

An account of the course of the Tides at Tonqueen in a Letter from Mr. Francis Davenport July 15. 1678. with the Theory of them, at the Barr of Tonqueen, by the learned Edmund Halley Fellow of the Royal Society.

WHEN the reported irregularity, of the *Ebbing* and *Flowing* of the *Sea* came first under my consideration at a distance, I was content to fancy that I had guessed aright in ascribing the occasion of it principally to the *Indraughts* and *outlets* of this *bay*, which as I Imagined might give (the different times of the year in respect of the *Monsoon's*, and the currents accordingly shifting with several other conceited coadjutant circumstances,) the most considerable share in the unusual course of the *Tides*, and that consequently it would scarce be possible to discover any constancy in them, if their regiment depended so much upon accidents and uncertainty's.

But during my continuance at *Batjba* I have observed such an order and constancy in the course of the *tides*, that notwithstanding I must needs confess it different from all that ever I observ'd in any other Port, yet not only from the coincidents of simular alterations on peculiar dayes of some particular *Moone's*, in different *monsoons* in respect of their increase and decrease, as well as from their keeping equal pace with the *Moon's* rising and setting in this *Horizon*, in respect of the duration of their *influx* and *reflux*, but also from that which seems to render them most irregular, *viz.* the constant falling back of the *flood* nearest 13 hours on every second day of the waters age and increase, so that at the end of 15 dayes there is an inversion of their motion in respect of their beginning to Flow and Ebb.

It is evident that they are regularly influenced though not reconcileable with a dependance on the *lunar* motion

tion so far as wholly to free the natural course from the interruption of some forreign intervening controulment.

Now for as much as it will be satisfactory enough for any mans benefit of the *tides* to know when the flood and ebb begins, and when there is the greatest and smallest influxes, without any nice discourse of the causes of their difference here, from those in other parts of the world, (a subject fitter for *Philosophers* then *Seamen*) I have here (to avoid overmuch tediousness) entred only the result of my unintermitted *observations*, of the *tides* dayly course, during my stay at *Batsha*, by which those *Commanders* who at this time of the year come before this *Barr*, may know when it will be most convenient to come over (supposing no *Pilate* goes off to bring them in) if they please to observe the following directions.

Directions concerning the choice of time in respect of
the Tides for coming over the Bar.

MY advice is, that upon the several following dayes of the *Moons* age in every particular month of the yeare, no *English Commander* should upon any occasion whatsoever adventure over this *Bar* unless he have a *Pilot* from the Shoare, who undertakes to bring him in, or that he hath only charge of some small *Bark* or *Junke*, that draws no more then 8 or 9 foot water.

In the $\left. \begin{matrix} 1 \\ 7 \end{matrix} \right\}$ *Moones*, from the $\left\{ \begin{matrix} 3 \\ 17 \end{matrix} \right.$ to the $\left. \begin{matrix} 7 \\ 21 \end{matrix} \right\}$ dayes of the *moones* age exclusively

In the $\left. \begin{matrix} 2 \\ 8 \end{matrix} \right\}$ *moones*, from the $\left\{ \begin{matrix} 1 \\ 14 \end{matrix} \right.$ to the $\left. \begin{matrix} 5 \\ 18 \end{matrix} \right\}$ dayes of the *moones* age exclusively,

and from the 27 of the $\left. \begin{matrix} 2 \\ 8 \end{matrix} \right\}$ *moones* to the 1st of the $\left. \begin{matrix} 3 \\ 9 \end{matrix} \right\}$ *moons* Excl.

- In the $\left. \begin{matrix} 3 \\ 9 \end{matrix} \right\}$ *moones*, from the $\left\{ \begin{matrix} 11 \\ 25 \end{matrix} \right.$ to the $\left. \begin{matrix} 15 \\ 29 \end{matrix} \right\}$ dayes of the *moones* age exclusively,
- In the $\left. \begin{matrix} 4 \\ 10 \end{matrix} \right\}$ *moones* from the $\left\{ \begin{matrix} 9 \\ 23 \end{matrix} \right.$ to the $\left. \begin{matrix} 13 \\ 27 \end{matrix} \right\}$ dayes of the *moones* age exclusively,
- In the $\left. \begin{matrix} 5 \\ 11 \end{matrix} \right\}$ *moones* from the $\left\{ \begin{matrix} 7 \\ 21 \end{matrix} \right.$ to the $\left. \begin{matrix} 11 \\ 25 \end{matrix} \right\}$ dayes of the *moones* age exclusively,
- In the $\left. \begin{matrix} 6 \\ 12 \end{matrix} \right\}$ *moones* from the $\left\{ \begin{matrix} 5 \\ 19 \end{matrix} \right.$ to the $\left. \begin{matrix} 9 \\ 23 \end{matrix} \right\}$ dayes of the *moones* age exclusively.

And excepting on these six days above mention'd in every respective *moone*, he may safely adventure over the *Bar* any day provided allways that he mistake not the time of the *tide*, but come over at half *Flood* or better, though he may take notice, that the best *Tides* will be about six or seven days after the waters first beginning to increase, and the first dayes of the waters increase are

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| In the $\left. \begin{matrix} 1 \\ 7 \end{matrix} \right\}$ <i>moones</i> on the | $\left. \begin{matrix} 5 \\ 19 \end{matrix} \right\}$ dayes. | } of the <i>Moones</i> age. |
| In the $\left. \begin{matrix} 2 \\ 8 \end{matrix} \right\}$ <i>moones</i> on the | $\left. \begin{matrix} 3 \\ 16 \\ 29 \end{matrix} \right\}$ dayes. | |
| In the $\left. \begin{matrix} 3 \\ 9 \end{matrix} \right\}$ <i>moones</i> on the | $\left. \begin{matrix} 13 \\ 27 \end{matrix} \right\}$ dayes. | |
| In the $\left. \begin{matrix} 4 \\ 10 \end{matrix} \right\}$ <i>moone</i> . on the | $\left. \begin{matrix} 11 \\ 25 \end{matrix} \right\}$ dayes. | |
| In the $\left. \begin{matrix} 5 \\ 11 \end{matrix} \right\}$ <i>moones</i> on the | $\left. \begin{matrix} 9 \\ 23 \end{matrix} \right\}$ dayes. | |
| In the $\left. \begin{matrix} 6 \\ 12 \end{matrix} \right\}$ <i>moones</i> on the | $\left. \begin{matrix} 7 \\ 21 \end{matrix} \right\}$ dayes. | |

It is needless to take notice in what *hours* the waters increase begins, because the regular course of the *Tides* is not from thence commenced, in respect of the time of Flowing and Ebbing.

The *Bar* it selfe being about a Mile and half in Length, and no where except in its first entrance exceeding half a Mile in Breadth, is very even, but yet affords considerably differing *foundings* in the same Age and time of the *tides*, according to the season of the *Year*, and which seems to be somewhat strange, hath the highest *Tides* in the *Northerly Monsoon*, as I have been informed by those who are seemingly best able to give an account thereof: and I must needs say, that the tryal I now made on the *Bar* did accord with what I understood from several of the *Fishermen* and others as to this *Month*, which induced me to enter this Information, that coming over at half flood (except on the dayes aforementioned as Dangerous to come over in) there will be found according to the age of the *Tides*.

In the	3 } 4 }	<i>Moones</i> from 16 to 21 feet water.
	5 }	
In the	6 } 7 }	<i>Moones</i> from 19 to 24 feet
	8 }	
In the	9 } 10 }	<i>Moones</i> from 21 to 27 feet
	11 }	
In the	12 } 1 }	<i>Moones</i> from 14 to 22 feet.
	2 }	

Always the higher the *Flood* the Lower the *Ebb*, so that according to the strength of the *Tides* at Low water, the *foundings* are from 6 to 13 feet.

NB. This *Bar of Tunking* is about 110 degrees of *Longitude* to the East of *London*, and in *Latitude* 20. 50.

On

On the first and second dayes of the waters increase the *influxes* are very small and uncertain, but afterwards the *Tides* for 13 dayes are constant in their course, one flood and one ebb being compleated in 24 hours time, equally sharing the space of a *Lunar* circuitiion of the Earth between them, and every *flood* beginning nearest $\frac{3}{4}$ of an hour later then the *precedent flood*, and also considerably increasing in the height of the *tide* every day from the 3^d unto the 6th and 7th dayes of the waters age, on which two dayes the *flood* runs very high, but on the 8th day (which may be accounted the last of the *spring tides*, the waters begin gradually to decrease again, retaining the same orderly difference of time in each *tide*, until the next following first day of the waters increase, when during two dayes unsettledness, there is a shifting of the *tides* in respect of the beginning of the *flood* and *ebb*, after which said shifting, a constancy in their inverted course, is again retained in the above mentioned order for 13 dayes following, as for *Example*.

On the 25 and 26 dayes of the 4th moone (4th and 5th of June 1678) in the latter end of *Aries*) being the first dayes of the waters increase, the *influxes* were very small (there happening on the 26th a falling back of the *tides* about 13 hours) but from the 27th (June 6. 78.) which was the 3^d day of the waters increase after the last quarter; unto the 9th day of the 5th moones age, (June 18. 1678) in \approx 20,) I noted a very constant course in the *tides*, every *flood* begining with the rising of the *moone* and ending at its setting, the following *ebb* in like manner continuing during the time of the *moones* absence from this *hemisphere*. But on the said 9th day of the 5th *moones* age (June 18. 1678) being the first day of the waters increase, their motion was scarcely perceptible; on the 10th day there was another falling back of the *tides* nearest 13 hours, and on the 11th day, (which was the 3^d day of the waters increase, after the first quarter of the *moones* age) the *flood* having (as I said) shifted the pre-

ceding day, took its turne to begin at the *moones* setting and end at its rising, and accordingly the tides successively following assumed & kept a constant regularity the *tides* being at highest the 16th of the *moone*, (1678. June 24. (« in middle of ») which was the seventh of the waters age, until the 23^d of the said *moones* age (July 1. 1678.) on which (being the first day of the waters increase) the influx was again scarcely discernable for its smallness.

On the 24th day the *tides* fall back (as I had found it twice before to have done on the same dayes of the waters age,) nearest 13 hours by which means the *flood* on the 25th day (which was the 3^d day of the waters increase after the last quarter of the *moone*) now again commenced with the rising *moone*, whereby it hath fallen out allways to be high water between *noone* and the following *midnight* every day during my stay here. (« last quarter 22 dayes, (« first quarter 8 dayes.)

So that it may pass into a *Corollary* viz. In the 4th 5th and 6th changes of the *moone* from the 3^d day of the waters age after the last quarter, to the 3^d day of the waters age after the first quarter of the following *moone*, the water begins to *flow* when the *moone* riseth, and to *ebb* again when it setteth in the *Horizon*, and the contrary to the 3^d day of *their* age after the last quarter, excluding allways their motion on the 2 first dayes of the waters increase, because of its smallness and uncertainty.

I am inform'd by the *inhabitants* hereabouts, that this may hold for a *rule* from the 2^d to the end of the 7th *moone* and that the *converse* thereof holds true in the other six months of the year, viz. from the 8th to the end of the first *moone*, according to which the *tides* will fall out to be at the highest in the evening for 6 months successively, and the other half year in the *morning*, that is to say between *midnight* and the following *moones*, and though I cannot aver the truth of it, yet I find that the
tide

tide last year in the 11th *moone*, which occasionally upon the Ship *Eagles* departure hence, I took some notice of, and entred in the close of my *Sea journal*, did fall out not disagreeing with what they affirme, and I am yet the rather induc'd to believe that in every *annual revolution* there may be such a constancy in this different motion of the *tide* appropriated to each moiety of the year, because, that dureing my dayes stay at *Batsba*; I have found the *predictions* of the *natives* confirmed by my owne *observations* of the *tides* falling out to be high water alwayes between *noone* and the succeeding *midnight* occasioned by the aforesaid falling back at the end of 15 dayes; so that on every 3d day of the waters increase, the *flood* begins at the hour whereon the day before it ended.

To prevent mistakes in the accompt of the *moones*, though the difference of *meridians* between this *place* and *London*, together with the different beginning of their *natural day* in their accompts here, from that of ours, and some imperfections from which their *Astronomical observations* are not free, may occasion a disagreement between our accompt and theirs, of the *moones* age, yet it will never be so considerable as to occasion any sensible, at least dangerous *error* in the above mentioned reckoning of the *tides*, provided the number of the moneth be not mistaken.

Wherefore it may be sufficient to informe those who use this *Port*, that the first change of the *moone* after the 15th day of *January* old stile, is reckoned for the begining of the *year*, and that *moone* being accompted the first, the rest follow in order until the expiration of the 12th which compleats their *year*, alwayes except only in their *leap years*, and then they have 13 *moones*, takeing in one extraordinary to make up the deficiency of the *moones* *epoch* in their accompt, in which year the first day of their new yeares *moone* falls out before the said 15th of *January*, as it did this year upon the 12th being *leap yeare* with them,

them, so that they reckoned two months for one this yeare, (that is to say the 2^d and 3^d *moones* after their *newyears* day) they called 2^d *moones*, for otherwayes this present *moone* which changed in *July* (the 8th) would have been the 7th, whereas now they count it but the 6th *moone*, and accordingly do the *tides* fall out, but this *leap yeare* being now past the first *moone* in the yeare must be reckoned to begin on the change next following the 15th of *January*, and all the other changes counted successively as before said until the intervention of another *leap yeare*.

Observations

A Theory of the Tides at the Bar of Tunking by the Learned Mr. Edm. Halley, Fellow of the Royal Society.

THe effect of the *Moon* upon the *waters*, in the production of the *tides* in this *port of Tunking*, is the more wonderful and surprizing, in that it seemes different in all its circumstances from the *general rule*, whereby the motion of the *Sea* is regulated, in all other parts of the world I have yet heard of. For first, each *flux* is of about 12 hours duration, and its correspondent *reflux*, as long, so that there is but one *high water* in 24 hours. Then there are in each month, two *intermissions* of the *Tides*, about 14 dayes asunder when there is no sensible *flood* or rising of the waters to be observed; but the *Sea* is in a manner stagnant. Thirdly, that the increase of the Water has its 14 days *period*, between the aforesaid *intermissions*; and at 7 days end, makes the highest *tides*, from which time the water again gradually abates, and the *flood* is weaker till it comes to a stagnation, both *increase* and *decrease* observing the same *rule* in being exceeding *slow* in their begining and end, and *swift* in the middle. Lastly, (and which is most odd) the *rising Moon* in the one half of each *month* makes high water, and the *setting moone* in the other half. These particulars considered together with the *Tables* shewing the days of the waters stagnation, in each moneth, gave me a light into the secret of this strange appearance, so as to be able to bring the hitherto unaccountable irregularity of these *Tides* to a certain rule. And first it appears by the latter of the two *Tables*, that the intermissions of the *Tides* happen nearly upon those days, that the *moon* enters the signs of *Aries* and *Libra*; or passes the *Equinoctial*; which divides the *Moons* course nearly into two equal parts, as well as the *Suns*, and from hence it follows that the *Tropical*

pical Moones in ☉ and ♃, are these which occasion the greatest flux and reflux; and for the rule of the change of the time of *high Water*, which Mr. *Davenport* calls a falling back of the *Tides*, the example he hath given us, lets us know, that the ☾ in *Northern* signs, brings in the *flood* whilst she is above the *Horizon*, so as to make *high water* at her setting, and on the contrary that whilst shee is in *Southern* signs, it flows all the time the *moon* is below the *Horizon*, and so make *high water* at her rising. But it is to be observed that though the *Moon* pass swiftly, from *South* to *North* when she is in or near ♋, and from *North* to *South* when in or near ♎; yet the *motion* of the *Sea* which is the cause of this *tide*, is scarce discernable for 3 or 4 days, when the *Moon* passes the said *Equinoctial* points; whence it appears that though the *declination* of ☾, or her distance from the *Equinoctial*, be that whereby these *Tides* are regulated, yet the increase and decrease of the *water* is by no means proportionate to that of the *declination* of *Luna*, that changing swiftly, where the increase of the *water* is observed to be most slow. It seems therefore, and I propose it as a probable conjecture, that the *increase* of the *waters* should be allways proportionate to the *Versed signs* of the doubled distances of the *Moon* from the *Equinoctial* points; Upon which *Hypothesis Figure 9.* will give an elegant *Synopsis* of the whole matter. Let AB be the bottom of the *Bar* of *Tunking*; CD a perpendicular thereto, whereon to measure the several depths of the *water*; Cv, C[☉] the mean depth, which is that whereat the *water* is stagnant upon the *moons* being upon the *Equinoctial* points, being commonly about 15 feet: C[☉] occid, the high water mark when the *Moon* is in ☉ or ♃ being about 24 foot. C[♃] occid the height of the Low water mark when the *Moon* is in ☉ or ♃, being about 6 foot; so that the greatest rise of the *Water* on the *Tropical Moons* will be about 18 foot; then dividing v ☉ and ☉ ♃ into two equal parts in EF, on those two points, as *Centers*, describe the 2 *Circles*, each of whose *Radii*, are
four

four feet and a half, which being kept between the *Compasses*, naturally divide the said *Circles* in the points δ , ω , ρ , κ , &c. through the which points if you draw lines parallel to the base A B they shall cut the *perpendicular* C D, in the heights of the *high* and *Low water* marks, which will be at the entrance of the *Moon* into the said *signs*. So the greatest depth of the *high water*, when the *Moon* enters δ , ω , ρ , κ , is but $17\frac{1}{4}$ feet, and the least at *Low water* $12\frac{1}{2}$ feet: but when she Enters Π , Ω , \rightarrow , ∞ , the *high-water* depth is $21\frac{3}{4}$ feet, the *Low-water* but $8\frac{1}{4}$ feet; as appears by the *figure*. And this Hypothesis not only agrees with all that Mr. *Davenport* hath observed himself, or collected from the *Natives*, but hath been found to hold true since in the year 1682 by the Ingenious Capt. *Knox*, in his *Voyage* to this *port*; so that there is no room to doubt of the truth thereof: By this *method* may the time and height of the *Tides* be with sufficient certainty computed, but to *philosophize* thereon, and to attempt to assign a reason, why the *Moon* should in so particular a manner influence the *waters* in this one place, is a task too hard for my undertaking, especially when I consider how little we have been able to establish a Genuine and satisfactory *Theory* of the *Tides*, found upon our own *Coasts*, of which wee have had so long Experience. It would be however a very acceptable thing if some curious *Navigators* would inform us, what *tides* or *Currents* are found at *Macao*, *Quemoy*, and other places on the *Coast* of *China* and on *Formosa*; it being most probable that this *flood* cometh out of the *North East*, alongst the *Coast* of *China*, for that the *Northerly Moonsoon* is found to occasion the highest *spring-tides*. There is yet another thing well worth Inquiry, that seeing that this motion of the *Sea* is more or less as the *Moon* is farther from or nearer to the *Equinoctiall*, it is not unlikely, that some years may have much higher *Spring-tides* than others, according to the Various *Obliquity* of the *Moons orbite* to the *Equinoctiall*, for when the ascending *Node* is in ν , (as it was anno 1671 and will be anno 1690)

the *Moon* in ♄ and ♃ deviates from the *Equator* full $28\frac{1}{2}$ degrees; and but $18\frac{1}{2}$ degrees, when the same *Node* is in *Libra*, as it was anno 1680; and I recommend as a very usefull *Querie*, for such as for the future shall use this *Port*, to examine whether the *Tides* are not in some years more *Vigorous* than in others, and particularly in the years but now mentioned; as likewise if there have been any *Inundations* occasioned by an extraordinary *flux* of the *Sea*, in what years the said *Inundations* have hap-
pened.

Defectus.