ON SEASONAL CHANGES IN SEA LEVEL

by J. EGEDAL, Danish Meteorological Institute

In the Tide Tables seasonal changes in sea level are given for some important ports. The changes vary in the northern hemisphere from about — 0.5 foot (15 cm.) in March or April to about + 0.5 foot (15 cm.) in October or November. In the southern hemisphere the minimum occurs in October or November and the maximum in March or April.

From the Tide Tables it will be seen that the changes may be rather different at two ports lying near to one another. This may be due to fact that the determination of the seasonal change is difficult. Semidiurnal and diurnal tidal harmonic constants may be determined from observations during one month, but the seasonal changes (Sa and Ssa) require observations for at least one year. As the period for Sa is of one year, observations during a single year may not be sufficient to average out the disturbances. Not only from a scientific point of view but also for practical purposes it should be desirable to obtain as reliable values for the seasonal changes as possible.

The disturbances originate from the effect of the wind and of changes in air pressure. It is well known that the surface of the sea will be elevated or depressed under the influence of the wind, but the magnitude of these changes depends on different circumstances. In special cases changes of up to 4 metres may occur. A rise in air pressure of 1 mm mercury will cause a sinking in sea level of 13 mm while a fall will cause a corresponding elevation of the sea level.

The seasonal changes are determined from monthly means, and it is clear that, if the mean value for a month is greatly affected either on account of actions of the wind or of abnormal air pressure, the seasonal changes will be determined with a certain error. The disturbances from the wind may to some extent be eliminated by excluding the values of especially disturbed days from the monthly mean. Disturbances from variations of air pressure may be eliminated by reducing the monthly mean in an appropriate way. To the mentioned effects for instance for the coasts of the Atlantic (Greenland) is added the effect of an annual variation of air pressure. Thus, in Southern Greenland the mean air pressure varies in the following manner :

Nanortalik (1900-1925) 700 mm +

Jan.	Febr.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
42.7	50.4	53.3	57.8	59.3	58.4	59.2	58.7	55.7	53.4	53.4	48.8

These variations correspond to a total variation of 15 cm (0.5 foot) of sea level. In places where the air pressure shows no annual variation it would be advisable to reduce the observed monthly means to mean air pressure, but in places where an annual variation of the air pressure exists, the monthly means should for practical reasons be reduced to normal air pressure of the considered month.

In order to illustrate the question results from tidal observations during one year from Julianehaab, in Southern Greenland, will be given below.

In the table are given the central days of different intervals of time (column 1) and the observed mean values of sea level for these intervals (column 2). In order to adjust the values, the annual (Sa) and semiannual (Ssa) terms are calculated and their sum is found under the heading : Adjusted values (column 3). Next the observed means are reduced to the air pressure 755 mm. mercury (column 4) and the means are adjusted (column 5). And lastly the observed means are reduced to normal air pressure for the considered time (column 6), and these means are adjusted (column 7)

Date 1	Observed Mean 2	Adjusted values 3	Observed Mean red. to 755 mm merc. 4	Adjusted values 5	Observed Mean red. to norm. air pressure 6	Adjusted values 7
1933 July 13	— 5.1 cm.	— 0.8 cm.	— 2.7 cm.	+ 0.5 cm.	— 9.3 cm.	— 5.3 cm.
Aug. 19	— 0.3	+ 1.0	+ 0.3	+ 3.5	— 5.4	— 1.4
Sept. 6	+11.6	+ 1.8	+10.1	+ 5.5	+ 5.9	+ 1.0
Oct. 1	— 3.9	+ 3.3	+ 4.3	+ 7.0	+ 0.5	+ 5.6
Oct. 25	+ 0.3	+ 7.2	+ 9.1	+ 8.5	+ 6.7	+ 9.4
Nov. 15	+13.8	+12.0	+ 7.6	+ 9.4	+ 8.8	+12.0
Dec. 16	+19.9	+16.6	+ 8.0	+ 7.3	+14.7	+15.9
1934 Jan. 15	+11.0	+14.4	+ 5.5	+ 3.9	+12.7	+12.8
Febr. 19	— 0.3	+ 1.5	— 1.8	— 4.4	+ 0.8	+ 2.6
Mar. 16	— 7.6	—10.7	—13.1	— 9.6	—12.0	— 7.4
Apr. 15	—24.0	—18.1	—11.3	—11.9	—18.9	—15.2
May 16	— 9.1	—15.2	— 8.2	— 9.0	—14.5	—14.6
June 15	— 7.6	— 7.0	— 0.9	— 3.7	— 7.7	— 9.2

The formulæ for the adjusted means are for observed means :

$$13.77\cos(t - 234^\circ) + 6.46 \cos (2t - 210^\circ) \text{ (cm)}$$

for observed means reduced to 755 mm. mercury :

$$10.1\cos(t - 211^\circ) + 2.4\cos(2t - 194^\circ) \text{ (cm)}$$

and for observed means reduced to normal air pressure for the considered time :

$$14.07\cos(t - 240^\circ) + 4.00\cos(2t - 202^\circ) \text{ (cm)}$$

The time t is reckoned from the vernal equinox.

The mean deviation between observed and adjusted values are in the three cases : ± 5.0, ± 2.5 and ± 2.8 cm, respectively.

Summarizing it should be stated

(1) that in cases where the annual variation of air pressure is negligible, tidal observations for such a number of years should be applied that the seasonal changes may be determined with a fair certainty.

(2) that in cases where the annual variation of the air pressure is significant, the seasonal changes should be determined from observed monthly means reduced to the normal air pressure for each month, and

(3) that the observed or reduced monthly means should be adjusted by applying the sum of the annual and semiannual terms.