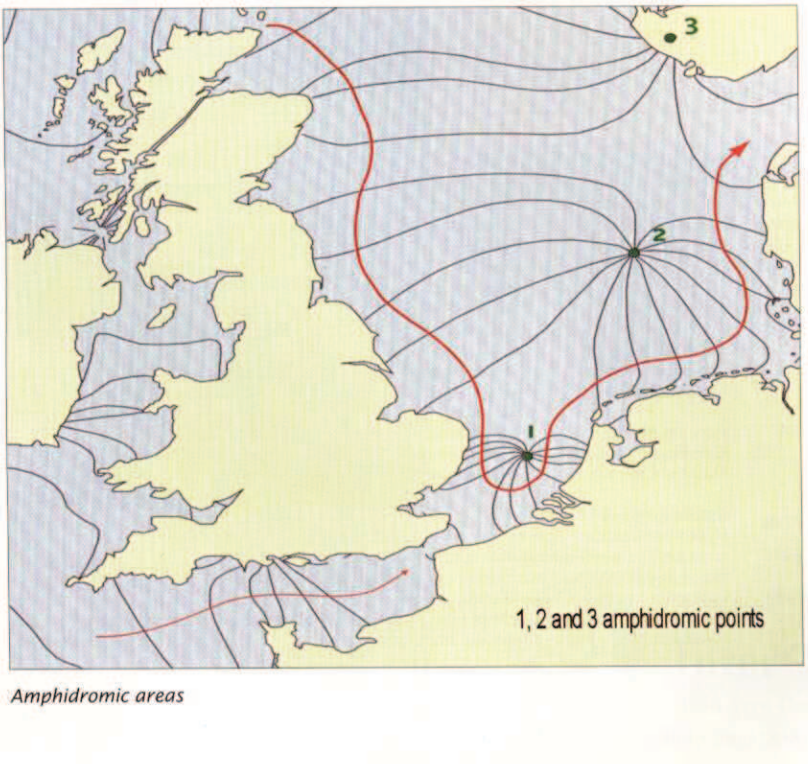
'Tides: A scientific history' by D.E. Cartwright FRS, Cambridge University Press 1999, ISBN 0.521.62145.3. The following story is, by contrast, about a practical solution in finding a successor for the bottom-mounted solid state tide gauge, as a standard instrument in use by the Hydrographic Service of the Royal Netherlands Navy since 1984. The advantage of mentioning David Cartwright's account is that for this story we will not have to go into detail about research on tides. As a first step PREMO (water level PREdiction MOdel, or MOdule) proved to be a very good 'new tide gauge', especially for off-line applications. In the future PREMO will have the power to be developed into a real-time on-line computer program for tidal reduction during hydrographic surveys. This article reflects the personal view of the author.

By H.A. Versteeg, Head of the tidal branch of the Hydrographic Service, The Netherlands

Tidal Reduction on Fairsheet Level

A modern approach to on-board prediction of water levels

The philosophy on tides was, and still is: tidal reduction must be executed with tide observations in the survey area. Using offshore bottom-mounted tide gauges it implies: after the survey has been completed. Not violating the tidal philosophy too much PREMO has proven its operational use.



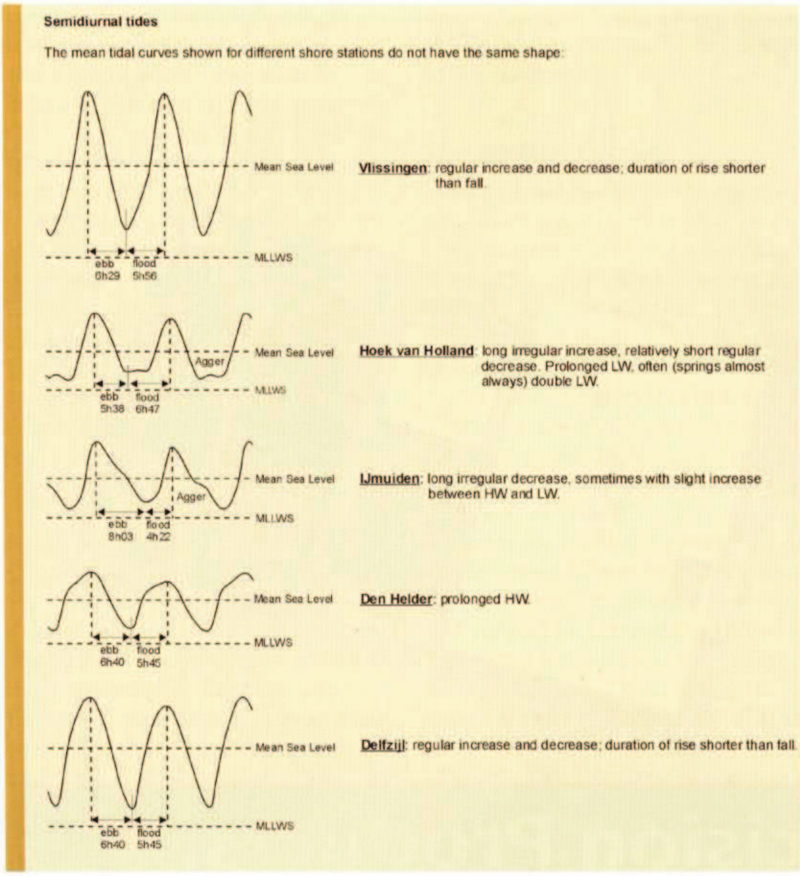
Amphidromic areas

Why Did We Use Offshore Tide Gauges?

Even before World War II the Netherlands' authorities did not believe in co-tidal, co-range transformation from shore stations to obtain tidal progress in offshore positions. Extrapolation of tidal heights obtained from shore-based stations is still considered to be not accurate enough in the coastal waters of The Netherlands and adjacent areas. Thus, in Netherlands' surveying practice, tidal data for reduction of soundings is generally obtained from offshore bottom tide gauges.

Tides along the Dutch Coast

The 'tidal legacy' from Belgium is relatively uniform; admittedly at Zeebrugge the distortion starts with a sharp rise after low water springs.



Tides along the Dutch coast

But that is nothing compared with the tidal progress along the short distances of the Dutch coast. In the coastal waters we change from double low waters at the Hook of Holland via so called aggers, caused by shallow water constituents at Scheveningen and IJmuiden, to double high waters at Den Helder. The Netherlands legacy to Germany is nicely shaped tides progressing from Eemshaven and Delfzijl into the German Bight. For the Netherlands part of the continental shelf we have an extra complication because we have to reckon with amphidromic areas between Den Helder and Lowestoft, and in the German Bight. But that is also relevant for other survey organisations in the southern part of the North Sea.

What Offshore Tide Gauges Did We Use?

After World War II, starting in 1948 time series were obtained from clockwork operated (Bourdon) pressure tide gauges, Type Smitt 1944. Except for the replacement of the mechanical timekeeper by an electronic one in the late seventies, these instruments served well up to 1984. That year the instruments were replaced by a new 'standard' solid state recorder: a Digital Autonomous Tide Gauge with 6,000 memory places (DAG6000). For The Netherlands continental shelf this instrument was considered universal for offshore purposes. With a Paroscientific sensor, range 0 – 6.8 bar (appr. 0 – 55 metres watercolumn) the output was mean pressure over 15 minutes. The early eighties state-of-the-art was elaborate with a semi-conductor memory as an exchangeable cartridge fitting into the tide gauge, a start-stop unit and a read-link unit (to a computer or teletype).

Disadvantages of Using Offshore Tide Gauges

All bottom-mounted tide gauges are subject to the same disadvantages: costs incurred by the deployment and the recovery of offshore tide gauges, including marker buoys and sinkers. In the southern North Sea area there is a fairly high risk of losing instruments during other activities, with the extra handicap of loss of data, and reduced quality of bathymetric information.

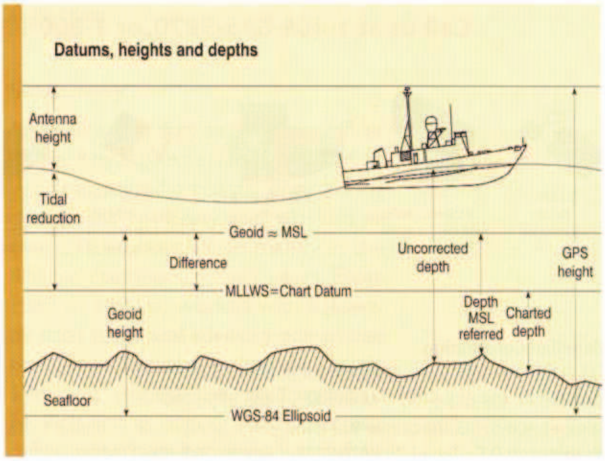
Without a surface link tidal data is only available after the survey, and in that case it is impossible to begin initial steps to real-time on-the-fly reduction. Moreover, in our case, there is no direct connection with our (semi-) automated reduction.

North Sea Reduction Chart; Tidal Reduction

The North Sea Reduction Chart 1988 (NSRC 88) is still in force, and will be so until the chart based on Lowest Astronomical Tide (LAT) is ready. The NSRC 88 is based on Mean Lower Low Water Springs, and the Zo-values are based on a numerical model available in a grid. The co-tidal lines of high and low water (HW & LW) are based on data supplied by member states of the North Sea Hydrographic Commission (NSHC). Tidal reduction with bottom gauges based on the NSRC 88 is in two stages: in a certain position the total reduction value consists of the time / tide dependent part referred to as Mean Sea Level (MSL) [from tide gauge referred to mean record level (MRL)], and the position dependent part referred to as Chart Datum (Zo-value in the grid).

Semi-automated Reduction

In a semi-automated reduction program tidal data is processed by algorithmic interpolation of tide gauge observations. With restrictions imposed by certain assumptions it is possible to approximate the water surface of an area not larger than 10 x 10 nautical miles by a two-dimensional plane. This plane is determined by at least three tidal



Tidal reduction

records, either from tide gauges or transformed records in cases of a shortage of actual information (i.e. failure of tide gauges). Calculated are (1) water level related to MRL (is approximately MSL), and (2) distance between MSL and Chart Datum in relation to all logged depths, positions and times. Several reduction support programs are used to get an optimal input for the main program. Due to the use of actual tidal data the main principles used in our method are applicable in any area with all sorts of tidal movements.

Our 'New' Tide Gauge

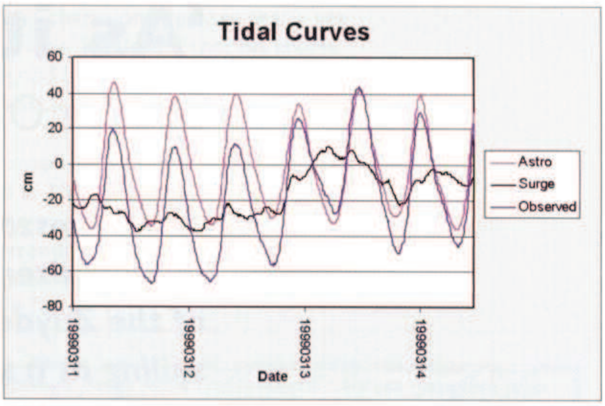
As a first step in overcoming the disadvantages of bottom tide gauges we searched for a substitute tide gauge which could bring tidal reduction more on-line. In the early nineties, in the Zeepipe project, numerical models had proven their operational values. The water level PREdiction MOdel (or MOdule) [PREMO] seemed very suitable for our applications. Admittedly in the first phase only for off-line use in addition to which the reduction of survey works for tides could still be done on board, after completion of the survey, but not any more in any given area. In 1992 the Hydrographer of the Royal Netherlands Navy commissioned Delft Hydraulics to perform an accuracy analysis of PREMO for realistic situations in various parts of the Southern North Sea, mainly on The Netherlands part of the continental shelf.

The PREMO Concept

The statistical results of the comparison between the observed water levels and the water levels predicted by PREMO were very adequate, and it was concluded that PREMO predicts water levels in target stations so that the results satisfy the requirements for hydrographical reduction. Therefore the Hydrographic Service procured a specially dedicated version of PREMO from Delft Hydraulics. For our service PREMO is a computer program for on board prediction of water levels at offshore locations (target stations). It calculates both tide and surge. The astronomical tide is calculated from a stored dedicated tidal database. That database is constructed using results of the Dutch Continental Shelf Model (DCSM), and the base is upgraded from available local tide observations.

PREMO the Tide Gauge

Normally in three PREMO surge stations the surge values are derived from the difference between observed and calculated tides at 10 minute intervals. In at least three target stations the computed and interpolated surge component is added to the astronomical tidal levels, again at 10 minute intervals. PREMO is now the new standard 'tide gauge', and we have overcome the disadvantages mentioned in paragraph 5. Moreover, we have not lost the connection with our automated reduction program, and it is possible to start with real-time on-the-fly tidal reduction. To provide PREMO with the necessary observed tides, to derive the surge component from shore and platform based stations, a database (AQUATUM) was installed in the hydrographic office at The Hague. All the data, mainly from Rijkswaterstaat, is collected, corrected and validated.



Tidal curves

Automated Checking

For the corrections we developed a routine called CoCo and FoFo: 'Controle' and 'Correctie' (inspection and correction) and 'Fout Ontdekking' and 'Fout Opheffing' (fault detection and neutralisation).

The year 1999 was used for operational evaluation and checking against the DAG 6000. This year will be used to make PREMO fully operational, and bottom-mounted tide gauges will then be used in out of area operations, and as back-up.

PREMO stations

Biography

After his active duty as a reserve officer in the Royal Netherlands Navy H.A. Versteeg joined a coastal engineering consultant company and worked all over the world, though mainly in the African continent, for six years. From 1969 till 1980 he worked with Rijkswaterstaat (technical advisory committee on protection against inundation). In 1980 he joined the Hydrographic Service, first as deputy head of nautical publications, later becoming head of the tidal branch. ■