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# Balanced data assimilation with a blended numerical model

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Physical imbalances introduced by local sequential Bayesian data assimilation pose a significant challenge for numerical weather prediction. Fast-mode acoustic imbalances, for instance, can severely degrade solution quality. We present a novel dynamics-driven method to dynamically suppress these imbalances. Our approach employs a blended numerical model that seamlessly integrates compressible, soundproof, and hydrostatic dynamics. Through careful numerical and asymptotic analysis, we develop a one-step blending strategy that switches between model regimes during a simulation. Specifically, upon assimilation of data, the model configuration switches for one timestep to either the soundproof pseudo-incompressible or hydrostatic regime, then reverts to the compressible regime for the remainder of the assimilation window. This regime-switching is repeated for each subsequent assimilation window. Idealised experiments with travelling vortices, buoyancy-driven rising thermals, and internal gravity wave pulses demonstrate that our method effectively eliminates imbalances from data assimilation, achieving up to two orders of magnitude improvements in analysis fields. While our studies focused on eliminating acoustic and hydrostatic imbalances, the underlying principle of this dynamics-driven method can be applied to address other imbalances, with significant potential for real-world weather prediction applications.

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