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Response to anonymous referee #2:

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Thank you very much for your thorough review, which helped us improve the draft for clarity. In response to your comments, L20 and L177 are updated, and one paragraph is added in L222-224. Typos are corrected as well. Please find our point-by-point response (in blue) to your valuable comments below.

This paper focuses on implementing Incremental Analysis Update (IAU) in MPAS-JEDI and evaluating its impact on model forecasts. IAU helps reduce initial imbalances in model forecasts caused by dynamical and physical balance issues during data assimilation, so model forecasts using IAU exhibit improved control over initial noise.

It's recommended to specify the control variables used in data assimilation and how to transform them into analysis increments.

- ⇨ The definition and the transformation of control variables are needed to avoid representing a static background error covariance (B) matrix explicitly. However, we used a pure ensemble-variational approach with no static error covariance, as already stated in L217-218. The static B is not even formulated in this draft since it was not available in MPAS-JEDI at the time of our IAU implementation. The introduction of control variables is important in the traditional variational approach, but it is not relevant to discuss them within the pure 3DEnVar context (with no static B). We decided not to include control variables here to stay focused on the IAU implementation, which only involves variable transformations between analysis and prognostic variables. It has nothing to do with the conversion from control to analysis variables, if any, which is done outside IAU. Thank you for your understanding.

I believe that an ensemble size of 20 is not sufficient for global analysis, despite using an ensemble with 100% background error covariance. It would be good to mention localization and ensemble spread inflation methods.

- ⇨ Thank you for your suggestion. Although this study is only meant to demonstrate the successful implementation of IAU, we agree with you that it would be good to mention the localization applied to the ensemble background error covariance. New lines are now added in 222-224 as "Due to the small ensemble size, we also apply the distance-based correlation function by Gaspari and Cohn (1999) using 1200 and 6 km as full-width radii for horizontal and vertical covariance localization, respectively."
- ⇨ However, the deterministic 3DEnVar updates a single analysis, for which we estimated the ensemble background error covariance based on ensemble forecasts from GEFS without ensemble inflation. As the inflation is not used, it is not mentioned here.

Regarding the ensemble Kalman filter used for the initial conditions of the ensemble forecast in the 3DEnVar system, clarification on its specifics would be beneficial for a comprehensive understanding.

- ⇨ This study did not employ ensemble Kalman filter, and ensemble forecasts were run from GEFS offline. As the 3DEnVar method used here only produces a single analysis (e.g., a single initial condition), this comment is not applicable to our study. But to emphasize the 3DEnVar algorithm used in this study, we added a new paragraph "For the minimization process, we employ an incremental approach (e.g., minimizing the cost function for increments) (Courtier et al. (1994)). in new L219-220.

In line 21 of the manuscript, there is an expression "It does not consider dynamical or physical balances across model grids or variables, nor does it account for the conservation of mass, momentum, or energy. Hence, the initial balance of the atmospheric flow can by disrupted by data assimilation when the initial state is replaced by the analysis state." While acknowledging that analysis increments from data assimilation might not fully reflect the model's balance, it's important to note that data assimilation does account for dynamical or physical balances across model grids or variables using background error covariance. For instance, temperature observations impact surrounding grids, affecting wind and humidity variables.

- ⇨ Thank you for your insight. You are correct that we can update unobserved states with observed variables in the DA procedure. But that can also be done through linear regressions, without imposing any dynamical or physical balance constraint, as often conducted in ensemble data assimilation. Here, we referred to the generic Kalman filter update, which is not specific to any particular DA algorithms or weather applications. You are also right in that the background error covariance is often estimated from sample forecasts (which employ governing equations for dynamics and physics), but that practice is primarily applied to variational approaches for atmospheric data assimilation. Please note that the particular way of estimating background error covariance is not required by the Kalman filter equation, or more generally, data assimilation. It is just one practical way of representing error statistics in numerical weather prediction models.
- ⇨ But in line with your perspective, we've now updated the statement as "It is not required to account for dynamical or physical balances across model grids or variables, nor does it ensure the conservation of mass, momentum, or energy.".

The authors notes at line 177 "it is easily extended for 4DIAU with varying weights over the IAU time window", However, transitioning from 3DIAU to 4DIAU may not be straightforward in the current version of MPAS-JEDI. Expanding to 4DIAU would necessitate multiple analysis increments over different times, requiring adjustments to the 4DEnVar and cycle suite.

- ⇨ We agree with you that 4DIAU would require some modifications associated with 4DEnVar and cycling scripts. In respect to your opinion, we've now changed "it is easily extended" to "it could be extended".

The following are minor correction requests.

- ⇨ Thank you for finding all the typos! Everything has been corrected except for the last comment. L240 (which is new L245) remains unchanged since ‘cycling’ itself is not considered plural.

L21: can by disrupted by data assimilation

-> can be disrupted by data assimilation

L30: the incremental analysis update (IAU) method was introduced in Bloom et al. (1996)

-> the incremental analysis update (IAU) method was introduced by Bloom et al. (1996).

L47: stability in the the fine mesh region.

-> stability in the fine mesh region.

L74: Details of the implementation is described

-> Details of the implementation are described

L110: and the second term in the right-hand side

-> first and the second term on the right-hand side

L195: while ensuring the model forecasts reproducible

-> while ensuring the model forecasts are reproducible

or while ensuring reproducibility the model forecasts are

L240: global analysis and forecast cycling was conducted

-> global analysis and forecast cycling were conducted