Initializing carbon cycle predictions from CLM by assimilating biomass and LAI observations

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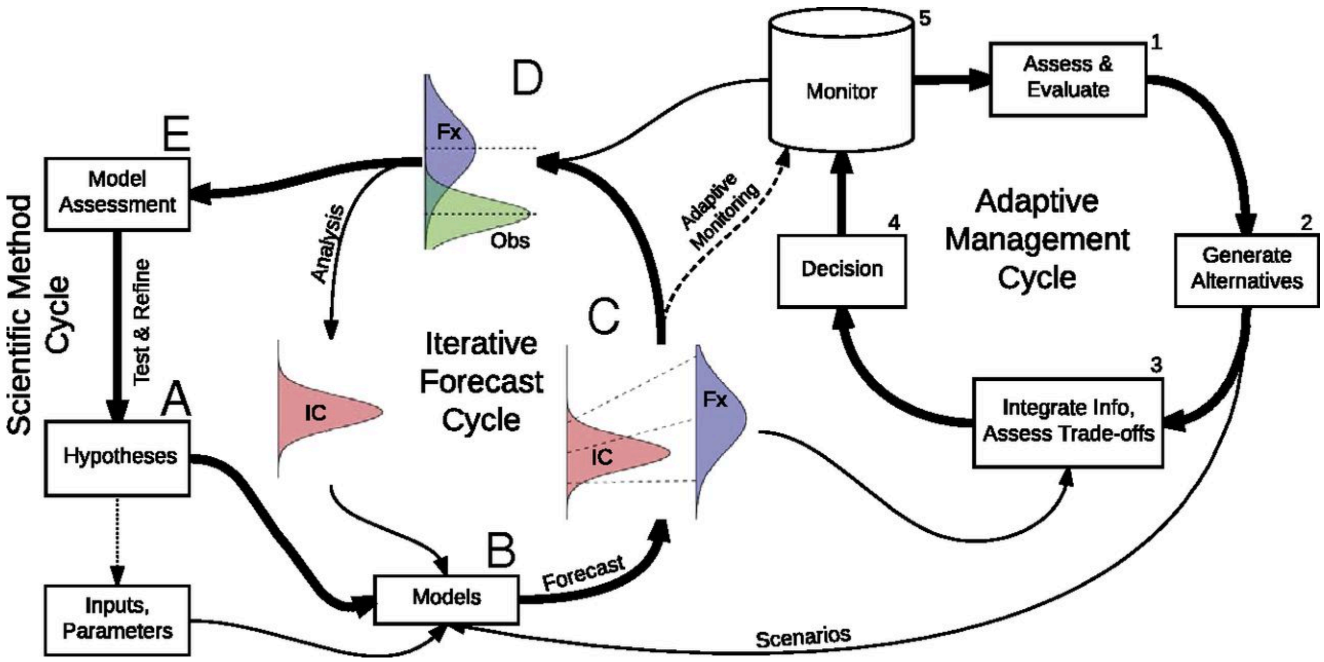
Why forecast the Carbon Cycle?

PNAS

Iterative near-term ecological forecasting: Needs, opportunities, and challenges

Michael C. Dietze[a,1], Andrew Fox[b], Lindsay M. Beck-Johnson[c], Julio L. Betancourt[d], Mevin B. Hooten[e,f,g], Catherine S. Jarnevich[h], Timothy H. Keitt[i], Melissa A. Kenney[j], Christine M. Laney[k], Laurel G. Larsen[l], Henry W. Loescher[k,m], Claire K. Lunch[k], Bryan C. Pijanowski[n], James T. Randerson[o], Emily K. Read[p], Andrew T. Tredennick[q,r], Rodrigo Vargas[s], Kathleen C. Weathers[t], and Ethan P. White[u,v,w]

PNAS 2018; published ahead of print January 30, 2018, https://doi.org/10.1073/pnas.1710231115



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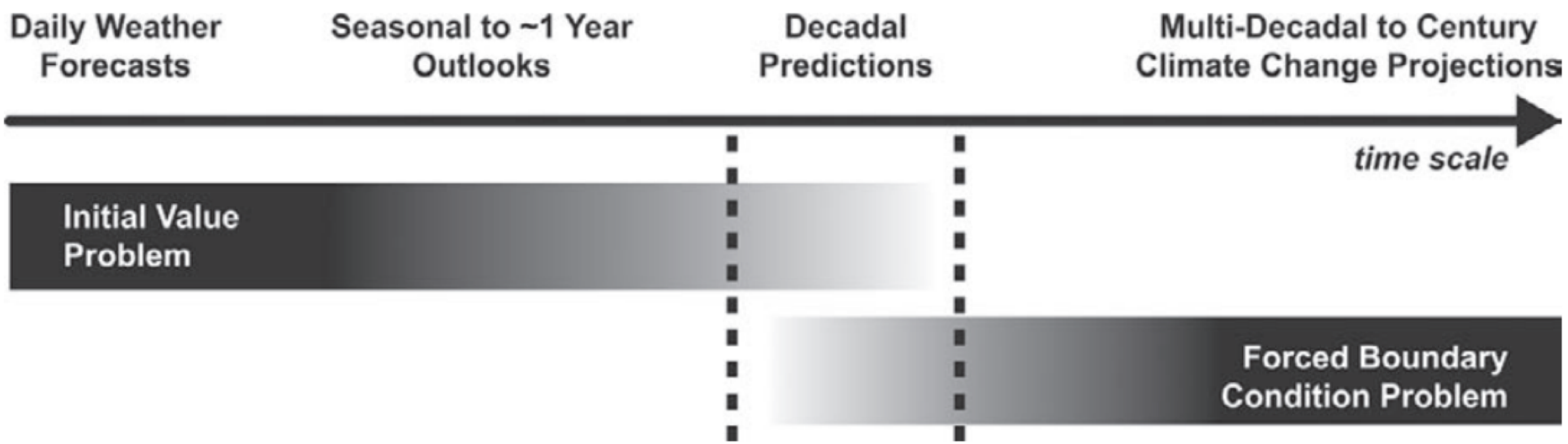
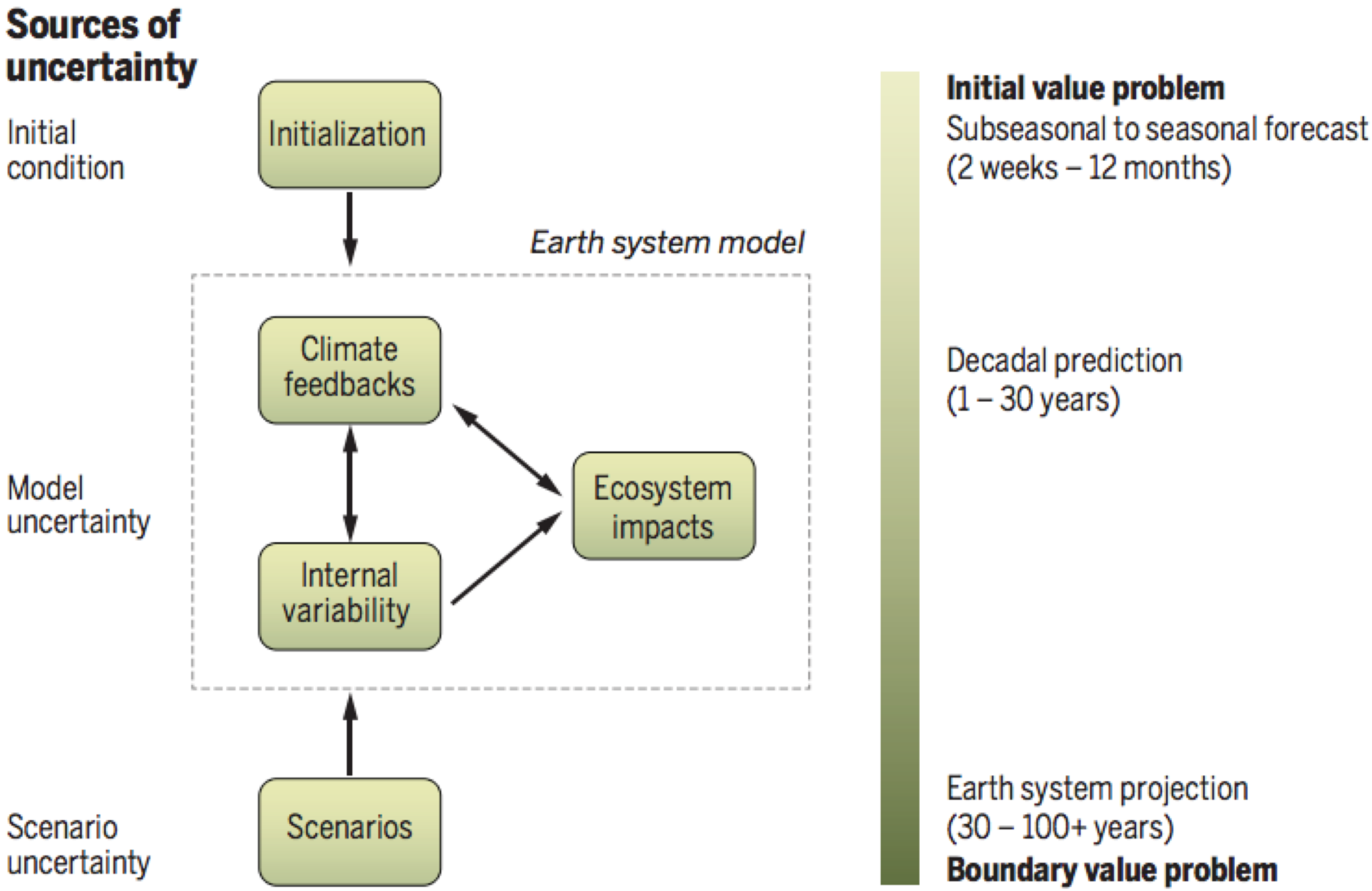
Dominant sources of uncertainty change



(Meehl et al., 2009)

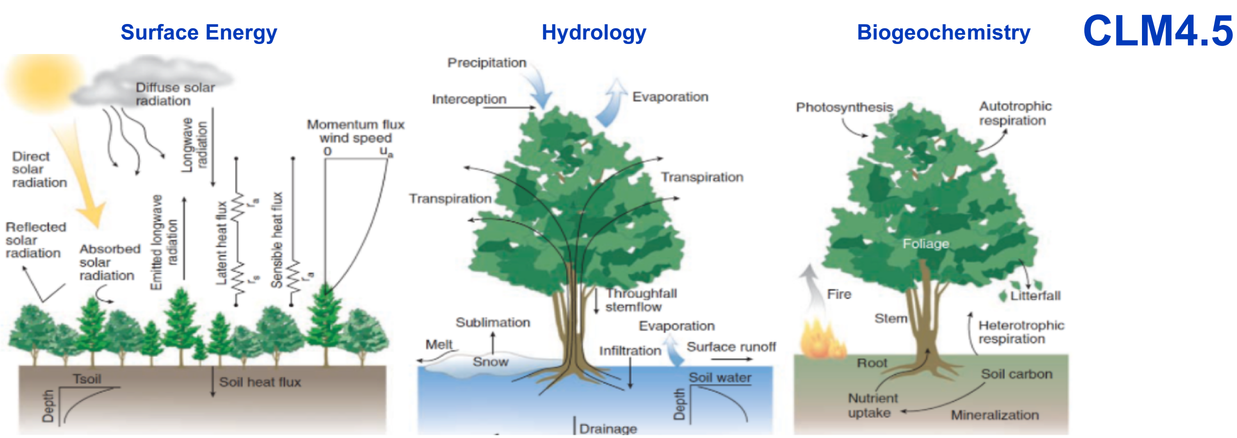
Dominant sources of uncertainty change



Bonan *et al.*, *Science* **359**, eaam8328 (2018) 2 February 2018

Community Land Model set up

- Multi-instance CLM4.5 BGC set up for a location in central New Mexico, USA
- PFT fractions of Bare, C4 grass, and Needleleaf Evergreen – Temperate
- Spun up by cycling 13 years of **ensemble** atmospheric reanalysis data



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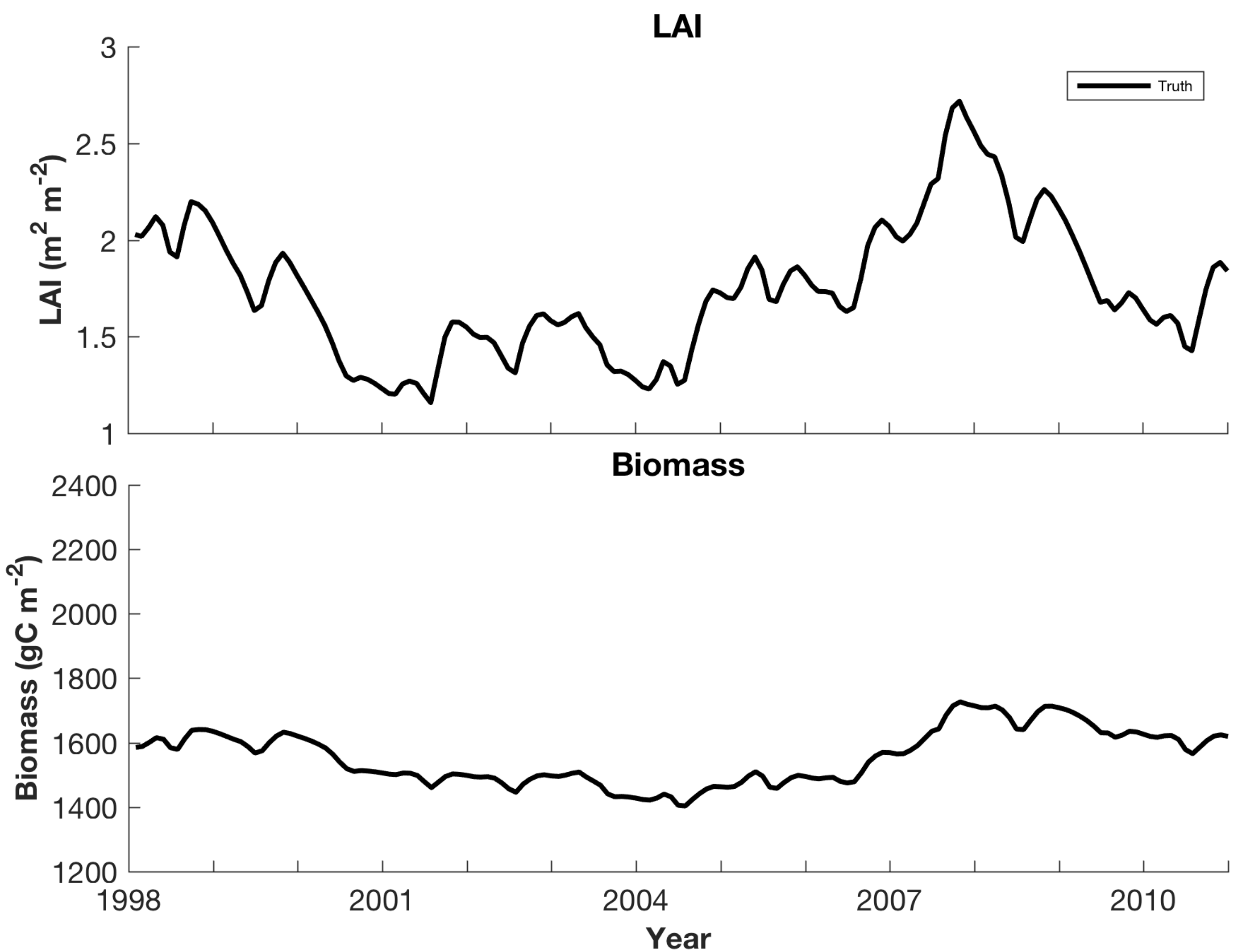
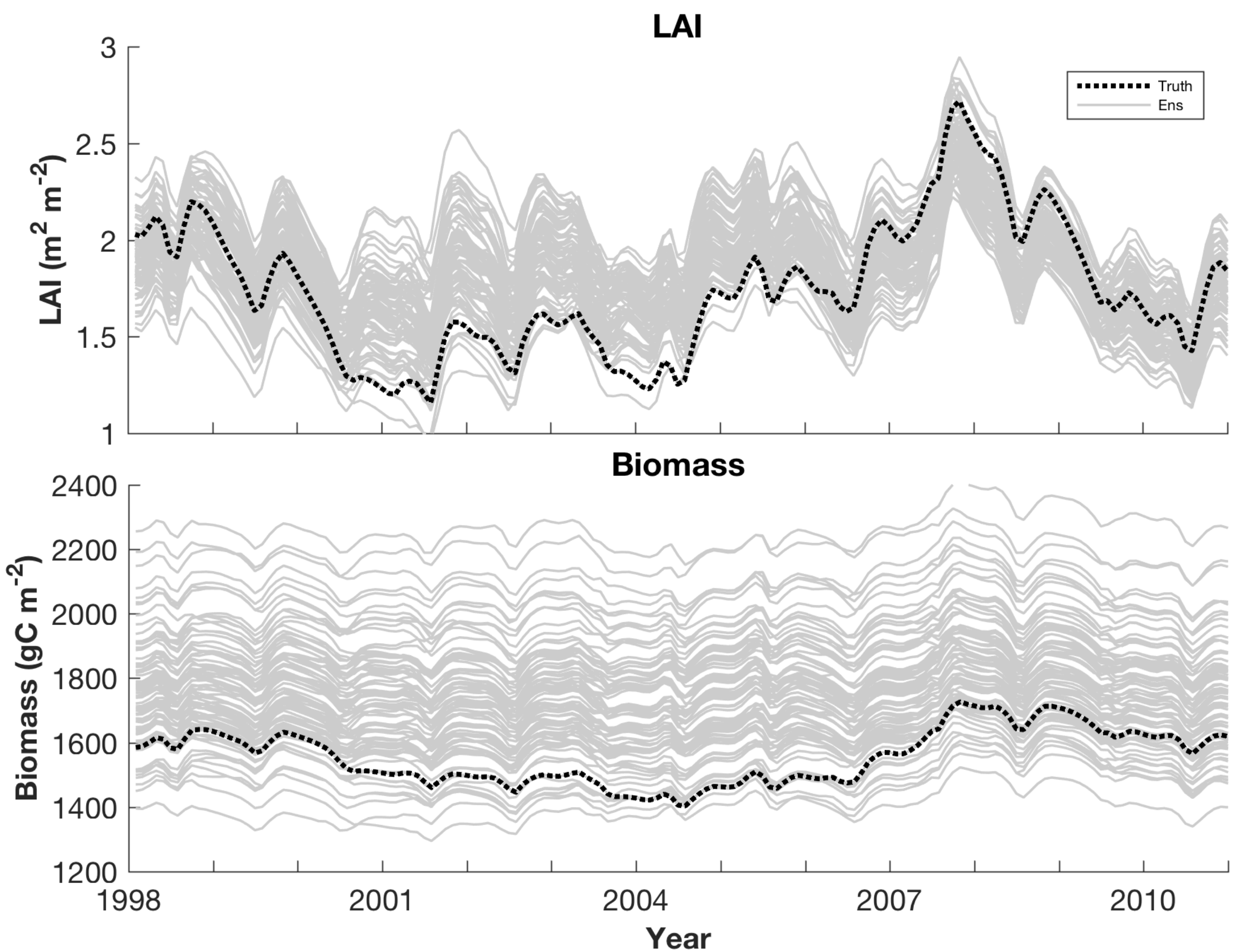
LAI and Biomass – single instance



LAI and Biomass – multi-instance



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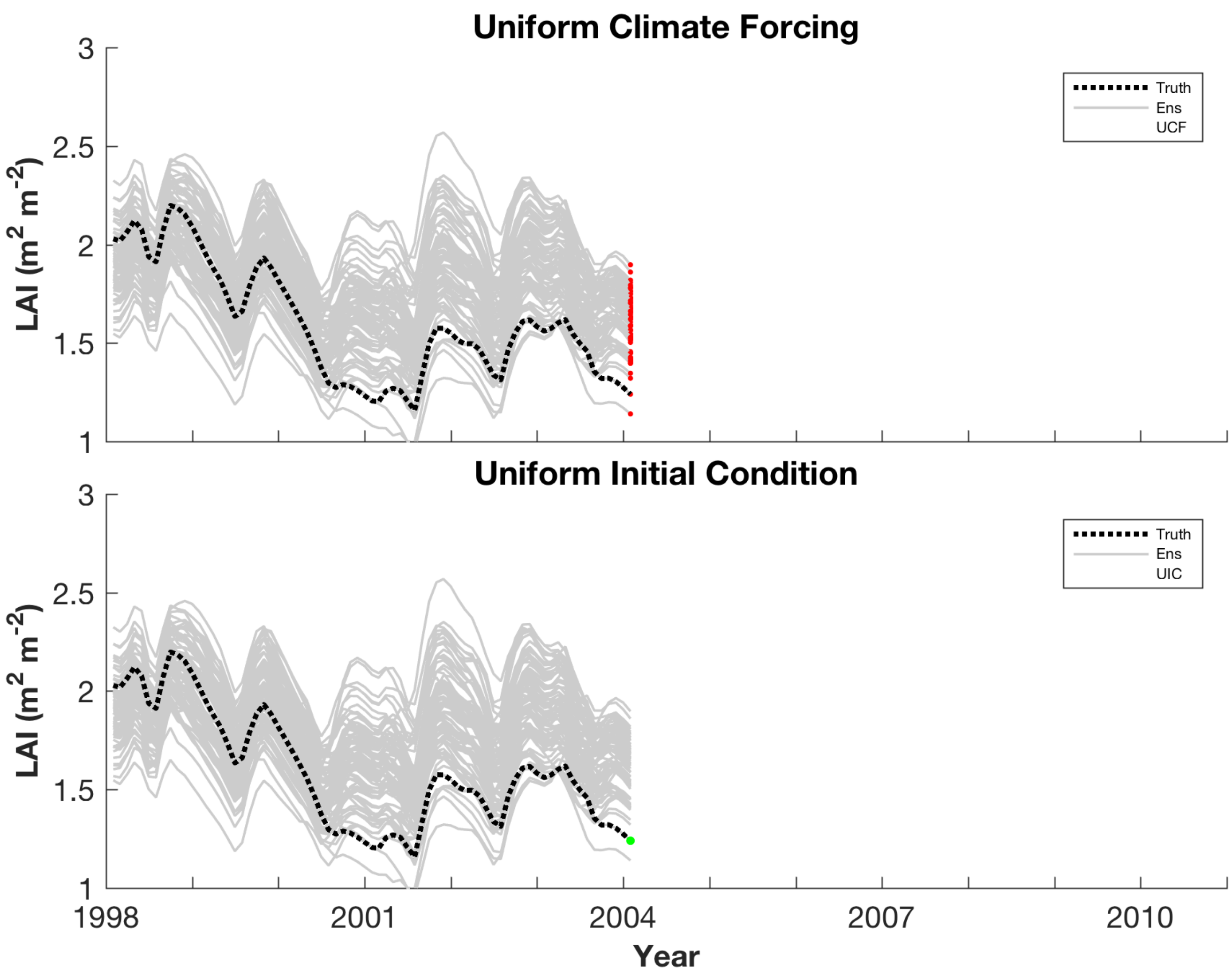
Uniform Climate Forcing v. Initial Conditions



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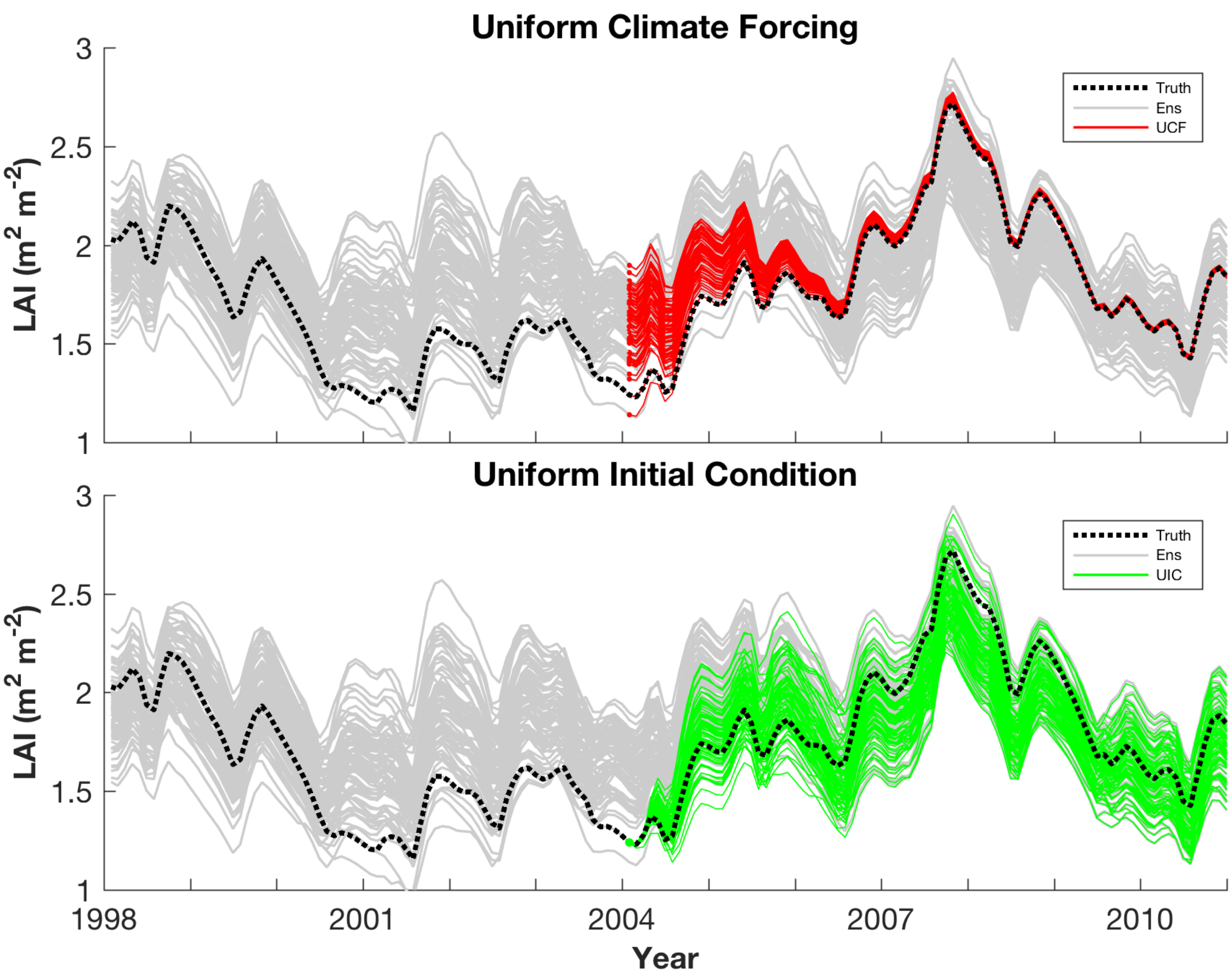
Uniform Climate Forcing v. Initial Conditions



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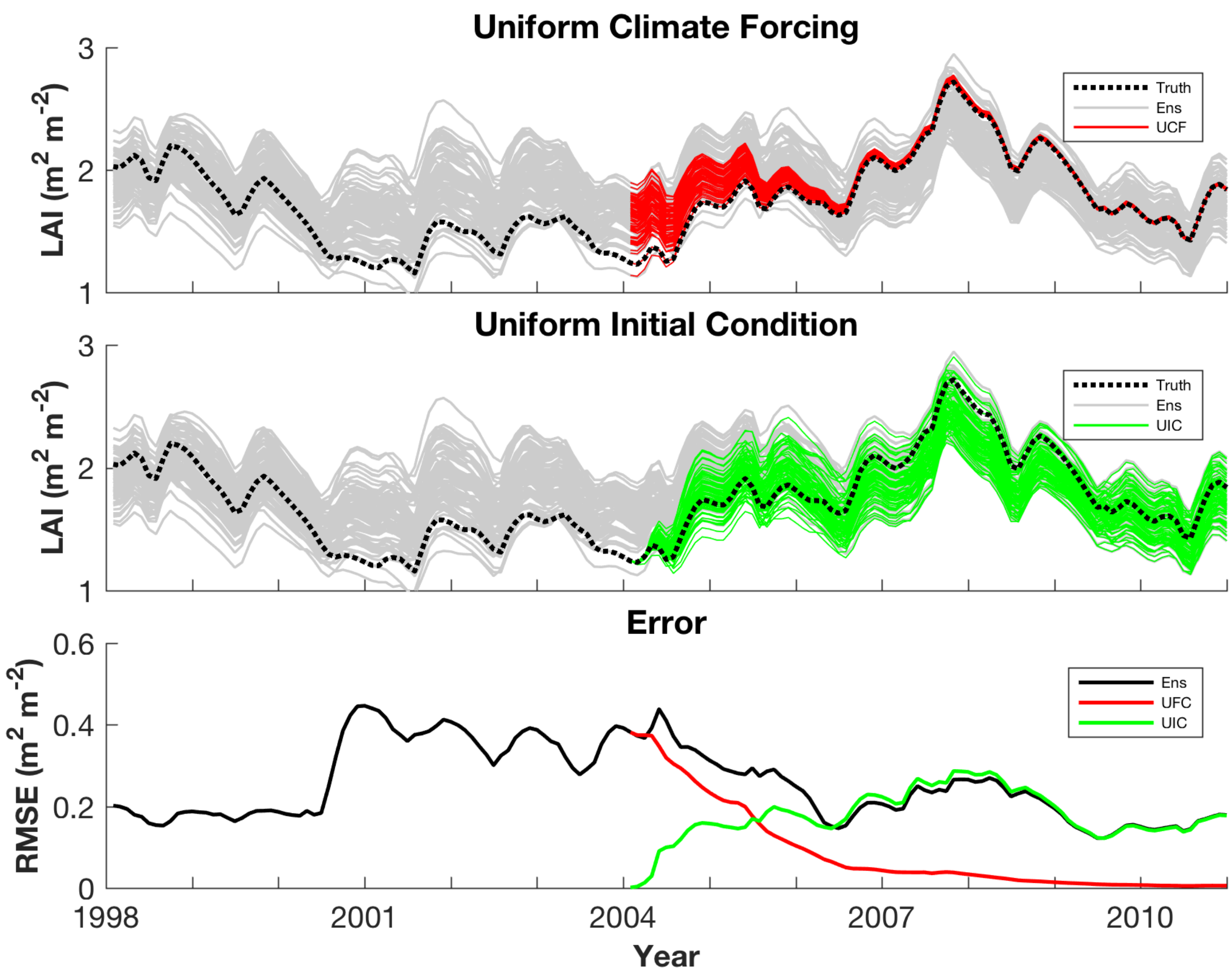
LAI – Error is reduced for 2.5 years



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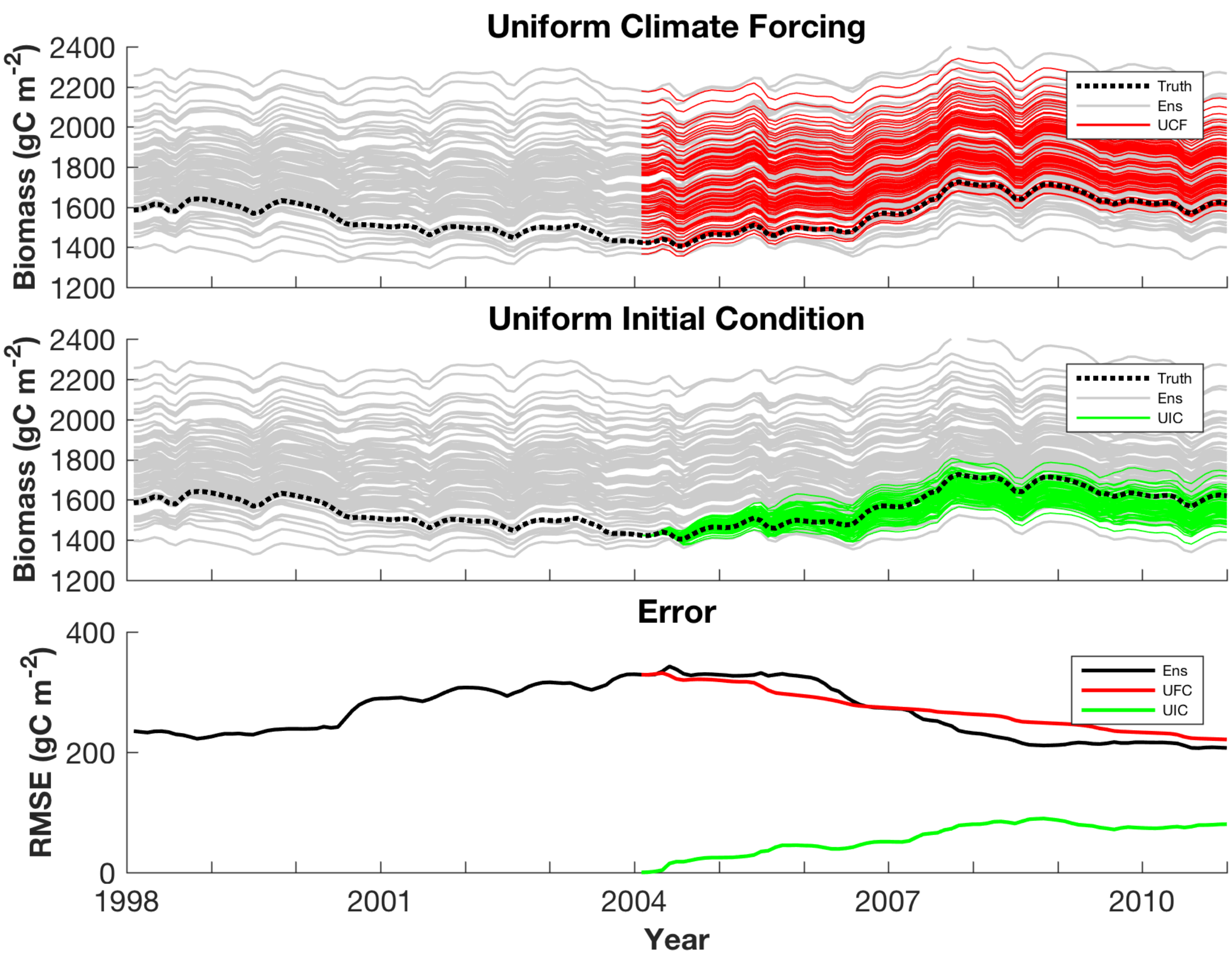
Biomass – Error is reduced for 7+ years



LAI and Biomass – observations

Monthly, 0.5° Aggregated MODIS LAI Observations

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, G01023, doi:10.1029/2006JG000168, 2007

Representing a new MODIS consistent land surface in the Community Land Model (CLM 3.0)

Peter J. Lawrence[1] and Thomas N. Chase[1]

Received 27 January 2006; revised 3 October 2006; accepted 14 November 2006; published 17 March 2007.

Annual, 0.25° Vegetation Optical Depth Biomass Observations

nature climate change

LETTERS

PUBLISHED ONLINE: 30 MARCH 2015 | DOI: 10.1038/NCLIMATE2581

Recent reversal in loss of global terrestrial biomass

Yi Y. Liu[1,2]*, Albert I. J. M. van Dijk[3,4], Richard A. M. de Jeu[5], Josep G. Canadell[6], Matthew F. McCabe[7], Jason P. Evans[1] and Guojie Wang[8]

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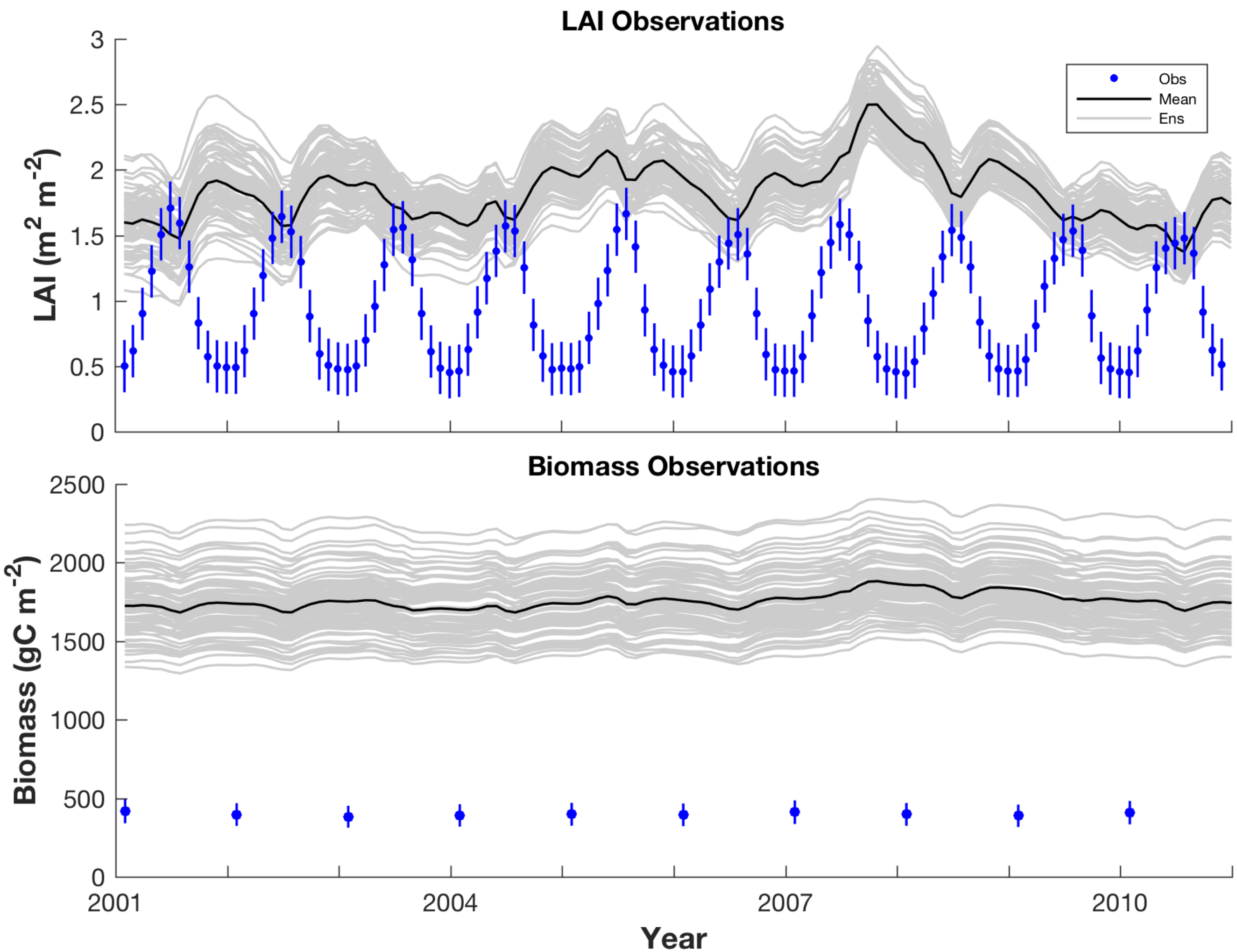
LAI and Biomass – observations



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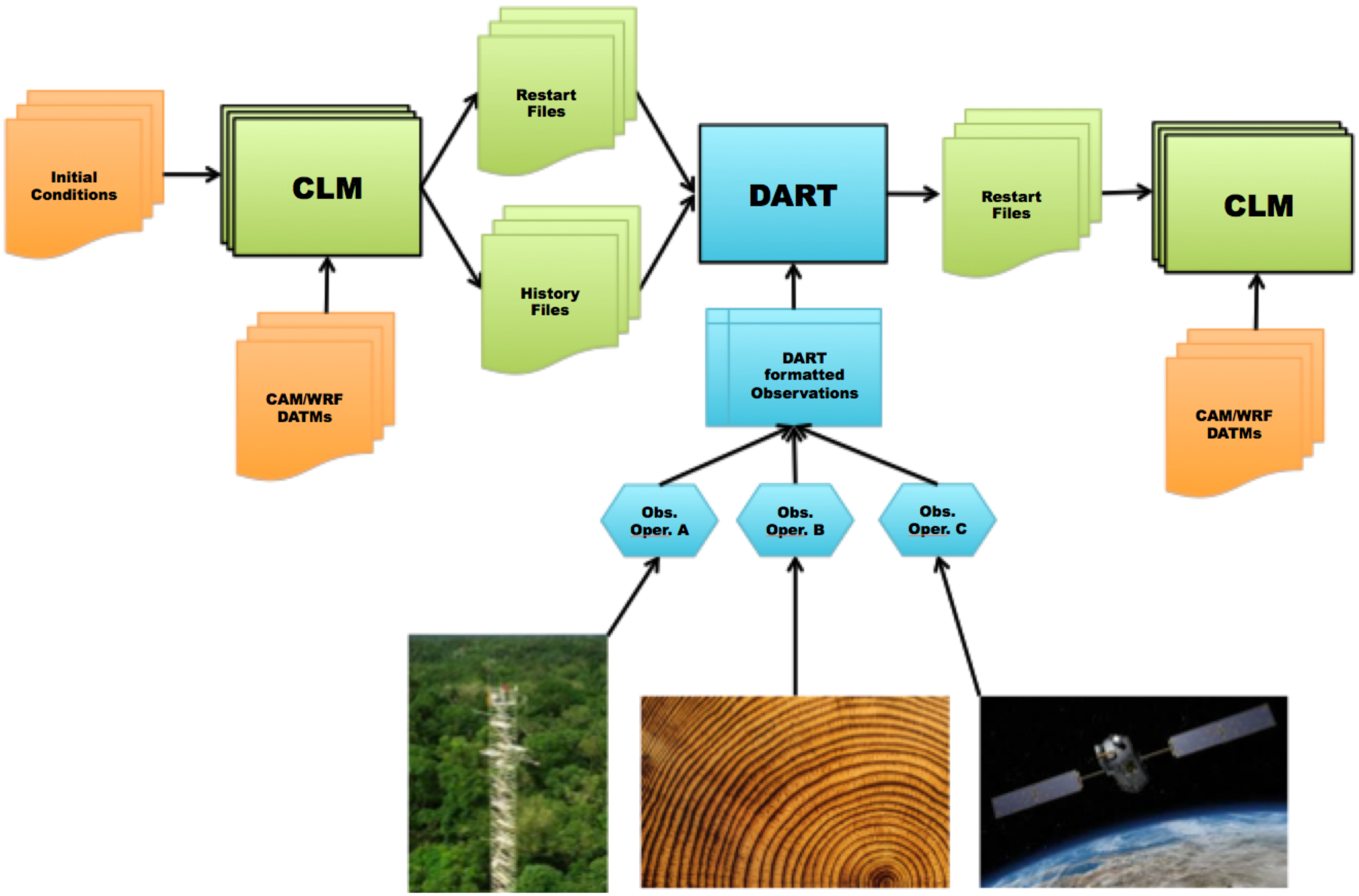
CLM-DART



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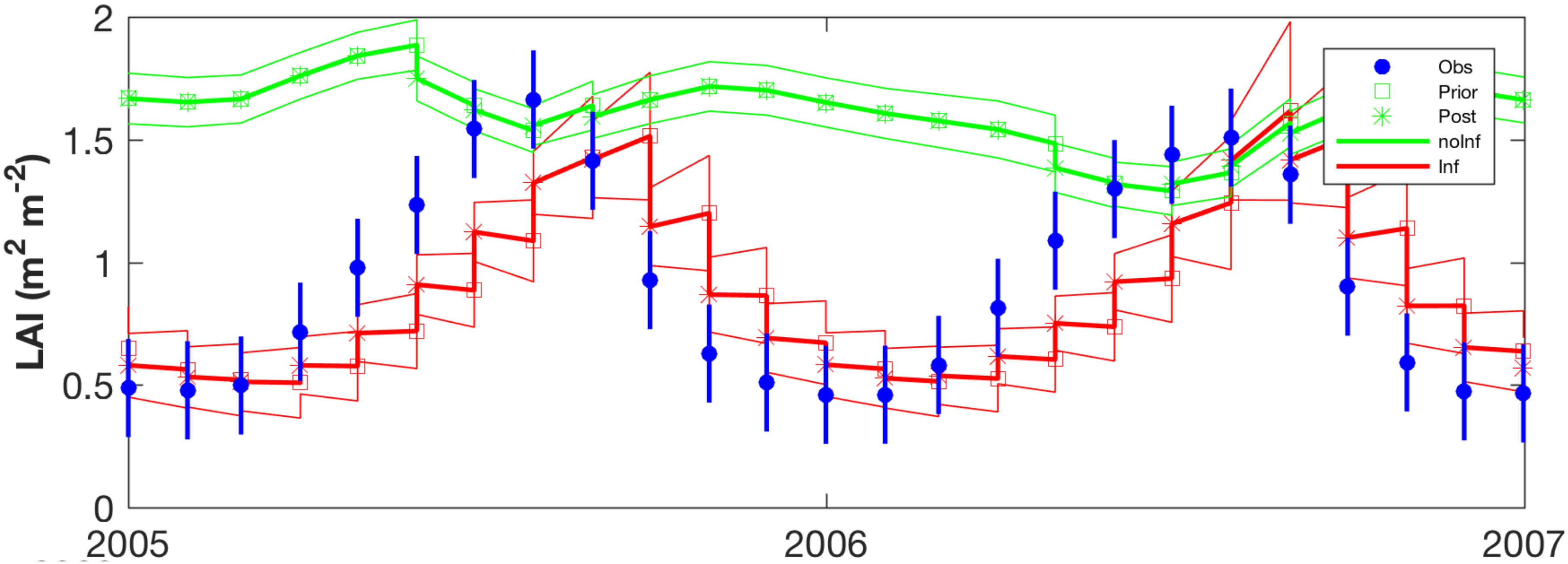
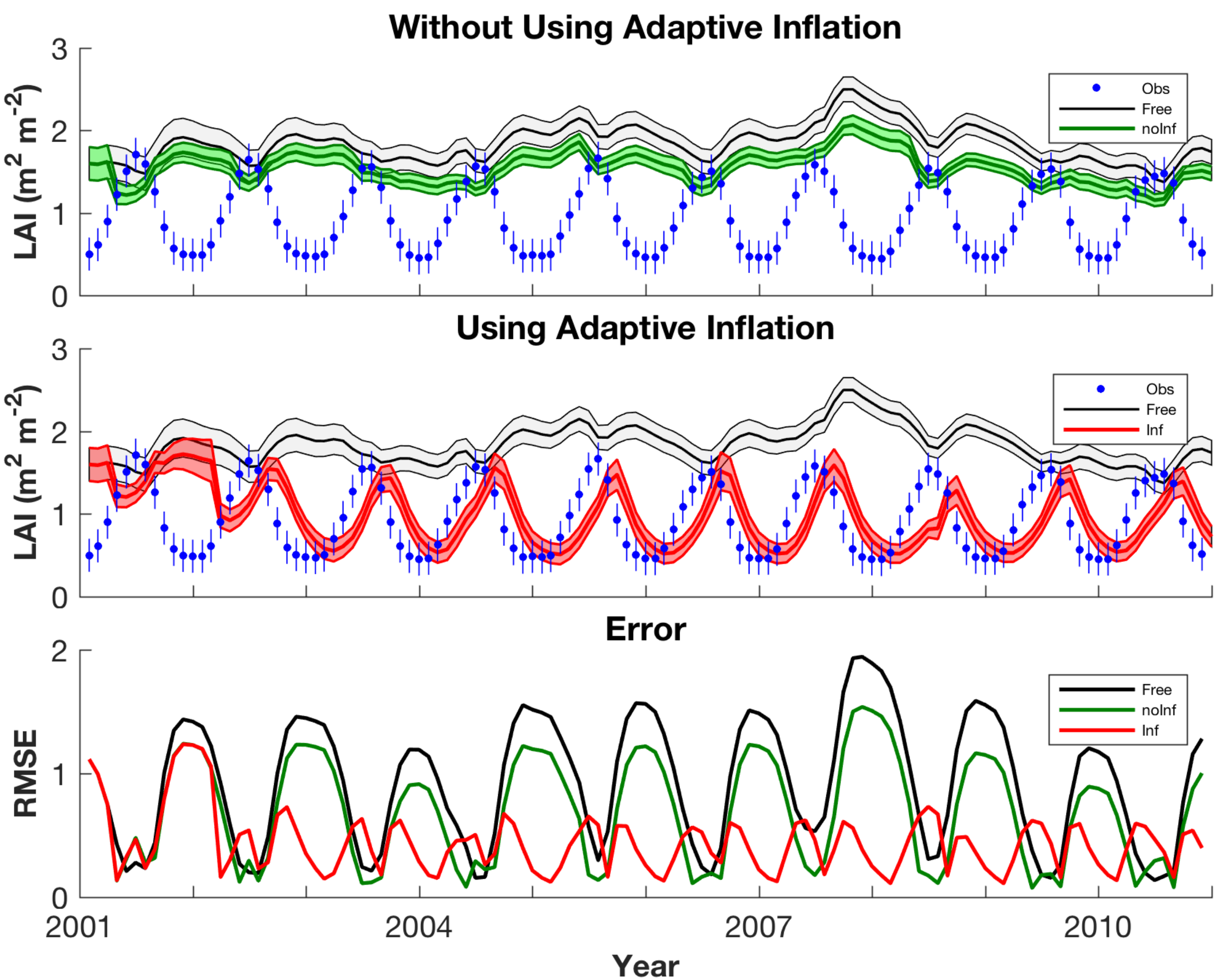
Ensemble forecast is updated by observations



Assimilating LAI requires adaptive inflation



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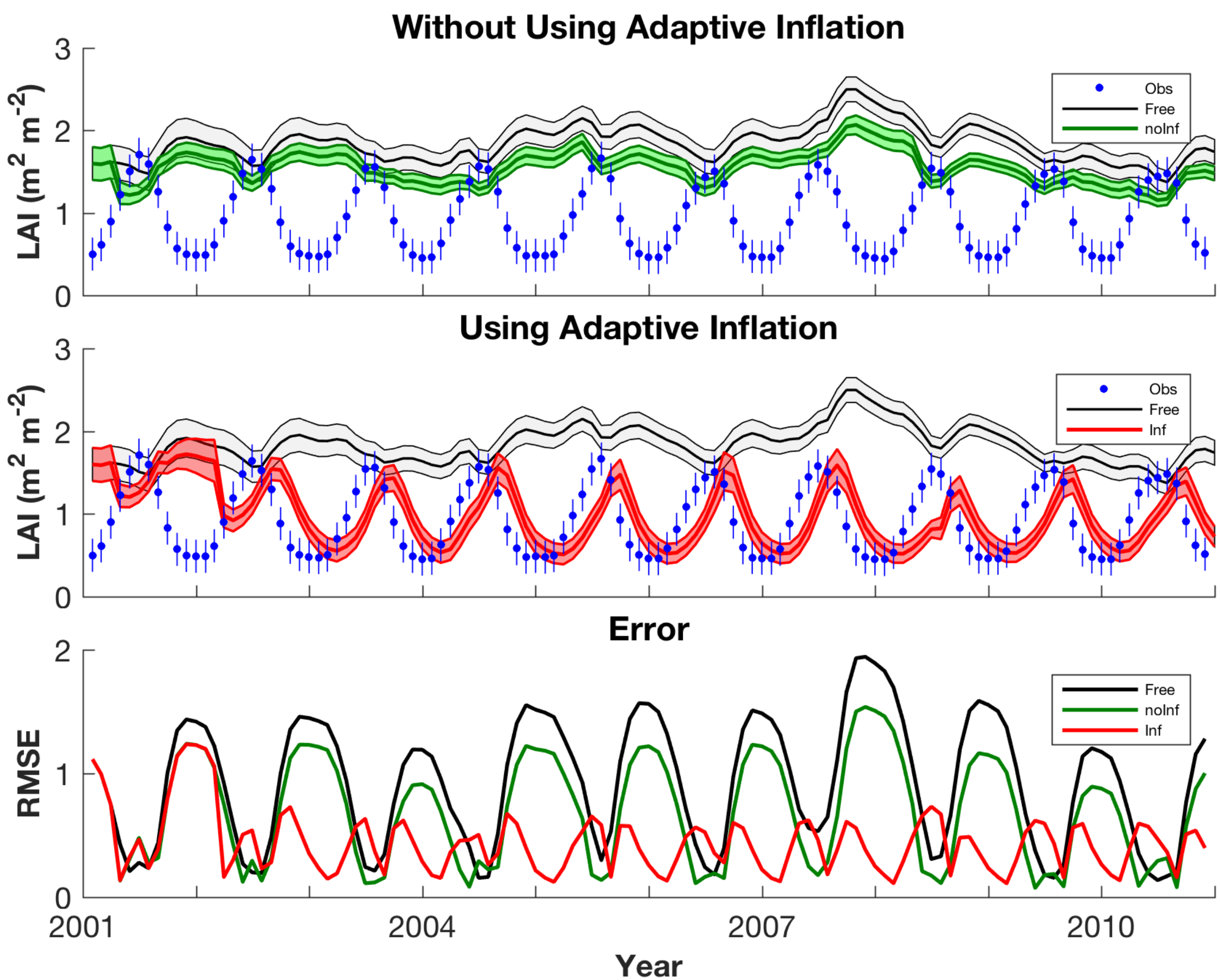
50% reduction in LAI RMSE with assimilation



RMSE
0.93
0.70
0.44

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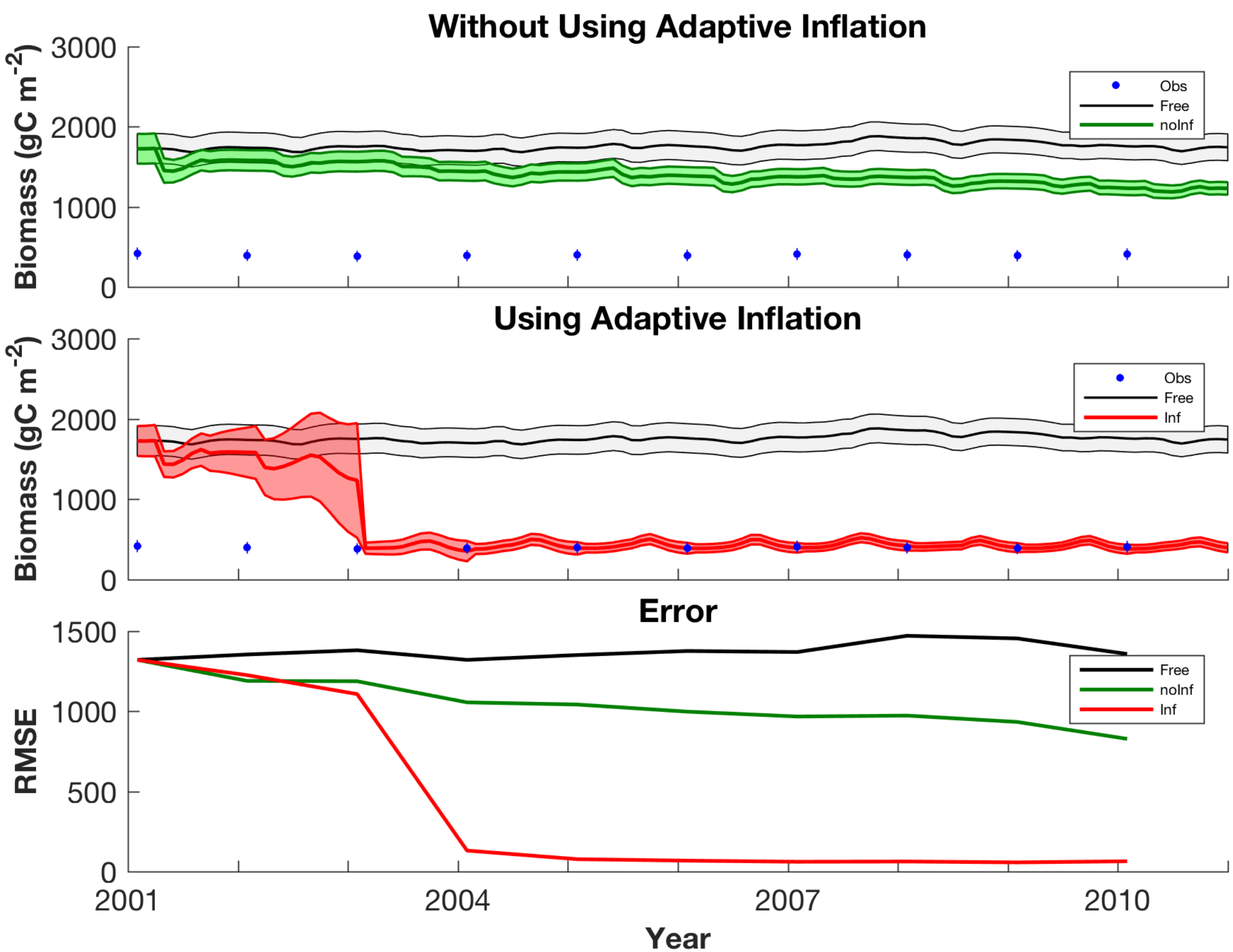
Assimilating Biomass using adaptive inflation



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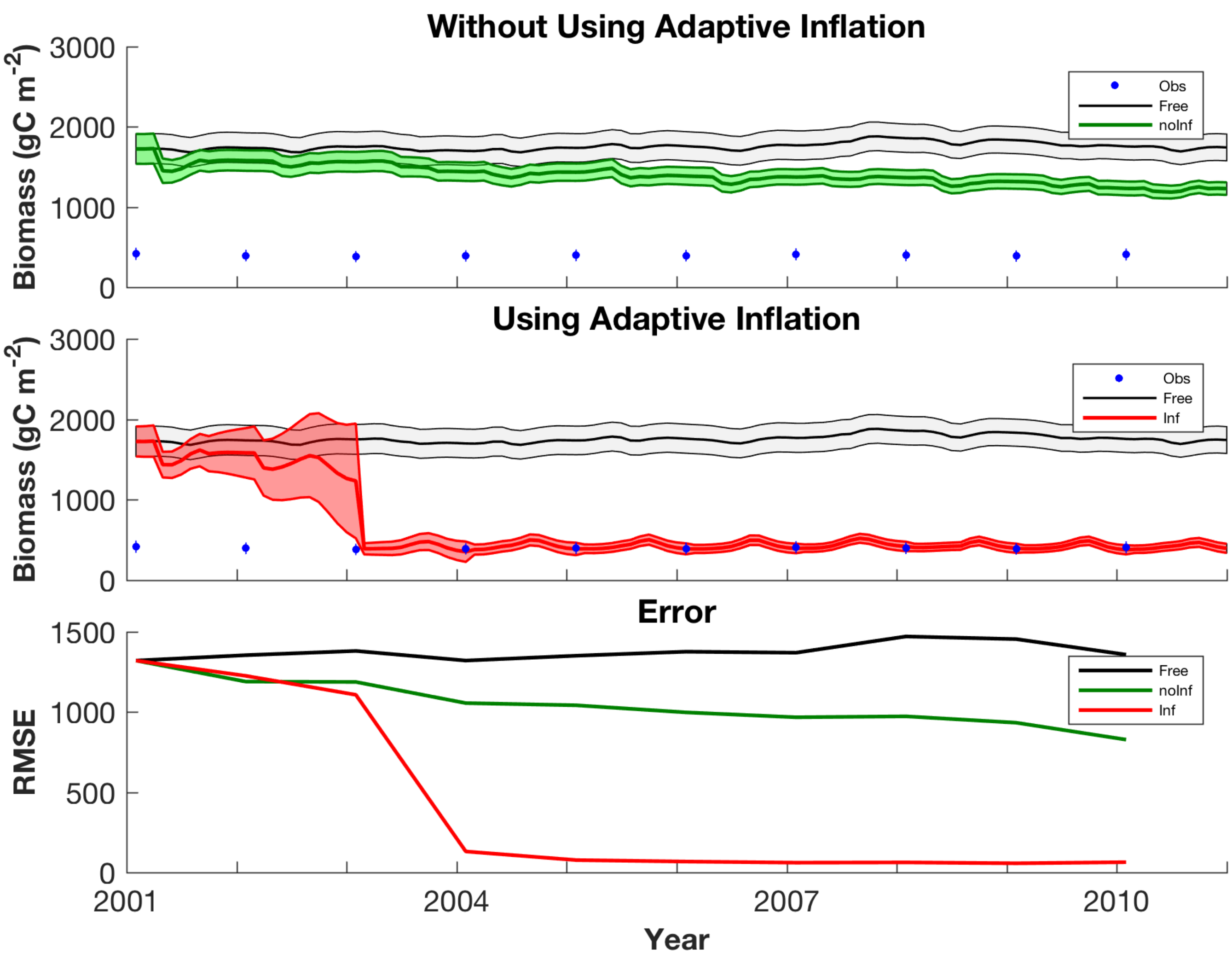
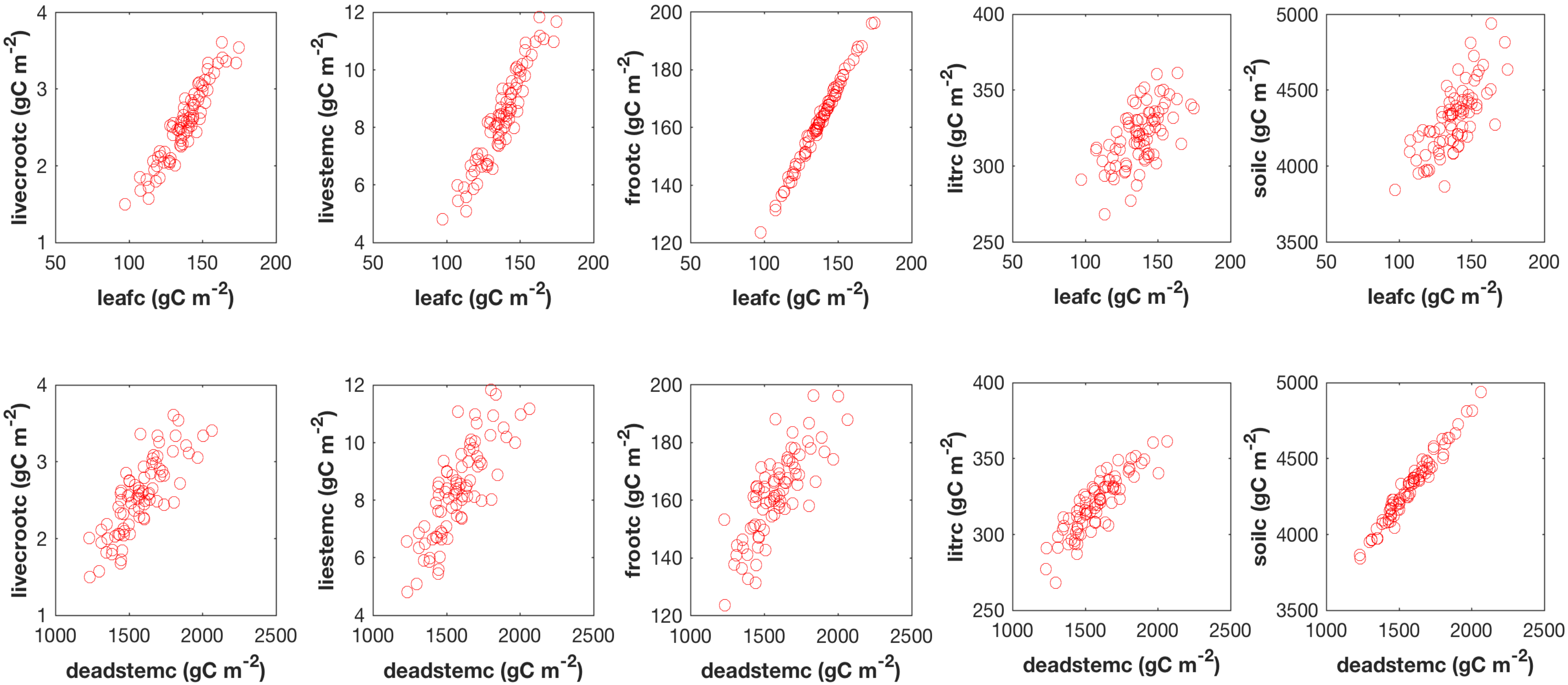
70% reduction in Biomass RMSE with assimilation

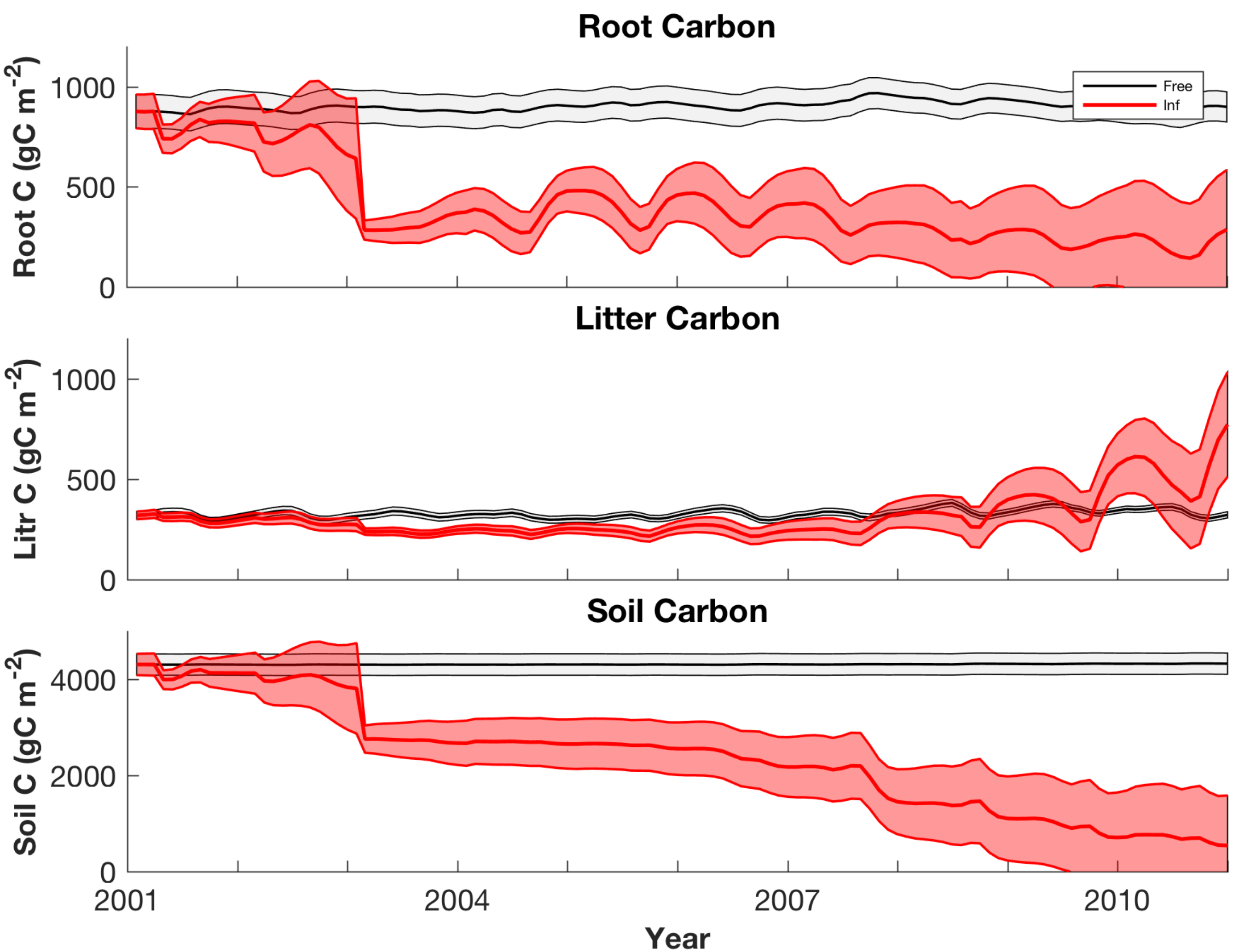


RMSE
1376
1049
417

Observed and unobserved states



Unobserved State variables are also updated



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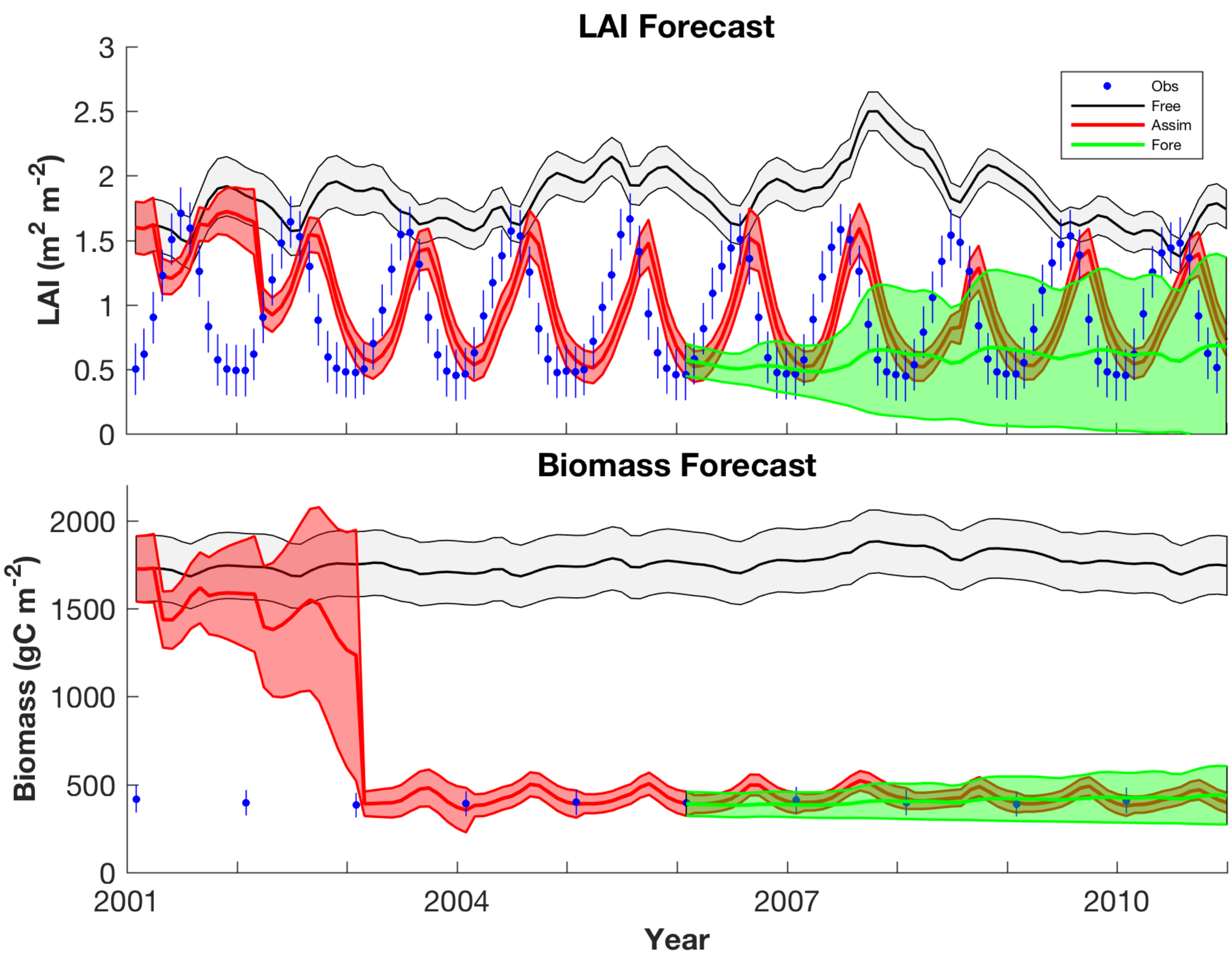
Longer-term forecasts are improved as well



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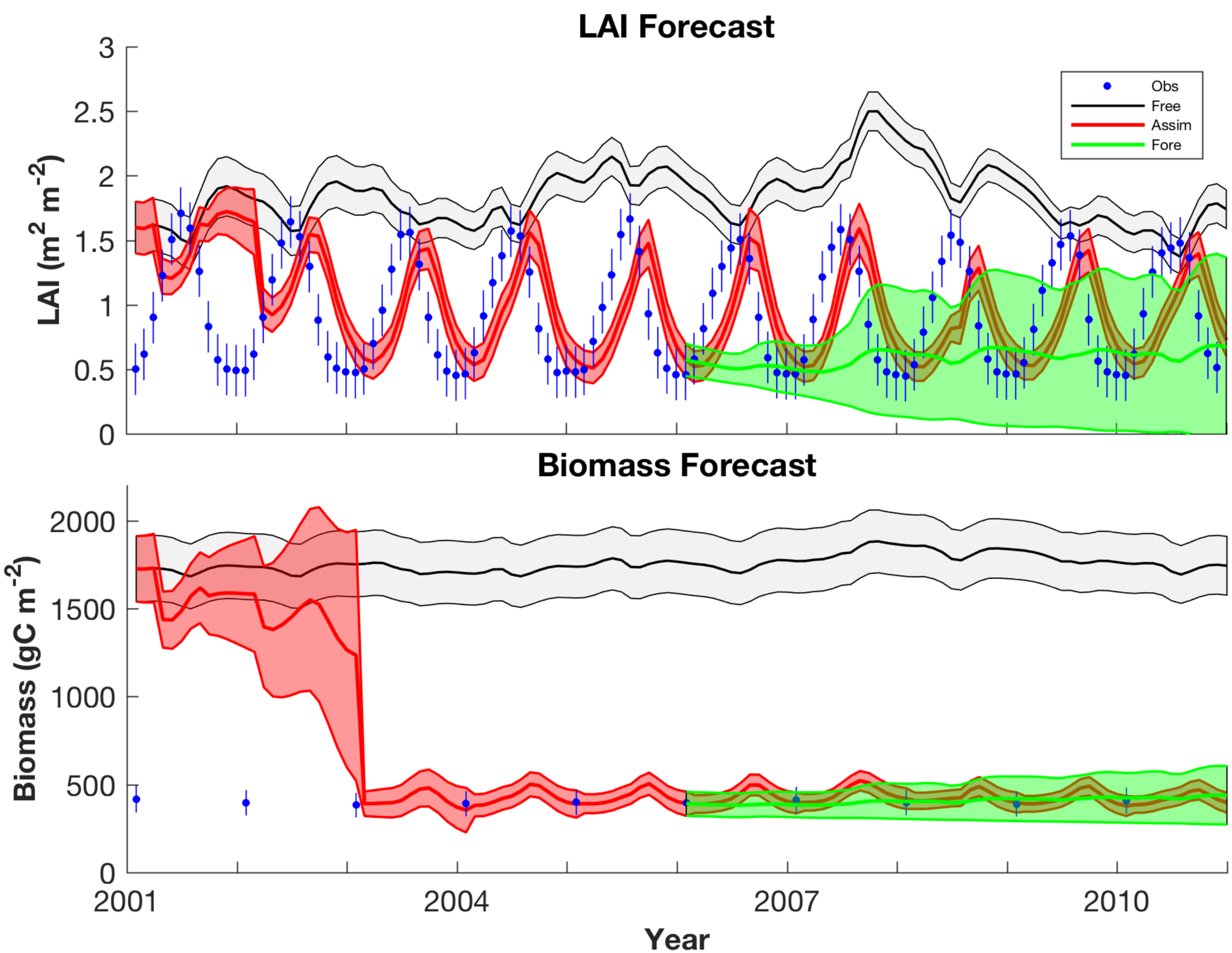
Longer-term forecasts are improved as well



RMSE
0.96
0.39
0.33

RMSE
1406
62
51

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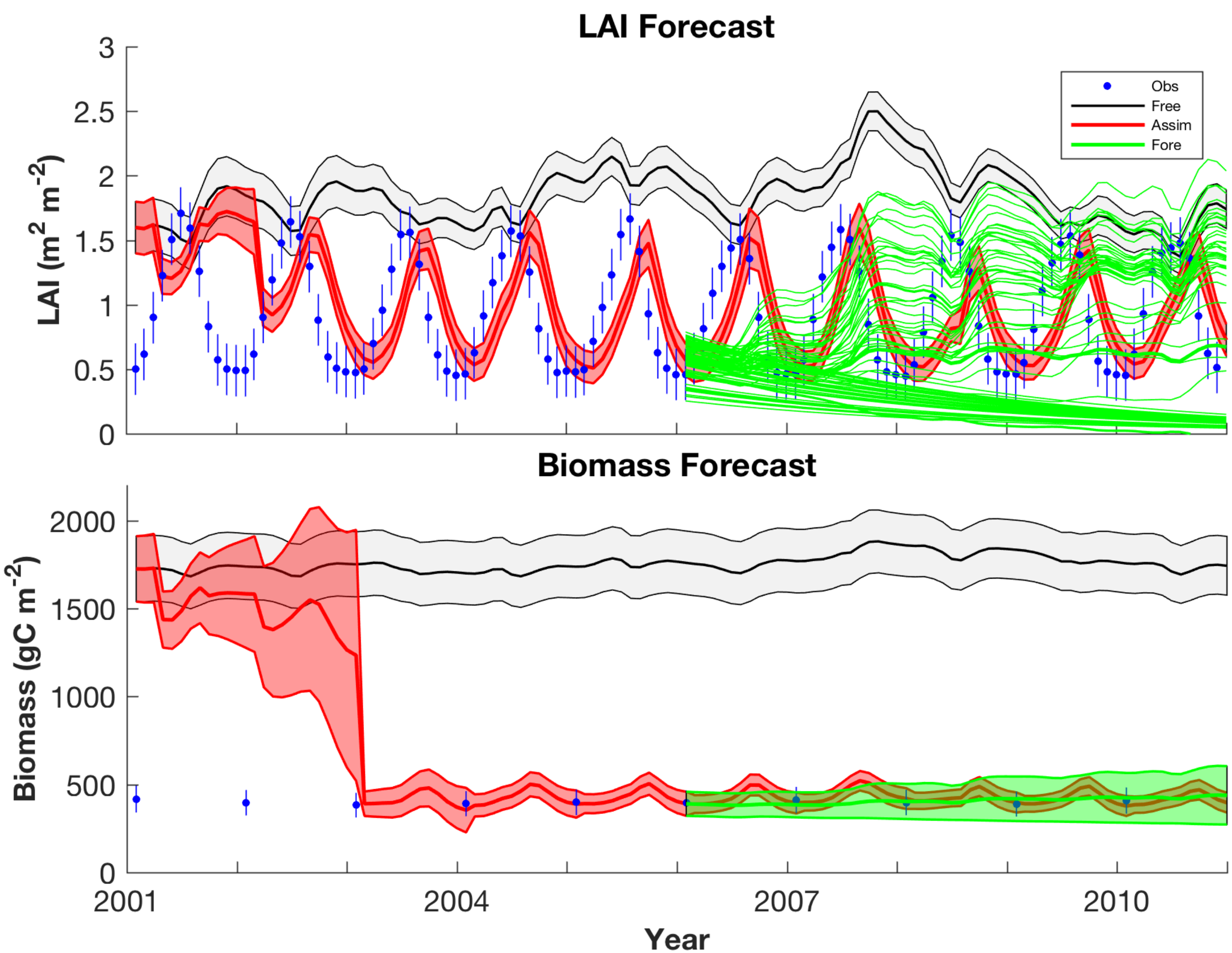
But interestingly the ensemble splits



RMSE
0.96
0.39
0.33

RMSE
1406
62
51

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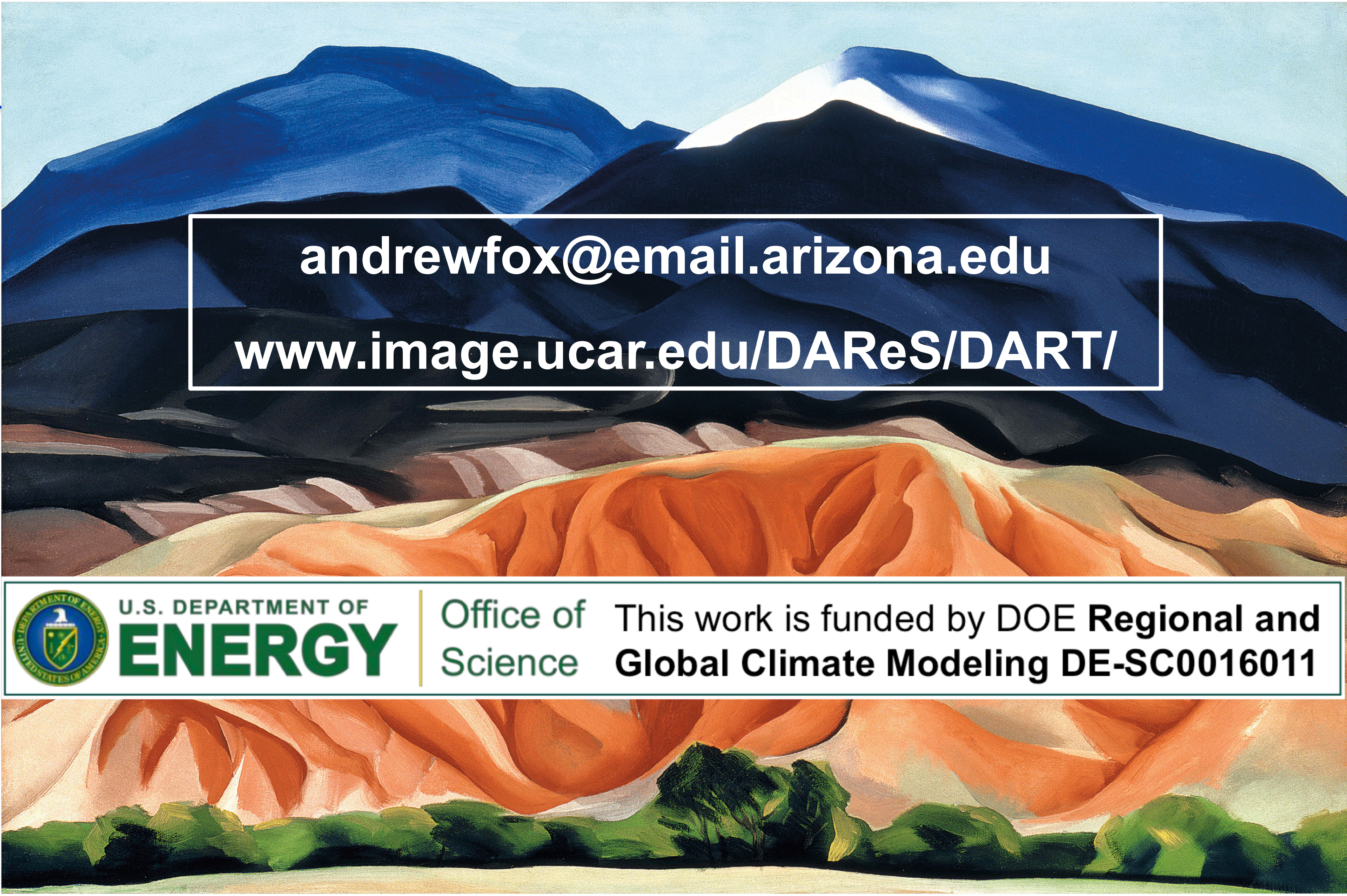
Key Points

1) Forecasts benefit from accurate initial conditions
2) Impact persists from years to decades for different C pools
3) Spun-up model had too high biomass, and inaccurate seasonal cycle in LAI
4) Large reductions in error during assimilation and forecast periods
5) Adaptive inflation is required to account for large model error



Georgia O’Keeffe – “Black Mesa Landscape”

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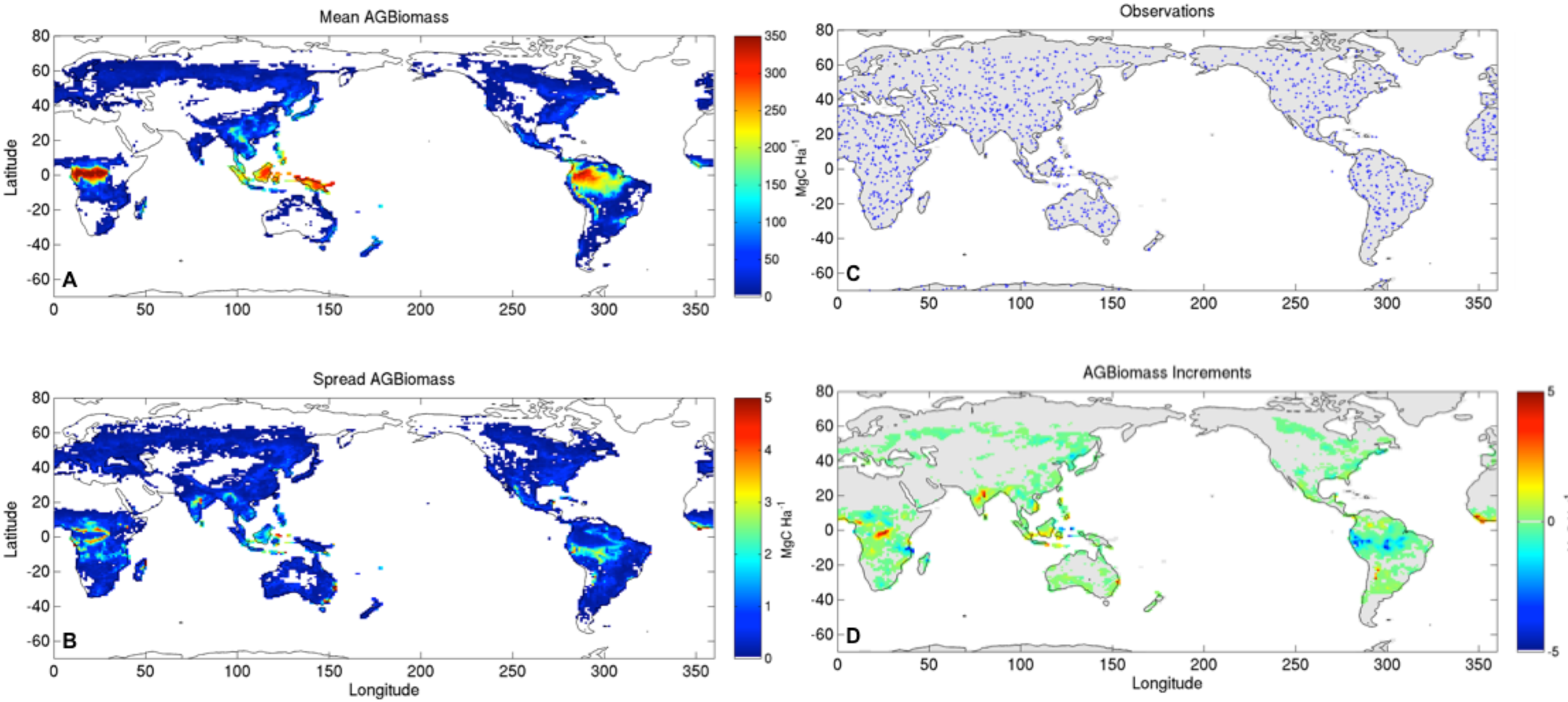
Global Biomass OSSE



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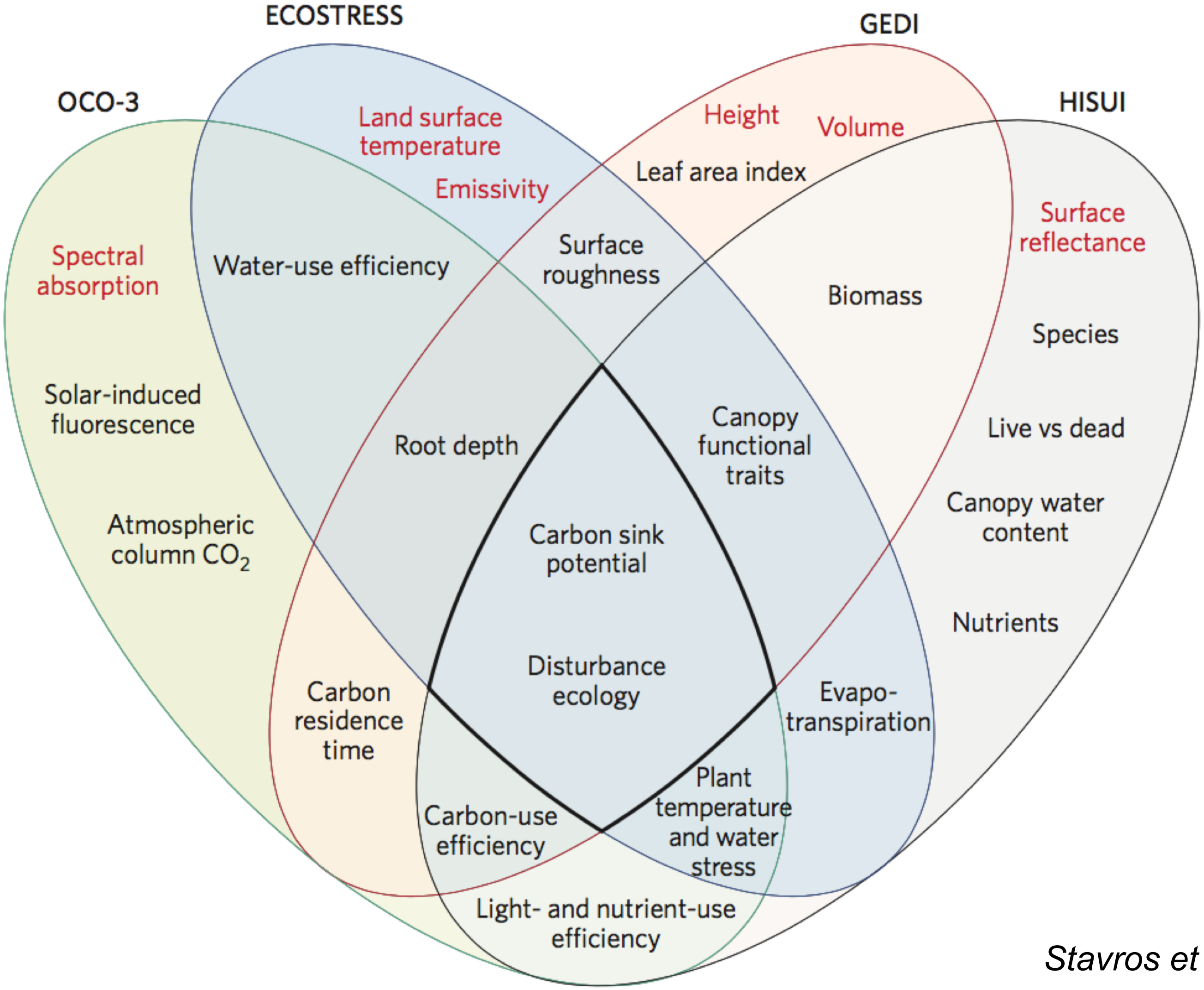
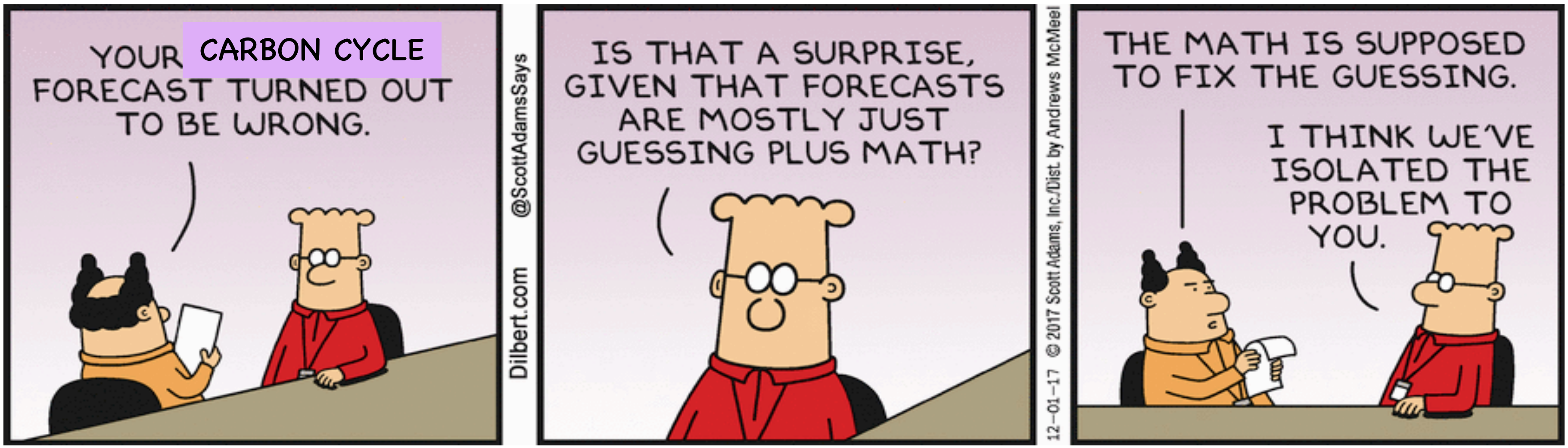
New observations from ISS



Stavros et al. 2017

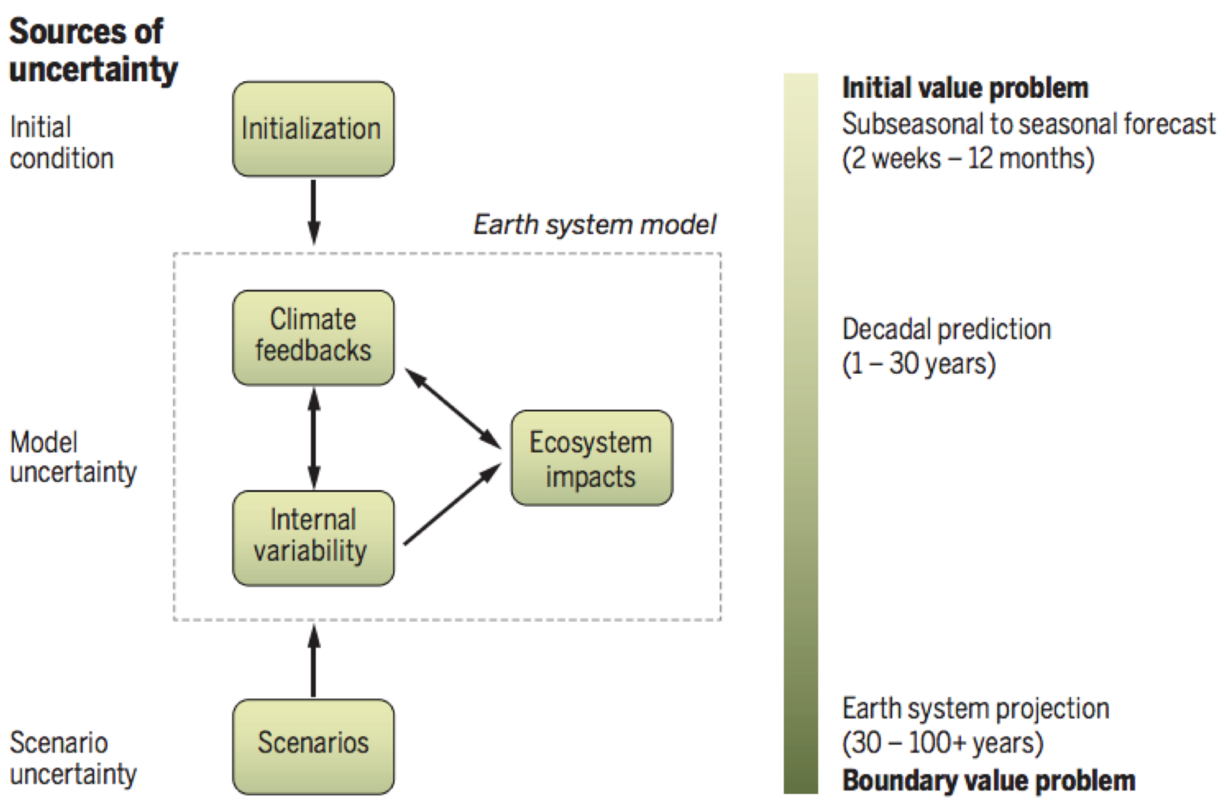
So, what about that model error?



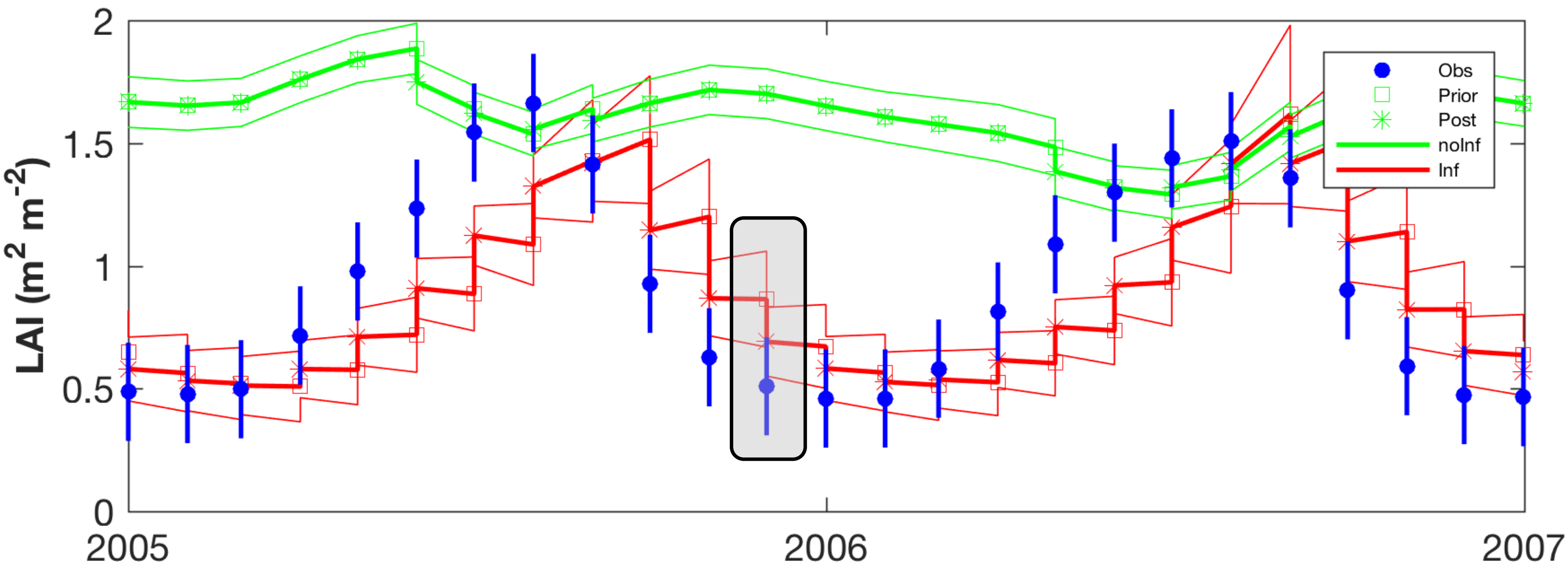
Sources of Uncertainty?

Climate, ecosystems, and planetary futures: The challenge to predict life in Earth system models

Bonan *et al.*, *Science* **359**, eaam8328 (2018)   2 February 2018



Ensemble forecast is updated by observations



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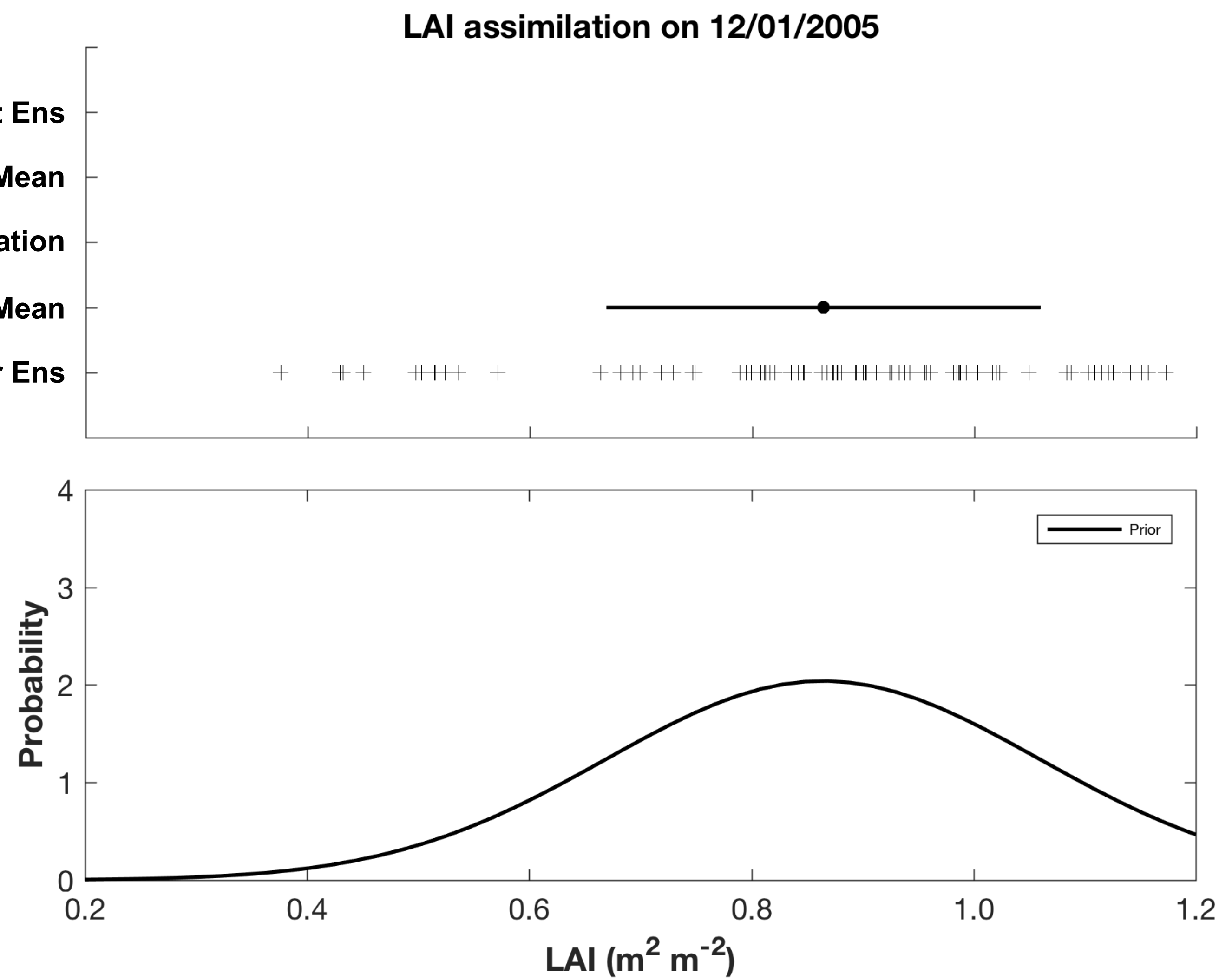
Normal is fitted to the prior/forecast ensemble…



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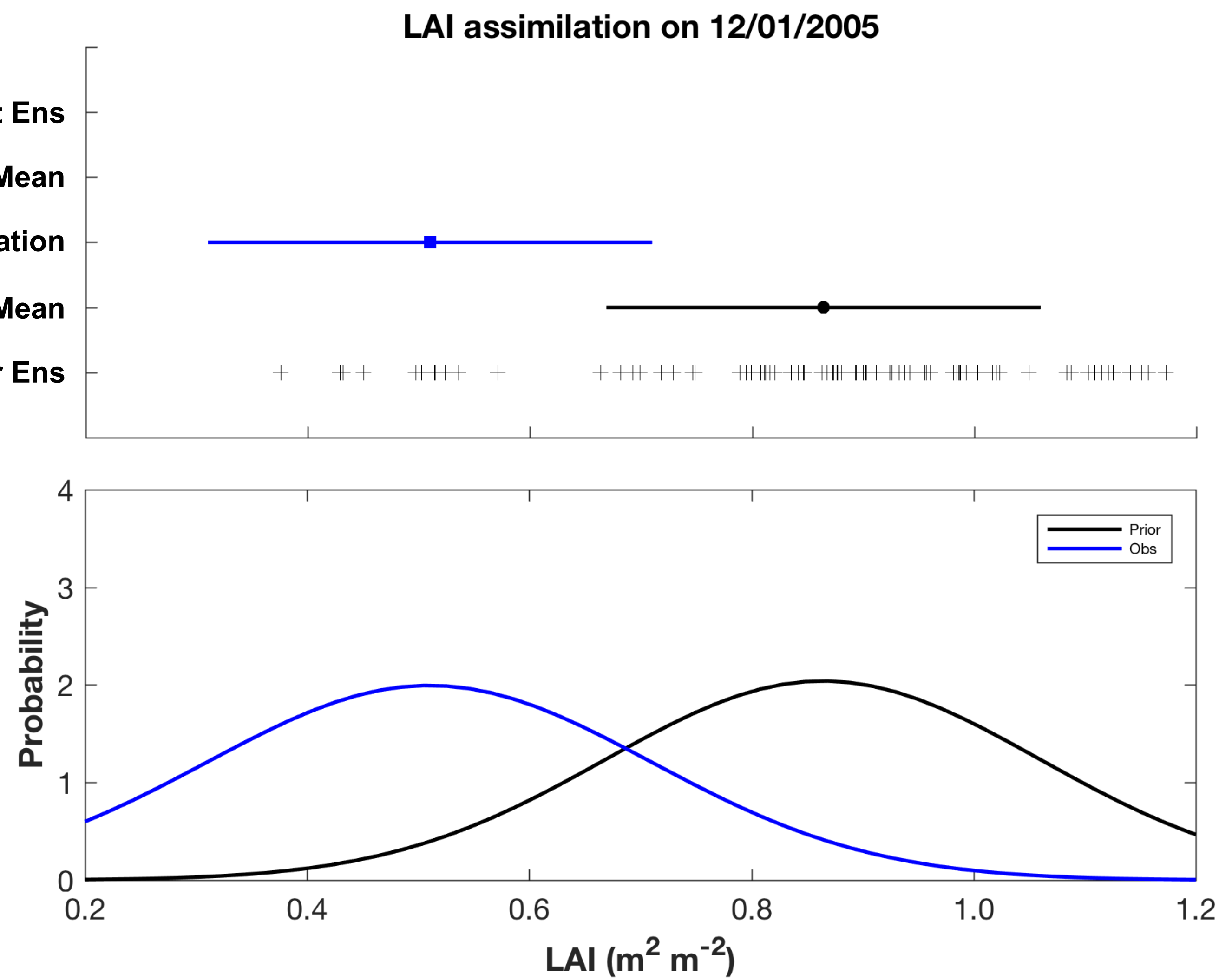
…we have an observation with an uncertainty…



...use EAKF to calculate posterior/analysis