

## Tidal Glossary

**Adapted from the Glossary in ‘Changing Sea Levels: Effects of Tides, Weather and Climate’ by David Pugh, Cambridge University Press, 2004 with permission of the author and publisher.**

**AGE OF THE TIDE:** old term for the lag between the time of new or full moon (SYZYGY) and the time of maximum spring tidal range. It can be estimated as  $(g_{S_2} - g_{M_2})^0$ , in hours.

**AMPHIDROME:** a point in the sea where there is zero tidal amplitude due to cancelling of tidal waves. **COTIDAL LINES** radiate from an amphidromic point and **CORANGE LINES** encircle it.

**APOGEAN TIDE:** tide of reduced range when the moon is near APOGEE, its furthest point from the earth in its elliptical orbit.

**BENCH MARK:** see TIDE GAUGE BENCH-MARK.

**BORE:** a tidal wave which propagates as a solitary wave with a steep leading edge up certain rivers. Formation is favoured in wedge-shaped shoaling estuaries at times of spring tides. Other local names include eagre (River Trent, England), pororoca (Amazon, Brazil), mascaret (Seine, France).

**CHART DATUM:** the datum to which levels on a nautical chart and tidal predictions are referred; usually defined in terms of a low-water tidal level, which means that chart datum is not a horizontal surface, but it may be considered so over a limited local area.

**CORANGE LINES:** lines on a tidal chart joining places which have the same tidal range or amplitude...also called coamplitude lines. Usually drawn for a particular tidal constituent or tidal condition (for example, mean spring tides).

**COTIDAL LINES:** lines on a tidal chart joining places where the tide has the same phase; for example, where high waters occur at the same time. Usually drawn for a particular tidal constituent or tidal condition.

**CRITICAL TIDAL LEVEL:** a level on the shore where the emersion/submersion tidal characteristics change sharply. Some biologists have suggested that zonation of plants and animals is controlled by a series of such levels, but detailed analysis of tidal statistics shows that the tidal transitions are seldom as sharply defined as the biological boundaries.

**CURRENT PROFILE:** the detailed variation of current speed and direction between the sea-bed and the sea surface.

**DATA REDUCTION:** the process of checking, calibration, and preparation necessary to convert raw measurements into a form suitable for analysis and application.

**DECLINATION:** the angular distance of an astronomical body north or south of the celestial equator, taken as positive when north and negative when south of the equator. The sun moves through a declinational cycle once a year and the moon moves through a cycle in

27.21 mean solar days. The solar declination varies between 23.5° N and 23.5° S. The cycles of the lunar declination vary in amplitude over an 18.6-year period from 28.5° to 18.5°.

DEGENERATE AMPHIDROME: a terrestrial point on a tidal chart towards which COTIDAL LINES appear to converge. "An imaginary point where nothing happens".

DIURNAL TIDE: once-daily tidal variations in sea level, which increase with lunar or solar DECLINATION north and south of the equator. When added to semidiurnal tides they can cause a DIURNAL INEQUALITY, a difference between the heights of the two high waters and of the two low waters of a lunar day.

DOUBLE TIDE: a double-headed tide with a high water consisting of two maxima of similar height separated by a small depression (double high water), or a low water consisting of two minima separated by a small elevation (double low water). Also known as an agger or gulder. Examples occur at Southampton, England; along the coast of the Netherlands; and off Cape Cod, USA.

EARTH TIDE: tidal movements of the solid earth, due to direct gravitational forcing and loading of the adjacent sea bed by marine tides.

EBB CURRENT: the movement of a tidal current away from the shore or down a tidal river or estuary.

ENDOGENOUS MECHANISM: an internal biochemical or physiological pacemaker for biological activity, as opposed for example to external tidal stimulation.

ENTRAINMENT: stimulation of an organism by local environmental factors, to adopt a new phase in its cycle of behaviour. For example, a short cold treatment in the laboratory can initiate new tidal rhythms in crabs, which have become inactive.

EQUILIBRIUM TIDE: the hypothetical tide, which would be produced by the lunar and solar tidal forces in the absence of ocean constraints and dynamics.

EQUATION OF TIME: the difference between real civil time and apparent solar time, due to the earth's elliptical orbit around the sun.

EQUINOXES: the two points in the celestial sphere where the celestial equator intersects the ecliptic; also the times when the sun crosses the equator at these points. The vernal equinox is the point where the sun crosses the equator from north to south and it occurs about 21 March. Celestial longitude is reckoned eastwards from the vernal equinox, which is also known as the 'first point of Aries'. The autumnal equinox occurs about the 23 September. The larger solar contribution to the semidiurnal tides leads to large tides at these times, known as equinoctial tides.

EULERIAN CURRENT: flow past a fixed point as measured, for example, by a moored current meter.

EUSTATIC SEA LEVEL CHANGES: world-wide changes of sea level due to the increase in the volume of water in the ocean basins. Volume changes are due to mass increases from melting of grounded ice, and thermal expansion or contraction of the oceans as they warm or

cool. Over geological time the shape and volume of the ocean basins themselves also evolve.

FIRST POINT OF ARIES: see EQUINOXES.

FLOOD CURRENT: the movement of a tidal current towards the shore or up a tidal river or estuary.

GEOID: the equipotential surface that would be assumed by the sea surface in the absence of tides, water density variations, currents and atmospheric effects. It varies above and below the geometrical ellipsoid of revolution by as much as 100 m due to the uneven distribution of mass within the earth. The mean sea level surface varies about the geoid by typically decimetres, but in some cases by more than a metre.

GLOSS: A world-wide network of sea-level gauges, defined and developed under the auspices of the Intergovernmental Oceanographic Commission. Its purpose is to monitor long-term variations in the Global Level Of the Sea Surface, by reporting the observations to the Permanent Service for Mean Sea Level.

GPS: a satellite-based Global Positioning System, capable of accurately locating points in a three-dimensional geometric framework.

GRAVITATION, NEWTON'S LAW OF: states that all particles in the universe are attracted to other particles with a force which is proportional to the product of their masses and inversely proportional to their distance apart.

GREENHOUSE EFFECT: the effect, analogous to that which operates in a greenhouse, whereby because of atmospheric effects the earth's surface is maintained at a much higher temperature than that appropriate to balance the incident solar radiation. Solar radiation penetrates the atmosphere, but some of the longer-wavelength return radiation is absorbed by the carbon dioxide, ozone, water vapour, trace gases and aerosols in the atmosphere. Observed increases in the concentrations of atmospheric carbon dioxide due to the burning of fossil fuels, and of other components, could lead to a steady increase of global temperatures: the resulting thermal expansion of the oceans and the melting of ice caps would increase sea levels. Concern about possibility coastal flooding due to this increase has stimulated recent research into climate dynamics.

GREENWICH MEAN TIME: time expressed with respect to the Greenwich Meridian (zero degrees longitude), often used as a standard for comparisons of global geophysical phenomena, including tidal constituents. More correctly called Universal standard Time (UST)

HARBOUR OSCILLATIONS: see SEICHE and TSUNAMI.

HARMONIC ANALYSIS: the representation of tidal variations as the sum of several harmonics, each of different period, amplitude and phase. The periods fall into three TIDAL SPECIES, long-period, diurnal and semidiurnal. Each tidal species contains GROUPS of harmonics, which can be separated by analysis of a month of observations. In turn, each group contains CONSTITUENTS, which can be separated by analysis of a year of observations. In shallow water, harmonics are also generated in the third-diurnal, fourth-diurnal and higher species. These constituents can be used for HARMONIC PREDICTION of tides.

HEAD: the difference in water level at either end of a strait, channel, inlet, etc.

HIGH WATER: the maximum water level reached in a tidal cycle.

HIGHER HIGH WATER (HHW): the highest of the high waters (or single high water) of any specified tidal day due to the enhanced diurnal declinational effects of the moon and sun.

HIGHER LOW WATER (HLW): the highest of the low waters of any specified tidal day due to the reducing declinational effects of the moon and sun.

HIGHEST ASTRONOMICAL TIDE: the highest tidal level that can be predicted to occur under any combination of astronomical conditions.

HYDRAULIC CURRENT: a current in a channel caused by a difference (sometimes called *head*) in the surface elevation at the two ends. Such a current may be expected in a strait connecting two bodies of water in which the tides differ in time or range. The current in the East River, New York, connecting Long Island Sound and New York Harbour, is an example.

HYDRODYNAMIC LEVELLING: the transfer of survey datum levels by comparing mean sea level at two sites, and adjusting them to allow for gradients on the sea surface due to currents, water density, winds and atmospheric pressures.

INDIAN SPRING LOW WATER: a tidal low water datum, designed for regions of mixed tides, which is depressed below mean sea level by the sum of the amplitudes of the principal semidiurnal lunar and solar tides and the principal diurnal tides ( $M_2+S_2+K_1+O_1$ ); originally developed for parts of the Indian Ocean.

INTERNAL TIDES: tidal waves which propagate at density differences within the ocean. They travel slowly compared with surface gravity waves and have wavelengths of only a few tens of kilometres, but they can have amplitudes of tens of metres. The associated internal currents are termed baroclinic motions.

INVERTED BAROMETER EFFECT: adjustment of sea level to changes in barometric pressure; in the case of full adjustment, an increase in barometric pressure of 1 millibar corresponds to a fall in sea level of 0.01 m. If there is this full adjustment, the observed pressures at the seabed are unchanged.

KELVIN WAVE: a long wave in the oceans whose characteristics are altered by the rotation of the earth. Tidal progression is mainly by Kelvin waves. In the northern hemisphere the amplitude of the wave decreases from right to left along the crest, viewed in the direction of wave travel.

LAGRANGIAN CURRENT: the movement through space of a particle of water as measured by drogues or drifting buoys.

LOCAL ESTABLISHMENT or LUNITIDAL INTERVAL: an old term for the interval of time at a particular location, between the transit (upper or lower) of the moon and the next semidiurnal high water. This varies slightly during a spring-neap tidal cycle. The interval at the times of full and new moon is called "high water full and change". See NON-HARMONIC tidal

prediction.

LONG WAVE: a wave whose wavelength from crest to crest is long compared with the water depth. Tides propagate as long waves. The speed of travel is given by:

$$(water\ depth * gravitational\ acceleration)^{1/2}.$$

LOW WATER: the minimum water level reached in a tidal cycle.

LOWER HIGH WATER (LHW): the lowest of the high waters of any specified tidal day due to the reducing declinational effects of the moon and the sun.

LOWER LOW WATER (LLW): the lowest of the low waters (or single low water) of any specified tidal day due to the enhancing declinational effects of the moon and the sun.

LOWEST ASTRONOMICAL TIDE: the lowest level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; often used to define CHART DATUM.

LUNAR DAY: the time of the rotation of the earth with respect to the moon. The mean lunar day is approximately 1.035 times the mean solar day.

LUNAR TRANSIT: passage of the moon over the local meridian; when it passes through the observer's meridian it is called the *upper transit*, and when it passed through the same meridian but 180 degrees from the observer's position it is called the *lower transit*.

MAELSTROM: a tidal whirlpool found between the islands of Moskenesy and Mosken in the Lofoten Islands of northern Norway. The term is generally applied to other tidal whirlpools.

MEAN HIGH WATER SPRINGS: average spring tide high water level, averaged over a sufficiently long period.

MEAN HIGHER HIGH WATER: a tidal datum; the average of the higher high water height of each tidal day, averaged over the United States NATIONAL TIDAL DATUM EPOCH.

MEAN LOW WATER SPRINGS: a tidal datum, the average spring low water level averaged over a sufficiently long period.

MEAN LOWER LOW WATER: a tidal datum, the average of the lower low water height of each tidal day observed over the United States NATIONAL TIDAL DATUM EPOCH.

MEAN SEA LEVEL: the arithmetic mean of hourly heights observed over some specified period (sometimes 19 years); often used as a datum for geodetic surveys.

MEAN SEA LEVEL TRENDS: changes of mean sea level at a site over long periods of time, typically decades, also called SECULAR changes. Global changes due to the increased volume of ocean water are called EUSTATIC changes; vertical land movements of regional extent are called EPERIOGENIC changes.

MEAN TIDE LEVEL: the arithmetic average of mean high water and mean low water. This level is not identical with mean sea level because of higher harmonics in the tidal

constituents.

**METEOROLOGICAL RESIDUAL:** that part of the observed sea level due to weather effects. See also **NON-TIDAL RESIDUAL**.

**METEOROLOGICAL TIDE:** see **RADIATIONAL TIDE**.

**MIXED TIDE:** a tidal regime where both the diurnal and semidiurnal components are significant.

**NATIONAL TIDAL DATUM EPOCH:** the specific 19-year period adopted by the National Ocean Service as the official time segment over which sea level observations are taken and reduced to obtain mean values for datum definition. The present Epoch is 1983 through 2001. It is reviewed annually for revision and must be actively considered for revision every 25 years.

**NEAP TIDES:** tides of small range, which occur twice a month, when the moon is in **QUADRATURE**.

**NODAL FACTORS:** small adjustments to the amplitudes and phases of harmonic tidal constituents to allow for modulations over the 18.6-year, the period of a nodal tidal cycle.

**NON-HARMONIC TIDAL ANALYSIS:** analysis and prediction using traditional methods such as the **LOCAL ESTABLISHMENT**.

**NON-TIDAL RESIDUAL:** the part of the observed sea level that is not due to tidal forces. Sometimes assumed to be the same as **SURGE** or **METEOROLOGICAL RESIDUAL**, but could include other effects such as seiches and tsunamis.

**NUMERICAL MODELLING:** calculations of the hydrodynamic responses of real seas and oceans to physical forcing by representing them as a set of discrete connected elements, and solving the hydrodynamic equations for each element in sequence.

**PERMANENT SERVICE FOR MEAN SEA LEVEL:** the organisation responsible for collection, analysis, interpretation and publication of mean sea level data from a global network of gauges. **PSMSL** is one of the Federation of Astronomical and Geophysical Data Analysis Services, under the auspices of the International Council for Science.

**PERIGEAN TIDE:** tide of increased range when the moon is near perigee, its nearest approach to the earth in its elliptical orbit. The effect is particularly evident in the tides along the east coast of Canada and the USA.

**POLE TIDE:** small variations in sea level due to the Chandler Wobble of the axis of rotation of the earth. This has a period close to 436 days. Maximum amplitudes of more than 30 mm are found in the Gulf of Bothnia, but elsewhere amplitudes are only a few millimetres.

**PRESSURE TIDE GAUGES:** instruments which measure the pressure below the sea surface; this pressure may be converted to sea levels if the air pressure, the gravitational acceleration and the water density are known.

**PROGRESSIVE WAVE:** a wave whose travel can be followed by monitoring the movement of

the crest. Energy is transmitted but the water particles perform oscillatory motions. See also KELVIN WAVE.

QUADRATURE OF MOON: position of the moon when its longitude differs by  $90^\circ$  from the longitude of the sun. The corresponding phases are known as first quarter and last quarter.

RADIATIONAL TIDES: tides generated by regular periodic meteorological forcing. These are principally at annual, daily and twice-daily periods.

RANGE: the difference between high and low water in a tidal cycle. Ranges greater than 4 m are sometimes termed macrotidal and those less than 2 m are termed microtidal. Intermediate ranges are termed mesotidal.

RECTILINEAR CURRENT: see REVERSING CURRENT.

RELATIVE SEA LEVEL: sea level measured relative to a local TIDE GAUGE BENCH MARK. Changes include both local vertical land movements, and local sea-level changes.

RESONANCE: The phenomenon of the large amplitudes that occur when a physical system is forced at its natural period of oscillation. Tidal resonance occurs when the natural period of an ocean or sea is close to the period of the tidal forcing.

RESPONSE ANALYSIS: the representation of observed tidal variations in terms of the frequency-dependent amplitude and phase responses to input or forcing functions, usually the gravitational potential due to the moon and sun, and the radiational meteorological forcing.

RETURN PERIOD: the average time between events such as the flooding of a particular level. This information may also be expressed as the level that has a particular return period of flooding, for example, 100 years. The inverse of the return period is the statistical probability of an event occurring in any individual year.

REVERSING CURRENT: a tidal current, which flows alternately in approximately opposite directions with a slack water at each reversal of direction. Also known as a RECTILINEAR CURRENT.

REVISED LOCAL REFERENCE: a datum level defined by the PERMANENT SERVICE FOR MEAN SEA LEVEL for each station, relative to which the mean sea level is approximately +7 m. Measurements at the location, over different periods and to different Tide Gauge Bench Marks are all related to this defined datum. The value of 7 m was chosen to avoid confusion with other local datum definitions.

ROTARY CURRENT: a tidal stream that flows continuously with the direction of flow changing through all points of the compass during a tidal cycle. Found away from coastal or shallow water flow restrictions, where REVERSING CURRENTS are more probable.

SEA LEVEL: the level of the sea after averaging out the short-term variations due to wind waves.

SEA LEVEL MEASUREMENTS: may be made in many ways. In all cases some means of averaging out the effects of waves is necessary. For the reading of tide poles the averaging is

by eye; in STILLING-WELLS the waves are damped out by a narrow constriction; acoustic, fixed radar and PRESSURE GAUGES may apply electronic averaging to rapid samples; satellite altimetry is corrected for general wave conditions within the footprint of the transmission.

SEA-LEVEL RISE: long-term increases of mean sea level. The expression is popularly applied to anticipated increases in EUSTATIC sea level due to the GREENHOUSE effect and associated global warming.

SEA SURFACE HEIGHT: the term often used for sea levels measured by satellite altimetry.

SEDIMENT TRANSPORT: the total sediment transported by a current is the sum of the BED LOAD, material partly supported by the bed as it rolls or bounces along, and the SUSPENDED LOAD in the water.

SEICHE: the oscillation of a body of water at its natural period. Coastal measurements of sea level often show seiches with amplitudes of a few centimetres and periods of a few minutes due to oscillations of the local harbour, estuary or bay, superimposed on the normal tidal changes.

SEMIDIURNAL TIDES: tidal changes of level twice in a lunar day. Worldwide, semidiurnal tides are the most important because the global ocean is near to resonance at the period of semidiurnal gravitational forcing.

SIDEREAL DAY: the period of rotation of the earth with respect to the vernal equinox (approximately 0.99727 of a mean solar day).

SLACK WATER: the state of a tidal current when its speed is near zero, especially the moment when a reversing (rectilinear) current changes direction and its speed is zero. For a theoretical standing tidal wave, slack water occurs at the times of high and of low water, while for a theoretical progressive tidal wave, slack water occurs midway between high and low water.

SPRING TIDES: semidiurnal tides of large range, which occur twice a month, when the moon is new or full.

STANDING WAVE: wave motion in an enclosed or semi-enclosed sea, where the incident and reflected progressive waves combine to give a node of zero tidal amplitude. Maximum tidal amplitudes are found at the head of the basin where reflection occurs. No energy is transmitted in a standing wave, nor is there any progression of the wave pattern.

STERIC LEVEL DIFFERENCES: sea level differences due to differences in water density.

STILLING-WELL GAUGES: instrument system for measuring sea levels; tidal changes of levels are detected by the movement of a float in a well, which is connected to the open sea by a restricted hole or narrow pipe. Wind waves are eliminated by the constriction of the connection.

STOLEN TIDE: a tide which approaches by stealth; particularly a local term for the high tides which creep up the gullies and marshes of coastal Lincolnshire, England.



STORM TIDE: the sum of a storm surge and astronomic tide. See STORM SURGE.

SURGE or STORM SURGE: a large change in sea level generated by extreme weather conditions, which, if they coincide with high tides, can cause severe coastal flooding. The term is sometimes applied to all meteorological effects on sea level.

SURVEY DATUM: the datum to which levels on land surveys are related; often defined in terms of a MEAN SEA LEVEL. Survey datum is a horizontal surface to within the accuracy of the survey methods.

SYZYGY: astronomical condition of alignment of the earth, moon and sun at new and full moon, the time of maximum spring tidal forcing. Also useful for crossword puzzles.

TIDAL CURRENT: periodic tidal water movement. See also TIDAL STREAM.

TIDAL CONSTITUENT: see HARMONIC ANALYSIS.

TIDAL EXCURSION: the LAGRANGIAN movement of a water particle during a tidal cycle.

TIDAL PRISM: the volume of water exchanged between a lagoon or estuary and the open sea in the course of a complete tidal cycle.

TIDAL RANGE: the difference between low and high water tidal levels, equal to twice the TIDAL AMPLITUDE.

TIDAL STREAM: horizontal water movements due to tidal forcing. Also known as TIDAL CURRENT.

TIDE GAUGE BENCH-MARK: a stable bench-mark near a gauge, to which tide gauge datum is referred. It is connected to local auxiliary bench-marks to check local stability and to guard against accidental damage. Tide gauge datum is a horizontal plane defined at a fixed arbitrary level below a tide gauge bench-mark.

TIDES: periodic movements which have a coherent amplitude and phase relationship to some periodic geophysical force.

TSUNAMI: waves generated by seismic activity, also called seismic sea waves. Tsunami are also popularly, but inaccurately, called tidal waves. When they reach shallow coastal regions, amplitudes may increase to several metres. The Pacific Ocean is particularly vulnerable to tsunami.

VANISHING TIDE: periods when the local semidiurnal and diurnal tidal constituents conspire to give several hours of relatively constant sea level.

VERNAL EQUINOX: see EQUINOXES.

ZONATION: the pattern of colonisation of the sea shore, whereby individual species flourish in bands associated with particular tidal levels.