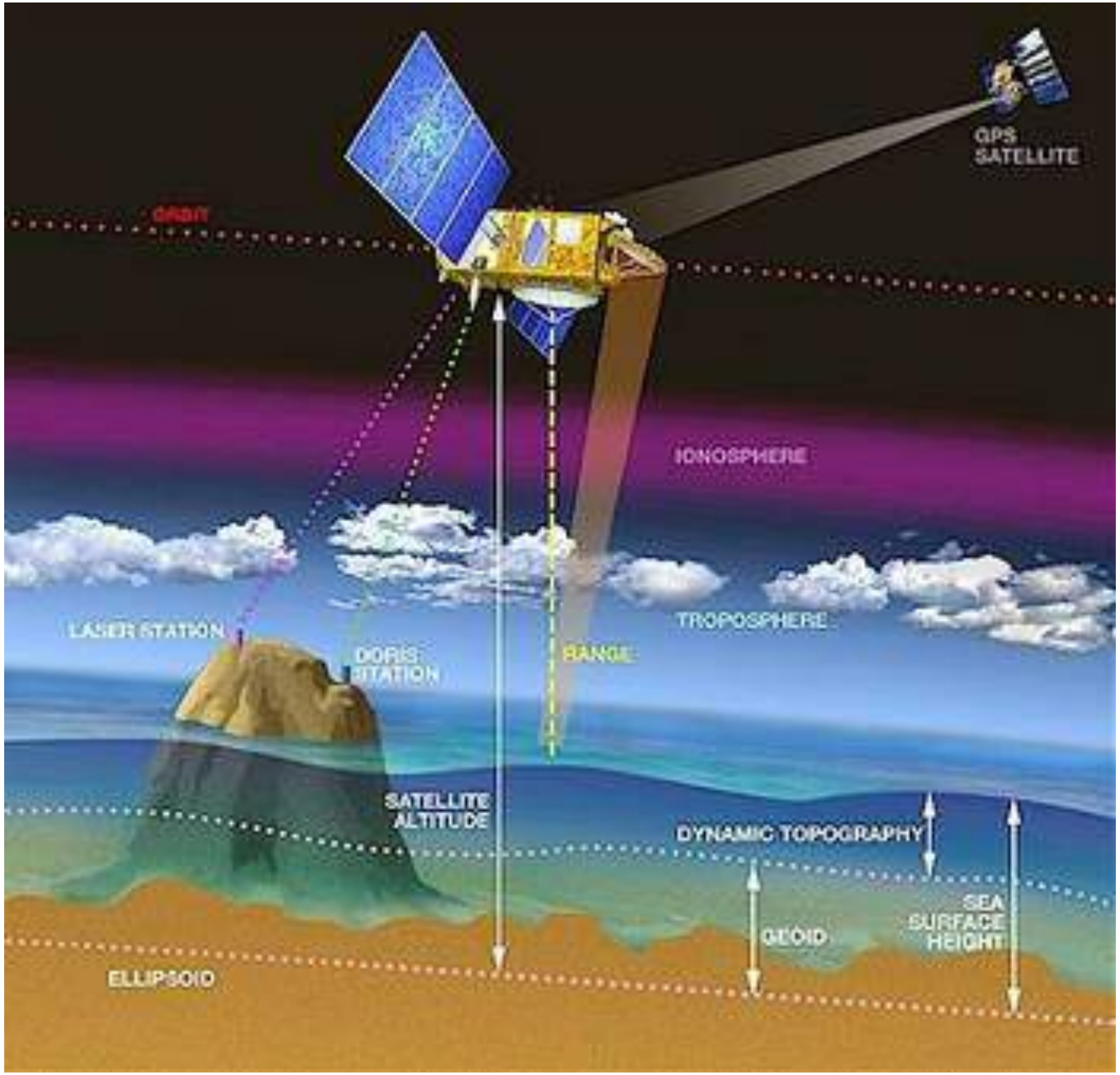
Ocean Tides

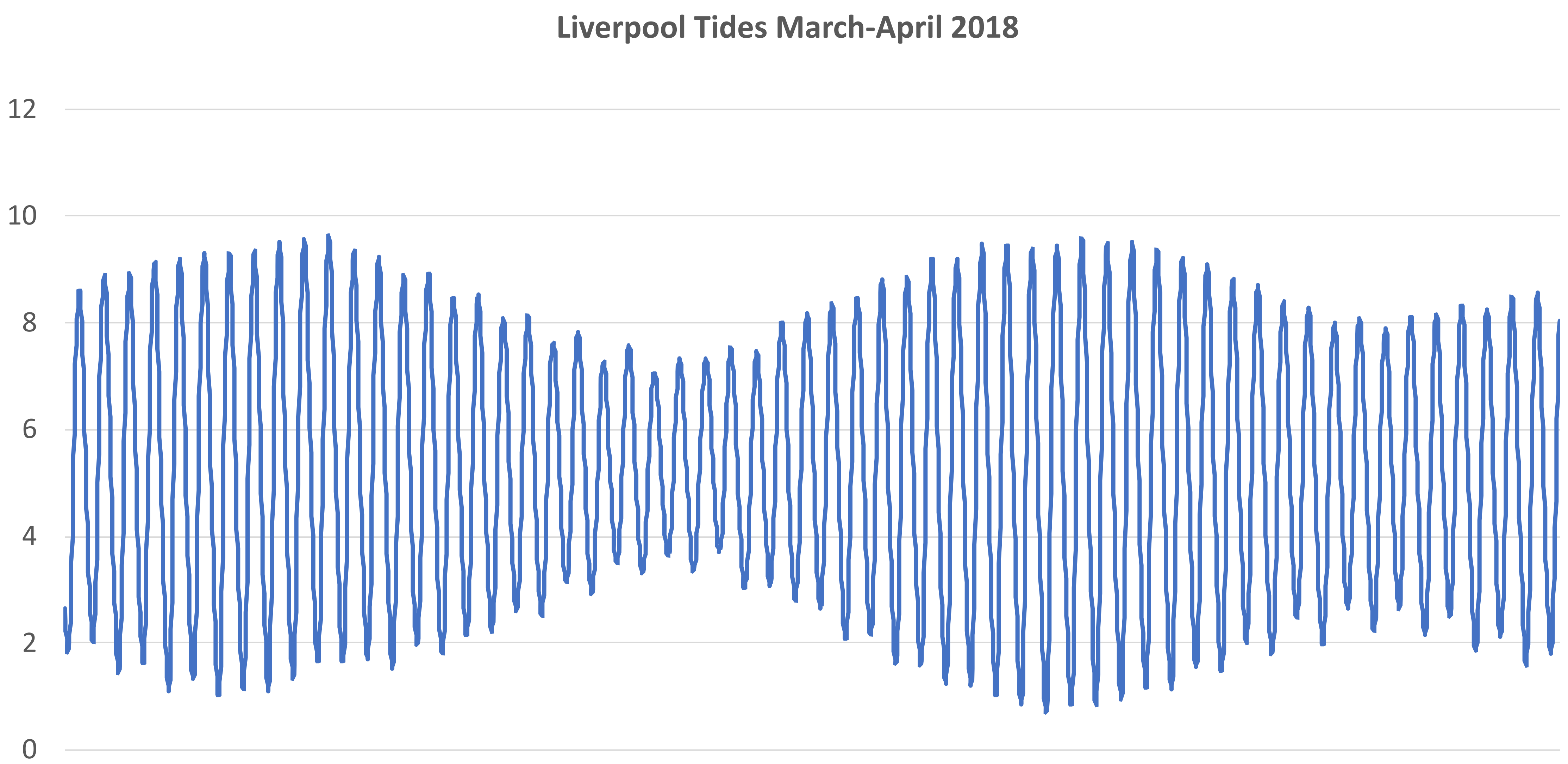
David Pugh

Maritime Museum
11 May 2019

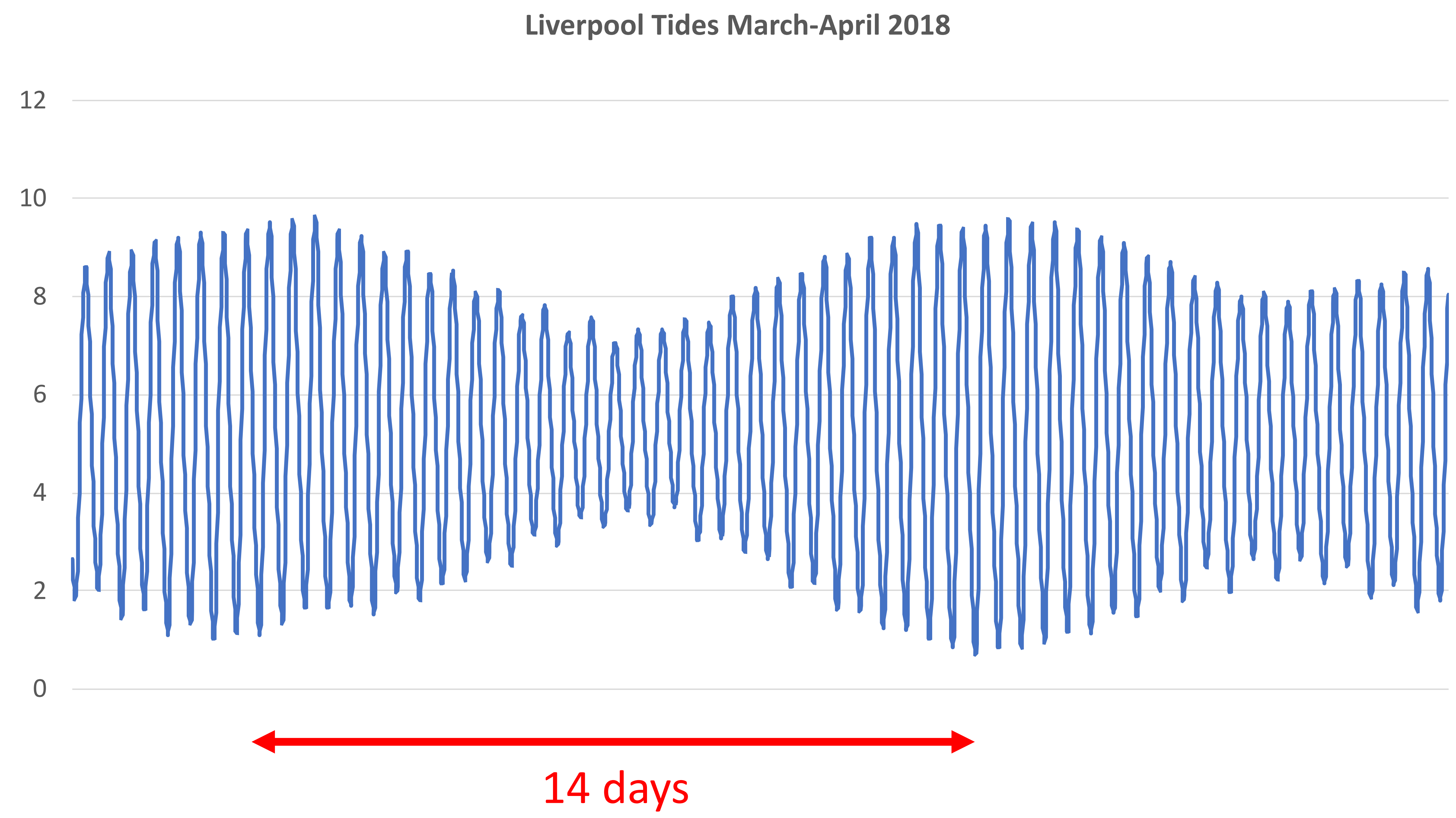

TIDAL DATUM
OLD DOCK SILL.
XXIV
XXIII
XXII
XXI
XX
XIX
XVIII

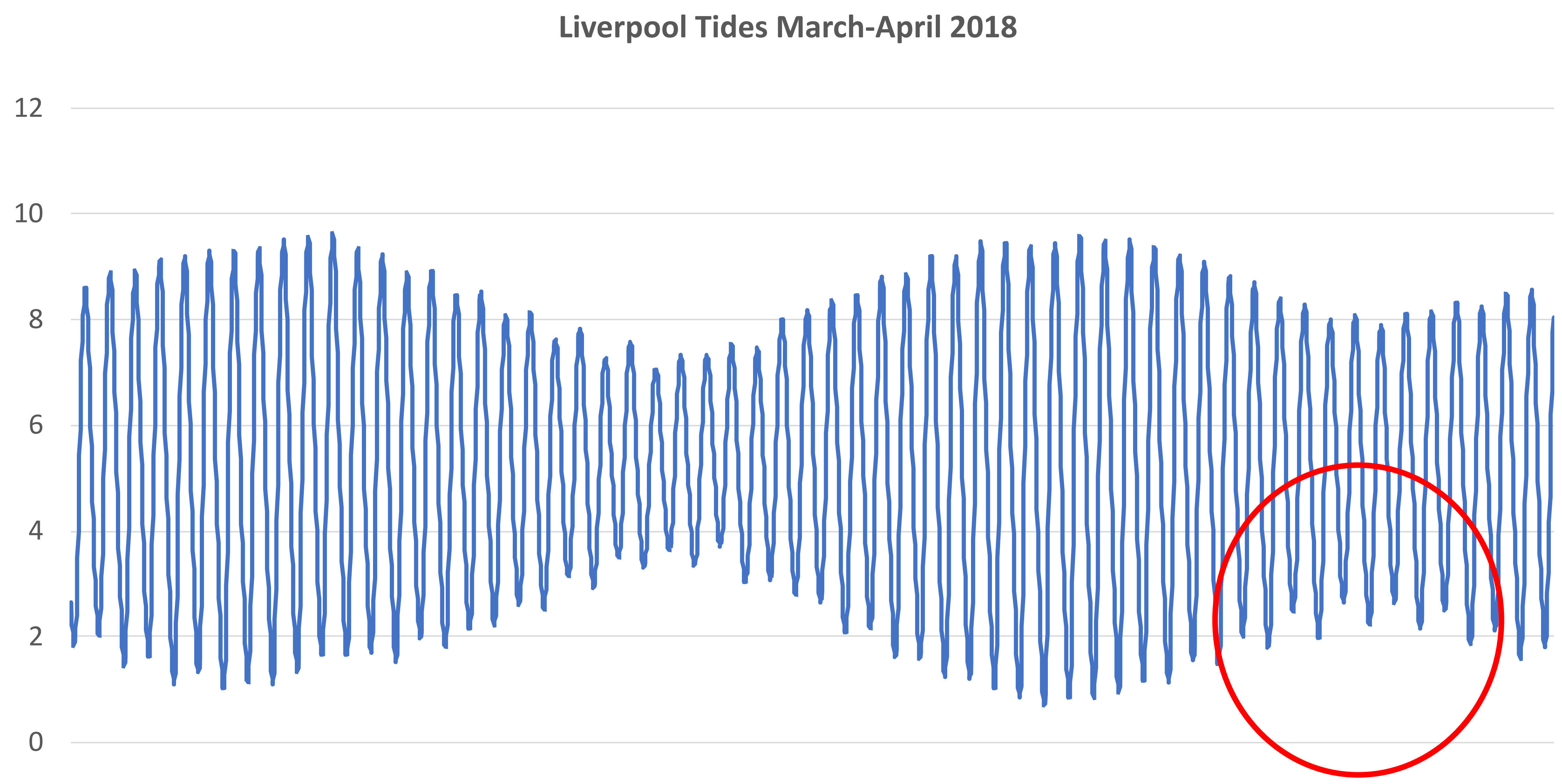

9
8
7

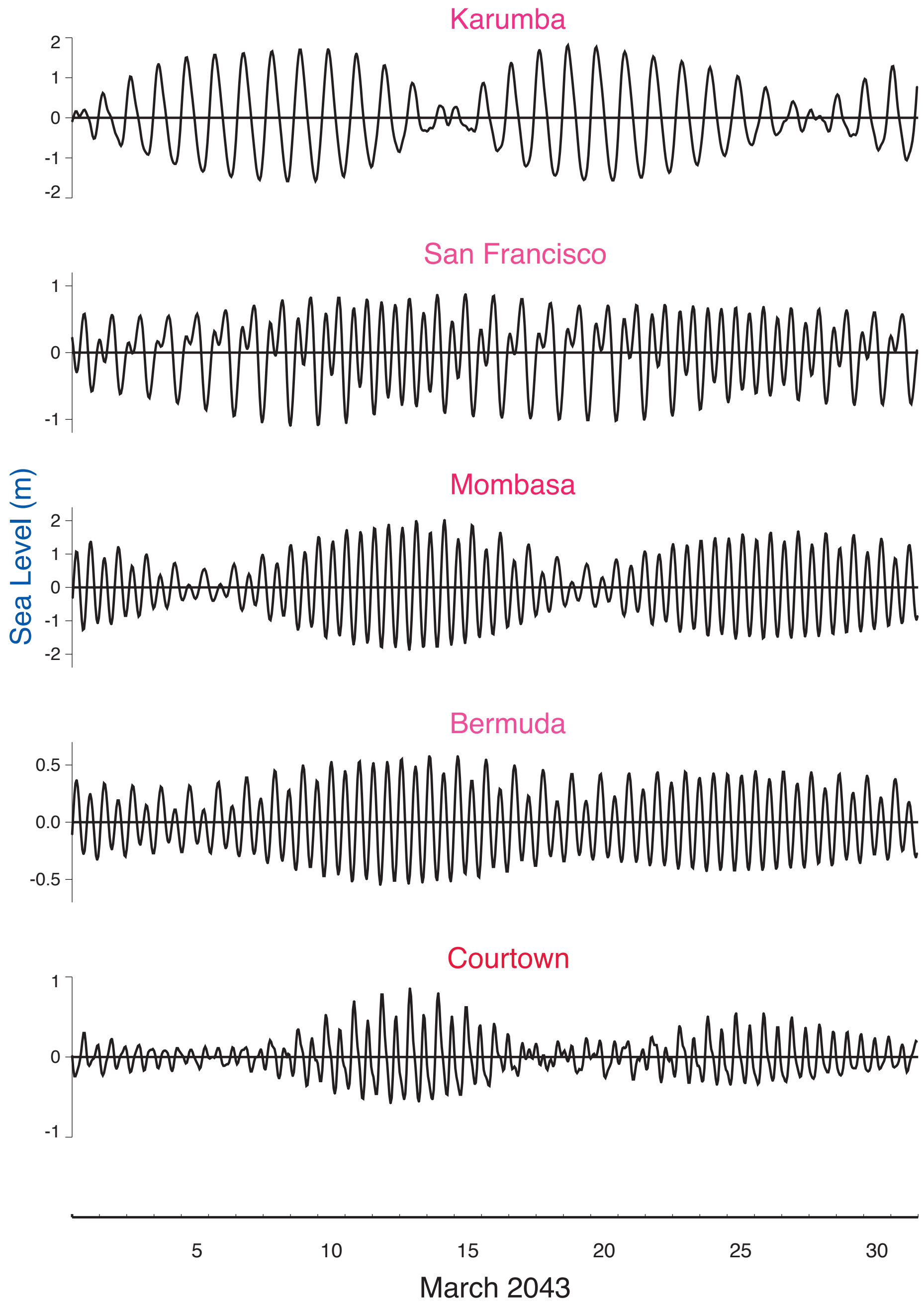

GPS SATELLITE
ORBIT
IONOSPHERE
LASER STATION
DORIS STATION
RANGE
TROPOSPHERE
SATELLITE ALTITUDE
DYNAMIC TOPOGRAPHY
SEA SURFACE HEIGHT
GEOID
ELLIPSOID



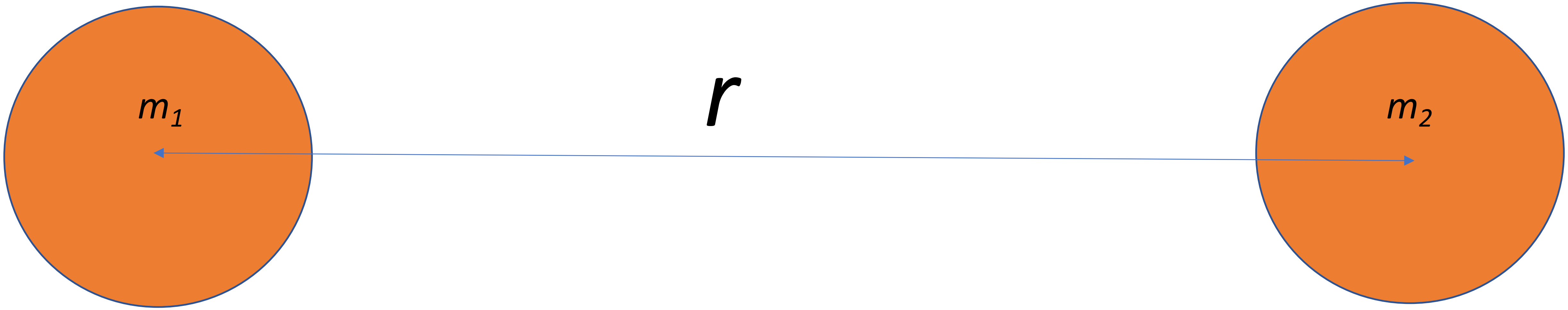
Average time from High Water to High Water is 12 hours and 25 minutes


Liverpool Tides March-April 2018
12
10
8
6
4
2
0
14 days

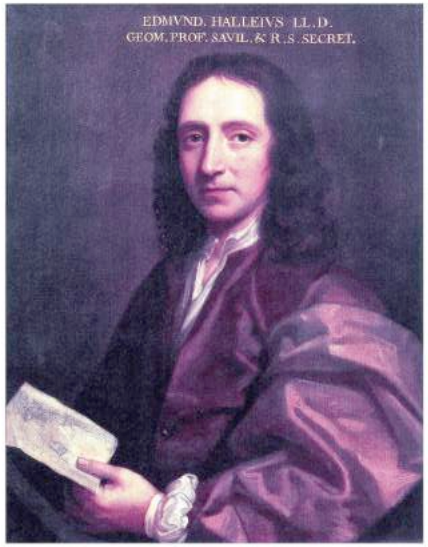

Liverpool Tides March-April 2018
12
10
8
6
4
2
0

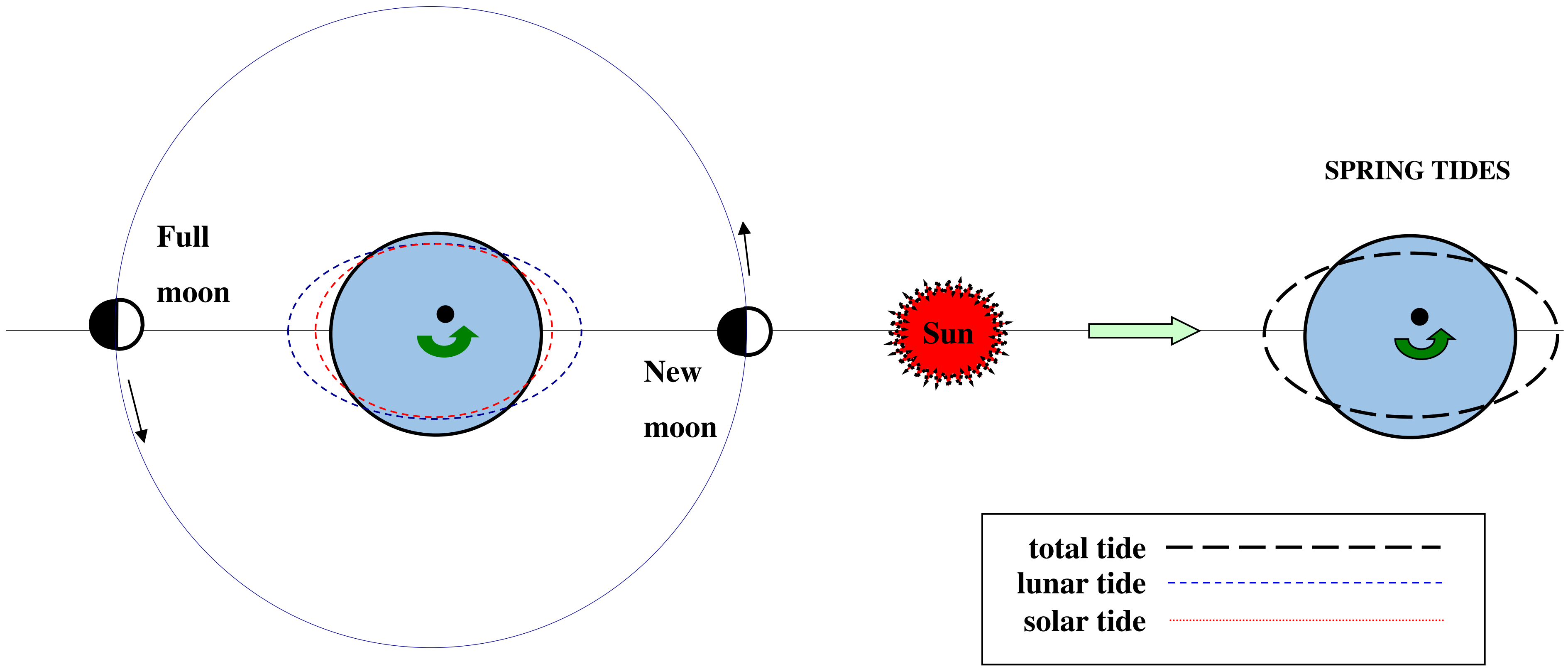

Karumba
San Francisco
Mombasa
Bermuda
Courtown
Sea Level (m)
2
1
0
-1
-2
0.5
0.0
-0.5
5
10
15
20
25
30
March 2043

1687 Newton’s Law of Gravitational Attraction



$$Force = G\frac{m_2 m_1}{r^2}$$



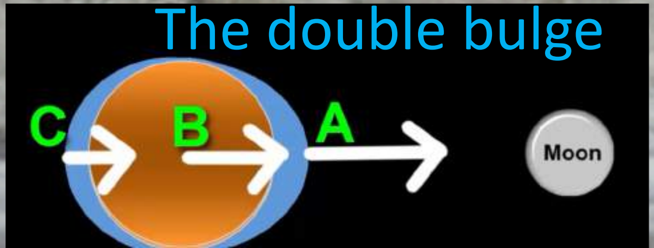

SPRING TIDES
Full
moon
New
moon
Sun
total tide
lunar tide
solar tide

a)

Relative sizes and separations

	Km	ratios
Sun	695500	109
Earth	6378	1
moon	1737	0.272
earth-moon	384400	60
sun-earth	149600000	23456

Scale demonstration



Applying the Cosine Law to the triange defined by OPM in Figure 3.4:

$$MP^2 = a^2 + R_l^{\,2} - 2aR_l \cos\phi$$

we have:

$$\Omega_p = -\frac{Gm_l}{R_l}\left[1 - 2\frac{a}{R_l}\cos\phi + \frac{a^2}{R_l^2}\right]^{-\frac{1}{2}}$$

which may be expanded as a series of Legendre polynomials:

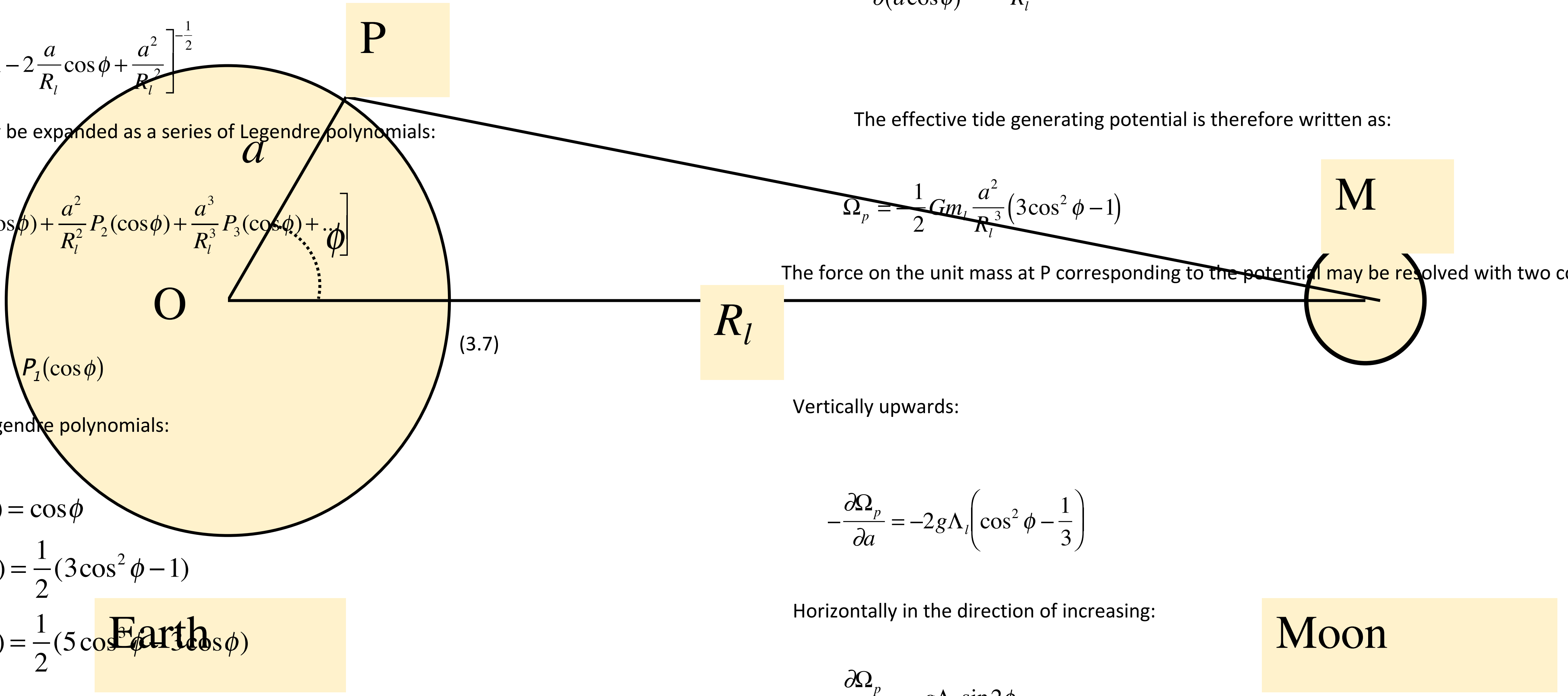
$$\left[1 + \frac{a}{R_l}P_1(\cos\phi) + \frac{a^2}{R_l^2}P_2(\cos\phi) + \frac{a^3}{R_l^3}P_3(\cos\phi) + \dots\right] \qquad (3.7)$$

The terms $P_1(\cos\phi)$ etc. are Legendre polynomials:

$$P_1(\cos\phi) = \cos\phi$$

$$P_2(\cos\phi) = \frac{1}{2}(3\cos^2\phi - 1)$$

$$P_3(\cos\phi) = \frac{1}{2}(5\cos^3\phi - 3\cos\phi)$$



the projected vector along OM, yields a gradient of potential:

$$-\frac{\partial\Omega_p}{\partial(a\cos\phi)} = -\frac{Gm_l}{R_l^{\,2}}$$

The effective tide generating potential is therefore written as:

$$\Omega_p = \frac{1}{2}Gm_l\frac{a^2}{R_l^{\,3}}\left(3\cos^2\phi - 1\right)$$

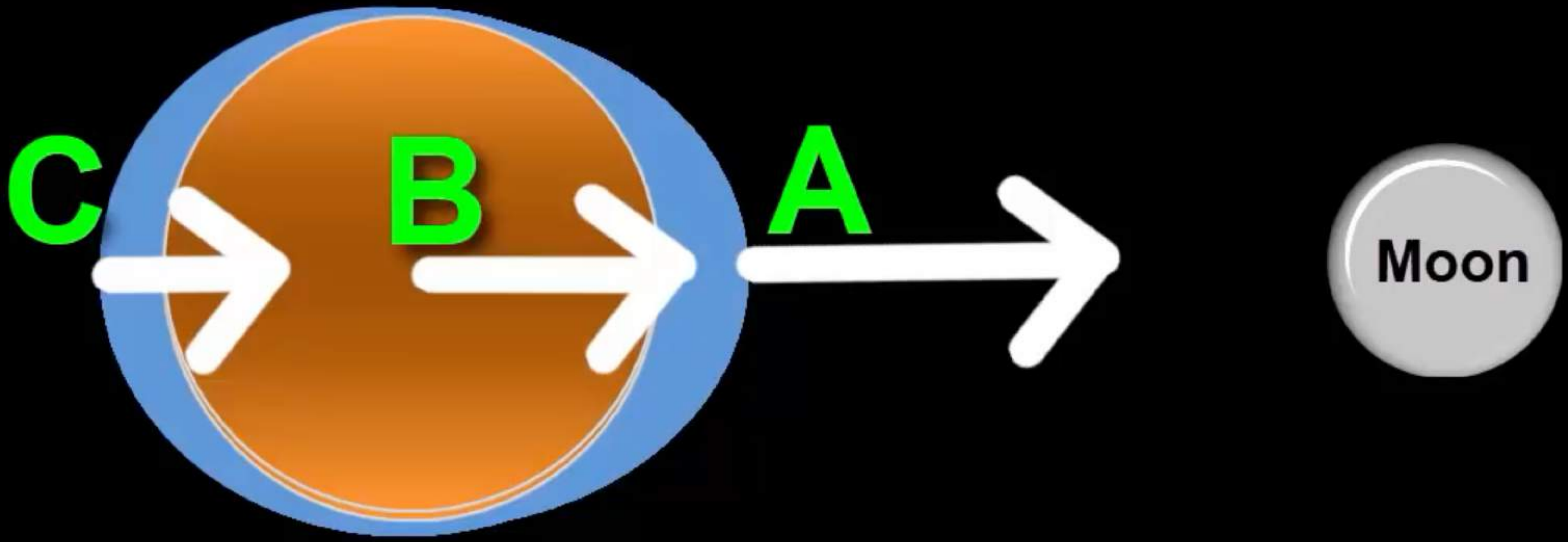
The force on the unit mass at P corresponding to the potential may be resolved with two components

Vertically upwards:

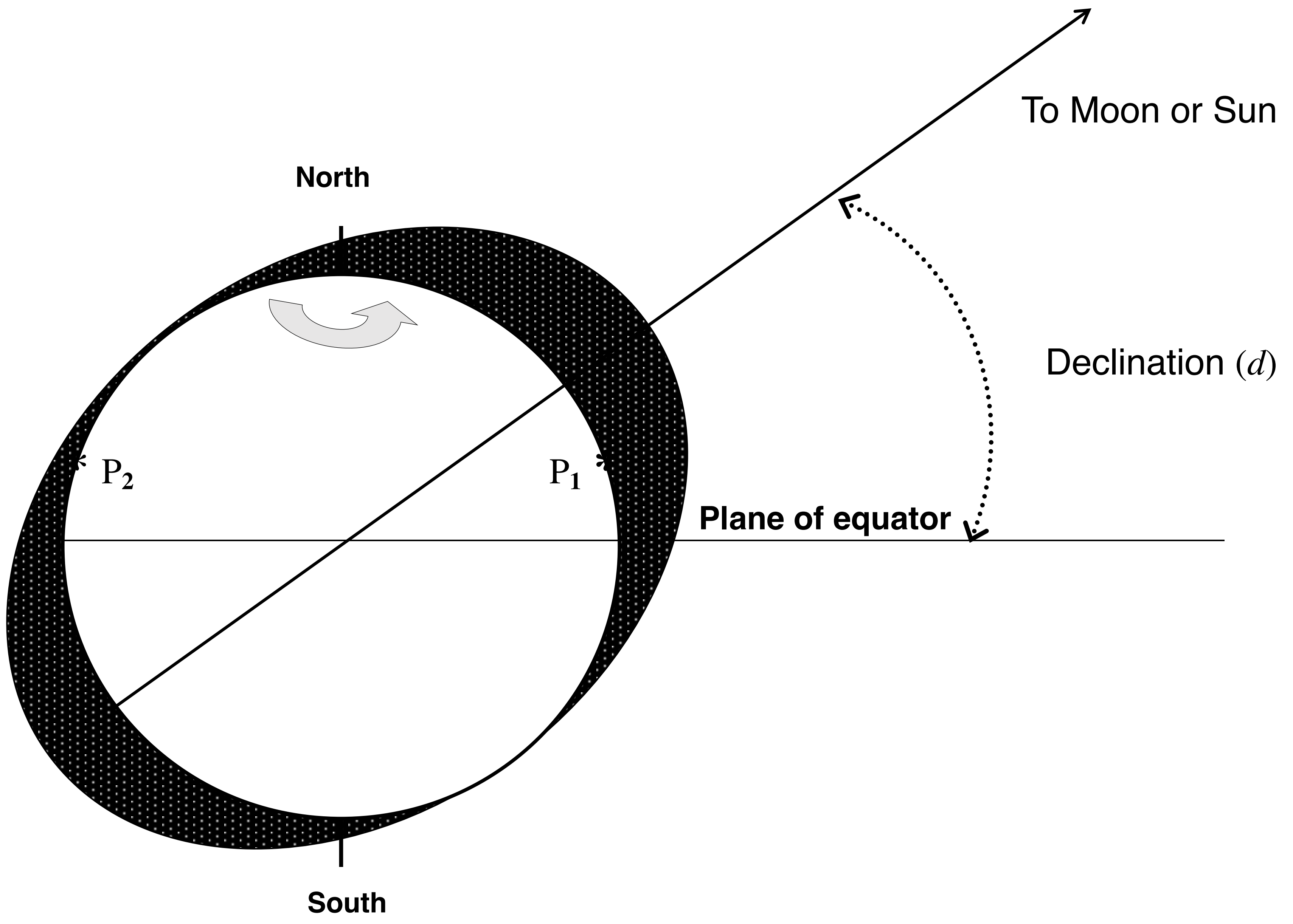
$$-\frac{\partial\Omega_p}{\partial a} = -2g\Lambda_l\left(\cos^2\phi - \frac{1}{3}\right)$$

Horizontally in the direction of increasing:

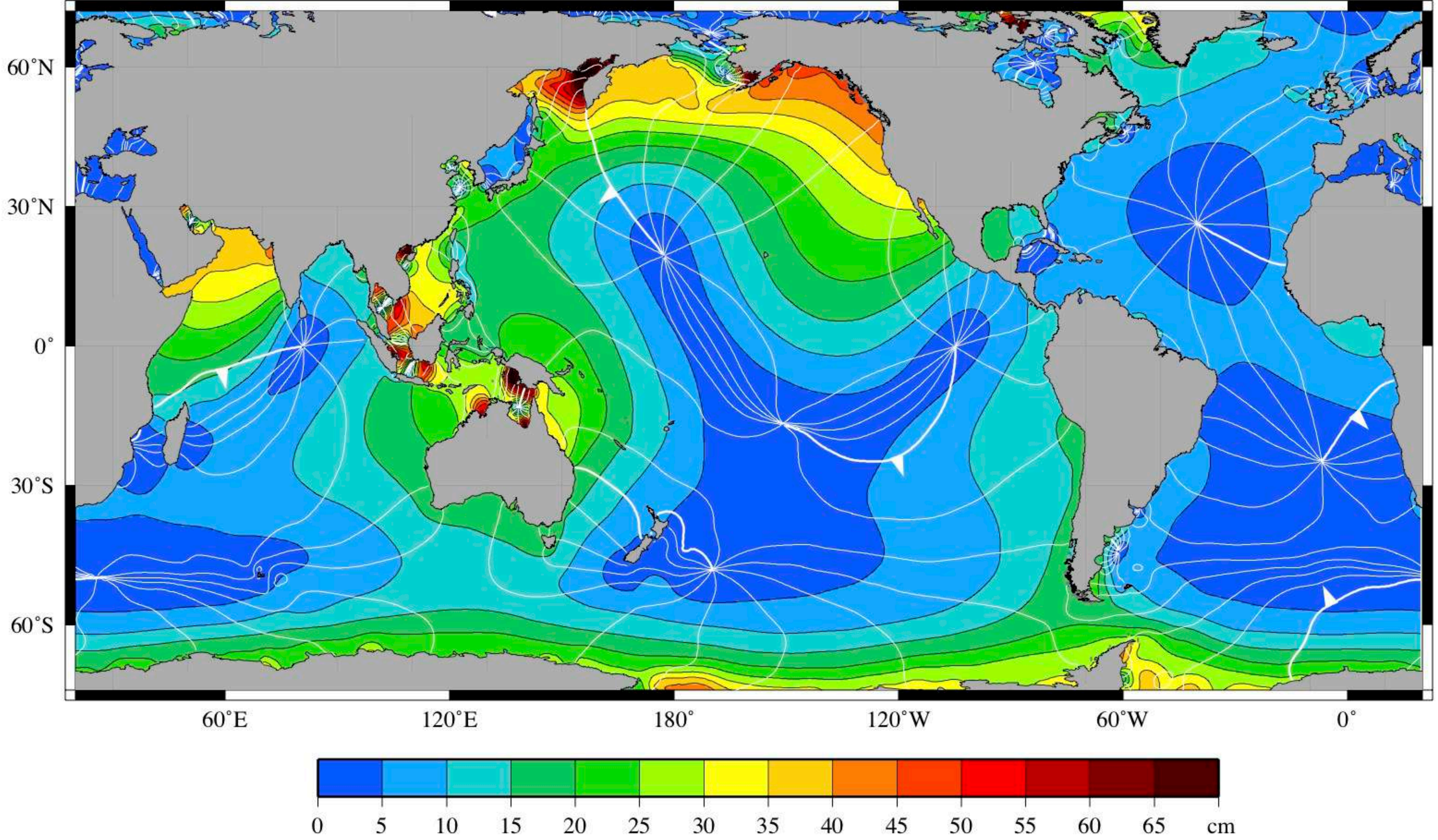
$$-\frac{\partial\Omega_p}{a\partial\phi} = -g\Lambda_l \sin 2\phi$$

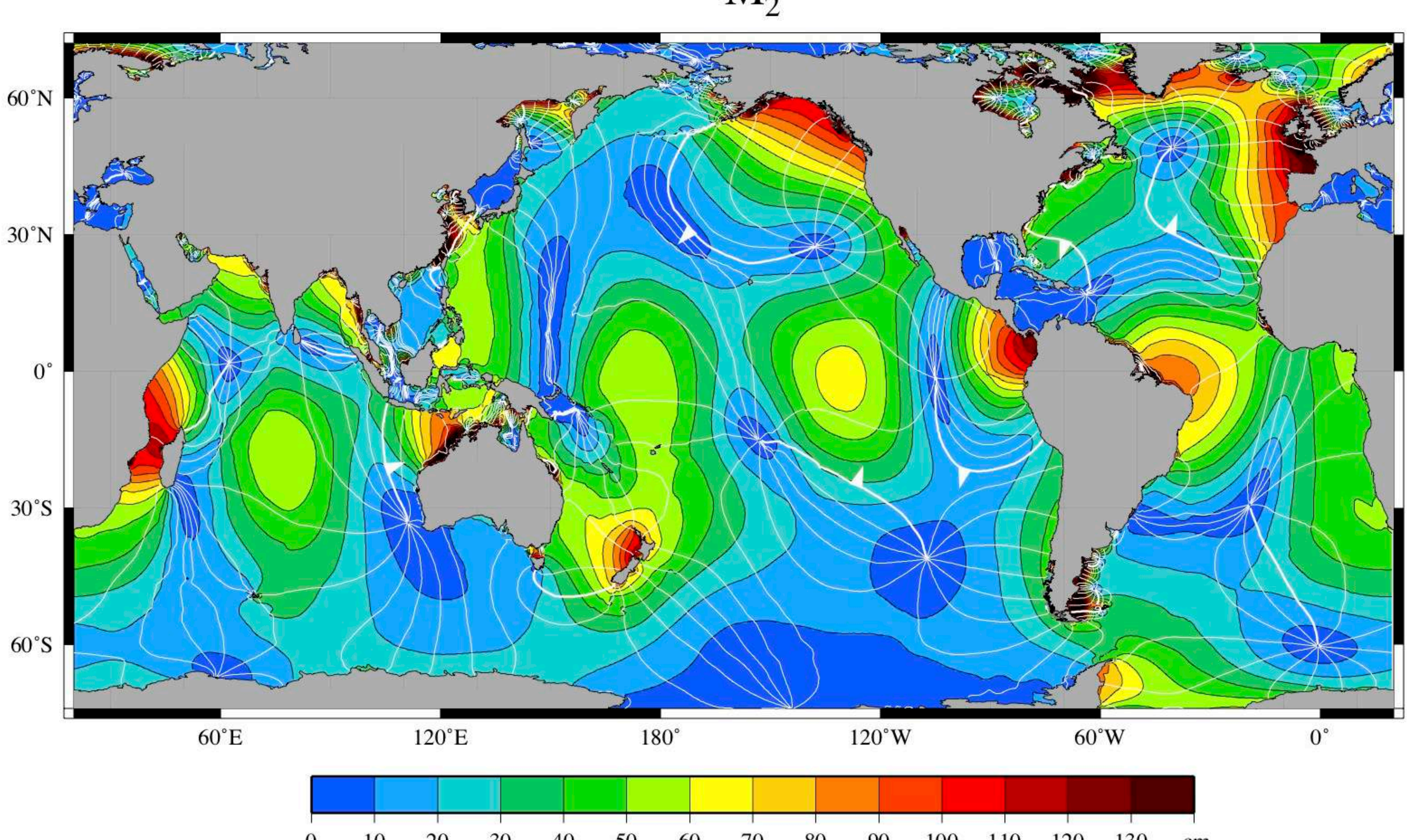

C
B
A
Moon


Earth
Spring Tide
New Moon
Moon
Sun



To Moon or Sun
North
Declination (d)
P2
P1
Plane of equator
South


60°N
30°N
0°
30°S
60°S
60°E
120°E
180°
120°W
60°W
0°
0
5
10
15
20
25
30
35
40
45
50
55
60
65
cm


M2
60°N
30°N
0°
30°S
60°S
60°E
120°E
180°
120°W
60°W
0°
0
10
20
30
40
50
60
70
80
90
100
110
120
130
cm

World’s biggest tides?


MailOnline
Newsflare

Maximum range 16.0 m

Baie aux Feuilles
Ungava Bay

Maximum range 15.8 m

Burncoat Head
Bay of Fundy

Are tides changing?

Are tides changing?

St Helena 1761-1971 less than 2% **RANGE** amplitude

Ireland 1842 to 2015 **TIME** changes less than 5 minutes

Liverpool **high waters** Philip Woodworth increase 0.5 m from 1768 to 2000

William Hutchinson, Dockmaster

With acknowledgements to Kelly Kemp, Eaglesby State School, Queensland

Web movie material

And www common domain images


Ocean Tides
The End
Maritime Museum
11 May 2019