Sea level is a surprisingly variable parameter

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Systematic records of sea levels began in the 19th century (links to Prince of Wales Island, Alaska). At the time, the objective was to create a standard for measuring elevations on land. Since the end of the 20th century, satellites (right) have been collecting sea level data which, in view of ongoing global warming, are of growing interest. Credit: NOAA, NASA

Every measurement starts at zero. This simple fact is anything but trivial when it comes to measuring geographic elevations, as opinions have long differed about how mean sea level should be defined. Sea level as a

reference point changes not only with the tides but also differs depending on the location at which it is measured. The fact that global warming is causing changes in sea levels does not make matters any easier. At the Max Planck Institute for the History of Science, Wilko Hardenberg focuses on this variable reference and its history.

How high is the sea? At first sight, the answer appears simple: zero metres. About 200 years ago, efforts were undertaken to precisely determine this zero point, or, to be more accurate, an average value of the sea level as a reference. The first self-recording gauges were constructed in the UK around 1830. These measuring instruments were able to record water levels regularly over long periods, allowing a mean sea level to be calculated from the individual measurements. In 1831, British engineer John Augustus Lloyd proposed using the value as a reference point for measuring elevations. The idea came to him while he was calculating the height difference between London Bridge and Sheerness at the mouth of the Thames.

From the mid-19th century, several countries established their own network of self-recording gauges. From the data obtained, they calculated the mean sea level and began to use it as a zero point for geodesics. Wilko Hardenberg from the Max Planck Institute for the History of Science believes that those efforts were beset by uncertainties from the outset. The geographer and historian is researching the origin of reference values used today to determine anthropogenic environmental changes. "Actually, the sea is unreliable as reference point. It is in constant motion. By establishing a zero point, you are artificially defining a yardstick, a boundary between sea and land that is decoupled from actual conditions."

The shifting sea

It did not take long for reality to catch up with the surveyors. In the

1860s, metrologists in Central Europe joined forces with the aim of precisely determining longitudes and latitudes in Europe. At the suggestion of the Prussian military land surveyor Johann Jakob Baeyer, the Central European Arc Measurement Committee was set up and charged with the task of defining a common reference point for measuring elevations. "At that time, it was assumed that all the seas surrounding Europe had the same surface level," Hardenberg says. "People were confident that a common reference point could be easily determined. However, when precise national measurements were compared, significant differences between the data of the various countries became apparent."

Land below sea level on the Mediterranean

Long debates followed, but no agreement. The national reference points remained in place, and this arrangement was confirmed once again in the late 1920s. The differences in elevation are quite significant: The Amsterdam level was adopted by the German Empire in 1879. Austria settled on the level in Trieste in 1875, which is 34 centimetres lower. The Kronstadt level used by Eastern European countries, which was measured between 1825 and 1839, sets the zero point 14 centimetres above the Amsterdam standard, while the Ostend level determined in Belgium is 230 centimetres lower.

The European Union has been trying to agree on a common level since the 1990s. The Amsterdam level was chosen as the reference point for the European Vertical Reference System (EVRS) – rather arbitrarily according to Hardenberg. "The irony is that this level does not even define a mean sea level but rather a high water point." Moreover, the level was defined as early as in 1683/84, well before precision measurements were possible. "Because the Mediterranean is low-lying, some areas measure below zero level on the Amsterdam scale. That is precisely what countries want to avoid, which is why they are sticking to

their own points of reference", the science historian explains. "And other reference systems exist anyway in the US and Canada."

Nowadays, sea level can be determined far more precisely with the help of satellite data. Of course, this does not solve the problem of standardization. Even differences in temperature and variations in salinity and continuous air and sea currents can result in differences of up to two metres.

Change in perspective from land to sea

Quite apart from the measurement of tall objects, the determination of sea level at the end of the 20th century has taken on new significance. Climate change has become central to research and also to the question of how global warming affects coastal water levels. In terms of sea level, this has shifted the scientific focus from land to water. The way in which this shift in perspective has occurred lies at the heart of Wilko Hardenberg's research project. "As a matter of fact, changes in mean sea level were investigated as early as in the 19th century," the science historian says. "At the time, however, they were not ascribed to a rise in water but to coastal subsidence. The first call to analyze sea level changes dates back to 1948."

Today, it is regarded as a fact that average sea levels have risen worldwide over the past 150 years. To determine the magnitude of the rise precisely, data from past centuries are invaluable. "It is important to know how the data were obtained," emphasizes Wilko Hardenberg.

The protracted debate about a common zero level has been eclipsed by the analysis of historical changes. Satellite data from the last 20 years show that sea levels vary greatly from region to region. Consequently, the focus is once again placed on regional levels. The first reliable data do not define a long-term average but rather a new zero point for

research.

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