;* and the mercury (were it not prevented from arriving at this depth from the water's being much earlier converted into the hardeſt ice) would mark that degree. But this point might be expected whenever there exiſted a concurrence of all the other circumſtances;—and if the waters of the ocean were heated by the warmth of the atmoſphere and the ſun alone, then the diffuſion of this heat would decreaſe in the water, in proportion to its depth, and in high latitudes and climates conſiderably cold, the ſea would always freeze in winter, not only on the ſurface, as in rivers, but in its whole depth: This being a neceſſary conſequence of the general principle in this caſe. But ſuch a caſe does not exiſt: Becauſe, although one of the general cauſes of the heat of the earth and of the water of the ocean, is the action of

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the rays of the ſun, which croſs the atmoſphere, there is doubtleſs another concurring with it, which is the internal heat of the globe, ſupported by ſubterraneous fires, and the principle of heat put in action, and variouſly diſtributed throughout the maſs: And perhaps ſome other cauſe, of which we are ignorant. All theſe modified in an infinite variety of ways diffuſe the heat as much as poſſible through every part, and where it meets with oppoſition, or does not ſufficiently pervade the matters to maintain their reſpective fluidity, there remain congealed.

In the caſe of which we treat, 31 degrees of heat, diminiſhed from the ſurface to 3900 feet, in a latitude, in which, from the reſpective poſition of the ſun, the heat of the atmoſphere and of the ſurface was very great, and ſhould vary but little in the equal alternative of days and nights; whence the bottom which might abſorb it and augment the cold, was very far diſtant, accounts, nearly, for the diminution of 15 degrees in a latitude of 44°. 52′. and wherein by the ſmall depth the bottom abſorbed a great part. This diverſity of circumſtances manifeſts, ſufficiently, that the cold muſt augment in 46 fathoms or 276 feet, in a proportion many times greater than that to which it augmented in 650 fathoms, or 3900 feet.

The difficulty of explaining the conſtant temperature of the water at 53°. from 3900 to 5346 feet, is greater; and it cannot be denied that the phenomenon has ſomething ſingular in it, in caſe it be aſcertained that the thermometer effectively falls to that depth; nor ſhall I attempt to explain it, as nothing could be urged but upon general principles.

However, the above obſervations do not deſtroy the experiments and hypotheſis of Williams. For when the thermometer is uſed in ſeas immediately under the line, the facts muſt be viewed in relation to that poſition, which may be very different from thoſe we have ſeen in the voyages of that obſerver. In them it is ſtated, that at ſundry periods of the year the heat of the water on the ſurface and that of the air were different and proportionate to the influence of the ſeaſon; but the difference between them was reſpectively the ſame in the ſame latitudes, and always very ſenſibly indicated the vicinity of banks and coaſts.

Under water this difference was inſenſible at the time of Ellis's obſervation, in a ſea of great depth. What this would be in ſeas interſperſed with eminences, banks, iſlands and channels, or encompaſſed by the coaſts in the ſame latitude, who could decide unleſs he were to take experience for his guide? For the temerity would be great to apply to this poſition of the globe that which has been obſerved in very diſtant latitudes.

For

For the ſame reaſon I do not ſpeak of the experiments of Marſigli, already cited, becauſe, they are not circumſtantial, and not having in my hands his hiſtory of the ſea, I can form no concluſion upon them; and what he does ſay, if it be certain, is that it neceſſarily depends on local cauſes, about which one cannot even hazard a conjecture.

Finally, from all that has been ſaid, the reſult on the memoir of Williams, is, that the application of the thermometer, to navigation, is a happy acceſſion and an additional aid, which, from the facility of its uſe, it might be expedient to promote, but being in its infancy, and hitherto confined to experiments made on a contracted ſcale, it would be proper to extend them to other climes and ſeas, in order to perfect the ſame, ſo far as to notice the deviations, and from them to form tables of the reſults, together with rules accommodated to the various ſeaſons of the globe. A ſimilar plan was begun on the variation of the needle, whence to form charts, which might ſerve for determining, nearly, *the longitude by the known change*. This project, however, being ſupplied with advantage by other means, has been abandoned from the deviations obſerved in the lines of variation. According to the idea of Williams, probably this ought not to have happened. The facts obſerved in a certain limit of ſea, and latitude, will always be the ſame, with the ſingle difference, ariſing only from the diverſity of ſeaſons.

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The celeſtial obſervations, which give the poſition of the ſhip, will never give the depth of the water or notice of approaching danger from an unknown coaſt. In fine, in a matter which is of ſo much importance to humanity, the light manifeſted in this memoir ſhould be purſued whilſt it remains unobſerved by a multiplicity of irregularities, or other obſtacles which would render the purſuit impoſſible.

(Signed) CIPRIANO VIMERCATI,
Director of the Marine Academies.

ISLE OF LEON, 20*th Dec.* 1793.

A Thermometrical Journal of the temperature of the atmosphere and sea, on a voyage to and from Oporto, with explanatory observations thereon. In a letter to DAVID RITTENHOUSE, L. L. D. *President of the American Philosophical Society.*

SIR,

Read Sept. 21st, 1792. ON the 15th of June last Capt. William Billings of this city, commander of the ship Apollo, presented the journals of his voyages to and from Oporto, for the inspection of the American Philosophical Society. As they were not accompanied by any explanatory memoir, I have extracted from them what alone differs from sea reckoning in general, and inclose a thermometrical journal of the temperature of the atmosphere and sea, which evidently appears to be the object of the communication. As it was proper to shew that these observations were not imaginary, and had arisen in the course of his voyages, Capt. Billings presented his whole journals, consisting of 73 pages in folio, with all the detail of a log book, which in original are deposited among the society's papers.*

As

* The temperature of the water was tried several times every day, but in this extract it was thought proper only to notice the important changes a succession of similar results being thought unnecessary.

As the experiments of this intelligent navigator, appear to be repetitions of those I made near two years before, which are related in my memoir, page 11, I beg leave to make the following observations on them:

By these journals it appears that in June, 1791, the water on the coast was at the temperature of 61°. by Fahrenheit, and in the Gulph stream at 77°. By my journals it will be found that in November, 1789, the water on the coast was at 47°. and in the Gulph stream at 70°. viz.

By Capt. Billings,		By my experiments.		diff. between June and Nov.
1791, June, coast,	61	1789, Nov. coast,	47	14°.
do. stream,	77	do. stream,	70	7
do. stream warmer,	16	do. stream warmer,	23	

Hence it may be concluded that although this difference of heat is more remarkable in winter than in summer, yet it is sufficient at all times to guide navigators, so as to take the benefit of its current in going from, and to avoid its opposition in coming to America. In the latter case, it has this additional convenience in correcting a reckoning; for if a navigator can, by this means, know the moment he is within the stream, he knows at the same moment his relative situation as to the coast; and if, by repeated experiment, this mode of correction should be found solid, it amounts, in effect, to

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a certainty of the longitude, at the precife time when it is important to be accurate.

Capt. Billings's courfe being nearly along the ftream, he found only fuch alteration in the heat of the water as may be accounted for by the cooling of the ftream itfelf, in its courfe to the northward, till he came to lat. 39. 0. N long. 56. 0. W (a-breaft of the banks of Newfoundland) when the mercury fell 10°. Doctor Franklin, in November, 1776, on board of the Reprifal, in lat. 41. N, long. 46. W, found about the fame difference; but the Reprifal had kept a courfe farther fouth and came into this cool water in a NNE direction; while Captain Billings being farther north, came in an eafterly direction, and of courfe might be as much within the influence of that chain of banks which extends from the longitude 45. W along the American coaft, as the Reprifal was when fo much farther to the eaftward. In November 1789, I found the fame difference in lat. 40. N long. 49. W, after failing in a direction about NE; and a line being drawn from the place where Captain Billings's change happened, to that where Doctor Franklin's thermometer fell, (in a direction about ENE) would nearly interfect the place where I obferved the fame alteration: this is about the fweep of the banks, known by frequent founding, as will be found by confulting the beft charts.—By the coincidence of thefe three journals, at fo great a diftance of time, and without

out any connection with each other, this important fact seems to be established. *A navigator may discover his approach towards objects of danger, when he is at such a distance as to be able easily to avoid them, by attentively examining the temperature of the sea.*

After having passed the banks Captain Billings found but little difference during 18 days sail, till he came near the European coast. The same uniformity appears in my journal on a voyage to England, page 23.

Captain Billings found the water to grow cooler three days before he made the land, and the mercury fell gradually from 65. to 60°. when the land appeared: This was in June. In November I found on approaching the English coast a gradual fall from 53. to 48°. and then we struck soundings. Here the difference between the sea and coast water was in both cases the same, though the heat of both varied with the season.

Returning from Oporto, Captain Billings marked his approach to, and departure from the western islands by the changes of his thermometer, but in this case the difference was small; because, owing to the climate and size of these islands, the land cannot be so cold as a northern continent naturally must be. Indeed, the usefulness of the thermometer seems to be applicable to the more dangerous situations, and not to islands in warm climates; I should suppose, for obvious reasons,

that

that the changes would not be great about the iſlands ſituated between the tropics. The ſhore of theſe iſlands is generally bold, and the land being very high, may be ſeen at a great diſtance. The climate is not ſubject to fogs, ſnow ſtorms, iſlands of ice, long nights, &c. ſo that, except hurricanes, (which are more fatal to ſhips in port than at ſea) there ſeems to be but little danger in ſuch navigation.

After leaving the weſtern iſlands, Captain Billings ſteered to the weſtward, being in nearly the ſame latitude on the 30th (37°. 47°. N) that he was on the 17th of Auguſt. (37°. 53°. N) But during the intermediate time he was driven, as winds prevailed, in a zig zag courſe, as far north as 39°. 4. N, and as far ſouth as 36°. 26. N. It appears alſo during this time that his thermometer varied from 1°. to 5°.; but it is to be remarked that there is a medium in his thermometrical variations anſwering to the medium of his latitude. When he was in 39°. 4. the thermometer marked 75°. and when in 36°. 26. it alſo marked 75°. but when in 38°. 12. it marked 70°. Now conſidering that he had the warm influence of the Gulph ſtream to the northward, and that the ocean water to the ſouthward muſt naturally be warmer than that more north, out of the ſtream, there ſeems to be a perfect agreement between theory and fact with regard to the uſefulneſs of the thermometer in diſcovering the courſe of this current.

rent. The ſame thing occurred in the courſe of my paſſage in the London packet with Doctor Franklin, (ſee Vol. 2, page 329, of the Tranſactions of this Society) in June 1785. The mean there was 73, while to the northward and ſouthward the thermometer marked 77.

Returning towards the coaſt of America, Captain Billings diſcovered his paſſage acroſs the Gulph ſtream by a ſudden fall in the mercury of 5°. from noon to night, and about 5°. farther weſt, by a further fall in the ſpace of 8 hours run, he diſcovered the coaſt, where he got ſoundings, before he ſaw the land.

The uſefulneſs of the thermometer as a nautical inſtrument is not confined to the diſcovery of an approach towards objects of danger *known to exiſt*; but it may, if attended to, diſcover others *not at preſent ſuppoſed to exiſt*, againſt which a navigator cannot be on his guard. Several charts, particularly one made by Governor Pownall, in September, 1787, point out rocks and breakers in the middle of the ocean; ſome are ſaid to be uncertain, others have been ſeen but once, and preſerve the names of their ſuppoſed diſcoverers. Theſe facts are generally doubted, and by ſome mariners have been ridiculed; but it ſhould be conſidered that in every inſtance where the diſcovery of theſe hidden dangers have been fatal, no one could eſcape to tell the melancholy

tale,

tale, and furely the number of miffing fhips juftifies a conjecture that fuch misfortunes have happened, and ought to influence every navigator to make accurate obfervations on the temperature of the fea during the *whole* of his voyage.

A gentleman of undoubted veracity related to me fome time fince, the following fact, which I mention on account of its aptitude to this fubject.

On a voyage from the Weft-Indies to England, the fmall veffel he was in, touched at Bermuda. On leaving that ifland, having fine weather and a fmooth fea, they failed along a ridge of rocks, feeing the bottom very plainly all the time, till the ifland was out of fight; in this place they fpoke a large fhip, the Captain of which, had no idea of his fituation; he had not noticed the bottom, and was failing in full confidence of being far from danger. On being defired to look over the fide of his fhip, the whole crew was in the utmoft confternation, and hove the fhip too, with all her fails fet. He was foon informed of his true longitude, and took a new departure. Had this Captain kept a thermometrical journal he would not, probably, have been fo deceived, and had he at this time been in a gale of wind, his error might have been fatal. Every body in this city remembers the dreadful cataftrophe of the fhip Faithful Steward, which was loft on this coaft, with

near

near 500 people on board, about ſeven years ſince. The Captain was ſo ſure of having ſufficient ſea room, that he did not think of ſounding, the weather was not boiſterous and had he known his ſituation he might have ſtood off during the night. But fearleſs of a danger he did not know, he ſtood on with full ſails, and was in an inſtant loſt; I think there were not above twenty ſouls ſaved. A thermometer regularly uſed would have given warning in time, and probably have ſaved theſe lives.

The impreſſion ſuch events have made on my mind, has induced me to be thus particular, and I the more readily do juſtice to the judicious example given to other Captains, by Captain Billings, becauſe I think the obſervations of a mariner, are more likely to be attended to by mariners, than any inſtruction given by a landſman. I think beſides, that the merit of Captain Billings, ought to be rewarded, by a publication of his laudable conduct, that he may enjoy the reputation to which he is juſtly entitled.

I am with great reſpect, Sir,
Your moſt obedient and
Moſt humble Servant,
JONATHAN WILLIAMS.

One of the Secretaries of the American Philoſophical Society.

A Thermometrical Journal of the temperature of the atmofphere and fea, on a paffage from Philadelphia to Oporto, in the Ship Apollo.

By Captain WILLIAM BILLINGS.

Dates. 1791.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
June 6	Sun rife.	38 56	75 7		61
	2 P. M.	38 38	74 28		66
	Sun fet.			65	66
8	10 A. M.				70
	Noon.	37 18	72 34	75	72
10	Noon.	38 3	68 49	73	77
11	Noon.	38 51	65 57	66	75
12	Noon.	39 2	63 22	71	71
14	Noon.	39 11	56 48		62
15	Noon.	39 37	53 43	71	65
July 2	Noon.	40 16	15 34	68	65
3	Noon.	40 5	13 23	68	64
4	Noon.	40 28	11 13	68	63
5	2 P. M.			68	63
	7 P. M.				60
	8 A. M.				57
	Noon.				55

NOTES.

June 6. Off Cape Henlopen.—N. B. The thermometer is on Fahrenheit's fcale and the longitude weft from London.—The days are reckoned to begin at noon and to end at the fucceeding noon according to the ufage of navigators.

June 8—10 A. M. Being the firft alteration in the heat of the water after leaving the coaft, it is fuppofed we entered the gulph ftream. The courfe is not acrofs, but rather along this current, fomewhat diagonally however.

June 10—noon. It is fuppofed we are in the middle of the Gulph ftream.

June 14—noon. This fudden fall of 9°. is fuppofed to be owing to the influence of the banks of Newfoundland which bear about N.

From the the 15th of June to the 2d of July, the variations in the heat of the fea water do not exceed two degrees, they need not therefore be noticed.

July 4. The water appears to have changed colour.

July 5—7 P. M. Land in fight, but frequently obfcured by fog.

July 6—8 A. M. Land diftant about 6 leagues.—Noon. Land diftant about 2 leagues, being the high land of Braganea Nova.

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A Thermometrical Journal of the temperature of the atmosphere and sea, on a passage from Oporto to Philadelphia, in the ship Apollo.
By Captain WILLIAM BILLINGS.

Dates. 1791.	Time.	Places in at Noon.				Temper. of	
		Lat. N.		Long. W.		Air.	Water.
Aug. 4	10 A. M.						57
	Noon.	41	7	9	4		60
5	Noon.	40	39	13	6	69	61
6	8 A. M.					69	65
	Noon.	40	35	17	6	69	67
7	10 P. M.	40	29	20	24	68	68
8	Noon.	40	24	22	1	69	68
9	Noon.	41	0	22	49	68	68
10	Noon.	40	13	22	39	68	68
11	Noon.	38	42	24	02	69	71
	10 P. M.						70
	Midnight						69
12	Noon.	37	57	24	55	72	70
14	Noon.	38	45	27	7	73	71
15	2 P. M.					72	70
	Sun set.					72	69
	Sun rise.						68
16	2 P. M.	38	24	27	51	73	70
	Sun set.						69
	10 P. M.						68
	Midnight						69
	Noon.	37	53	27	20	73	72
17	10 P. M.					70	72
	Noon.	37	7	27	39		73
18	Noon.	36	36	28	44		73
19	Noon.	36	9	31	39		73
20	Noon.	36	26	34	31	74	75
21	10 P. M.					74	74
	10 A. M.						70
	Noon.						69
22	Noon.	38	24	36	48		69
23	Noon.	38	43	38	49	74	73
24	10 P. M.	38	43	38	49	74	73
	Noon.	38	44	41	32		71
25	Noon.	39	04	44	17		75
26	Noon.	38	56	46	44		75
27	Noon.	38	12	50	10		70
28	Noon.	37	2	51	28		75
29	Noon.	38	8	52	31	74	74
30	Noon.	37	47	53	20	74	75
31	10 P. M.					72	70
	Noon.	39	20	53	20		69
Sept. 1	Noon.	40	41	54	7	71	74
2	Midnight					72	71

A

A Thermometrical Journal of the temperature of the atmosphere and sea, on a passage from Oporto to Philadelphia, in the ship Apollo.
By Captain WILLIAM BILLINGS.

(Continued.)

Dates. 1791.	Time.	Places in at Noon. Lat. N.		Long. W.		Temp. of Air.	Temp. of Water.
Sept. 2	Noon.	40	57	55	26	70	72
3	Midnight						71
	Noon.	40	56	57	51	70	73
4	Noon.	39	10	59	18	74	74
5	Noon.	39	17	61	11	74	76
6	Midnight						77
	Noon.	40	6	63	20	74	78
7	Noon.	40	36	66	3		75
8	Noon.	40	1	67	23	73	77
9	10 P. M.					71	73
	Midnight						72
	4 A. M.						71
	Noon.	39	29	71	17		73
10	Noon.	39	19	72	8	73	73
11	Noon.	39	4	72	33	74	75
12	Noon.	38	57	73	21	74	74
13	Noon.	38	53	72	31	74	75
14	Noon.	39	21	73	31	75	73
15	6 P. M.					74	69
	8 A. M.						68

NOTES:

August 4—10 A. M. Port barr: bearing ESE distant 7 leagues.

August 10.—But about half of degree difference of latitude for these 5 days past, and little or no change in the temperature of the sea.

August 11—noon. 1 and ½ degree southing water 3°. warmer.—4 P. M. made the island St. Michael; island, dist. 4 leagues, tacked and stood off.—5 A. M. tacked and stood to the southward.

August 15—4 P. M. Made the island Tercera,

August 16—Sun rise. Near Tercera, St. George's, and Pico in sight. —10 P. M. Close in with St. George's.

August 17—noon. Land out of sight.

Sept. 6—Midnight. This rise indicates the Gulph stream.

Sept. 9—10 P. M. This fall indicates the western side of the Gulph stream.

Sept. 15—8 A. M. Sounded in 25 fathoms.

DIRECTIONS

DIRECTIONS

FOR

USING

THE THERMOMETER

IN

NAVIGATION,

WITH

Miſcellaneous Remarks.

ADDRESSED

To all Naval Commanders.

" Diligence and Attention are the parents of good luck."
Poor Richard.

ADVERTISEMENT.

☞ *THE writer means to speak to* ALL *Navigators; it is hoped therefore, that those who find the following directions unnecessary, will pardon the repetition of what they well understand, in consideration for those who may not be so well informed.*

DIRECTIONS TO NAVIGATORS.

TAKE with you at leaſt three thermometers, for fear of accidents. Let them be kept in one place ſome days previous to your ſailing, in order to try their uniformity. The plate ſhould be of ivory or metal, for wood will ſwell at ſea, and as the glaſs tube will not yield, it is for this reaſon very liable to break; bell metal is the beſt. Let the inſtrument be fixed in a ſquare metal box, the bottom of which, as high as the mark 30°. ſhould be water tight, ſo that in examining the degree of heat, the ball may be kept in the water; the remainder of the length ſhould be open in front, with only two or three croſs bars to ward off any accidental blow, like the thermometer uſed by brewers. Fix one inſtrument in ſome part of the ſhip in the ſhade, and in open air; but as much out of the wind, and in as dry a place as poſſible. The after part of one of the after ſtaunchions, under the quarter rail may anſwer, if no better place can be found.

Let the ſecond inſtrument be neatly ſlung with a ſufficiency of line to allow it to tow in the dead water of the wake.

Put

Put the third away fafely in your cheft, to be ready to fupply the place of either of the others.

When you make your obfervations, begin by noting the ftate of the air from the inftrument on deck. Throw the other out of the cabin window, and let it tow two or three minutes, then draw it up and examine it the inftant you can bring it to your eye, with the ball *ftill in water*, and note the degree: This is a neceffary precaution for the mercury will foon fall when the thermometer is wet, efpecially if expofed to any wind. When you examine the water at night take care not to heat the inftrument by a candle which fhould be always in a lantern; do not touch the tube, nor breathe upon it, while you examine it; leaft you fhould communicate heat by the touch, or take it away by caufing an evaporation, which is the effect of blowing upon a wet thermometer.

Endeavour to make all your experiments in an uniform manner, do not try the water one day out of the cabin windows, another over the fide, or in a bucket; but keep to one fteady rule; it is not fo material which way you do it, as it is to do it always the fame way. If a bucket be ufed let it tow long enough to take away its heat, for the cook may have had it full of hot water.

Pay

Pay conſtant attention to the changes in the temperature of the air, and compare them daily with the changes in that of the water. This will account to you for the alterations on the ſurface of the ſea, (eſpecially in calm weather) which naturally follow the alterations in the incumbent atmoſphere: The difference between deep water and ſoundings will, under the ſame temperature of the atmoſphere, ſtill be the ſame. If, when in open ſea, you ſhould perceive a ſmall change in the water, without being able to account for it by an alteration of latitude, or of the weather, you may ſuſpect a current from the northward if colder, from the ſouthward if warmer; and as circumſtances may permit, you will do well to aſcertain it.

Compare your obſervations from time to time with thoſe mentioned in the journals and noted on the chart, and if you find any difference when in the ſame ſituation, repeat your experiments, ſo as to be ſure that the error is not on your ſide.

Although it is not pretended to give accurate accounts, from the few experiments that have been made, it is preſumed that the following will be found near the truth.

On the COAST *of* EUROPE.

From the channel of England to the Tagus it will be generally found, that the water over ſoundings is about three degrees colder than at ſea. And that the firſt ſymptom of ſoundings is at a great diſtance from the land, for the coaſt (unlike that of America) approaches from an imperceptible depth to ſoundings ſo gradually that it is not eaſy to ſay when you can get the ground. But were you to approach the rocks of Scilly, weſtern coaſt of Ireland, Orkneys, &c. the alteration would probably be ſudden and very deciſive.

On the COAST *of* NORTH AMERICA.

At the edge of the Grand bank the water is 5 degrees colder than the deep ocean to the eaſtward. The higheſt part of the Grand bank is 10. colder ſtill, or 15. colder than the ocean eaſtward.

As the banks deepen between them and the coaſt of Nova Scotia, the water grows about 6°. warmer till you get quite within them, when it riſes to about the temperature of the deep ocean without; on ſoundings the mercury will again fall to the temperature of the inner banks. So that in coming from the eaſtward a fall of 5°. will indicate your entrance on the edge of the Grand bank, and a further fall of 10°. will indicate your being in ſoundings. Paſſing the ſummit of the banks a riſe of 6°. will ſhow the weſtern edge of the Grand bank, and a further riſe to the temperature of the deep ocean without will indicate the deep water within the banks. When the mercury falls again to the temperature of the inner banks, you ſtrike ſoundings on the coaſt of Nova Scotia.

An

An important obſervation occurs here. The iſle of Sable is a little bank of ſand above water, which receives heat readily from a hot ſun and communicates it rapidly to the ſhoals under water, upon the principle mentioned as to land-locked places. If therefore you come too near that iſland in hot weather the thermometer will probably vary from theſe rules, in that caſe you may get bottom. If however, the previous obſervations are well made, you need not be in danger, for you can by your meridian altitude, ſhape your courſe as far to the northward or ſouthward as you chooſe.

On the coaſt of New England off Cape Cod, the water out of ſoundings is 8°. or 10°. warmer than in ſoundings, and in the ſtream it is about 8°. warmer ſtill: So that in coming from the eaſtward a fall of 8 degrees, will indicate your leaving the ſtream, and a further fall of 8 degrees, will indicate your being on ſoundings.

On the coaſt from Cape Henlopen to Cape Henry, the water out of ſoundings is 5 degrees warmer than in ſoundings, and in the ſtream about 5 degrees warmer ſtill: So that in coming from the eaſtward a fall of 6 degrees will indicate your leaving the ſtream, and a further fall of 5 degrees will give notice of ſoundings.

By this ſort of compariſon a Navigator may readily aſcertain when he leaves the ſtream and enters on ſoundings.

foundings. It is not prefumed to fpeak pofitively as to the degrees, except where it has been proved by experiment.

A fhort time fince, the writer met with an excellent meteorological work, entitled " An eftimate of the temperature of different latitudes." By Richard Kirwan, Efq. F. R. S. a celebrated Englifh philofopher, who has enriched the fund of fcience with feveral ufeful works. It is difficult to make an extract from this book without injury, becaufe the whole is fo interefting, that to do it juftice all fhould be read.

The note D is fubjoined to fhew how neceffary it is to combine a knowledge of the fea with that of the atmofphere, and to ftimulate Navigators to make numerous and accurate obfervations.

On CURRENTS, *&c.*

As to the courfe of the ftream, its eddy and other currents in the Atlantic ocean, it is proper to quote the teftimony of others, before conclufions are prefumed to be drawn from the writer's own obfervations. To place thefe in a clear point of view, arrows are made on the chart indicating the names of the obfervers. Thus the arrows L mark the currents defcribed in the extracts of a journal kept on board the Britifh fhip of war Liverpool, in the appendix, page 35. The arrows T mark the eddy within the Gulph ftream, mentioned by Capt.

Capt. Truxton in the ſubjoined note A. The arrows G mark the currents obſerved by Sir Eraſmus Gower of the Britiſh ſhip of war Lion, according to the notes B and C; and the arrows M mark the currents obſerved by Capt. Mackintoſh of the Engliſh Eaſt India company's ſhip Hindoſtan, according to note C. The other arrows are taken from the obſervations mentioned in the foregoing journals with the concurrence of the Captains on board of whoſe ſhips they were made.

With this teſtimony before us, and with the authority of Doctor Franklin for the accumulation of water by the power of ſteady and uniform winds, let us turn our attention to the tropical regions.

The diurnal revolution of the globe, would naturally cauſe an apparent current of air from the eaſtward, if there were no other cauſe, for the atmoſphere not being abſolutely confined to the ſurface, does not ſo immediately partake of that motion. This is more ſenſible about the equator, not only becauſe it being the largeſt circle the diurnal motion is greater there, but the various cauſes of wind in every direction do not exiſt ſo ſtrongly in the torrid, as in the temperate and frigid zones. But there conſtantly exiſts a cauſe of wind from the north on one ſide, and from the ſouth on the other ſide of the line where the ſun is vertical, owing to the rarifaction of the air by heat, which

the

the air from the northern and ſouthern regions is conſtantly ruſhing in to ſupply. It is a fact well known to all Navigators, that the ſouthern trade winds are compoſed of ſouthern and eaſtern breezes; and the northern trade winds are compoſed of northern and eaſtern breezes; when thoſe are of equal ſtrength, the wind blows exactly NE on one ſide, and SE on the other ſide of the before mentioned line. But at all times it blows between theſe points, except in caſe of a tornado or hurricane: Theſe winds according to Doctor Franklin's obſervations, force the water into the gulph of Florida, which iſſuing thence round the cape and through the Bahama iſlands, make our Gulph ſtream.

This water ſo driven from the eaſtward acroſs the Atlantic to the gulph of Florida, muſt leave a vacancy for other water to be conſtantly coming in to ſupply its place. Do we not therefore find that the ſouthern currents marked by Sir Eraſmus Gower, Capt. Mackintoſh and others, are a perfectly natural and infallible conſequence of the foregoing theory.

It may not be amiſs in this place to note the conſtant current into the Mediterranean. Why, it may be aſked, is there not a reflux from that ſea upon the ſame principle as we find a reflux from the gulph of Florida? This apparent phenomenon becomes, from ſelf-evident principles, a natural event, when we conſider the following facts. The climate of the Mediterranean sea must occasion great evaporation from its surface; the prevailing winds, from the causes instanced in the theory of the trade winds, must carry this evaporation over the African high lands, where it serves to form those rainy seasons for which that country is so remarkable, and runs into other seas; some indeed is returned by the Nile, but this is too small a quantity to supply the waste, for that is the only great river in the whole of its southern and eastern borders. The evaporation that may occasionally be directed eastward and southward, when it falls in rain, forms rivers which are lost in the Persian gulph or the Red sea, while the rivers on the northern side of the Mediterranean only supply the evaporation of the gulphs, bays, &c. into which they run; and the Black sea and Archipelago have occasion for all thewater that runs into them to supply their own evaporation. Hence the Mediterranean must have a constant supply from the Atlantic to keep up its level with that ocean, and hence there is a constant current running into it. The gulph of Florida on the contrary receives from our western mountains an immense quantity of water by means of the Mississippi and other rivers, which more than supply its evaporation, and make the stream so much the stronger.

Little need be said about the eddy current, because every man who has rowed along shore in a river, or is in any respect acquainted with the tides must understand

it,

it, and that ſuch an eddy exiſts in the Gulph ſtream, is proved by Capt. Truxton's obſervations in the note A, and the inſtances mentioned in the foregoing memoirs of ſhips being farther a-head than they were ſuppoſed by reckoning to be. When the ſtream has paſſed the banks of Newfoundland there is no other obſtacle to check its courſe, it therefore naturally ſpreads itſelf in ſuch directions as tend to the common level: We have already ſeen, that in a direction from the weſtern iſlands to the Canaries there is a conſtant current; and muſt not that invite other water from the northward and weſtward of it to ſupply its place? May we not hence conclude that the Gulph ſtream makes a ſweep in the direction deſcribed, only loſing its name of ſtream, as it alſo loſes (on the north ſide at leaſt) its diſtinctive quality of heat: Indeed it is probable that as it turns to the ſouthward into warmer water, it may be diſcovered by its want of heat, incomparison to the waters of ſouthern climates, until the equilibrium of heat is reſtored.

The currents ſo common among the Weſt India iſlands are probably the termination of the ſweep of currents juſt deſcribed; and when the gulph of Florida diſgorges the water, it again becomes the Gulph ſtream. The importance of knowing how near to the coaſt a ſhip may venture, and how to diſtinguiſh the Gulph ſtream from the water between it and the coaſt is immenſe when applied to our coaſting trade; for by this advantage

advantage we can be ſure of a favorable current either way, and a ſmall veſſel might make a ſhort voyage from Halifax to Georgia, which is thought by ſome a longer one than to Europe. Suppoſe you had the wind a-head all the way. Take your departure and ſtand for the ſtream; as ſoon as you find the water to increaſe in heat about half as much as you know it would when in the ſtream; heave about and ſtand for the coaſt, you will infallibly diſcover the edge of ſoundings by the cooling of the water; then ſtand off again, and ſo on to the end of the voyage, when it is almoſt certain that the diſtance would be run in a ſhorter time than if there were no ſtream; for you would have a favorable inſide or eddy current. On the return paſſage, take your departure and run off till you get into the hotteſt water, which will be the middle of the ſtream, and take the advantage of its current.

The following fact may ſerve to illuſtrate the propriety of theſe directions: In June laſt the mail packet for Charleſton had twenty-five days paſſage in going, but returned in ſeven. The Captain accounted for this by having calms, or very light airs, and a northerly current. This was the true cauſe. He was in the middle of the ſtream, where there generally are calms or light airs: The edges only, which come in contact with colder regions, being tempeſtuous. After being in the latitude of Cape Hatteras, he found himſelf in that of Cape Henry. The veſſel however, got there at laſt; and on the return voyage the Captain ſteered the ſame courſe back again, and with the ſame light airs he performed the voyage in ſeven days. Had this Captain known the uſe of the thermometer, need he have been much longer in going than in coming?

A ſafe coaſting trade is at all times an object for this country, but in war time the benefit is immenſe. We might convey ſupplies from one end to the other of our coaſt, by keeping juſt on the edge of ſoundings, where (always knowing the true bearings and diſtances of the land, which a foreign enemy might not know) our veſſels could by ſteering for the land, put an end to a chace which through fear of danger, an enemy would probably be obliged to abandon.

JONATHAN WILLIAMS.

NOTES,

NOTES, &c.

A.

Extract from Truxton's Remarks, Instructions, and Examples.

"THE direction or course of the Florida Gulph stream may also be relied on, *as I often tried its rate of going, by anchoring a boat in a calm (with a rope made fast to an iron pot, the rope from 150 to 200 fathoms in length, and the pot from 18 to 25 inches in diameter, according to the size of the boat) and heaving the log, whereby its rate of going was ascertained, and found to be seldom less than one knot, and never more than two knots and a half per hour; that is to the northward of Cape Hatteras; but to the southward and westward of that Cape, it no doubt often runs much stronger; and the nearer the channel between Florida and the Bahamas, the stronger of course. The width of this stream I have fixed also, by trying the current; and, when opportunities offered, in passing or repassing it, by making observations of the heavenly bodies: Add to which, I have been attentive in ascertaining the temperature of the water, and comparing it with that of the air, as recommended

* See Truxton's chart.

mended by that great philosopher, the late Dr. Franklin.† The temperature of the air and water, without the stream, is generally about the same; that is, the difference seldom exceeds two or three degrees: Sometimes the air is the warmest; at other times the water."

"In the stream, the water is always much warmer than the air: indeed, I have known it ten degrees warmer; but so soon as you get within the stream, the water becomes colder than the air; and the more so, as you get on soundings, and approach the shore. If mariners, who have not the opportunity of determining their longitude by celestial observations, will only carry with them a good thermometer, and try the temperature of the water, and compare it with that of the air every two hours, they may always know when they come into, or go out of, the Gulph stream: Indeed, I always made a practice, when at sea, of comparing the temperature of the air and water daily, and often very frequently throughout the day during my voyage; whereby I immediately discovered any thing of a current that was going, and afterwards found its strength and direction by observations for the latitude and longitude. It is of the utmost consequence, in making a passage to and

† The reader will perceive by the foregoing observations, that besides the comparison of the temperature of the air, with that of the water, it is proper to compare the heat of the water in different places one with another.

and from Europe, to be acquainted with this Gulph ſtream; as by keeping in it, when bound eaſtward, you ſhorten your voyage; and by avoiding it when returning to the weſtward, you facilitate it inconceivably; ſo much ſo, that I have frequently when bound from Europe to this country, ſpoke European ſhips, unacquainted with the ſtrength and extent of it, off the banks of Newfoundland, and been in port a very conſiderable time before them, by keeping out of the ſtream; whereas they lengthened their paſſage by keeping in it. The general courſe of the Gulph ſtream being marked on the chart, I would adviſe thoſe who make the northern paſſage from Europe, never to come nearer the inner line of it by choice than 10 or 15 leagues; and then the probability will be, that their paſſage will be aſſiſted by the help of a counter current, which often runs within it. In coming off a voyage from the ſouthward, be ſure to ſteer NW when approaching the ſtream, if the wind will permit you, and continue that courſe until you are within it, which may be eaſily known by the temperature of the water, as before mentioned. I have always conſidered it of the utmoſt conſequence when bound in, to croſs the Gulph ſtream as ſpeedily as poſſible, leſt I ſhould be viſited by calms or adverſe winds, and by that means drove far out of my way, which would prolong the voyage conſiderably, eſpecially in the winter ſeaſon."

B.

B.

Extract from Sir George Staunton's account of an Embassy to China. Vol. 1, Eng. Ed. p. 88. Amer. Ed. p. 31.

"SIR Erasmus Gower observed that all ships bound from Europe for the island of Madeira, will discover that their way is influenced by a current or set, from the western ocean into the bay, formed between Ushant and Cape Finistere, and into the Mediterranean; and as well as his observations in five visits to Madeira could enable him to ascertain, such current should be estimated to set SE about 11 miles in 50 leagues."

C.

Extract from Staunton's Embassy. Vol. 1, Eng. Ed. p. 88. Amer. Ed. p. 45.

"SIR Erasmus Gower observed in proceeding to Teneriffe a constant current setting to the southward, at the rate of a mile an hour, equal to 22 miles in the distance between that island and Madeira."

"Captain Mackintosh of the Hindostan, who had made twenty passages in this route, generally experienced a current from the 39th degree of latitude to that of the

Canaries.

Canaries. In this part of the ocean he formerly found from repeated and accurate obſervations, that this current ſet 3 degrees 50 minutes ESE. He found it ſtrongeſt oppoſite to the entrance into the Mediterranean or ſtraits of Gibralter; and in one voyage the current was computed by his time keeper to ſet about 40 miles a-day. This current inclines more ſoutherly as it approaches the Canaries. It ſtrikes on the coaſt of Barbary and takes about Cape Bojador, different and oppoſite directions, near in ſhore one part running to the northward towards the Mediterranean, and the other to the ſouthward along the coaſt towards the equator."

D.

Extracts from Kirwan's Eſtimate of the Temperature of different Latitudes.

"WE may obſerve, that the heat and cold of different countries are tranſmitted from one to the other by the medium of winds. How the air of a cold country is determined to flow towards a warmer, is eaſily underſtood; but by what means warm air is determined to flow towards cold countries, is ſomewhat difficult to explain. I ſhall here mention three cauſes that occur to me, wiſhing for a fuller explanation from others."

"Firſt, if a ſtrong northerly wind prevails in the direction of the meridian oppoſite to London, as in the

the country of the Tſchutſchi, in the eaſtern extremity of Aſia, this current muſt be ſupplied by air from the North Pole; and this in its turn by air ſouth of the Pole in the direction of the meridian of London."

"2dly. If from any tract in the upper regions of the atmoſphere, two currents of air flow in oppoſite directions, as ſometimes happens, the inferior air being leſs compreſſed, will become ſpecifically lighter; and currents of air in oppoſite directions to the upper currents, will take place."

"3dly. I conceive that when eaſterly and weſterly winds meet with unequal force, one of them may be reflected northwards."

"SOME ſituations are better fitted to receive or communicate heat than other ſituations; thus high and mountainous ſituations being nearer to the ſource of cold, muſt be colder than lower ſituations; and countries covered with woods, as they prevent the acceſs of the ſun's rays to the earth, or to the heaps of ſnow which they may conceal, and preſent more numerous evaporating ſurfaces, muſt be colder than open countries, though ſituated in the ſame latitude; and ſince all tracts of land preſent infinite varieties of ſituation, uniform reſults cannot here be expected. It remains then, that we ſeek for a ſtandard ſituation, with whoſe temperature in every latitude we may compare and appreciate the temperature of all other ſituations in the ſame latitudes,

tudes, on water only. Now the globe contains, properly ſpeaking, but two great tracts of water, or oceans: one, the Atlantic, ſeparating Europe and the weſtern ſide of the old continent from America; and the other, the Pacific, dividing Aſia from America; both of which I divide into north and ſouth, as they lie on the northern or ſouthern ſide of the equator."

"In this immenſe tract of water I choſe that ſituation for a ſtandard, which recommends itſelf moſt by its ſimplicity and freedom from any but the moſt permanent cauſes of alteration, viz. that part of the Atlantic that lies between the 80th degree of northern and the 45th of ſouthern latitude, and extending weſtwards as far as the Gulph ſtream,* and to within a few leagues of the coaſt of America; and all that part of the Pacific ocean, reaching from lat. 45°. N to lat. 40°. S, from the 20th to the 275th degree of longitude, eaſt of London, which is by far the greater part of the ſurface of the whole globe. Within this ſpace it will be found that the *mean annual temperature* is, as expreſſed in the following table. I have added the temperature of latitudes beyond 80 degrees in the northern hemiſphere, though not ſtrictly within the ſtandard."

N "*TABLE*

* Dr. Blagden, in an ingenious paper in the Philoſoph. Tranſ. for 1781, has ſhewn that the temperature of this ſtream is conſiderably greater than that of the adjacent part of the Atlantic.†

† *It was before diſcovered by Dr. Franklin, ſee journal on board of the Pennſylvania Packet, Capt. Oſborne, in 1775, and on board of the Repriſal, Captain Wyckes, in 1776.*

" *TABLE of the Mean Annual Temperature of the Standard situation, in every Latitude.*

Lat.	Temp.	Lat.	Temp.	Lat.	Temp.
90	31	61	43,5	32	69,1
89	31,04	60	44,3	31	69,9
88	31,10	59	45,09	30	70,7
87	31,14	58	45,8	29	71,5
86	31,2	57	46,7	28	72,3
85	31,4	56	47,5	27	72,8
84	31,5	55	48,4	26	73,8
83	31,7	54	49,2	25	74,5
82	32	53	50,2	24	75,4
81	32,2	52	51,1	23	75,9
80	32,6	51	52,4	22	76,5
79	32,9	50	52,9	21	77,2
78	33,2	49	53,8	20	77,8
77	33,7	48	54,7	19	78,3
76	34,1	47	55,6	18	78,9
75	34,5	46	56,4	17	79,4
74	35	45	57,5	16	79,9
73	35,5	44	58,4	15	80,4
72	36	43	59,4	14	80,8
71	36,6	42	60,3	13	81,3
70	37,2	41	61,2	12	81,7
69	37,8	40	62	11	82
68	38,4	39	63	10	82,3
67	39,1	38	63,9	9	82,7
66	39,7	37	64,8	8	82,9
65	40,4	36	65,7	7	83,2
64	41,2	35	66,6	6	83,4
63	41,9	34	67,4	5	83,6
62	42,7	33	68,3	0	84"

"WITH respect to the annual temperature, we may remark: 1st. That within 10 degrees of the poles the temperatures differ very little; neither do they differ much within 10 degrees of the equator."

"2dly. The temperature of different years differ very little near the equator, but they differ more and more, as the latitudes approach the poles."

"3dly. It scarce ever freezes in latitudes under 35°. unless in very elevated situations, and it scarce ever hails in latitudes higher than 60°.*"

"4thly. Between latitudes 35°. and 60°. in places adjacent to the sea, it generally thaws when the sun's altitude is 40°. and seldom begins to freeze, until the sun's meridian altitude is below 40°."

"IN every latitude, the mean temperature of the month of April, seems to approach very nearly, to the mean annual heat of that latitude; and, as far as heat depends on the action of the solar rays, the mean heat of every month, is as the mean altitude of the sun, or rather, as the sine of the sun's mean altitude during that month."

"Hence the mean heat of April, and the sines of the sun's altitude being given, I find the mean heat of May, by this analogy. As the sine of the sun's mean altitude in April, is to the mean heat of April, so is the

* 9 Vet. Com. Petrob.

the ſine of the ſun's mean altitude in May, to the mean heat of May. In this manner, I find the temperatures of June, July and Auguſt: But this rule would give the temperatures of the ſucceeding months much too low; becauſe, it does not comprehend the quantity of heat accruing to the atmoſphere by communication of the internal heat of the globe, which in every latitude is nearly the ſame, as the mean annual heat of that latitude. Hence, the real temperature of theſe months, muſt be looked upon as an arithmetical mean, between the aſtronomical, and terreſtrial heats. Thus, in lat. 51°. the aſtronomical heat of the month of September, is 44°. 66, and the mean annual heat is 52°. 4; therefore, the real mean heat of this month, ſhould be $\frac{44,6 + 524,}{2} = 48,4$, which is more conformable to obſervation."

"It may indeed be ſaid, that not only the ſun's altitude in every month, but alſo the duration of its light over the horizon, ſhould be taken into conſideration. And, without doubt, this, and ſome other circumſtances taken into account by Mr. De Mairan, ſhould not have been omitted by me, if all the circumſtances productive of cold, could alſo be ſubjected to calculation; but ſome of theſe can no way be eſtimated; for inſtance, the cold produced by evaporation: therefore, by way of compenſation, ſome of thoſe productive of heat, ſhould alſo be omitted; and in effect, the approximation of the calculated, to the real heat, is

much

much greater when this element is left out. Thus the temperature of June in lat. 51°. including this circumſtance, is 70°.; whereas, in fact, the mean heat of June, in London, is only 63. nor does it exceed 66°. even at Paris, lat. 48°. 50′. However, after going through a tedious calculation, I ſtill found the reſults to agree but ill with obſervation; and therefore, the enſuing table, is not to be looked upon as deduced from fixed principles, but rather partly from principles, and partly from what appeared to me, after ſtudying a variety of ſea journals, moſt conformable to obſervation. And, as a table of the mean monthly temperatures of different latitudes at ſea, can never be had by obſervation, I flatter myſelf that ſuch a table as this, made as correct, as the nature of things will allow, may in ſome meaſure ſupply its place."

"*From this Table we may learn,*

1ſt. To find the mean heat of the firſt, and laſt half of any month."

"Find the mean betwixt the ſtandard heat of any month, and the ſtandard heat of the ſucceeding; this will be the mean of the laſt fifteen days of the preceding, and the firſt fourteen or fifteen days of the ſucceeding month."

"2dly. To find the uſual extremes whether of heat, or of cold, that take place in any month."

"Find

" Find the difference of the monthly and annual temperatures; this difference *added* to the monthly temperature, gives the temperature of the hotteſt day, that is uſually found in any month; or being *ſubtracted* gives the coldeſt day, uſually obſerved within the month: By day, I mean the ſpace of twenty-four hours. Thus in London, the annual temperature being 52°. and the temperature of January 36°. the difference is 16, conſequently the warmeſt day in January is 52°. and the coldeſt 20°."

" The greateſt cold within the twenty-four hours, generally happens half an hour before ſun riſe, in all latitudes. The greateſt heat in all latitudes between 60°. and 45°. is found about half paſt two o'clock in the afternoon; between lat. 45°. and 35°. at two o'clock; between lat. 35°. and 25°. at half paſt one; and between lat. 25°. and the equator, at one o'clock."

" On ſea, the difference between the heat of day and night, is not ſo great as on land, particularly in low latitudes."

" The coldeſt weather in all climates, generally prevails about the middle of January, and the warmeſt in July, though, aſtronomically ſpeaking, the greateſt cold ſhould be felt at the latter end of December, and the greateſt heat in the latter end of June; but the earth requires ſome time to take, or to loſe the influence of the ſun, in the ſame manner as the ſea with reſpect to tides, does that of the moon."

" *TABLE*

" *TABLE of the Monthly Mean Temperature of the Standard, from lat.* 80°. *to lat.* 10°.

Latitude	80°	79°	78°	77°	76°	75°	74°	73°	72°	71°	70°	69°	68°	67°	66°	65°	64°	63°
January	22,	22,5	23,	23,5	24,	24,5	25,	25,5	26,	26,5	27,	27,5	27,5	28,	28,	28,	29,	30,
February	23,	23,	23,5	24,	24,5	25,	25,5	26,	26,5	27,	27,5	28,	28,	28,5	29,	30,	31,	32,
March	27,	27,5	28,	28,5	29,	29,5	30,	30,5	31,	31,5	32,	32,5	33,	33,5	34,	35,	36,	37,
April	32,6	32,9	33,2	33,7	34,1	34,5	35,	35,5	36,	36,6	37,2	37,8	38,4	39,1	39,7	40,4	41,2	41,9
May	36,5	36,5	37,	37,5	38,	38,5	39,	39,5	40,	40,5	41,	41,5	42,	42,5	43,	44,	45,	46,
June	51,	51,	51,5	52,	52,	52,	52,5	53,	53,5	54,	54,	54,5	54,5	54,5	55,	55,	55,5	55,5
July	50,	50,	50,5	51,	51,	51,	51,5	52,	52,5	53,	53,5	53,5	53,5	54,	54,5	54,5	55,	55,
August	39,5	40,	41,	41,5	42,	42,5	43,	43,5	44,	44,5	45,	45,5	46,	47,	48,	48,5	49,	50,
Septem.	33,5	34,	34,5	35,	35,5	36,	36,5	37,	38,	38,5	39,	39,5	40,	41,	42,	43,	44,	45,
October	28,5	29,	29,5	30,	30,5	31,	31,5	32,	32,5	33,	33,5	34,	34,	35,	36,	37,	37,5	38,
Novem.	23,	23,5	24,	24,5	25,	25,5	26,	26,5	27,	27,5	28,	28,5	29,	30,	31,	32,	32,5	33,
Decem.	22,5	23,	23,5	24,	24,5	25,	25,5	26,	26,5	27,	27,5	28,	28,	29,	30,	30,5	31,	31,

Latitude	62°	61°	60°	59°	58°	57°	56°	55°	54°	53°	52°	51°	50°	49°	48°	47°	46°
January	31,	32,	33,	34,	35,	36,	37,	38,	39,	40,	41,	42,	42,5	42,5	43,	43.5	44;
February	33,	34,	35,	36,	37,	38,	39,	40,	41,	42,	43,	44,	44,5	44,5	45,	45.5	46,
March	38,	39,	40,	41,	42,	43,	44,	45,	46,	48,	49,	50,	50,5	51,	52.5	53,	53.5
April	42,7	43,5	44,3	45,09	45,8	46,7	47,5	48,4	49,2	50,2	51,1	52,4	52,9	53,8	54.7	55.6	56.4
May	47,	48,	49,	50,	51,	52,	53,	54,	55,	56,	57,	58,	58,5	59,	60,	61,	62,
June	56,	56,	56,	56,5	57,	57,	57,5	58,	58,5	59,	59,	60,	61,	62,	63,	64,	65,
July	55,5	55,5	56,	56,5	57,	57,5	58,	59,	60,	61,	62,	63,	63,5	64,	65,	66,	67,
Auguft	51,	52,	53,	54,	55,	56,	57,	58,	59,	60,	61,	62,	63,5	64,	65,	66,	67,
Septem.	46,	47,	48,	49,	50,	51,	52,	53,	54,	55,	56,	57,	58,5	59,	60,	61,	62,
October	39,	40,	41,	42,	43,	44,	45,	46,	47,	48,	49,	50,	50,5	51,	52,	53,	54,
Novem.	34,	35,	36,	37,	48,	39,	40,	41,	42,	43,	44,5	46,	46,5	47,	48,	49,	50,
Decem.	32,	33,	34,	35,	36,	37,	38,	39,	40,	41,	42,	44,	44,5	45,	46,	47,	48,

Latitude	45°	44°	43°	42°	41°	40°	39°	38°	37°	36°	35°	34°	33°	32°	31°	30°	29°	28°
January	44,5	45,	45,5	46,	46,5	49,5	51,	52,	53,5	55,	56,5	59,5	63,	63,	63,	63,5	63,5	63,5
February	46,5	47,	48,	49,	50,	53,	56,5	58,	60,	61,	62,	63,	64,5	66,	67,	68,5	68,5	69,5
March	54,5	55,5	56,5	58,5	59,5	60,	60,5	61,	62,	63,	64,	65,	66,5	67,5	68,5	69,5	71,	72,
April	57,5	58,4	59,4	60,3	61,2	62,1	63,	63,9	64,8	65,7	66,6	67,4	68,3	69,1	69,9	70,7	71,5	72,3
May	63,	64,	65,	66,	67,	68,	69,	70,	70,5	71,	71,5	72,	72,5	73,	73,	73,5	74,5	75,5
June	66,	67,	68,	69,	70,	70,5	71,	71,	71,	71,5	71,5	72,	72,5	73,	73,	73,5	74,5	75,5
July	68,	69,	69,5	70,	70,	71,	71,	72,	72,	72,5	72,5	72,5	72,5	73,	73,	73,5	74,5	75,5
August	68,	69,	69,5	70,	70,	71,	71,	72,	72,	72,5	72,5	72,5	72,5	73,	73,	73,5	74,5	75,5
Septem.	63,	64,	66,	68,	69,5	70,5	71,	71,5	72,	72,5	72,5	72,5	72,5	73,	73,	73,5	74,	75,5
October	55,	56,	57,	58,	59,	60,	61,	62,	63,	64,	65,	66,	67,5	68,5	69,5	70,5	71,	72,5
Novem.	51,	52,	53,	54,	55,	56,	57,	58,	59,	60,	61,	62,	63,	64,5	65,5	66,5	68,	69,
Decem.	49,	50,	51,	52,	53,	54,	55,	56,	57,	58,	59,	60,	61,	62,5	63,5	64,5	66,	67,

Latitude	27°	26°	25°	24°	23°	22°	21°	20°	19°	18°	17°	16°	15°	14°	13°	12°	11°	10°
January	64,	64,5	65,5	67,	68,	69,	71,	72,	72,5	73,	73,5	74,	74,5	75,	76,	76,5	77,	77,5
February	69,5	70,5	71,	62,	72,	72,5	74,	75,	76,	76,5	77,	77,5	78,	78,5	79,	79,5	79,8	80,
March	72,5	73,	73,5	74,5	75,	75,5	76,	77,	77,5	78,	78,5	79,	79,5	80,	80,8	81,	81,5	81,8
April	72,8	73,8	74,5	75,4	75,9	76,5	77,2	77,8	78,3	78,9	79,4	79,9	80,4	80,8	81,3	81,7	82,	82,3
May	76,	76,5	77,5	78,	78,5	79,5	80,	80,5	81,	81,5	82,	82,5	83,	83,	83,5	84,	84,	84,3
June	76,	76,5	78,	78,5	79,	79,5	80,	80,5	81,5	82,	82,5	83,	83,5	83,8	84,	84,3	84,6	84,8
July	76,	76,5	78,	78,5	79,	79,5	80,	80,5	81,5	82,	82,5	83,	83,5	83,8	84,	84,3	84,6	84,8
August	76,	76,5	78,	78,5	79,	79,5	80,	80,5	81,5	82,	82,5	83,	83,5	83,8	84,	84,3	84,6	84,8
Septem.	76,	76,5	77,5	78,	78,5	79,	79,5	80,	81,	81,5	82,	82,5	83,	83,	83,5	84,	84,3	84,6
October	72,5	73,	73,5	74,5	75,	75,5	77,	78,	79,	80,	81,	81,5	82,	82,5	83,	83,5	83,8	84,
Novem.	69,5	71,5	72,	73,5	74,	74,5	75,	75,5	76,	77,	78,	78,5	79,	79,5	80,	80,5	80,8	81,
Decem.	67,5	68,5	69,5	70,5	71,	71,5	72,	72,5	73,	74,	75,	75,5	76,	76,5	77,	77,5	78,	78,

TEMPERATURE OF THE SEA.

N. lat.			Heat at the Surface.	Depth. Feet.	Heat.
70°	May	12	36°	502	39
		17	37°	540	39
	June	9	44°	558	40
	July	7	46°	420	44
68°		8	47°	1560	52
65°		9	48°	1280	48
		10	52°	846	45 *
27°	Jan.	3	64°	540	58 †
0			84°	3600 & 5346	53 ‡

* Phil. Tr. 1770, p. 39.

† 2 Bergm. Erde Kugel, p. 119.

‡ Phil. Tr. 1752, p. 213.

" But Lord Mulgrave found the temperature of the ſea, at great depths, in high latitudes, much colder; he does not indeed mention, the temperature of the ſurface, but it is preſumed, it did not differ much from that of the air; perhaps the reaſon was, that the newly melted ice, had then deſcended, though the firſt experiment cannot be explained, even on that hypotheſis.

Lat. N.			Heat of Air.	Depth.	Heat of the Sea.
67°	June	20	48°.5	4680	26°
78°		30	40°.5	708	31°
69°	Aug.	31	59°.5	4038	32°

Obſervations

Obfervations of Meffrs. Wales and Bayley.

Lat.		Air.	Surface.	Depth. Feet.	Heat of the Sea.
0	Sept. 5	75°.5	74°	510	66°
24° S	26	72°.5	70°	480	70°
34°.44′	Oct. 11	60°.5	59°	600	57°

Obfervations of Mr. Bladh.*

Lat.		Air.	Surface.	Depth. Feet.	Heat of the Sea.
57° N	Jan. 8	46°	37°	6	40°
	10	43°.6	43°.6	50	43°.6
55°.40	20	47°	40°	110	51°.5
39°.30	28	53°	59°	110	59°
2°.55	Feb. 25	81°	81°	58	81°
2°.50	26	83°	84°.5	110	81°"

* Suenfk. Handling. 1781.

E.

IN the foregoing extract it is faid that in lat. 67°. at the depth of 4680 feet, Lord Mulgrave found the temperature of the fea water at 26°. which is 6°. below the freezing point. This is a feeming contradiction. But it may be confidered that 32°. is the point of the flighteft congellation in river water. Sea water freezes with more difficulty becaufe the falt muft firft be feparated, for at the furface all ice is frefh.

The hypothefis intimated in the introduction to this work proceeds upon the principle, that although the ice formed at the furface of the fea is always frefh, yet a degree

degree of cold may happen which would make *falt ice*; or, in other words, a degree of cold may occur which would precipitate the falt, and combine it with ice. We know that the Academicians at Peterfburg, in 1759, by means of fnow and nitre reduced the mercury in a thermometer to a folid ftate, which bore the compreffion of the hammer. What fluid could refift congellation longer than mercury? Hence, by the conjecture that the bottom of the fea is ice, it is intended to convey an idea of much colder ice, than fuch as our winters produce.

F.

METHOD of comparing Fahrenheit's thermometer with that of Reaumer, fo that either inftrument may anfwer for nautical ufe.

N. B. The freezing point by Fahrenheit's fcale is 32°. by Reaumer's it is o.

It requires nine degrees on Fahrenheit's fcale to make four on Reaumer's, therefore to graduate an inftrument according to both, obferve this rule:

From any given degree of Fahrenheit deduct the freezing point 32°. then divide the remainder by nine, and afterwards multiply this ninth part or quotient by four and the anfwer will be degrees according to Reaumer.

To reverse this operation—Divide any given degree of Reaumer by four, and multiply the quotient or fourth part by nine, to the product add 32 . the freezing point and the answer will be degrees according to Fahrenheit.

EXAMPLE.

Take Fahrenheit's degree of - - - - - -	122°
Deduct the freezing point, - - - - - - -	32
Divide this by nine, - - - - - - - - - -	90
Quotient, - - - - - - - - - - - - - - -	10
Multiply this $\frac{1}{9}$th part by - - - - - - - -	4
An equivalent degree of heat by Reaumer,	40

REVERSE.

Take Reaumer's degree of - - - - - - -	40°
Divide this by 4,	
Quotient, - - - - - - - - - - - - - - - -	10
Multiply this $\frac{1}{4}$th part by - - - - - - - -	9
Product, - - - - - - - - - - - - - - - -	90
Add the freezing point, - - - - - - - -	32
An equivalent degree of heat by Fahrenheit,	122°

ERRATA.

Introduction, page 10, line 2d, for " at 32°. and must not that be ice?" read *below* 32°. and *may* not that be ice?

Page 48, line 18, for " perpendicularly" read *vertical.*

Page 53, line 6, for " unobserved," read *unobscured.*

POSTSCRIPT.

The foregoing part of this work was printed before any communication could be made to Capt. Truxton on the ſubject; and the whole was ſent to preſs before the letter, of which the following is an extract, came to hand.

As experiment is the only proper teſt of uſefulneſs, and as the opinion of a well known nautical character is more likely to inſpire confidence among navigators than any thing the writer himſelf could ſay; the motive for adding this poſtſcript becomes too ſtrong to be reſiſted.

Extract of a Letter from THOMAS TRUXTON, Eſq. to JONATHAN WILLIAMS.

" *Perth Amboy*, 12*th Aug.* 1799.

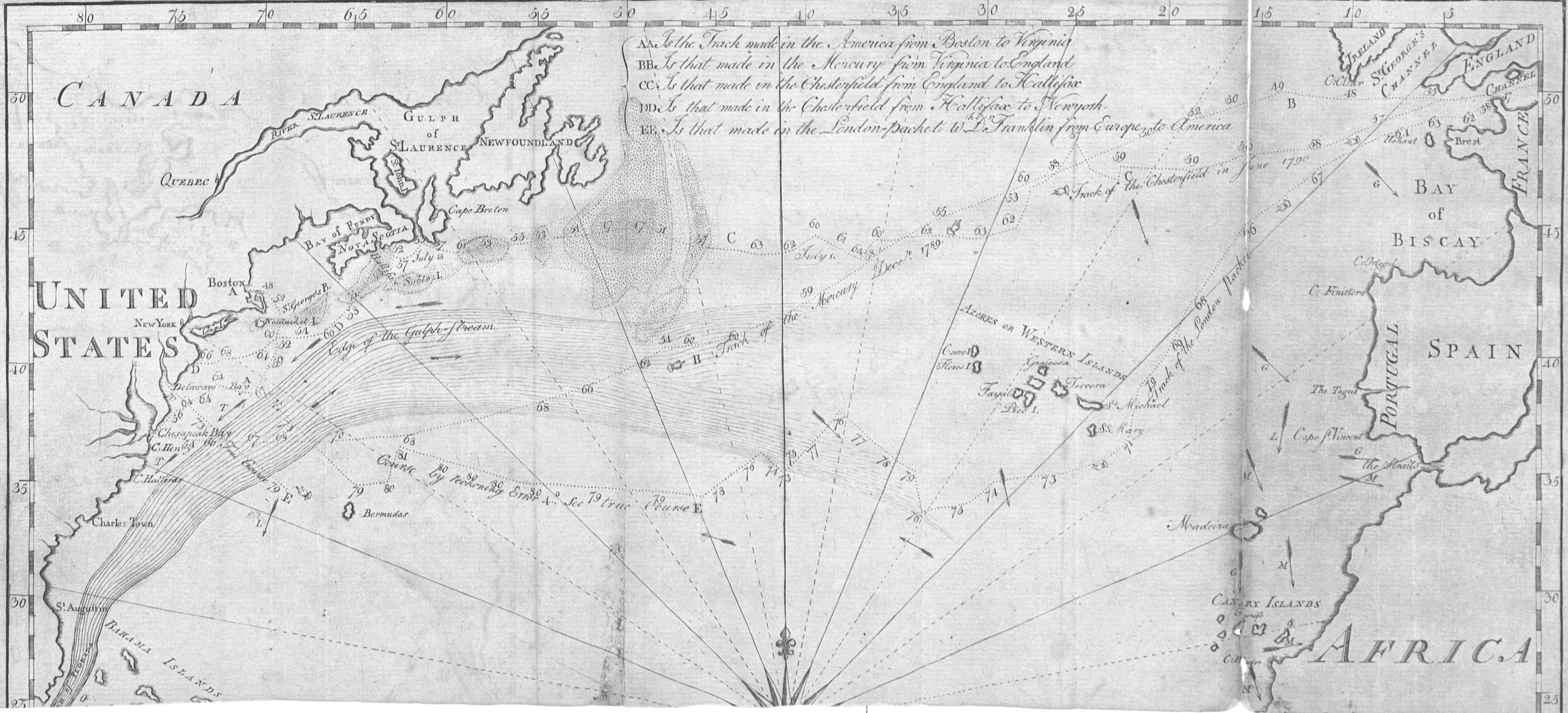
" *YOUR publication will be of uſe to navigation, by rendering ſea voyages ſecure, far beyond what even you yourſelf will immediately calculate, for I have proved the utility of the thermometer very often ſince we ſailed together, not only in croſſing and re-croſſing the Gulph ſtream that runs along our coaſts, but in the Ethiopean, Indian, Arabian and Chineſe ſeas, gulph of Bengal, gulph of Siam, the various ſtraits in the eaſtern world, and in many other parts of the globe.*

" *It*

"*It will be found a most valuable instrument in the hands of mariners, and particularly so to those who are unacquainted with astronomical observations, and calculations for determining the longitude at sea; these particularly stand in need of a simple method of ascertaining their approach to, or distance from the coast, especially in the winter season; for it is then that passages are often prolonged, and ships blown off the coast, by hard westerly winds, and vessels being in the Gulph stream, without its being known; on which account they are often hove too, by the Captain's supposing themselves near to the coast, when they are very far off, and by this means favorable spirts of wind are lost: On the other hand ships are often cast on the coast by sailing in the eddy of the stream, which causes them to out-run their common reckoning: Every year produces new proofs of these facts, and of the calamities incident thereto.*"

☞ Should a second edition appear proper, it is hoped that the writer will have it in his power to add not only these communications, but the experiments of many other Navigators. With this view, and in the mean time to prevent erroneous editions, the copy-right to this work is secured according to law.

J. W.


AA. Is the Track made in the America from Boston to Virginia
BB. Is that made in the Mercury from Virginia to England
CC. Is that made in the Chesterfield from England to Hallifax
DD. Is that made in the Chesterfield from Hallifax to S. Newyork
EE. Is that made in the London-packet w. Dr. Franklin from Europe to America
CANADA
UNITED STATES
GULPH of St. LAURENCE
NEWFOUNDLAND
RIVER St. LAURENCE
QUEBEC
Cape Breton
BAY of FUNDY
NOVA SCOTIA
Boston
NEW YORK
Delaware Bay
Chesapeak Bay
C. Hatteras
Charles Town
St. Augustin
BAHAMA ISLANDS
Bermudas
Edge of the Gulph-Stream
Track of the Mercury Decr. 1789
Track of the Chesterfield in June 1790
Track of the London packet
Course by reckoning
AZORES OR WESTERN ISLANDS
Graciosa
Tercera
St. Michael
St. Mary
Madeira
CANARY ISLANDS
AFRICA
SPAIN
PORTUGAL
FRANCE
BAY of BISCAY
ENGLAND
IRELAND
St. GEORGE'S CHANNEL
CHANNEL
Brest
C. Ortegal
C. Finistere
The Tagus
Cape St. Vincent
the Straits

DISTRICT OF PENNSYLVANIA—*To wit:*

Be it remembered, THAT on the ninth day of Auguſt, in the twenty-fourth year of the Independence of the United States of America, JONATHAN WILLIAMS, of the ſaid diſtrict hath depoſited in this office the title of a book, the right whereof he claims as AUTHOR, in the words following, *to wit:*—

" THERMOMETRICAL NAVIGATION.
" *Being a ſeries of experiments and obſervations, tending*
" *to prove, that by aſcertaining the relative heat of the ſea*
" *water from time to time, the paſſage of a ſhip through*
" *the Gulph ſtream, and from deep water into ſoundings,*
" *may be diſcovered in time to avoid danger, although*
" *(owing to tempeſtuous weather) it may be impoſſible to*
" *heave the lead or obſerve the heavenly bodies. Extracted*
" *from the American Philoſophical Tranſactions, vol. 2*
" *& 3. With additions and improvements.*—

" God helps them that help themſelves."
" *Poor Richard.*"

In conformity to the act of the congreſs of the United States, intituled " An Act for the encouragement of learning by ſecuring the copies of maps, charts and books to the authors and proprietors of ſuch copies during the times therein mentioned."

D. CALDWELL,
Clerk of the diſtrict of Pennſylvania.