

## ***Interactive comment on “Multi-sensor in situ observations to resolve the sub-mesoscale in the stratified Gulf of Finland, Baltic Sea” by U. Lips et al.***

**U. Lips et al.**

urmas.lips@msi.ttu.ee

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Multi-sensor in situ observations to resolve the sub-mesoscale in the stratified Gulf of Finland, Baltic Sea

U. Lips et al.

Response to Referee 2 (E. Svendsen) 1. Scientific significance: The paper touch upon a very important issue, namely the effect sub-mesoscale processes have on vertical mixing and thereby supply of nutrients to the euphotic layer impacting primary production and thereby the whole ecosystem. Most numerical models do not have

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sufficient spatial resolution to handle these processes, and it is a big challenge to find a good way to parameterize these processes in larger scale models. Assessment of the importance of sub-mesoscale processes is not new, however the compilation of different in situ data to give a 3(4)D view of the processes is to my knowledge quite unique.

2. Scientific quality: The scientific approach and applied methods are valid. However, my main concern about the paper is how the data are discussed and analysed, the readability. Many time series (wind, hydrography and Chla from different sources) are discussed separately by describing many individual events, and the reader is “drowning” in many event descriptions, having a hard time to connect the links between wind events, up-downwelling, sub-mesoscale features and Chla/prim.prod.

Response: We agree that the description of time series was too lengthy, and the text is shortened in the revised manuscript. We tried to present the data in a more readable form, e.g. to have links between the different sub-chapters and figures. See also the response below where it is justified why we prefer to keep the original structure of the manuscript.

One of the key findings is the typical -2 slope in the horizontal wave number spectra, however it is only in the final discussion they describe what this physically/practically means, namely that sub-mesoscale processes are more energetic than suggested by the quasi-geostrophic theory of turbulence in the ocean interior (maybe obvious to specialists in turbulence). In this respect I would also like to see some quantitative “thoughts” on how much it changes the actual vertical mixing/vertical transports and how we maybe can use this to improve the parameterization in numerical models.

Response: This is a very relevant comment. Nevertheless, we think that to have reliable estimates of changes in vertical mixing/transport and to propose improved parameterization in numerical models is too large topic to be included in the present paper. We have plans to conduct such analysis and to present the result in a separate paper.

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Several places there the direct effect of wind mixing is mentioned. This is more related to the cubed wind speed (than the wind speed), and I suggest including simple time series of cubed wind speed (based on the highest possible resolved data and thereafter averaged to a suitable (daily?) time-resolution).

Response: Times series of wind vectors is replaced by time series of wind stress vectors. See the comment below. Time resolution of the used data series is 3 hours.

3. Presentation quality and specific comments As mentioned above, I would suggest to delete the detailed and lengthy descriptions of the individual data series, and rather focus on fully descriptions of the individual events. This could mean rearranging some of the figures.

Response: We prefer to keep the structure of the paper as it was in the submitted version. Nevertheless, we agree that the description of time series was too lengthy, and the text is shortened in the revised manuscript. The decision to keep the original structure is justified by the main aim of the paper to reveal general statistical characteristics of sub-mesoscale features/variability and relate them to the mesoscale background. The individual events are analyzed in separate papers for some data (e.g. summer 2010 results are presented by Lips and Lips, 2014) or will be a subject of next papers (e.g. events in summer 2012).

Some specific comments: a. Most figures have too tiny text on the axis. Especially I had a very hard time with this on the important Fig.3. This must be changed.

Response: Fig. 3 is revised.

b. Suggest to change “sub-mesoscale” to “sub-mesoscale features” in the title.

Response: Done.

c. When first mentioning the spectral slope (-2 versus -3) in the introduction they should say what this actually/physically means (see comment above on this).

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Response: Done. The sentence introducing this issue is complemented in the revised manuscript. It reads: "It has been shown that if the spatial resolution of numerical models was increased the spectral slope converted rather to -2 than -3 (Capet et al., 2008) suggesting that sub-mesoscale processes play an important role in the energy cascade from larger to smaller scales."

d. Suggest adding some names on countries and the Baltic (No American would know where this is on earth).

Response: Done.

e. The data from the ferry is assumed to have 160m resolution. I guess this is assuming the ferry always have the same constant speed, independent of weather etc. If this is not the case, how would it affect the results?

Response: The ferry speed certainly influences the data quality and calculation results. For instance, the changes in the speed cause changes also in the flow through time of water through the sea chest and, thus, the time lag between the water intake and actual measurements (as described in the manuscript). One of the advantages of using data from a regular ferry line is that they always try to keep the schedule, which means also the speed along the ferry route. In a few occasions, the ferry speed was clearly higher than an average of 15-16 knots. Since the system also records the ferry speed as a background parameter, we were able to identify those occasions and did not include such data in the analysis.

f. Related to Figure 2 I would also would like to see time series of cubed wind speed and take this into the discussions/descriptions

Response: Times series of wind vectors is replaced by time series of wind stress vectors. We prefer to present wind stress instead of cubed wind speed since wind stress is the main forcing behind kinetic energy in the sea. The aim is to show that the sub-mesoscale processes play an important role in the energy cascade from larger to

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smaller spatial scales.

g. Fig. 3: In addition to not being able to read the axis text and numbers, it took me a long time to understand the figure. I think some better description on how the data are combined in the different cubes would help.

Response: Done.

h. It is mentioned that the spectral slope are up to -3.7, but it is unclear where this is found. (Max values in the table is -2.6)

Response: The slopes estimated based on single crossings reached the value -3.7 (see Fig. 4). In the table average values for certain periods are given.

i. In Fig 6 it is not described which line is what

Response: Explanation is added in the figure legend.

j. In 3.5 you should also mention that convergence/divergence may rapidly change the concentration of Chla

Response: Relevant text about the role of the convergence of surface waters (Chl a) and possible impact of re-stratification is given in the Discussion section.

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