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Ocean Science
Discussions

Interactive comment on "Electromagnetic characteristics of ENSO" *by* Johannes Petereit et al.

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We thank the reviewer for carefully reading our manuscript and providing many helpful scientific and technical remarks. The resulting changes improved the manuscript greatly.

General comments:

-"*There are in my opinion some logically important steps missing in sections 2.1 and 2.1, which purport to explain how the interaction between tidal motions, the Earth's magnetic field and the local T/S structure in the tropical Pacific gives rise to measurable magnetic field anomalies.*"

We improved and restructured the mentioned sections in order to add more background

on EMOTS and to clarify the link between the induced electrical current and the resulting electromagnetic signals. Also, we tried to focus on the advantage of the strict periodicity and the consequent detectability which distinguishes the oceanic tidally-induced signals from signals induced through other oceanic processes.

-"*Firstly, is there a fundamental limit to the smallest measurable magnetic signal in the ocean? How large is the effect of internal waves and other small-scale oceanic motions on the magnetic anomaly, compared with that due to the predictable tidal signal? Are there any foresee- able improvements in technology that would reduce the SNR to enable these signals to be detected?*"

In order to address this important issue, we discussed the theoretical measurability and recent advances in the magnetometer technology in section 3.1. We think that the added context will help to clearly classify the presented model study as currently impracticable but with possible future applications.

-"*Secondly, ... Are there any real advantages of the technique discussed in this paper over conventional monitoring of standard hydrographic fields (e.g. the TAO/TRITON array)?*"

Given the current situation of not being measurable, we refrain from an in-depth discussion of this issue in the paper. However, we addressed this issue briefly in the introduction.

The oceanic tidally-induced magnetic fields, detectable in Swarm observations, are able to provide information of the ocean from sea surface to ocean bottom and have therefore several applications appart from detecting ENSO. We believe that the presented study, if applicable in the future, would be a complementary technology to the existing techniques.

Specific Comments:

We included all specific comments proposed by the rewiever. In the following, we

respond specifically to the issues related to substantial manuscript adoptions in section 2.2, 3.1, 3.2 and 4.

2.2 EMOTS

-"*Perhaps,... there doesn't seem to be a clear link between the induced currents* j_{M2} *in the previous section and the measurable resulting magnetic field...*

-"*Also, are the EMOTS measurable in the magnetic or electric field? ... this is not stated explicitly here.*"

We implemented necessary changes to answer these questions. Also, we addressed this issue in our answer to the general comments (please see above).

-"*Finally, I think this would be a suitable place for an error analysis of the predicted signals. ...how large is the contibution of the other, more stochastic flow components ... relative to the tidal signal?*"

This is a very interesting question. More stochastic components have the disadvantage of not having a distinct frequency which would allow a straightforward extraction from magnetometer observations. Therefore, their induced magnetic field may not be detectable directly. Their indirect effect on the T/S structure and the resulting conductivity on the other side may be detectable through variations of EMOTS. Their contribution can be expected to be in the same order of relative conductance changes in the water column. Given the ratio between ocean depth and total change in conductivity, the resulting effect onto the conductance (integrated conductivity) and therefore the EMOTS may be minute.

We addressed this issue briefly in the updated manuscript.

-"*What magnitude of variability of local geomagnetic field?*"

The influence of the secular variation onto the EMOTS has not been investigated so far. Previous studies have neglected this effect even on longer time-scales under the

assumption that B_{Earth} is very well known and the linear contribution of B_{Earth} to j_{M2} can be removed accordingly. However, given the necessary precision needed to detect the presented signals, a subsequent study investigating this issue might be necessary.

-"*What are the current measurement limits?*"

Please see below.

3.2 Spatio-temporal anomaly development

-"*It would be helpful to discuss here how the computed* B_r *anomalies relate to the noise levels and to instrumental measurement capabilities*"

We realize that the issue may have been addressed too briefly in section **3.1**. That's why we rearranged this section and discussed this issue in more detail. We included recent advances compared to current measurement limits of the Swarm satellites. Furthermore, we discussed that, despite those recent advances, an actual implementation of the presented techniques requires further advances for an in-field applicable technical realization. We chose this section, since we mention the magnitude of the signals here for the first time.

4 Conclusion

-"*...It would be useful here to include something about at least about the possibility of improving the detection threshold – is this at least theoretically possible?*"

In addition the changes in section 3.1 (please see above), we changed this section accordingly and moderated the previous claims.

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