**Geoscientific
Model Development
Discussions**

Interactive comment on "Physically-based data assimilation" *by* G. Levy et al.

G. Levy et al.

gad@nwra.com

Authors' Response to Interactive comment Anonymous Referee #1

Referee's question # 1: Why "physically- based"? Where is the "physics"?

Response: The choice "physically-based" indicates that, in distinction from other traditional assimilation methods that are based on statistical estimation theory, the procedure whereby the model state is adjusted maintains the physical principles embodied in the model. In other words, we have the model physics (or dynamics) evolve to a better agreement with the observed state at a future time, rather than through implementing the innovation as a (statistically optimized) differential to model variables, "forcing" the model to better agree with the observations but also potentially generating noise through imposing a non-realizable (non-physical) model state. From a model physics (dynamics) perspective, this is a more natural (physical) way to assimilate. When ap-

plied to model and directly observed variables, we achieve model realizable field like a 4D assimilation would but with significant computational savings. When used with lower dimensional information as we do here, there is not a direct analog in existing data assimilation methods (see response to following points). We welcome a suggestion for an alternative wording, and wonder if additional explanation beyond what we have already included is called for.

We can add this explanation to the introduction on page 520 after line 24 where we first use the term rather than leaving it to page 521 in the paragraph starting at line 14.

Referee's question # 2: Relation between the low-dimensional model features and model variables According to section 2.1, the low-dimensional model features can be transformed into the model variables. If the model variables are diagnostic ones, which can be derived from the low-dimensional features, control variables of the data assimilation need to include the low-dimensional features alone, and the rest model variables can be excluded. In this case, the computational costs for the data assimilation can be reduced as a matter of course, even using the traditional data assimilation methods. Where is the advantage of the proposed method?

Response: On the contrary, in section 2.1 we say that it is not necessary to transform low-dimensional features into model variables. And, in fact, there is no direct transformation of lower dimensional features and information into model variables and in most models the lower dimensional information is not resolved or used.

Referee's question # 3: Relation between the traditional data assimilation methods

Response: Traditional data assimilation techniques fall into two main categories: empirical methods such as dynamic relaxation or nudging, and methods based on statistical estimation theory, which include optimal interpolation, 4D assimilation, and Kalman filtering. We discuss those and our choice to test our scheme in a physically based nudging context in pages 519-520. Much of the discussion in sections 2.1 and 2.2 revolves around how our scheme can complement the traditional methods by incorpo-

rating the lower dimensional information and using fuzzy verification. We hope that, with the additional information we provide in response to comments 1, 2, and 4, the relationship of our scheme with existing data assimilation methods becomes clearer.

Referee's question # 4: Necessity of the fuzzy verification metric

Response: The reviewer is correct: the fuzzy verification metric is a core idea. The reason for such a metric has not been clearly articulated in the paper. In the winter, the leads or discontinuities in sea ice are regions where the relatively warmer ocean is exposed to the cold atmosphere. New ice forms rapidly in these regions and as it forms, brine is ejected into the upper ocean. This denser water sinks and contributes to the conveyor-belt circulation. If forces change and leads close, the thinner ice in the leads can be forced up into ridges or down into keels, increasing the amount of ice that can be stored in a given area. Thus, leads and ridges (the linear kinematic features in the model and observations) are crucial for global climate models. However, their exact location is not important. Thus, our climate predictions would probably be fairly accurate if we predict leads of approximately the right size and in roughly the right location. Thus we do not want a metric that compares model and observation point-wise, rather we want a metric that tells us the simulation is ok if we got the leads 'roughly' right. That's what our assessment is meant to accomplish. We suggest adding this motivation to section 2.4.

Referee's question # 5: Description of the sea-ice model

Response: We thought a description of the model would be useful if a reader wanted to understand precisely how the physics comes in to the the physically-based assimilation, but put the model description in an appendix so as not to distract the reader from the main topic of the paper. However, if the editor would like us to try to shorten the description or even omit it, we can stick to just giving a citation.

Referee's question # 6: Examination of the result: Why the differences appear between the control run and the experimental run? Why is the control and the experimental runs

produce skills not in-phase?

Response: We are not sure what the reviewer means by 'not in-phase'. We are guessing that the reviewer thinks the two curves in Figure 2 should always be the same distance apart and move up and down together. There is no reason for the two curves to be the same distance apart – we are solving a nonlinear problem. However there are similar trends in both curves, both have a period where the model spins up; then they both have a region of positive skill, first increasing, then leveling off and then decreasing. With the preconditioning (one step assimilation) the spin up is shorter, and the level portion of the curve, where positive skill is maintained, is longer.

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