On Tidal Energy Horizontal Circulation

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The local horizintal flux of tidal energy is characterized by the surface density $\omega = \rho g h \xi \vec{u}$ (ρ - sea water density, g - gravitation, h - depth, ξ - tidal surface elevation, $\vec{u}$ - vertically averaged tidal current velocity vector). In general the flux vector ω comprises active and reactive components whose relation determines the local structure of a tidal wave. If the tidal current is rectilinear (reciprocating) the both components are of the same direction , but if the current is rotary (the hodograph of $\vec{u}$ for a tidal harmonic constituent being an ellipse) the directions of active and reactive flux components differ, the former being determined by the direction of current at the time of high water and the latter - by that of current at the time of zero tidal elevation. It may be shown that in this case the hodograph of ω is alse elliptic and the both ellipses (current and energetic) are geometrically similar having the same oblatness and orientation. The simultaneous representation of the both ellipses may be used as an informative diagram.

In general the horizontal energy flux provides the transfer of tidal energy from sources to sinks. This transfer is realized in form of tidal waves which can be either free or forced determining, correspondingly, either induced (co-oscillating) or proper tide. Considering the instantaneous and 'net' (timely averaged) values of energey flux in free waves of Kelvin, Sverdrup and Poincare types and in amphidromic systems formed by these waves one can reveal a number of specific characteristics of the energy horizontal circulation spatial pattern. So in adjacent amphidromies resulting from interference some close energy circulations around the amphidromic points with different sence of rotation take place their geometry depending on the amplitude and phase relationships of partial waves, the angle of waves crossing and the Coriolis parameter f. Owing to Coriolis force the cum-sole circulations are more intensive than the contra-solem ones. In case of interference of two opposite Kelvin waves in a channel-like basin with the breadth b some ' energetic countercurrent' may arise near one of channel sides if the amplitude relation of

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waves exceeds exp($-fb/\sqrt{gh}$). If a Kelvin wave reflected in the head of a gulf the superposition of arising standing Poincare waves provides the energy transfer across the gulf completing the contrary fluxes by a 'transversal link'. At the same time at a distance from the head the existing transversal phase changes are not related to any transversal energy flux. In progressive Sverdrup waves, where the equality of potential are kinetic energies is violated, the longitudinal flux component is purely active whereas the transversal component is purely reactive. If the normal reflection of Sverdrup wave from the shoreline is not total the net fluxes deviate from the normal to the coast and if the reflection is the total the (ω) vector field is separated into zone with net fluxes having opposite directions. When the reflection of Sverdrup waves is oblique resulting in progressive Poincare waves a specific effect may appear consisting in formation of stripe-like alongshore zones in which the energy flux is directed opposite to the wave phase velocity. Finally, the reflection of progressive Poincare waves in the head of a wide gulf-like basin leads to intensive cum-sole energy circulations around the central 'axial' amphidromic points accompanied by the relatively weak contra-solem circulations around 'coastal' amphidromies. If the Poincare wave reflection is total one can say that Coriolis force makes it possible the energy fluxes to arise, but only in form not modifying integral energy balance and tolerating nothing but closed circulations around amphidromies.

Energy fluxes in forced waves are considered by using the simplest solutions for semidiurnal tidal movements in channels of constant depth oriented along the equator or a latitude parallel. With absence of dissipation and energy radiation the energy budget is to be maintained by the work done by tide-producing force i.e. the actions of astronomical sources and sinks must be balanced. In this case the horizontal energy depends considerably on the geometry (length and depth) of a basin. If the length is relatively small (under the first resonance) the eastern half of the basin represents the energy source and the western half is the sink the wave motion transporting the energy from east to west. After passing the resonance(for a long basin) the situation changes : as a result of general response phase inversion the source changes places with sink and energy is now transported from west to east.

Some generalization of these results to case of basins loosing energy on their ends (what may be achieved by introducing of 'impedence' boundary conditions imitating partial radiation or 'contour' dissipation of energy) makes it possible to consider the influence of 'geophysical energy suction' on resulting horizontal fluxes. In this case a divergence of fluxes out of an inner region is possible. It may be shown that in some cases geophysical sinks not only ' takes on themselves' some part of energy expenditures but also may stimulate the energy income by intensifying the astronomical sources whereas the astronomical sinks generally weaken. The resulting tidal motions may be interpreted as progressive-standing waves whose progressive part is reducing when approaching the resonance and is growing when approaching the antiresonance.. After each passing a next resonance the direction of progressive part propagation changes inversely according to the changement of the horizontal flux of energy.