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Supplement of

The Land Variational Ensemble Data Assimilation Framework: LAVEN-DAR v1.0.0

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S1 Overview

For the supplementary material in section S1.1 we include additional twin experiments using the same error statistics as used in the real world experiments in the main paper, in section S1.2 we include a hindcast for 2009 where we have run JULES, with our prior and posterior parameters found for 2008, into 2009 to judge against independent unassimilated data and in section 5 S1.3 we include the posterior correlation matrix from the Mead experiment.

S1.1 Additional twin experiments

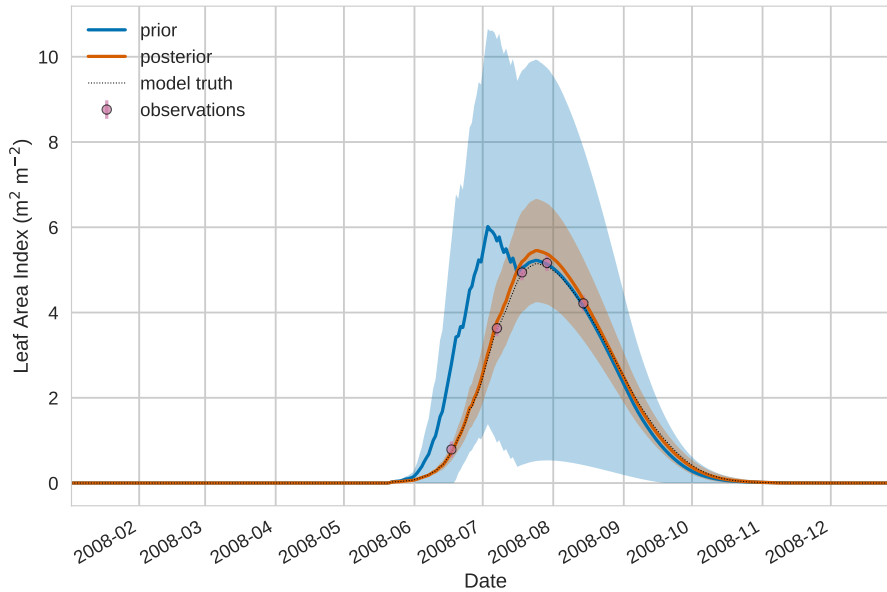


Figure S1. 4DEnVar twin results for leaf area index using 50 ensemble members. Blue shading: prior ensemble spread ($\pm 1 \sigma$), orange shading: posterior ensemble spread ($\pm 1 \sigma$), pink dots: observations with error bars, dashed black line: model truth.

parameter	x_{true}	x_b	x_a	x_b % error	x_a % error
α	0.055	0.067	0.060	22.4	9.2
n_{eff}	0.00057	0.00062	0.00054	9.5	2.8
f_d	0.0096	0.0087	0.0086	9.8	10.8
μ	0.020	0.024	0.023	18.7	13.2
ν	4.0	4.16	3.89	4.0	2.6
γ	17.6	20.7	17.9	17.6	1.6
δ	-0.33	-0.30	-0.29	9.8	11.5

Table S1. 4DEnVar twin results and percentage error for each of the seven optimised parameters when an ensemble of size 50 and Mead real-world experiment error statistics are used in experiments.

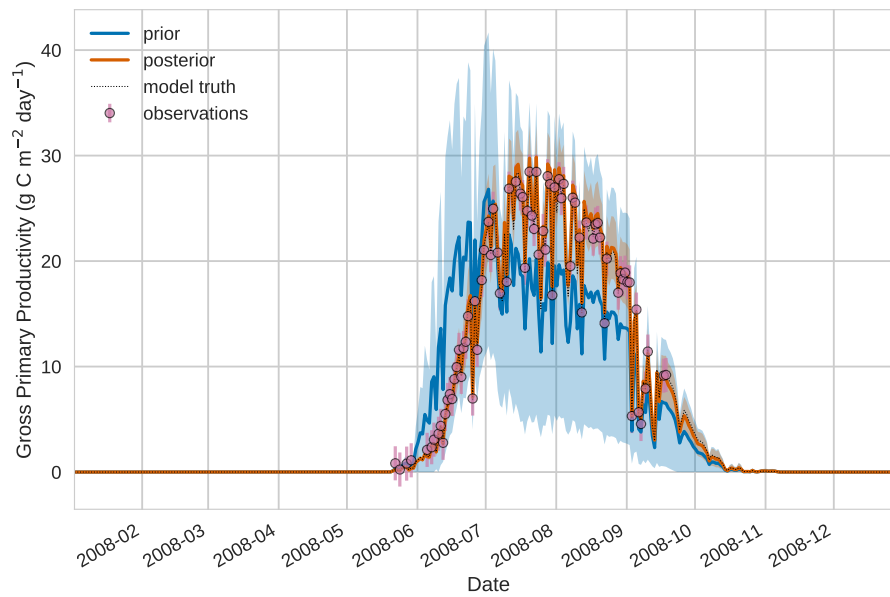


Figure S2. 4DEnVar twin results for gross primary productivity using 50 ensemble members. Blue shading: prior ensemble spread ($\pm 1 \sigma$), orange shading: posterior ensemble spread ($\pm 1 \sigma$), pink dots: observations with error bars, dashed black line: model truth.

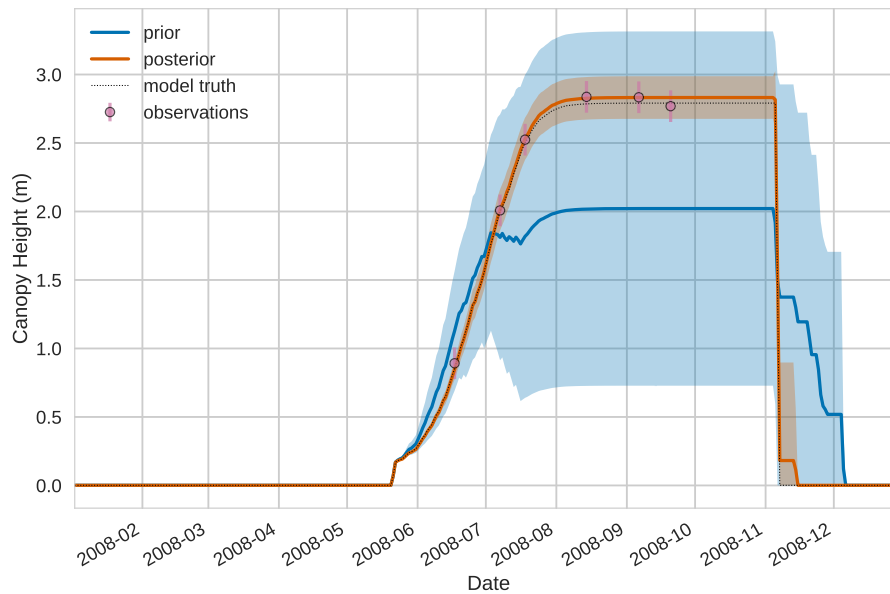


Figure S3. 4DEnVar twin results for canopy height using 50 ensemble members. Blue shading: prior ensemble spread ($\pm 1 \sigma$), orange shading: posterior ensemble spread ($\pm 1 \sigma$), pink dots: observations with error bars, dash black line: model truth.

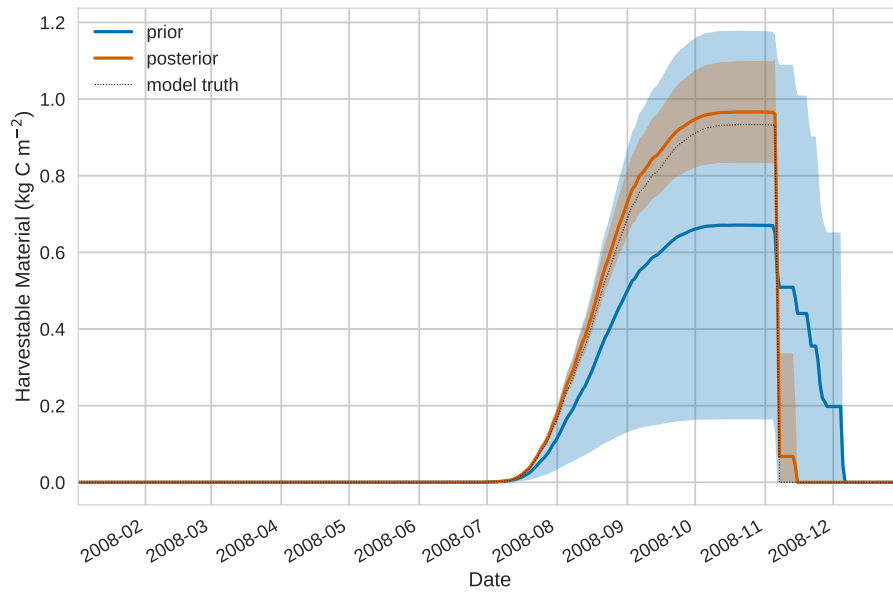


Figure S4. 4DEnVar twin results for harvestable material using 50 ensemble members. Blue shading: prior ensemble spread ($\pm 1 \sigma$), orange shading: posterior ensemble spread ($\pm 1 \sigma$), pink dots: observations with error bars, dashed black line: model truth.

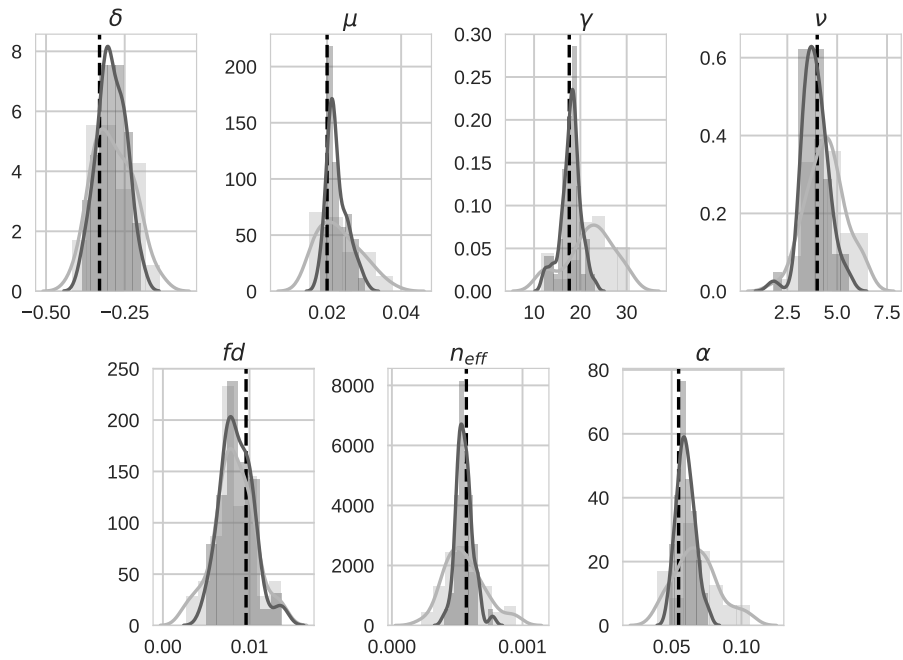


Figure S5. 4DEnVar twin distributions for the 7 optimised parameters for both the prior ensemble (light grey) and posterior ensemble (dark grey). The value of the model truth is shown as a dashed vertical black line.

S1.2 Real-world hindcast for 2009

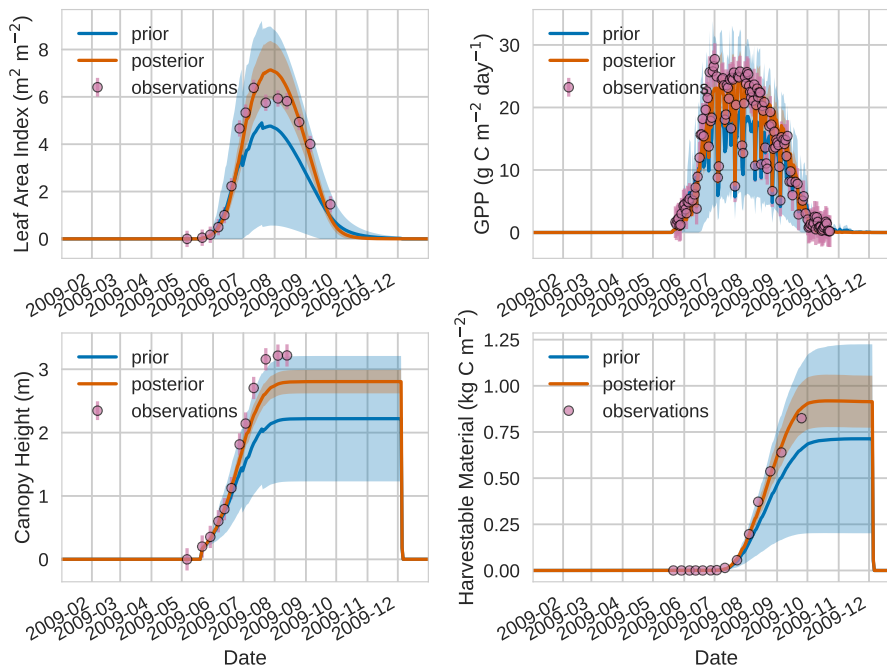


Figure S6. 4DEnVar hindcast results for 2009 using 50 ensemble members. Blue shading: prior ensemble spread ($\pm 1 \sigma$), orange shading: posterior ensemble spread ($\pm 1 \sigma$), pink dots: observations with error bars, dashed black line: model truth.

Variable	x_b RMSE	x_a RMSE	Reduction
LAI	1.15	0.61	47%
GPP	3.84	2.01	47%
Canopy height	0.62	0.28	54%
Harvestable material	0.07	0.02	70%

Table S2. 4DEnVar Mead 2009 hindcast observation RMSE for 4 variables when an ensemble of size 50 is used in experiments.

S1.3 Mead experiment correlation matrix

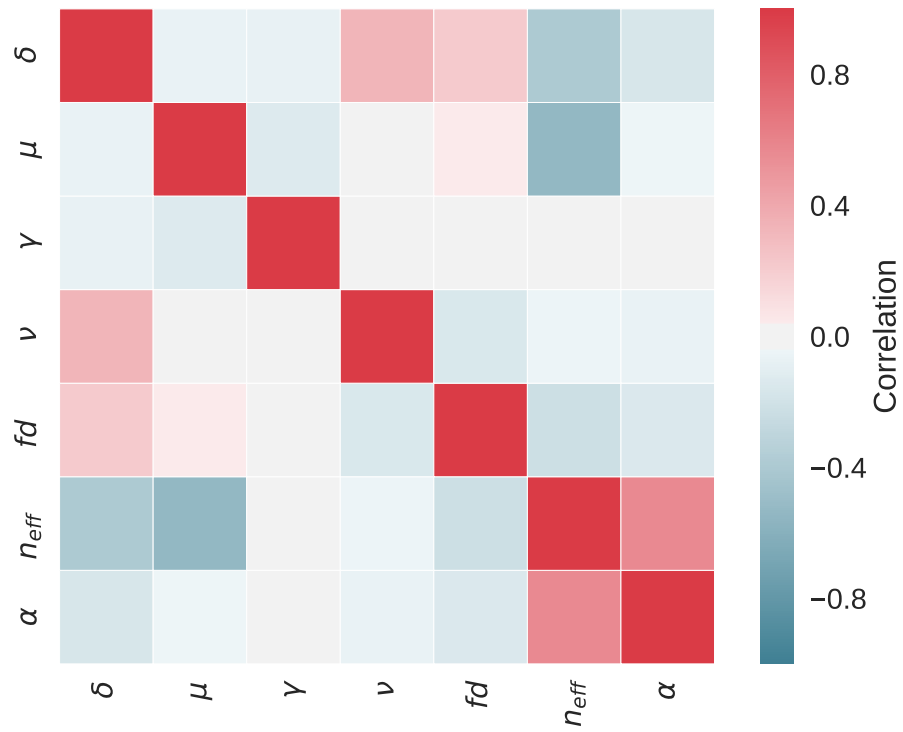


Figure S7. Posterior correlation matrix for Mead data assimilation experiment