

***Interactive comment on* “On available energy in the ocean and its application to the Barents Sea” by R. C. Levine and D. J. Webb**

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The two main comments made by the Topic Editor appear to miss part of the argument of the paper. Here we expand the argument slightly - we hope to make it clearer.

We start with Eqn. 9, which gives the energy (our available energy, AE) that may be extracted by the movement of an element of water from one part of the ocean to another. The derivation up to this point shows that the available energy depends only on the change in the enthalpy of the partical and its change in gravitational potential energy.

In our derivation, the element of water is first extracted from its initial position in the ocean. It is then moved outside the ocean to a new position. Finally it is

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reintroduced into the ocean. During this process the pressure acting on the partical will change but the energy required or released by the process is independent of the way this change occurs - as long as the process is adiabatic (i.e the process is both reversable and adiathermal, only involving work on an otherwise isolated system).

Because of this independence, we can imagine a situation in which the changes in pressure and gravitational potential energy occur precisely as would occur if the partical moved along a path in the ocean and experienced the pressures at each point in the ocean as it passed. Doing this would not change the amount of energy required or released.

If we do this, we see that because of the form of Eqn. 9, the change in AE can be expressed as a path integral as shown in Eqn. 10. Note that because it has been derived from Eqn. 9, the enthalpy H here is not the enthalpy of the ocean, but the enthalpy our element of fluid would have if moved adiabatically to that point in the ocean. Similarly in Eqn. 11 and 12, P is the pressure the element would experience at that point in the ocean and the density ρ , specific volume V and enthalpy H are the properties it would have at that point.

1.1 Comment 2

This states that Eqn. 11 is incorrect. It is possible that this is a result of thinking that H in Eqn. 11 is the enthalpy of the background ocean. However as explained above this is not the case.

Alternatively, it may be a result of thinking that the element of fluid will change in temperature as the pressure changes and that this will change the enthalpy. However the 'natural' way of writing the enthalpy is as a function of entropy S and pressure P (see for example Pippard, Chapter 5 - reference given in the paper). In

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our problem pressure is changing and indeed temperature may change but because the motion is adiabatic, the entropy remains constant and any change in temperature does not change the enthalpy.

A more text book way of obtaining the same result is to use the differential for of the enthalpy function (see Pippard, Chapter 5 again). This gives:

$$dH = TdS + VdP.$$

In our problem because the changes are adiabatic, dS is zero, so:

$$dH = VdP.$$

The result is also be obtained by combining Eqn. 7 and Eqn. 3. Thus:

$$dH/dx = VdP/dx,$$

and as the same is true in the y and z directions, Eqn. 11 follows.

1.2 Comment 1

This states that 'under hydrostatic balance the last term in Eqn. 13 that involves a density difference does not appear'.

We believe this conclusion is a result of the misunderstanding referred to above. In the path integral of Eqn. 13, we use the hydrostatic approximation to replace the vertical pressure gradient at each point on the path by a term involving the background density. Thus ρ is the density our fluid element would have at that point on the path and ρ_0 is the density of the background ocean at the same point. In general the densities

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are not the same, so the term is non-zero, i.e. it does appear.

Having checked through the manuscript we realise that there could be a confusion between the ρ_0 as used in Eqn. 13 and its use in Eqn. 18 and later where, because of the path chosen, it refers only to the density in the reference water column. In a revised manuscript we will ensure that this difference is made clearer.

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