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 regimen depended so much upon accidents and uncertainty's.

But during my continuance at Batsha 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 coincidences of similar alterations on peculiar days of some particular Moon'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 1 3 hours on every second day of the waters age and increase, so that at the end of 1 5 days 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 foreign intervening control-ment.

Now for as much as it will be satisfactory enough for any man's 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 daily 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 days 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 \( \frac{1}{2} \) Moones, from the \( \frac{3}{17} \) to the \( \frac{7}{21} \) days of the moons age exclusively

In the \( \frac{2}{8} \) Moones, from the \( \frac{1}{14} \) to the \( \frac{5}{18} \) days of the moons age exclusively,

and from the \( \frac{27}{8} \) of the \( \frac{2}{9} \) Moones to the \( \frac{1}{2} \) of the \( \frac{3}{9} \) Moons Excl.
In the $\{3\}$ moones, from the $\{9\}$ to the $\{11\}$ dayes of the moones age exclusively,

In the $\{4\}$ moones from the $\{9\}$ to the $\{13\}$ dayes of the moones age exclusively,

In the $\{5\}$ moones from the $\{7\}$ to the $\{11\}$ dayes of the moones age exclusively,

In the $\{6\}$ moones from the $\{5\}$ to the $\{9\}$ dayes of the moones age exclusively.

And excepting on these six dayes 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 dayes after the waters first beginning to increafe, and the first dayes of the waters increale are:

<table>
<thead>
<tr>
<th>Moone</th>
<th>Dayes</th>
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<tr>
<td>7</td>
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Of the Moones age.
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 itself being about a Mile and half in Length, and nowhere except in its first entrance exceeding half a Mile in Breadth, is very even, but yet affords considerably differing soundings 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 lay, that the trial 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 days aforementioned as Dangerous to come over in) there will be found according to the age of the Tides.

\[
\begin{align*}
\text{In the} & \quad \text{Moones from 16 to 21 feet water,} \\
3 \quad & \text{Moones from 19 to 24 feet} \\
4 \quad & \text{Moones from 21 to 27 feet} \\
5 \quad & \text{Moones from 12 to 22 feet.} \\
6 \quad & \text{Moones from 16 to 21 feet water,} \\
7 \quad & \text{Moones from 19 to 24 feet} \\
8 \quad & \text{Moones from 21 to 27 feet} \\
9 \quad & \text{Moones from 12 to 22 feet.} \\
10 \quad & \text{Moones from 16 to 21 feet water,} \\
11 \quad & \text{Moones from 19 to 24 feet} \\
12 \quad & \text{Moones from 21 to 27 feet} \\
13 \quad & \text{Moones from 12 to 22 feet.}
\end{align*}
\]

Always the higher the Flood the Lower the Ebb, so that according to the strength of the Tides at Low water, the soundings 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 completed in 24 hours time, equally sharing the space of a Lunar circulation of the Earth between them, and every flood beginning nearest 3/4 of an hour later then the precedent flood, and also considerably increasing in the height of the tide every day from the 3rd 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 unferledness, 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 25th a falling back of the tides about 13 hours) but from the 27th (June 6. 78.) which was the 3d day of the waters increase after the last quarter; unto the 9th day of the 5th moones age, (June 18. 1678) I noted a very constant course in the tides, every flood beginning with the rising of the moone and ending at its letting, 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 3d day of the waters increase, after the first quarter of the moones age) the flood having (as I said) shifted the preceding
ceding day, took its turne to begin at the moones letting
and end at its rising, and accordingly the tides successi-
vely following assumed & kept a constant regularity the
tides being at higheft the 16th of the moone, (1678. June
24. C in middle of ») which was the seventh of the wa-
ters age, until the 23d of the said moones age (July 1.
1678.) on which (being the first day of the waters in-
crease) the influx was again scarcely discernable for its
smallnes.

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 3d day of the waters in-
crease after the last quarter of the moone) now again com-
menced 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. (C last
quarter 22 dayes, C 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 3d day of the wa-
ters age after the last quarter, to the 3d day of the wa-
ters age after the first quarter of the following moone,
the water begins to flow when the moone rileth, and to ebb
again when it seteth in the Horizon, and the contrary
to the 3d day of their age after the last quarter, exclud-
ing allways their motion on the 2 first dayes of the wa-
ters increase, because of its smallness and uncertain-
ty.

I am inform'd by the inhabitants hereabouts, that this
may hold for a rule from the 2d to the end of the 7th
moone and that the converse thereof holds true in the o-
ther 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 higheft in the evening for 6 months suc-
cessively, 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 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 affirm, and I am yet the
rather indu'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, be-
cause, that during my ... days stay at Batzba; I have
found the predictions of the natives confirmed by my
owne observations of the tides falling out to be high wa-
ter always between noone and the succeeding midnight
occasioned by the aforesaid falling back at the end of 15
days; 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 na-
tural day in their accompts here, from that of ours, and
some imperfections from which their Astronomical observ-
ations are not free, may occasion a disagreement be-
tween 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 reck-
oning 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, always except only in their
leap years, and then they have 13 moones, taking in one
extraordinary to make up the deficiency of the moones
epall 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 2d and 3d moones after their newyears day) they called 2d moones, for otherways 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 seems 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 days a under 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 beginning 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 moon 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 those 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 she 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 passes swiftly, from South to North when she is in or near V, and from North to South when in or near Libra; yet the motion of the Sea which is the cause of this tide, is scarce discernible 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 always proportionate to the Versed signs of the doubled distances of the Moon from the Equinoctial points; Upon which Hypothecis Figure 9. will give an elegant Synopsis of the whole matter. Let AB be the bottom of the Bar of Tunking; CD a perpendicular thereeto, 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 V 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 through which 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 B, is but 17 feet, and the least at low water 12 feet; but when she enters C, the high-water depth is 21 feet, the low-water but 8 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 upon, 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 we 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, along the Coast of China, for that the Northerly Monsoons are found to occasion the highest Spring-tides. There is yet another thing well worth Inquiry, that seeing his 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 orbit; to the Equinoctiall, for when the ascending Node is in V, (as it was anno 1671 and will be anno 1690)
the Moon in ° and 0 deviates from the Equator full 28½ degrees; and but 18½ degrees, when the same Node is in Libra, as it was anno 1680; and I recommend as a very useful question, 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 happened.