The Community Land Model: version 5.

parameterization, senstivities, calibration with observational data

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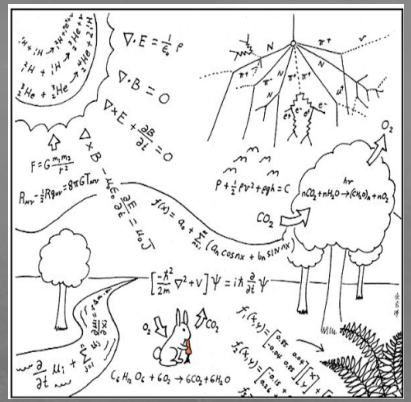


NCAR: Rosie Fisher, Dave Lawrence, Ben Sanderson,, Sean Swenson, Will Wieder, Gordon Bonan, Keith Oleson, Peter Lawrence, Danica Lombardozzi, Justin Perket, Ahmed Tawfik, Liz Burakowski, Yaqiong Lu.
Software: Erik Kluzek, Ben Andre, Bill Sacks, Mariana Vertenstein.
External: Charlie Koven, Bill Riley, Chonggang Xu, Daniel Kennedy, Pierre Gentine, Mingjie Shi, Josh Fisher, Andrew Slater, Andrew Fox, Quinn Thomas, Hongyi Li, Ashehad Ali, Kyla Dahlin, Mathew Williams, Marysa Laguë, Jingyung Tang, Bardan Ghmire, Zack Subin.

The new model is imperfect!

Model GPP – Fluxnet MTE GPP

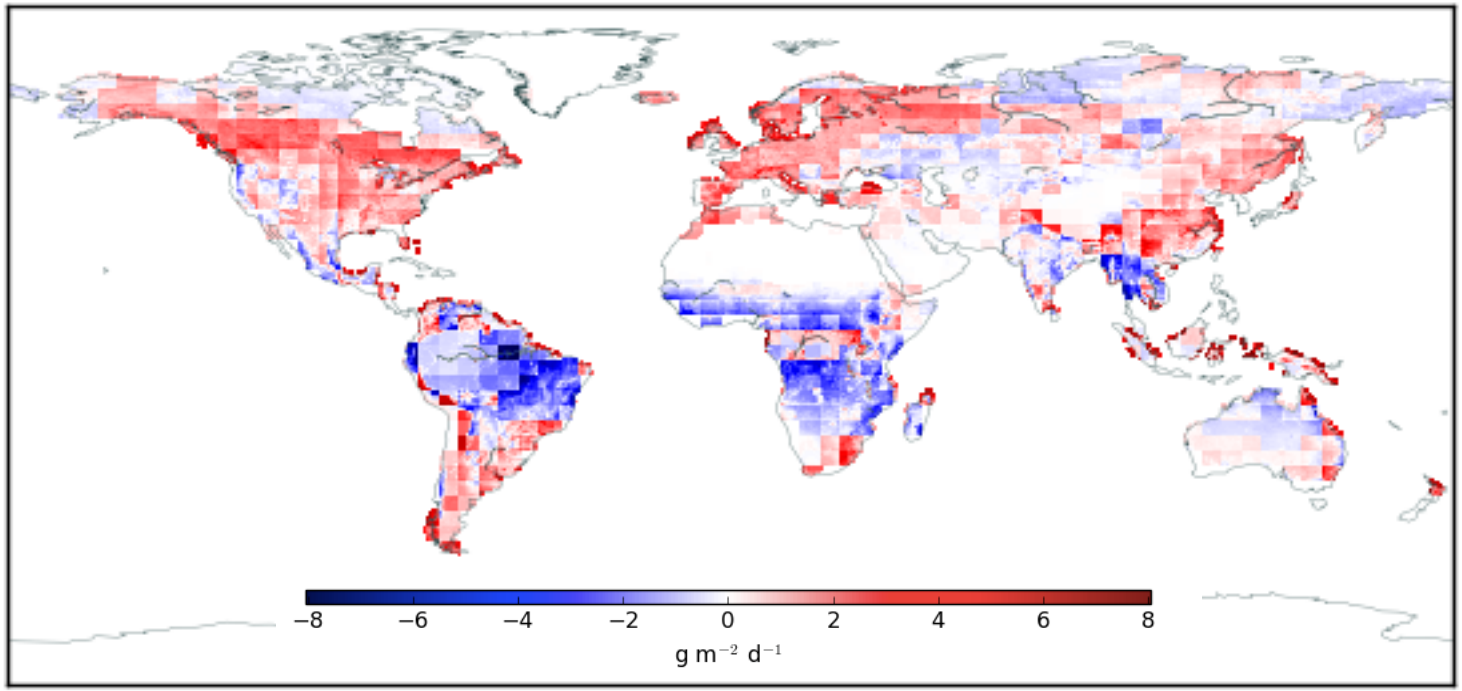
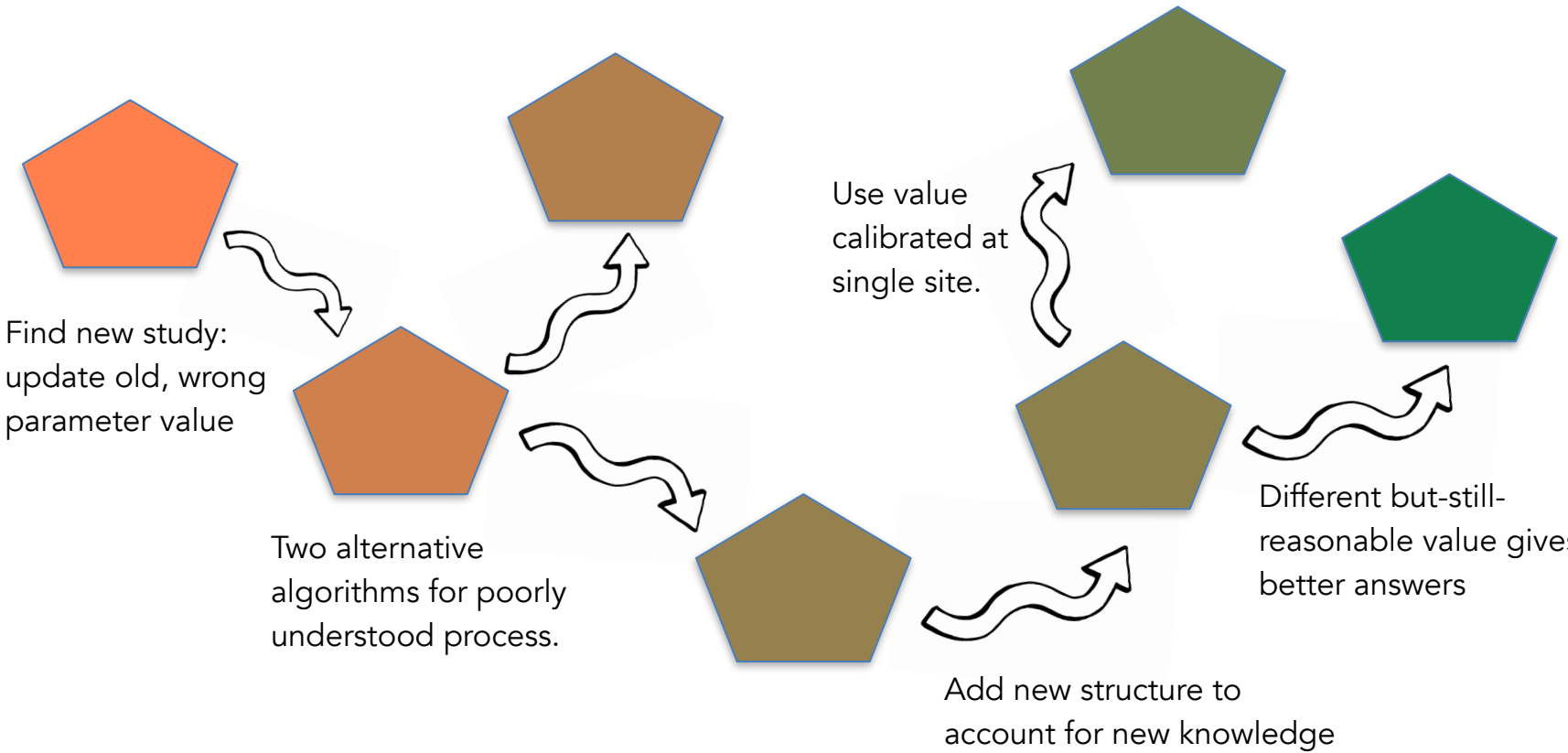


Image from Nathan Collier and http://climate.ornl.gov/~ncf/CLM5beta/

Now what? The Game of Climate Model Biases



How can you tell whether problems are

structural

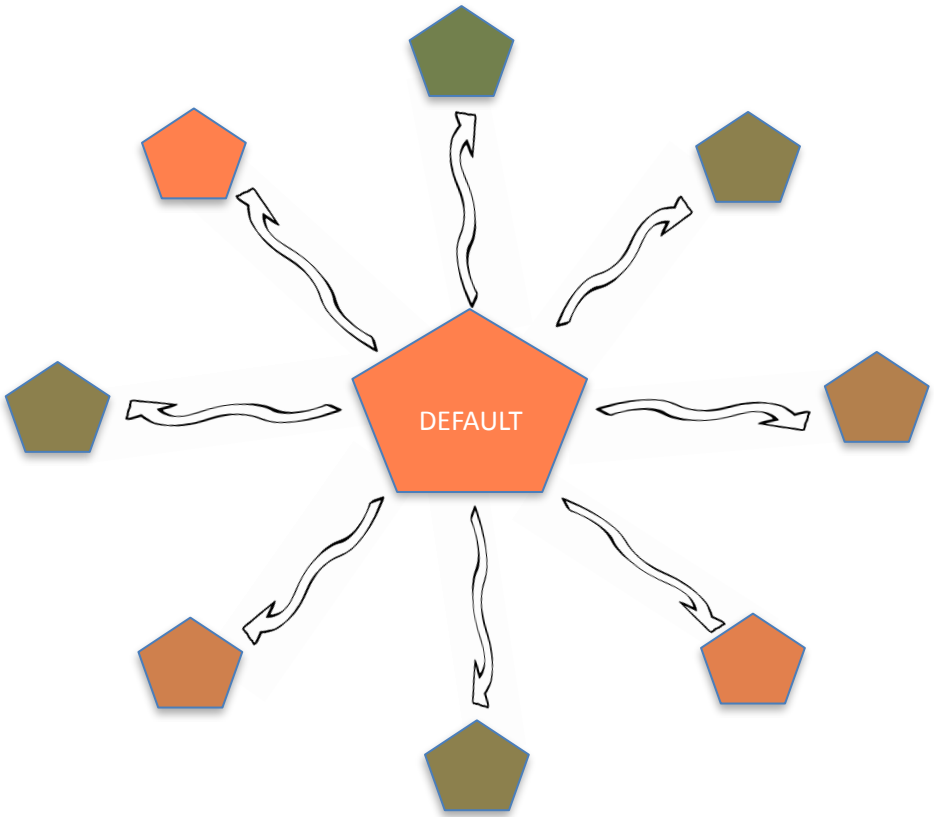
or

parametric

?

Parameter Exploration

One-At-A-Time
sensitivity analysis

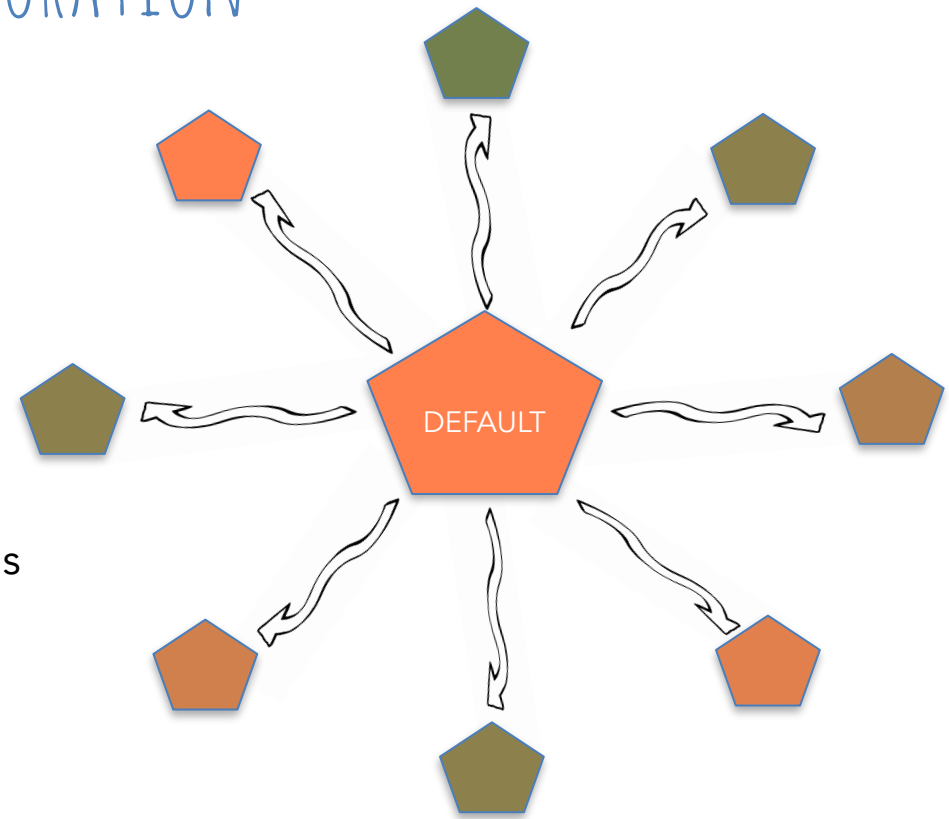


Parameter Exploration

One-At-A-Time sensitivity analysis

Global 4x5° runs

'Expert Judgment' to narrow parameter fields



Parameter Exploration

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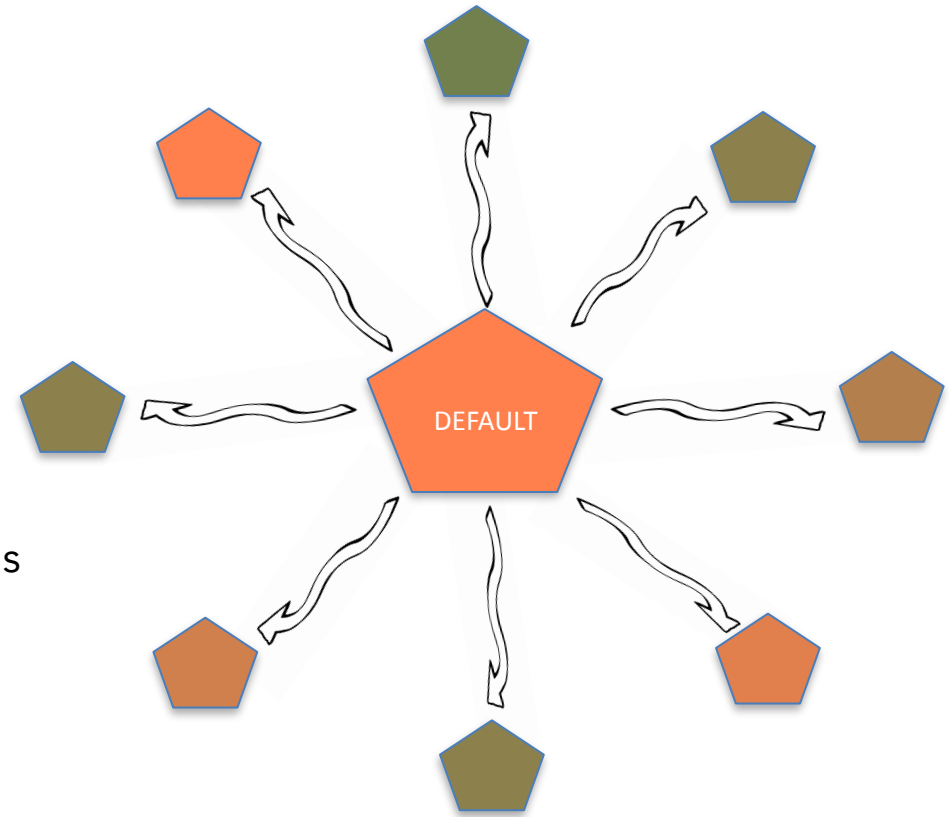


Spin up 'default' version to Pre-I CO2

Perturb parameters

Run for 60 more years at PI CO2.

Elevate CO2 to present (380ppm)

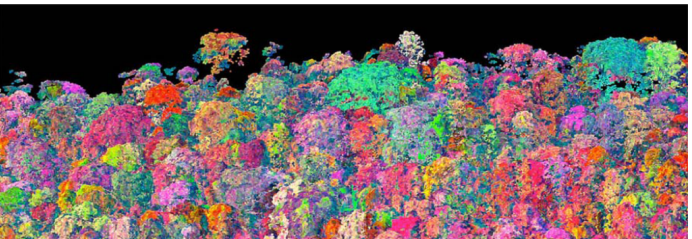
Run for 20 more years

Aren't we supposed to have parameters we can measure?.

Aren't we supposed to have parameters we can measure?.

Specific Leaf Area (SLA) from TRY database

Existing Plant Functional Types are **not** a good predictor of many traits



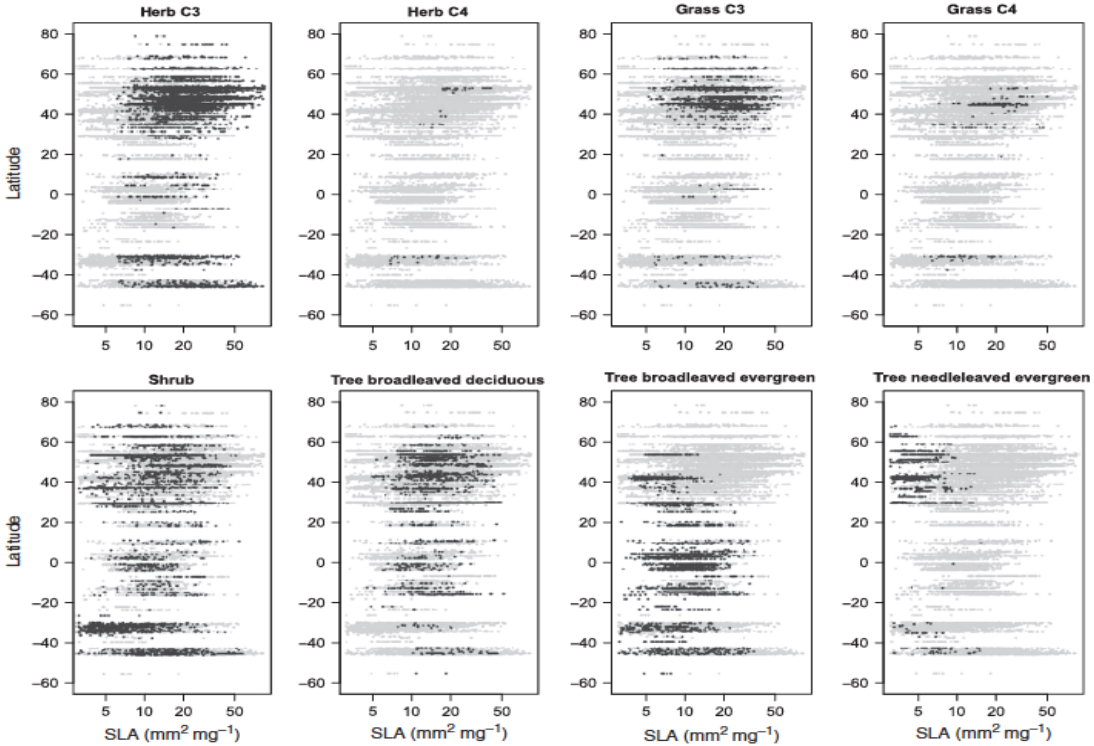


Fig. 6 Worldwide range in specific leaf area (*SLA*) along a latitudinal gradient for the main plant functional types. Grey, all data; black, data for the plant functional group (PFT) under scrutiny.

So, if we calibrate the model to the observations...

...is it cheating?

Is it cheating?

YES

We shouldn't fit to the same data we are testing the model with

We should be able to observe model parameters

NO

There is nothing magic about the existing parameter values

They have both observation error and real variation

It is better to calibrate objectively than iteratively

We can (and will!) be transparent about our process

We can isolate structural bias or other issues if calibration fails

We need a robust simulation of the present day to say sensible things about the future

The chosen ones: reduced parameter space

cn_s1 : Soil C:N ratio pool 1

cn_s2 : Soil C:N ratio pool 2

knitr_max : max rate of nitrification

FUNfracfixers : frac of vegetation that can fix N

slatop : Specific Leaf Area (TRY)

leaf_cn : Leaf C:N ratio (TRY)

froot_leaf : Fine root:leaf ratio

gr_perc : Growth respiration fraction

r_mort : Stem turnover rate (mortality)

mbb_opt : Ball-Berry stomatal slope

N_costs : Costs of active N uptake

denit_coef : Denitrification coefficient

denit_exp : Denitrification exponent

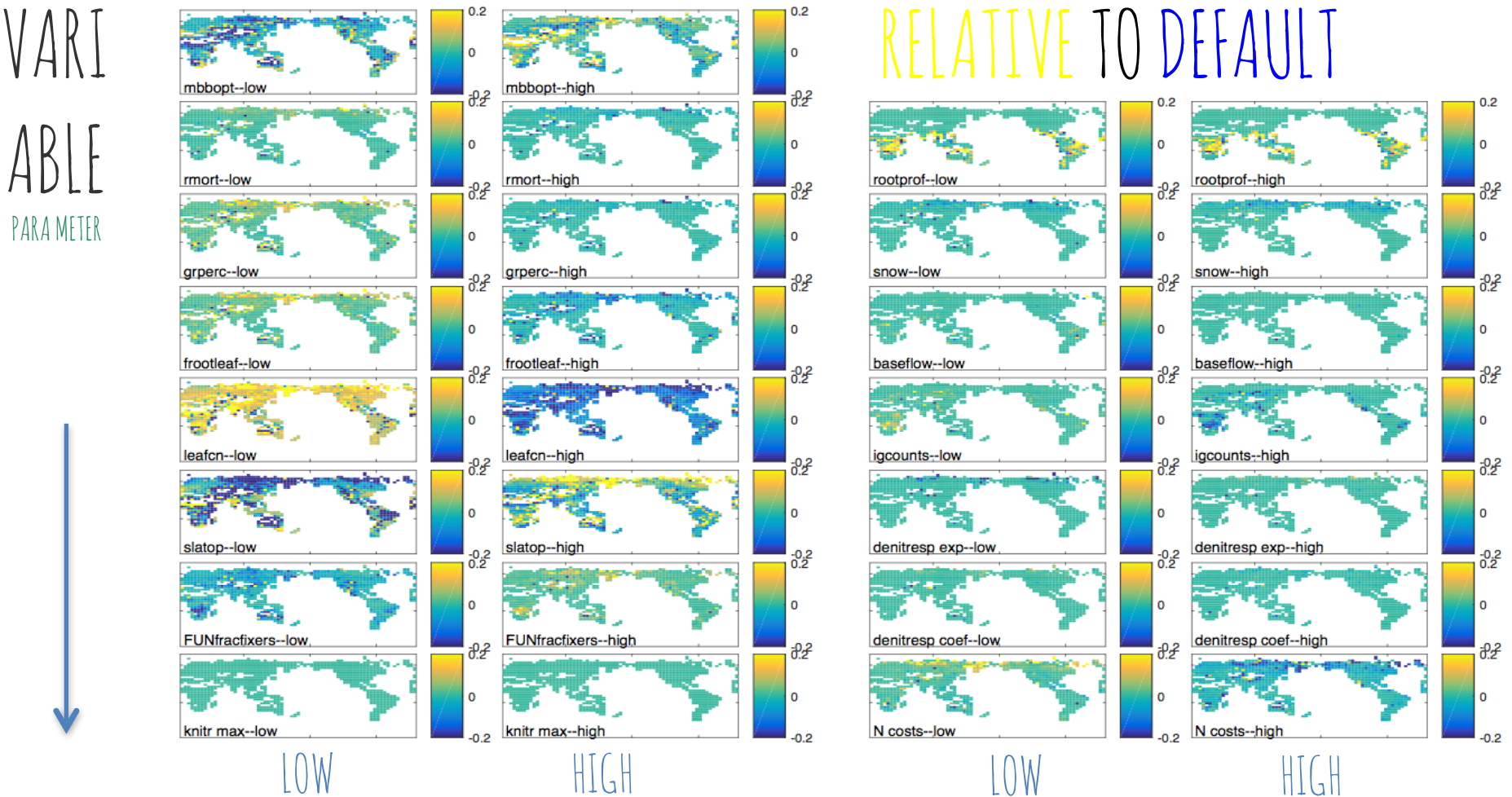
ig_counts : Fire ignition counts

baseflow : Rate of water loss to rivers

snow : 2 snow density parameters

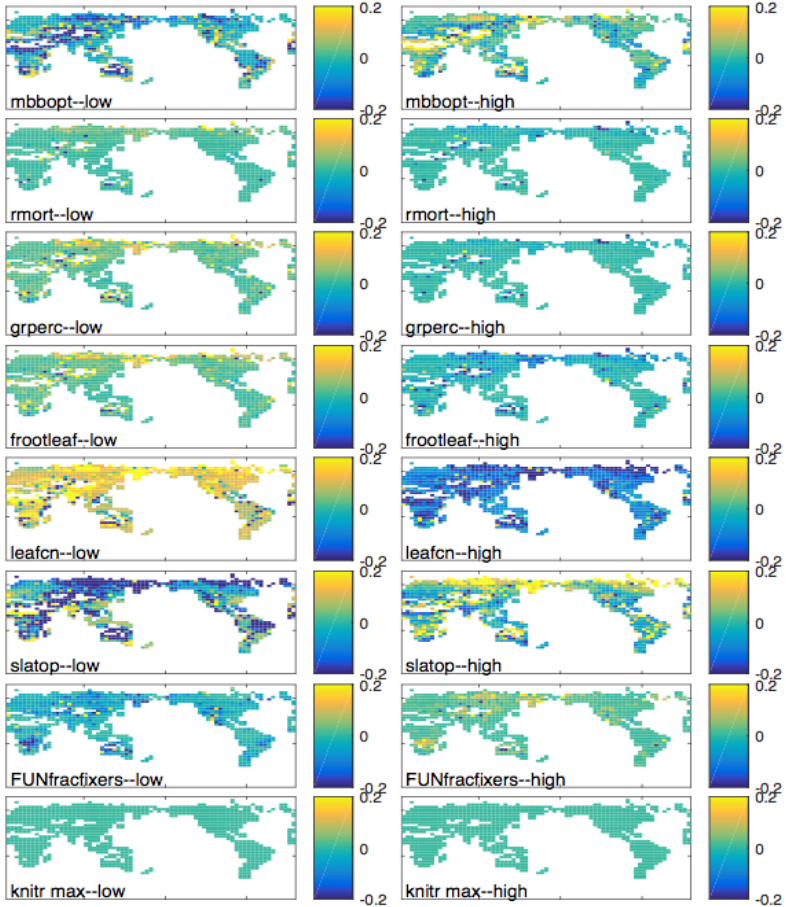
root_depth : Exponent of root profile

Ranges from literature, or logic/judgement

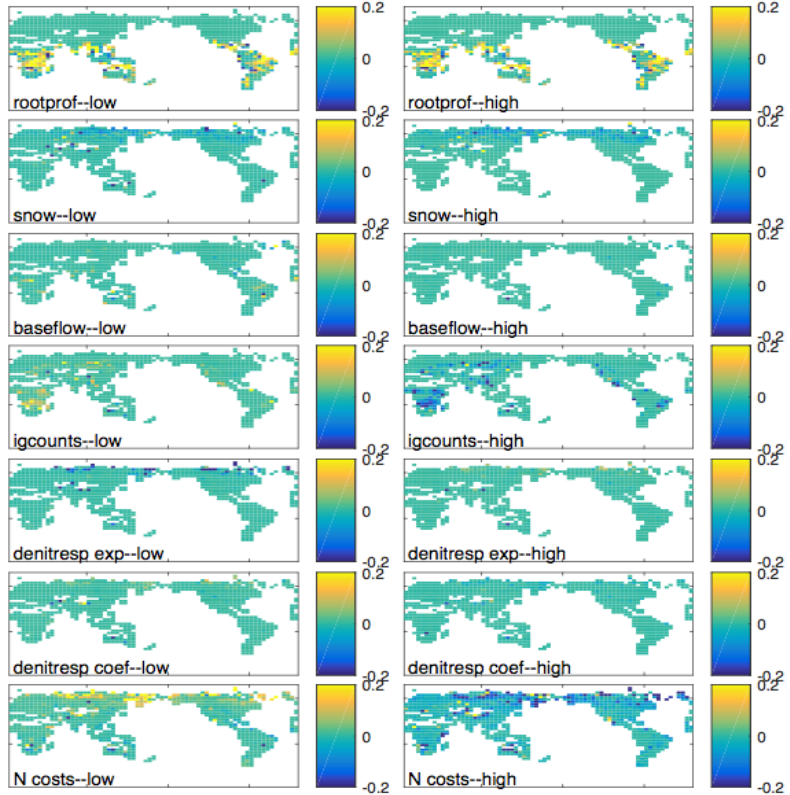

VARIABLE PARAMETER
RELATIVE TO DEFAULT
mbbopt--low
mbbopt--high
rmort--low
rmort--high
grperc--low
grperc--high
frootleaf--low
frootleaf--high
leafcn--low
leafcn--high
slatop--low
slatop--high
FUNfracfixers--low
FUNfracfixers--high
knitr max--low
knitr max--high
rootprof--low
rootprof--high
snow--low
snow--high
baseflow--low
baseflow--high
igcounts--low
igcounts--high
denitresp exp--low
denitresp exp--high
denitresp coef--low
denitresp coef--high
N costs--low
N costs--high
0.2
0
-0.2
LOW
HIGH
LOW
HIGH

GPP

RELATIVE



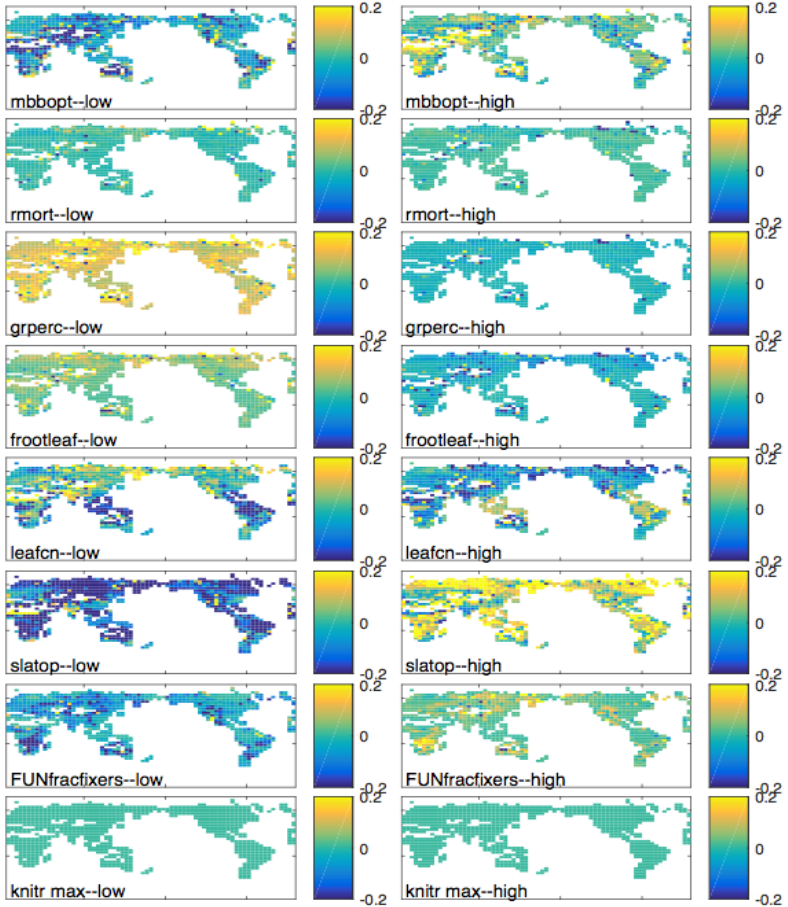
LOW HIGH



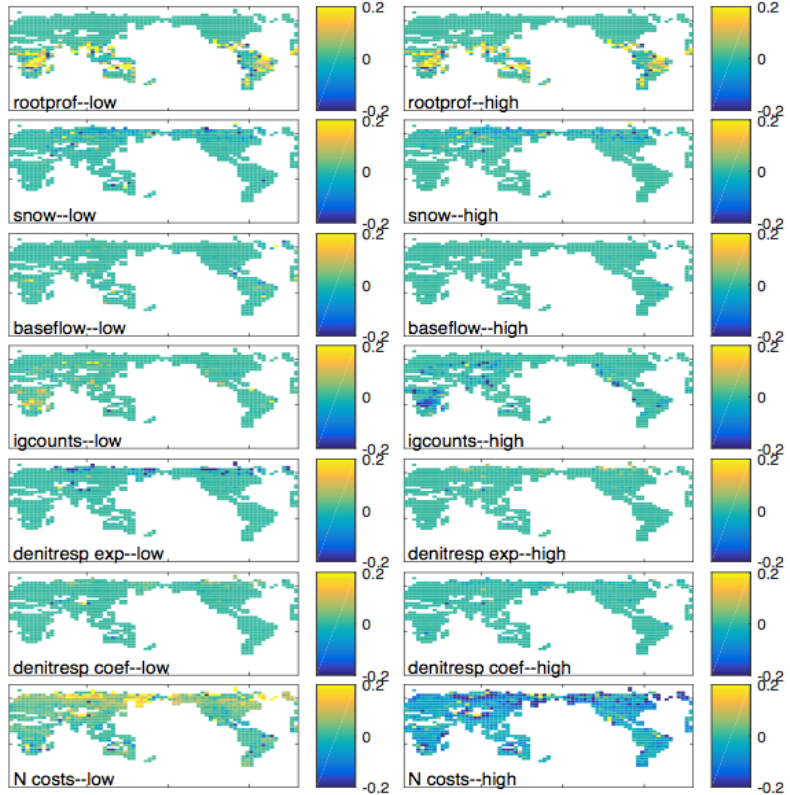
LOW HIGH

NPP

RELATIVE



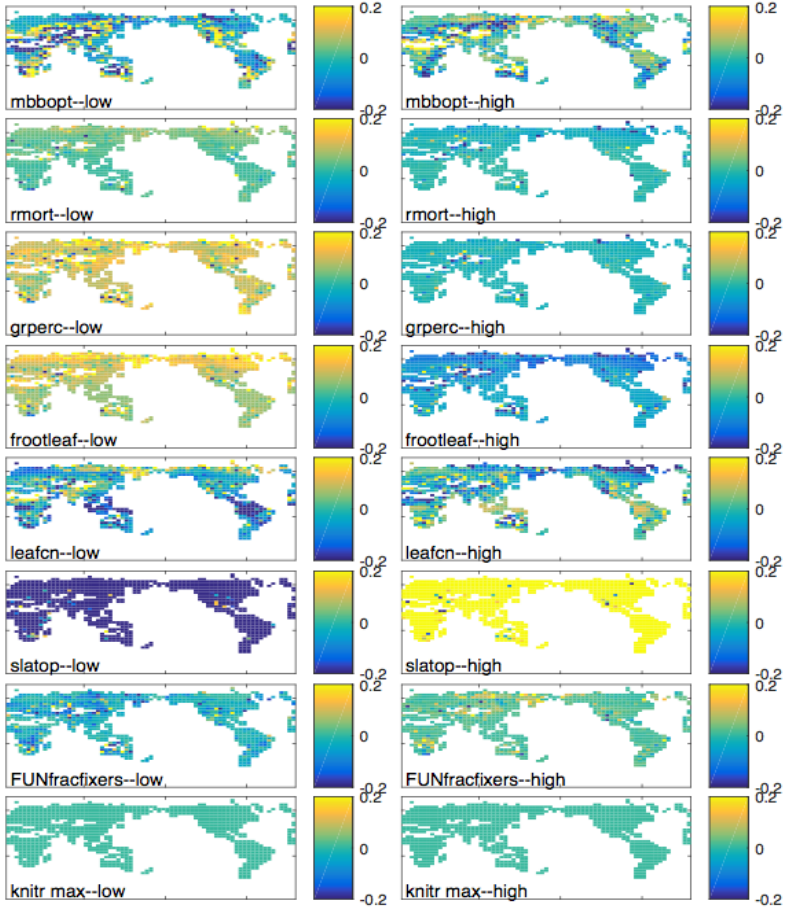
LOW HIGH



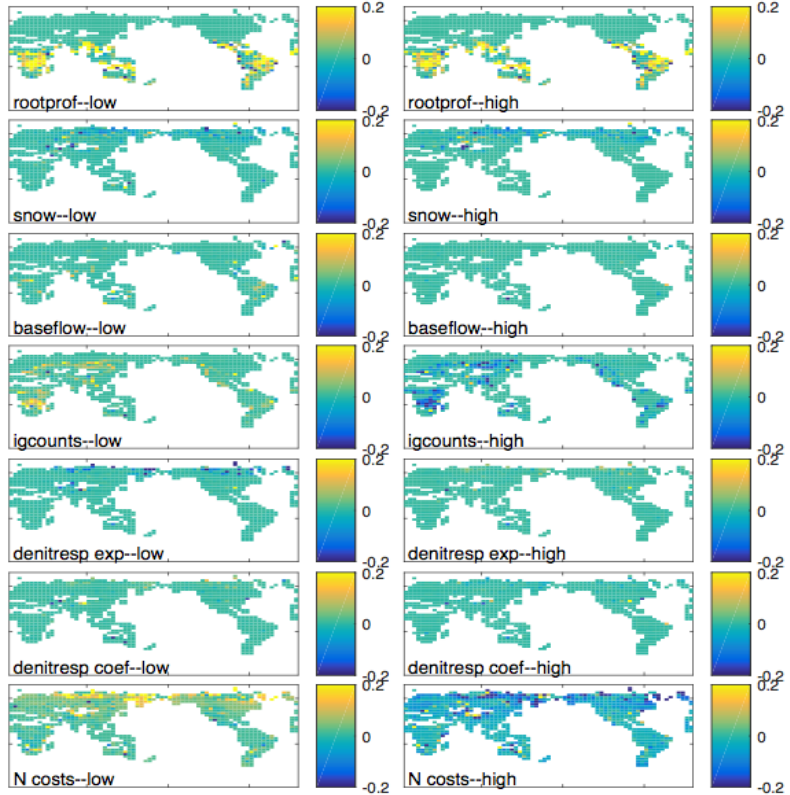
LOW HIGH

LAI

RELATIVE



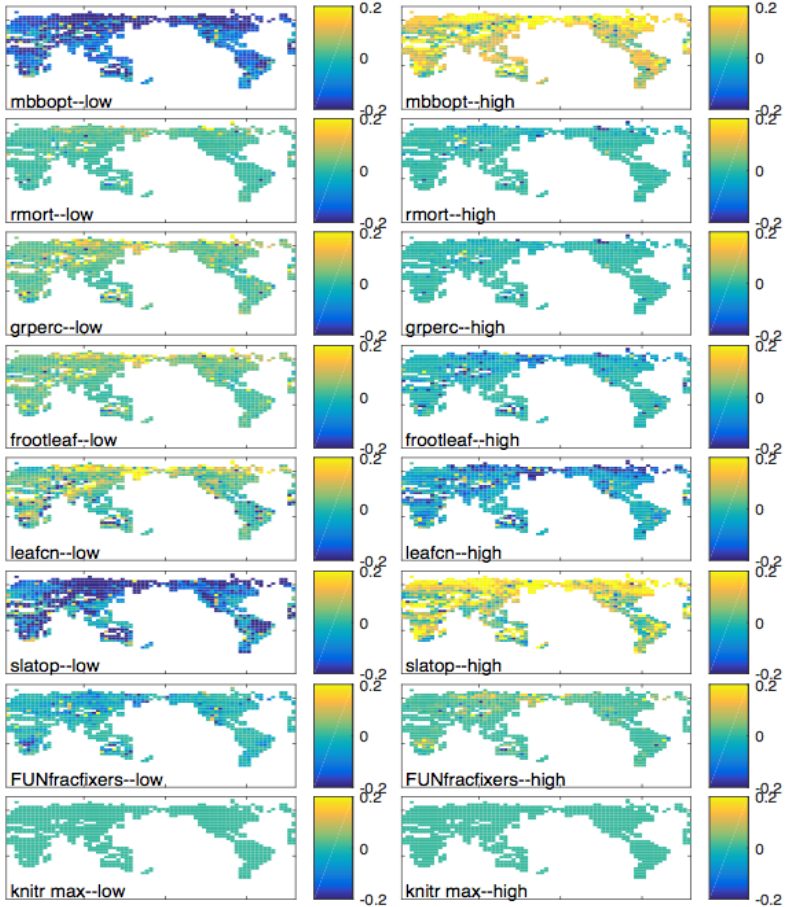
LOW HIGH

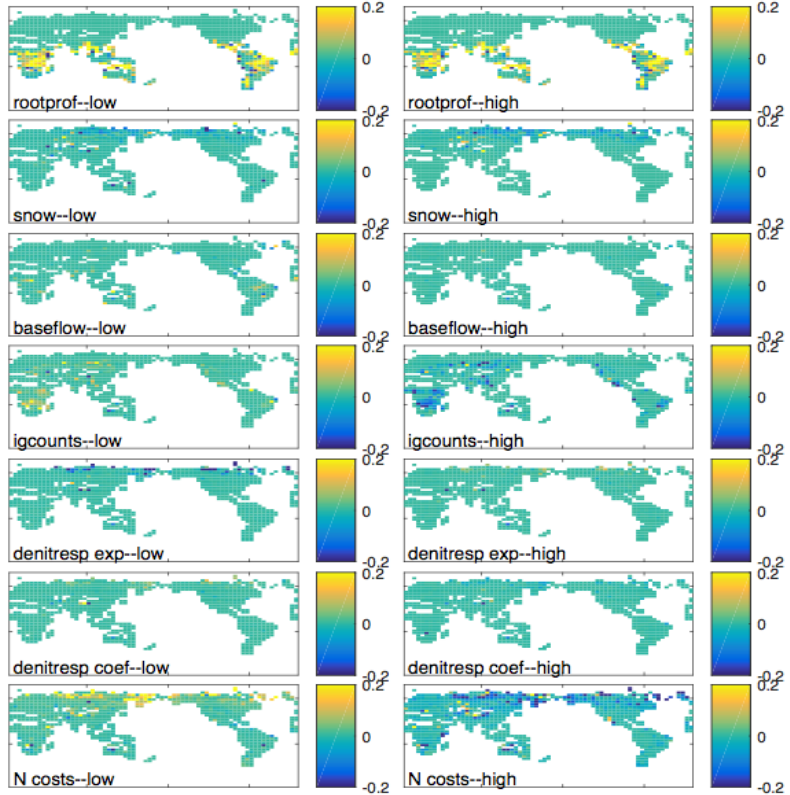


LOW HIGH

QVEGT

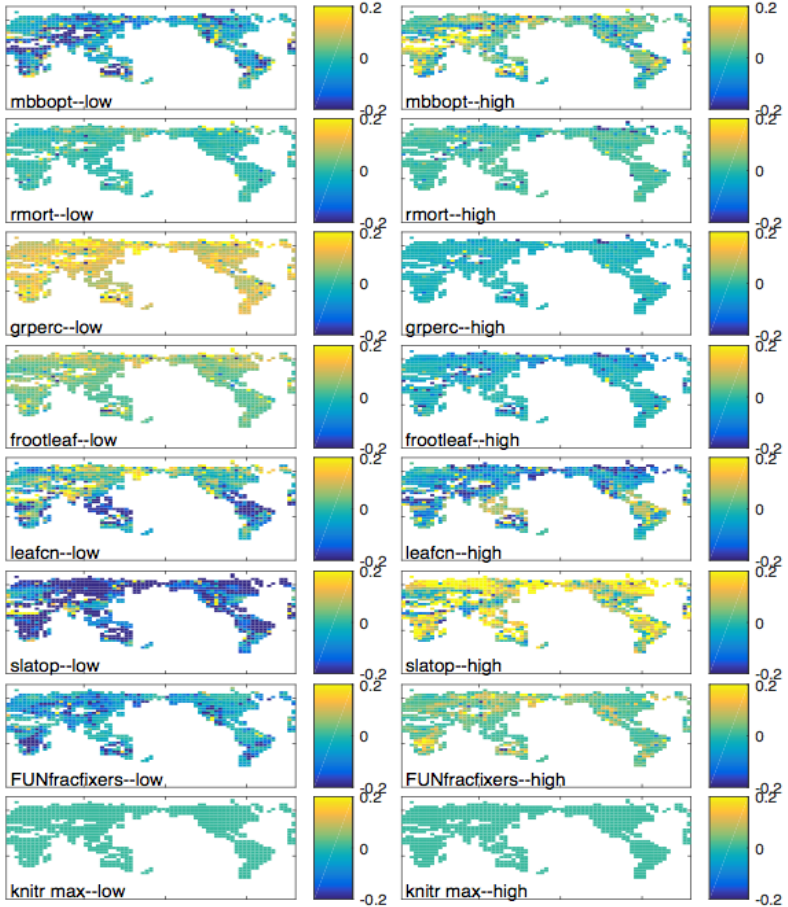
RELATIVE



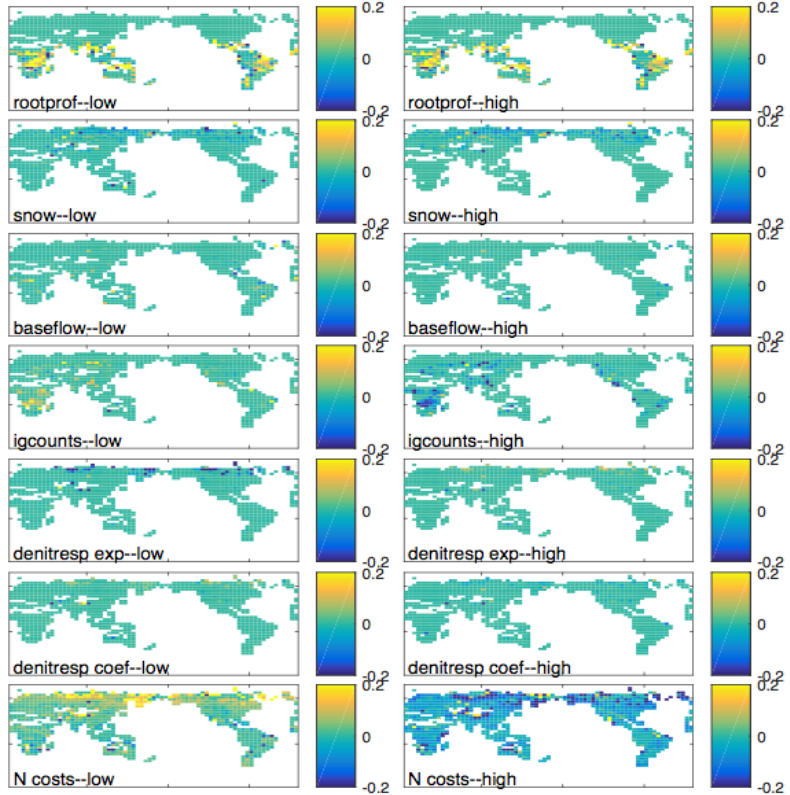


NPP

RELATIVE

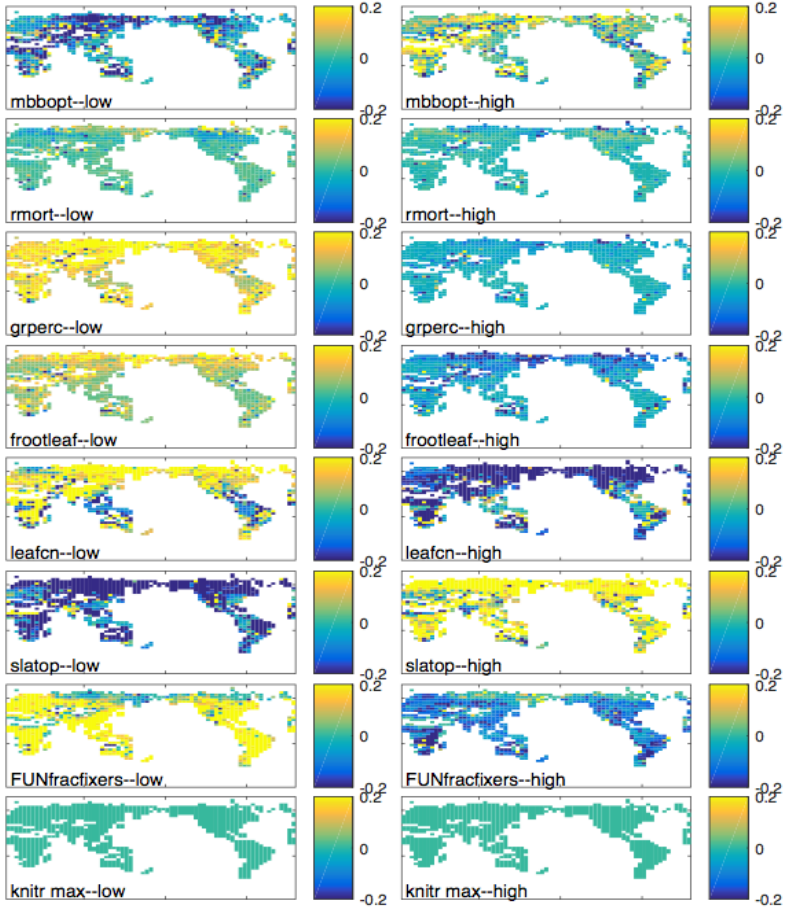


LOW HIGH

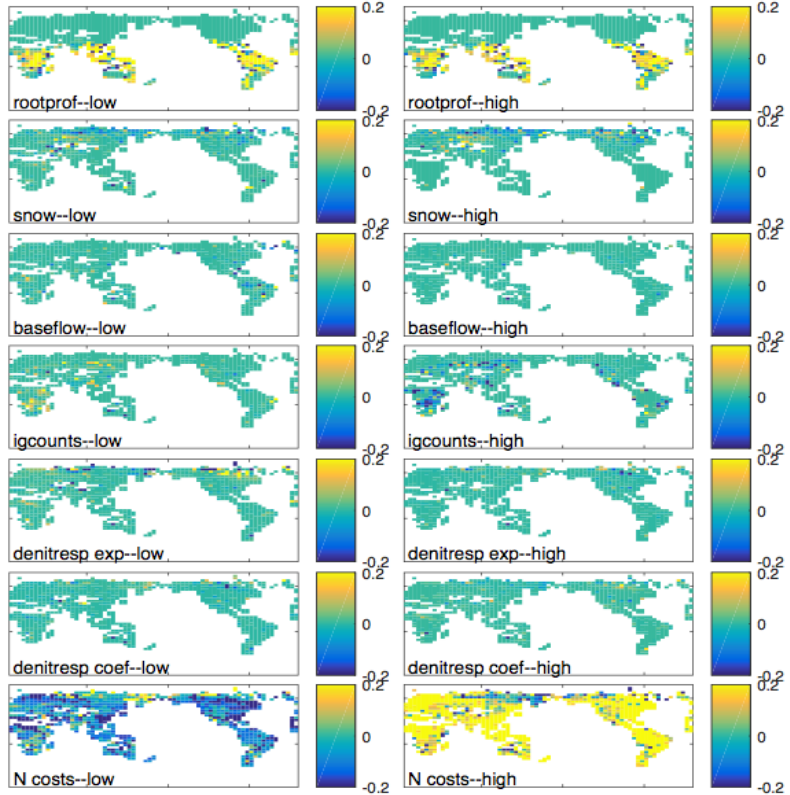


LOW HIGH

NPP FOR



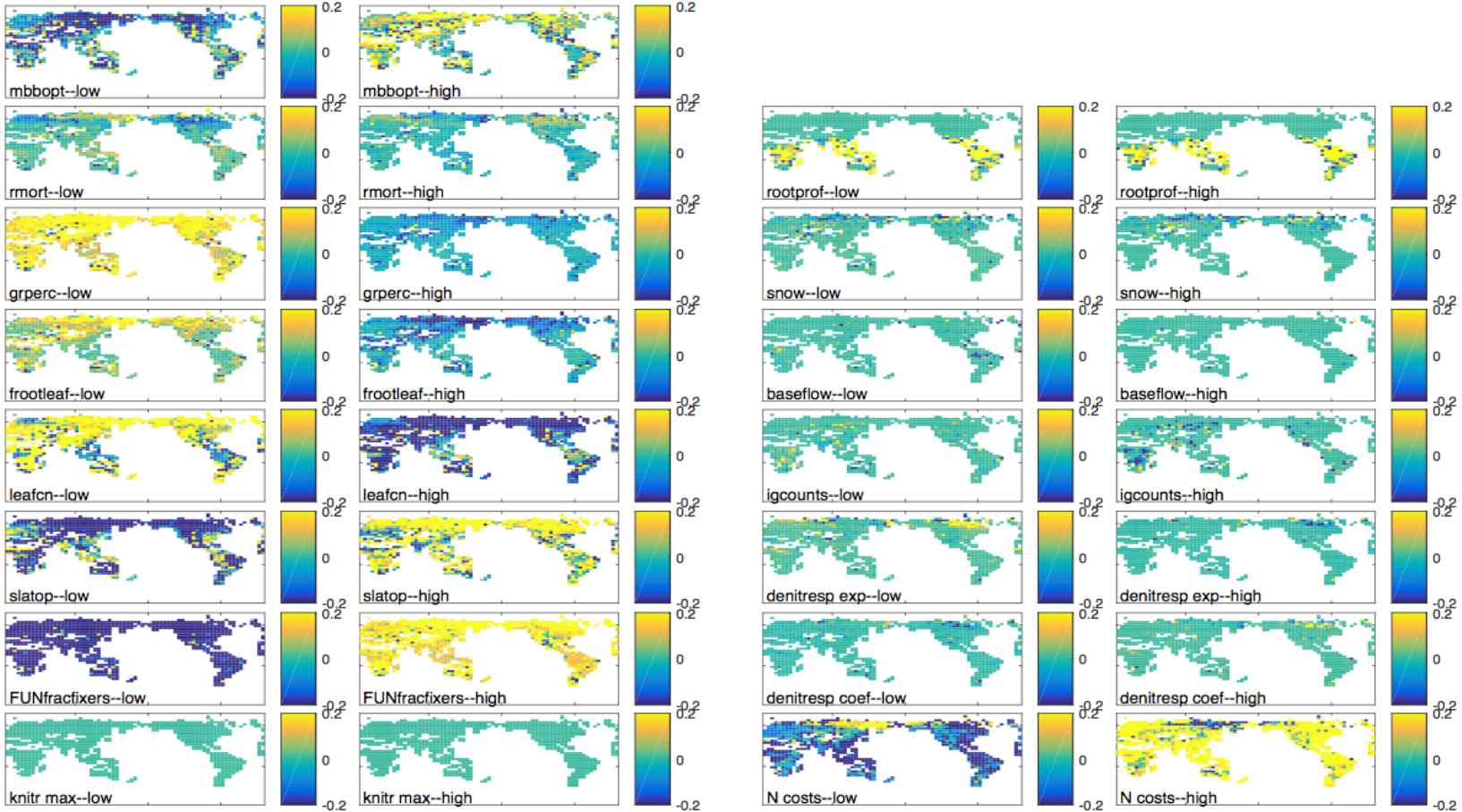
LOW HIGH

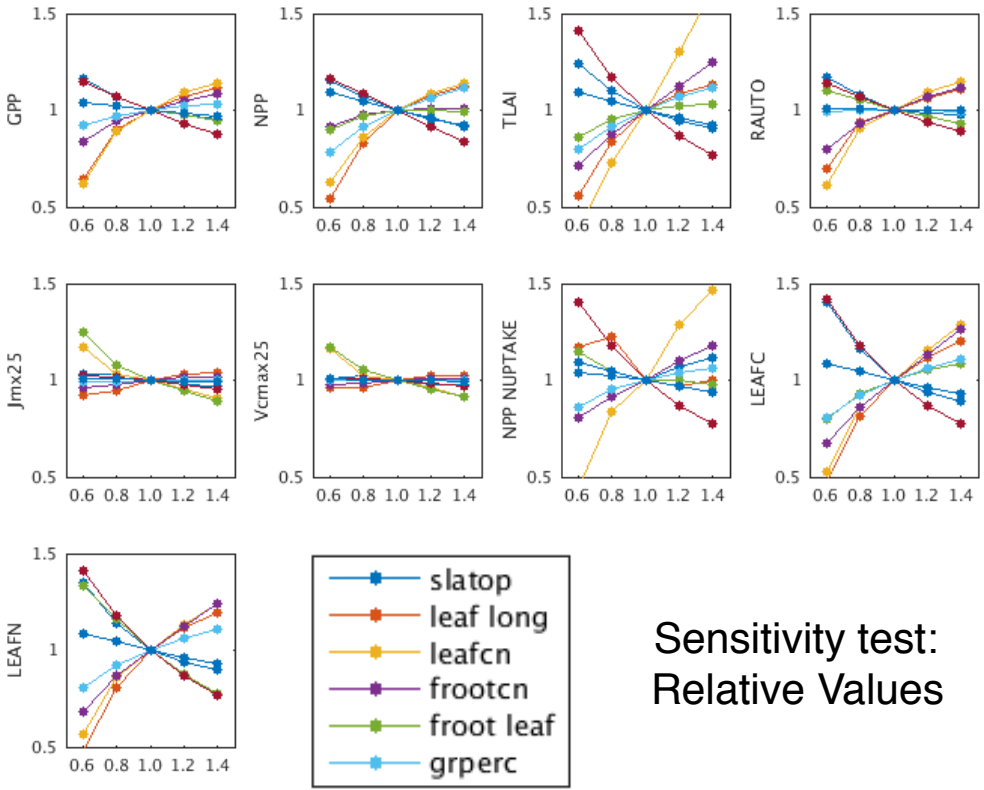


LOW HIGH

NFIX

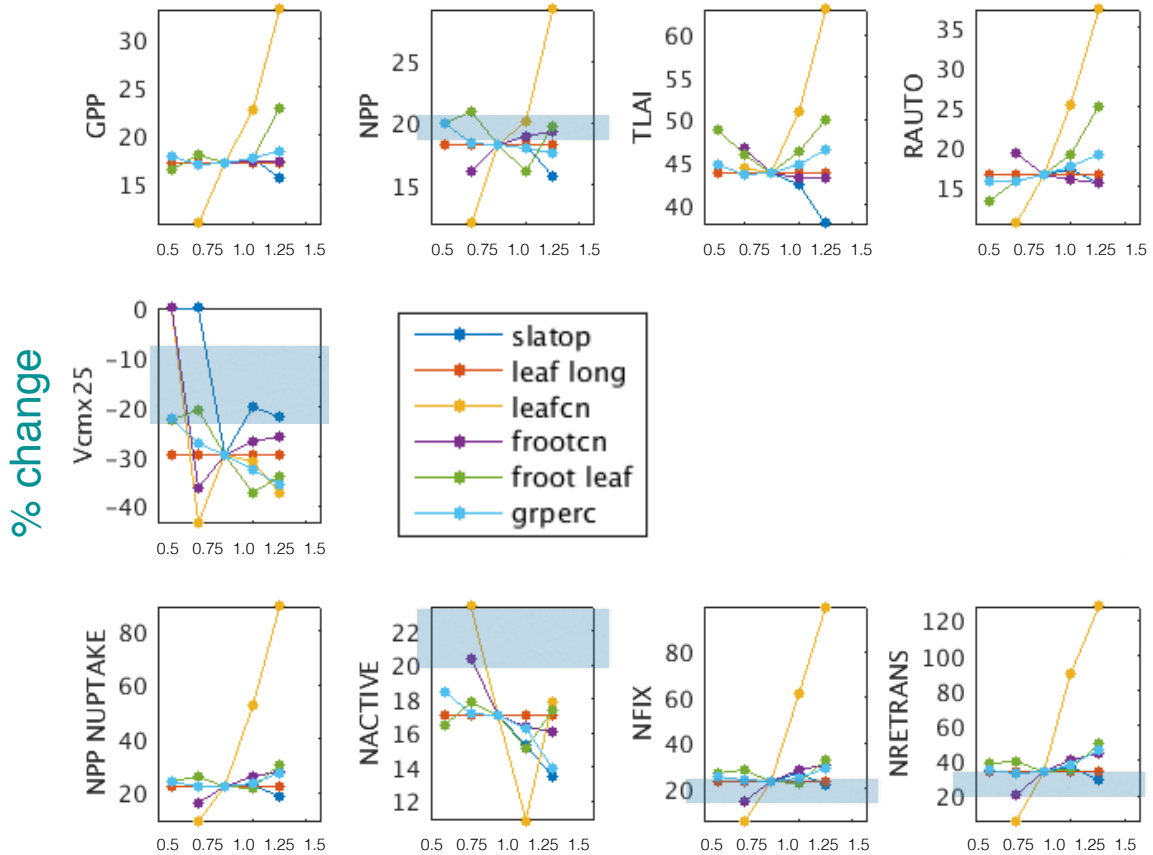
RELATIVE





Sensitivity test:
Relative Values

Elevated CO2 response (400 to 650 ppm - Oak Ridge, TN)



Conclusions of perturbations.

There are no nasty surprises

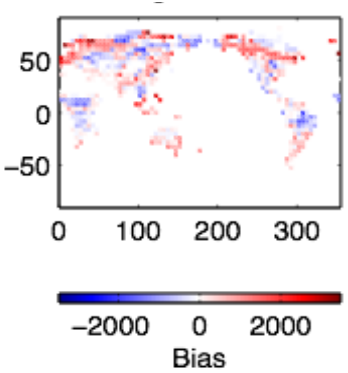
The model works as we might intuitively expect it to

Many alternative Nitrogen cycles (high and low fixation/loss rates) are possible within similar-looking carbon cycles.

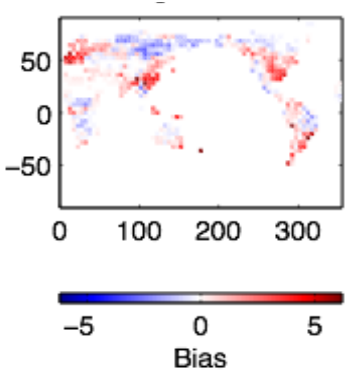
Where we are

Current CLM5 tag has:

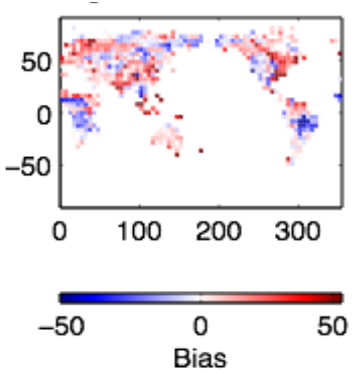
- Low Amazon GPP
- Overproductive Boreal Forest
- LAI too high in temperate forested regions
- Latent heat flux too low in Amazon



gC/m^2/year

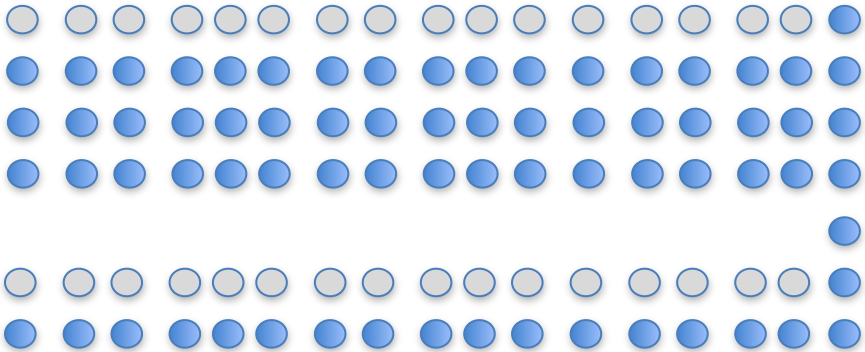


unitless



Wm^-2

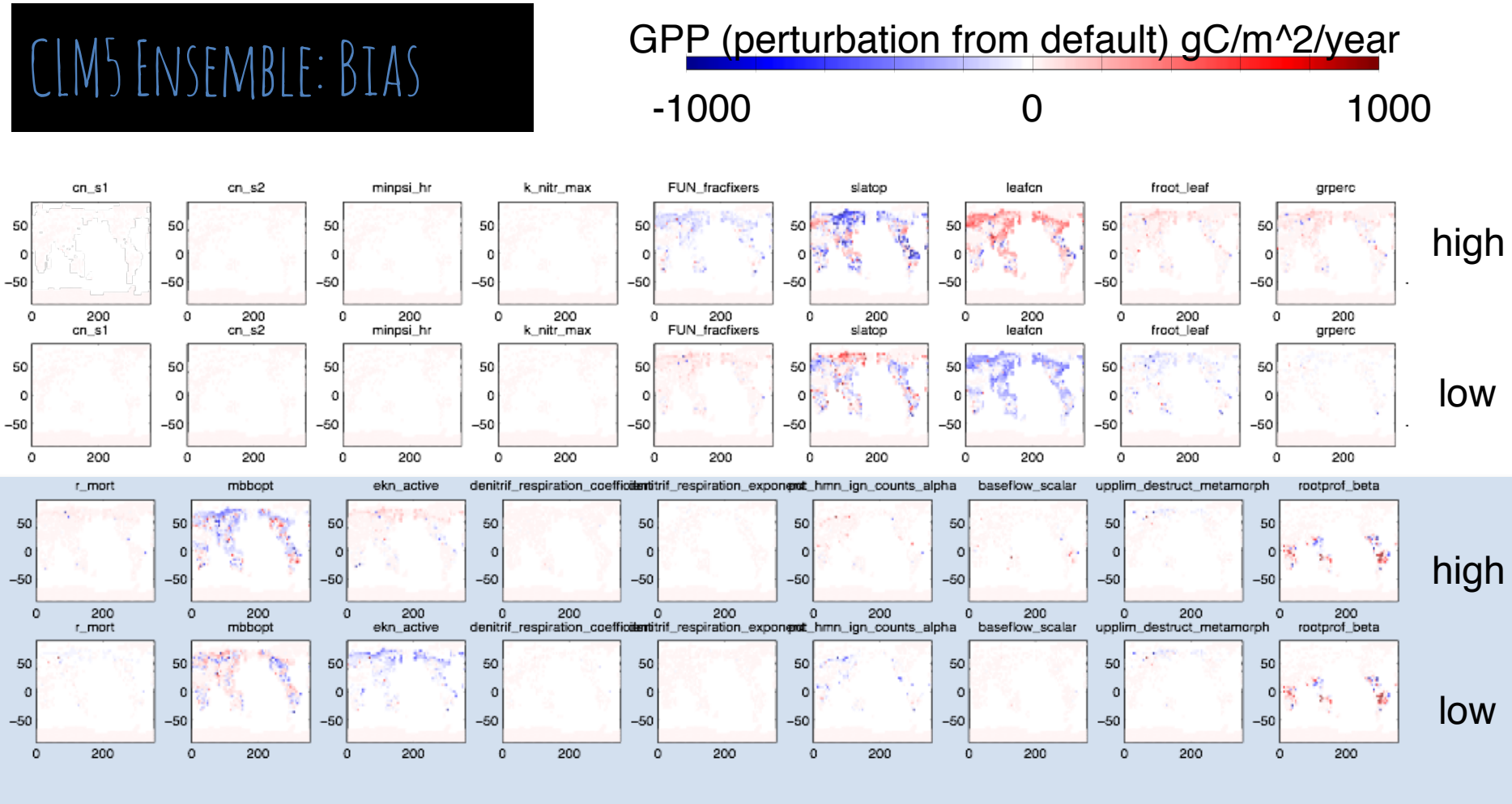
CLM5: The Curse of Dimensionality



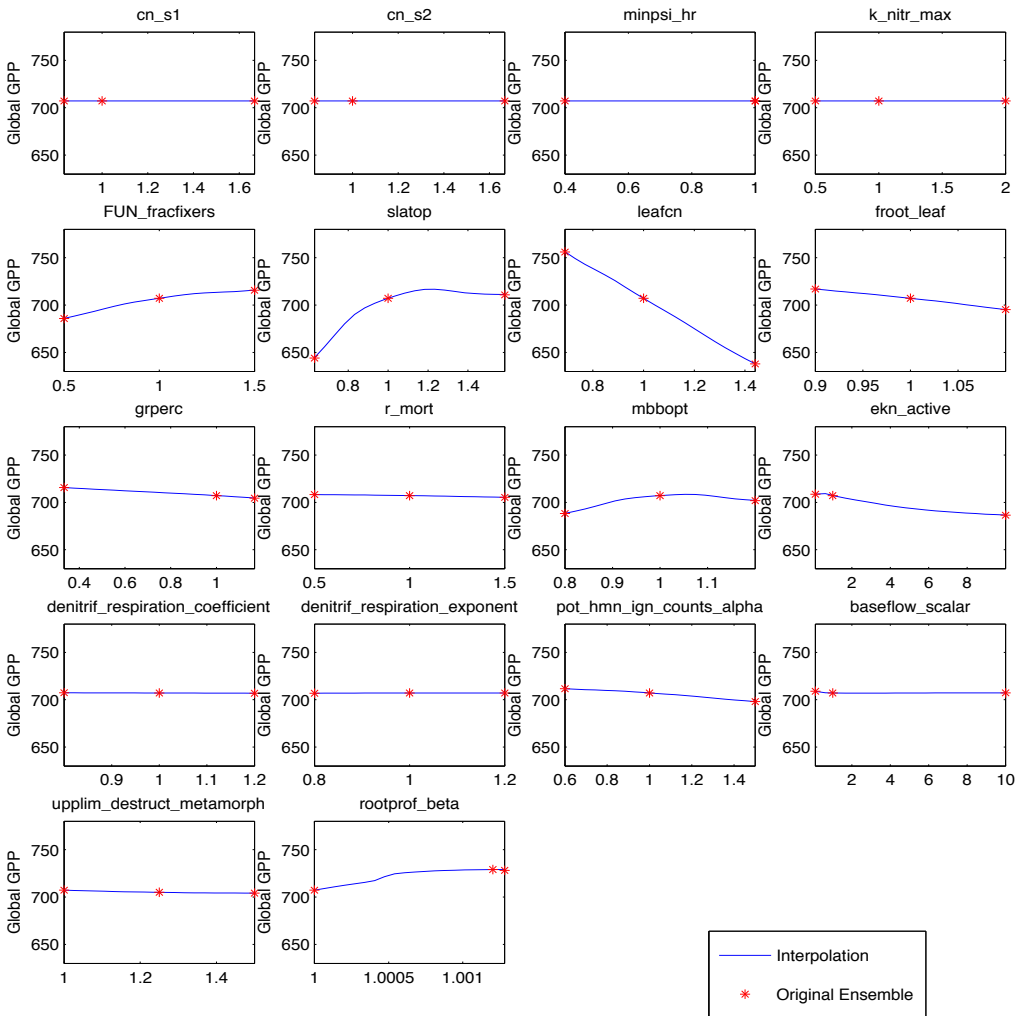
'cn_s1'
'cn_s2'
'minpsi_hr'
'k_nitr_max'
'FUN_fracfixers'
'slatop'
'leafcn'
'froot_leaf'
'grperc'
'r_mort'
'mbbopt'
'ekn_active'
'denitrif_respiration_coefficient'
'denitrif_respiration_exponent'
'pot_hmn_ign_counts_alpha'
'baseflow_scalar'
'upplim_destruct_metamorph'

82 (!) free parameters

CLM5 Ensemble: Bias

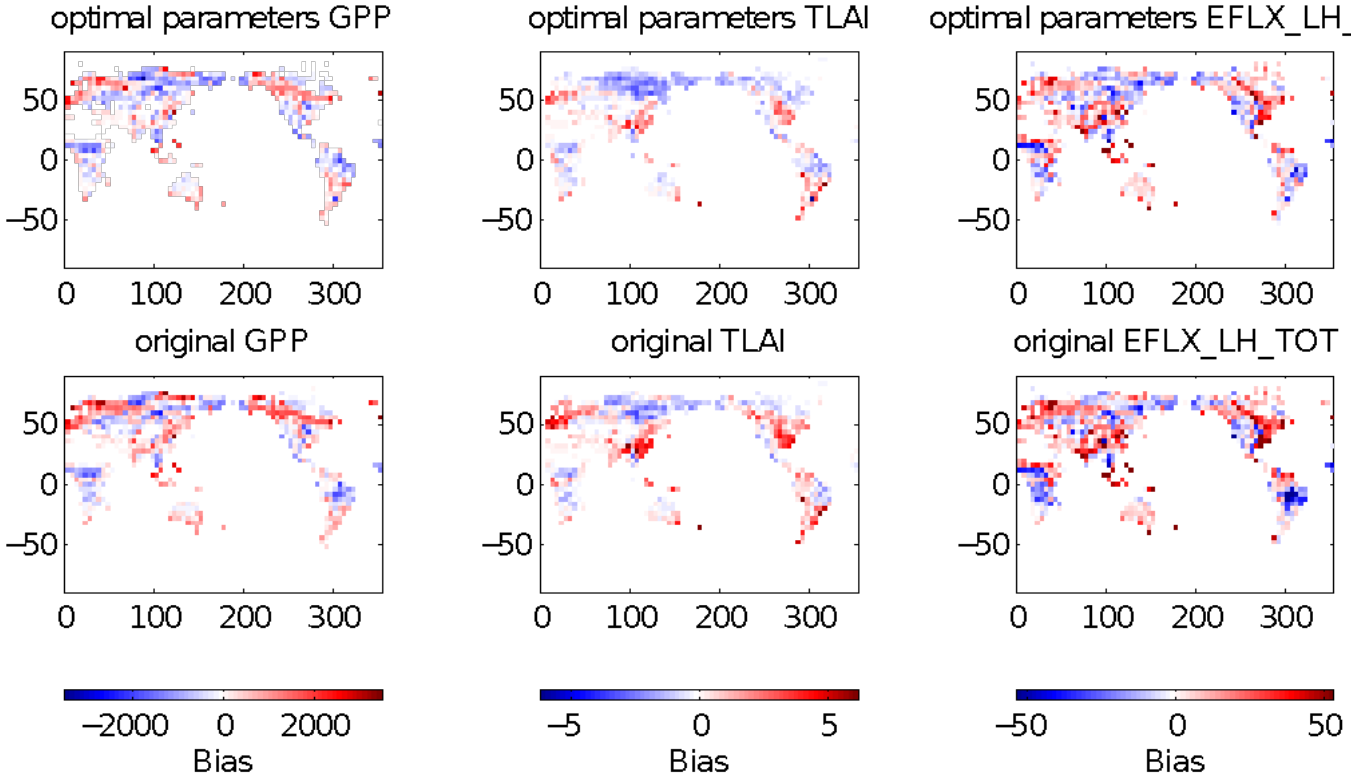


Build a Simple Emulator



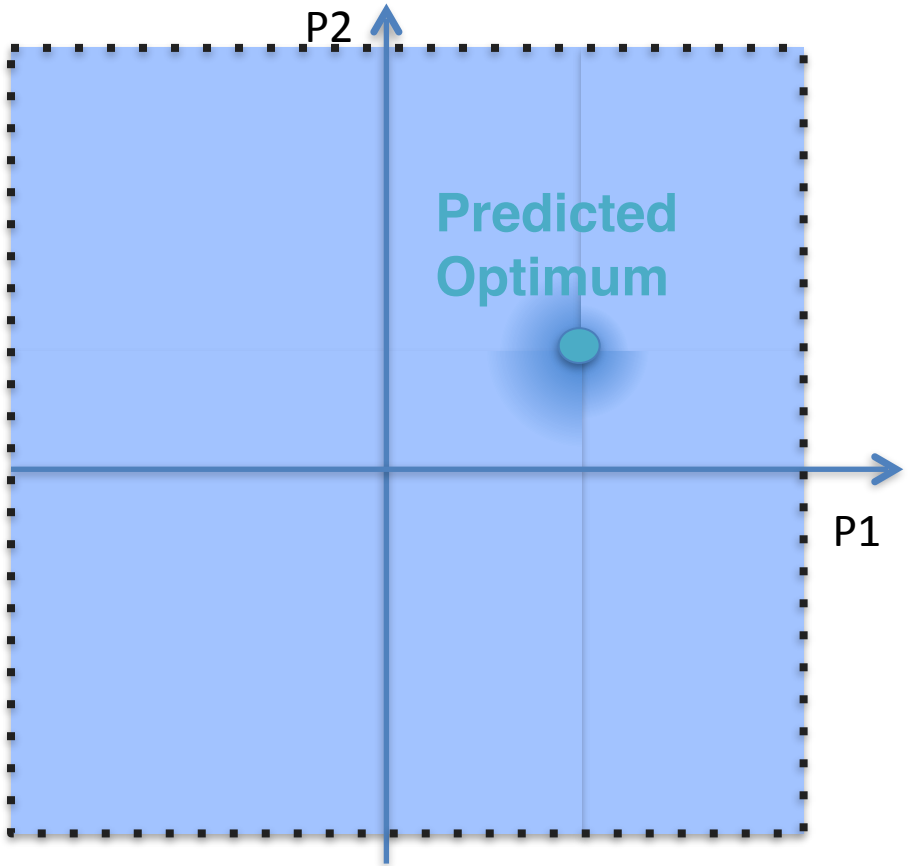
A FIRST ATTEMPT

- Boreal GPP bias reduced 50%
- LAI temperate biases significantly reduced
- LH biases improved slightly
- Amazon GPP bias persistent



Sanderson, Fisher et al. in prep

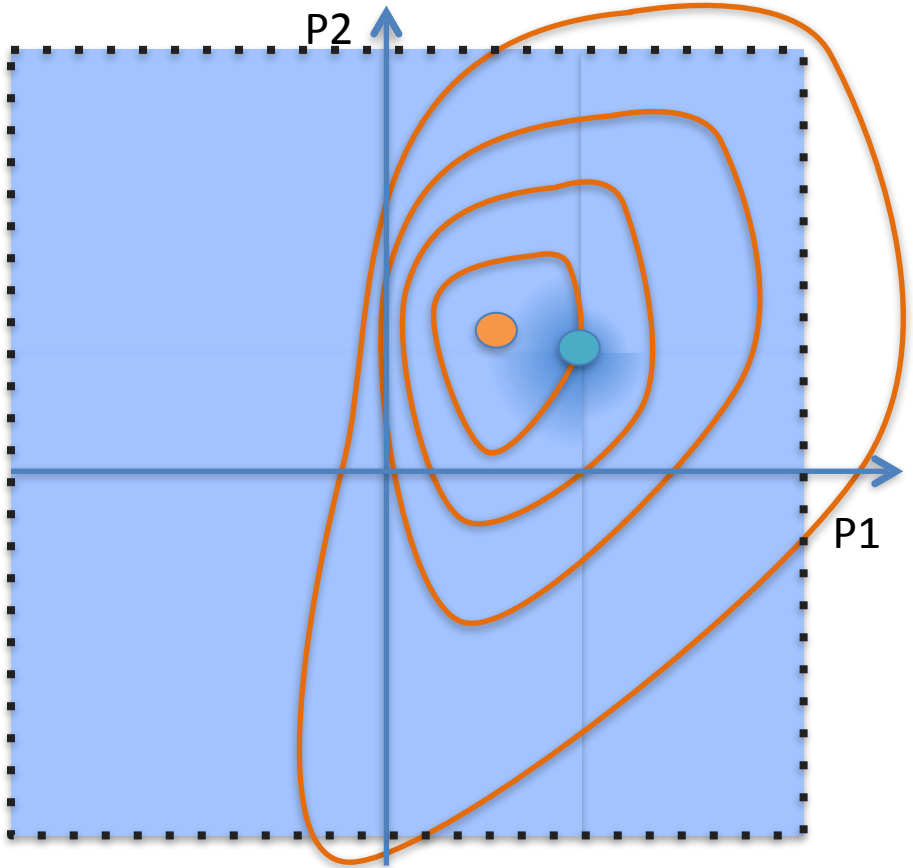
Next steps



First Order ensemble

Next steps

Iterate from best predicted point in parameter space



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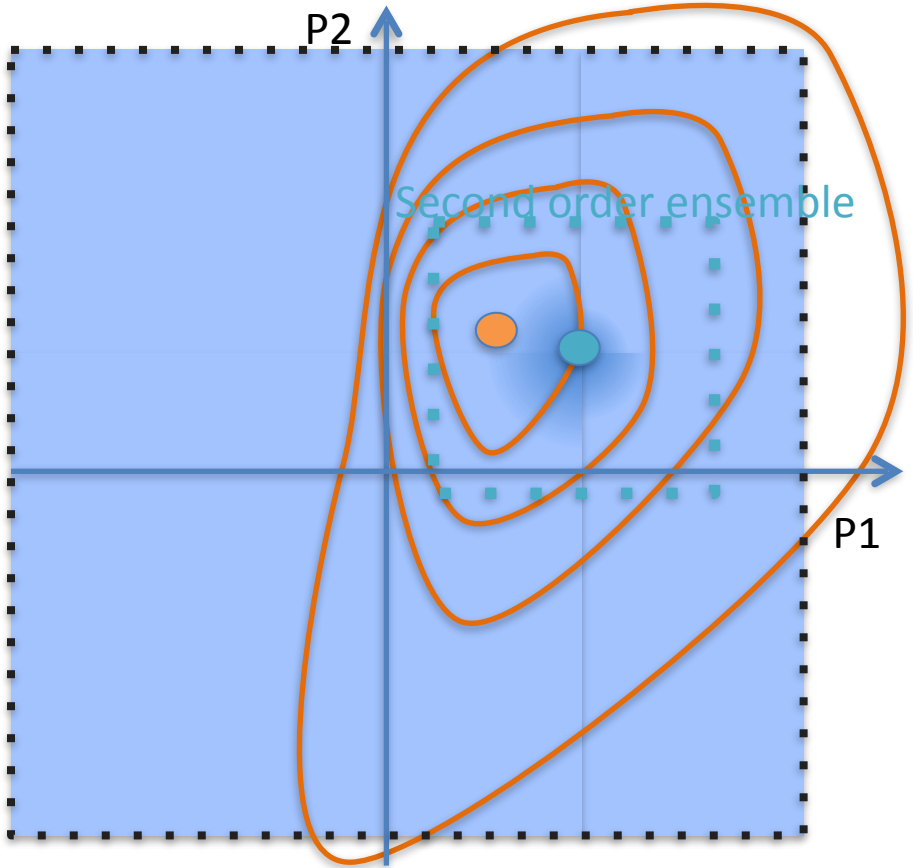


A MODIFIED ENSEMBLE

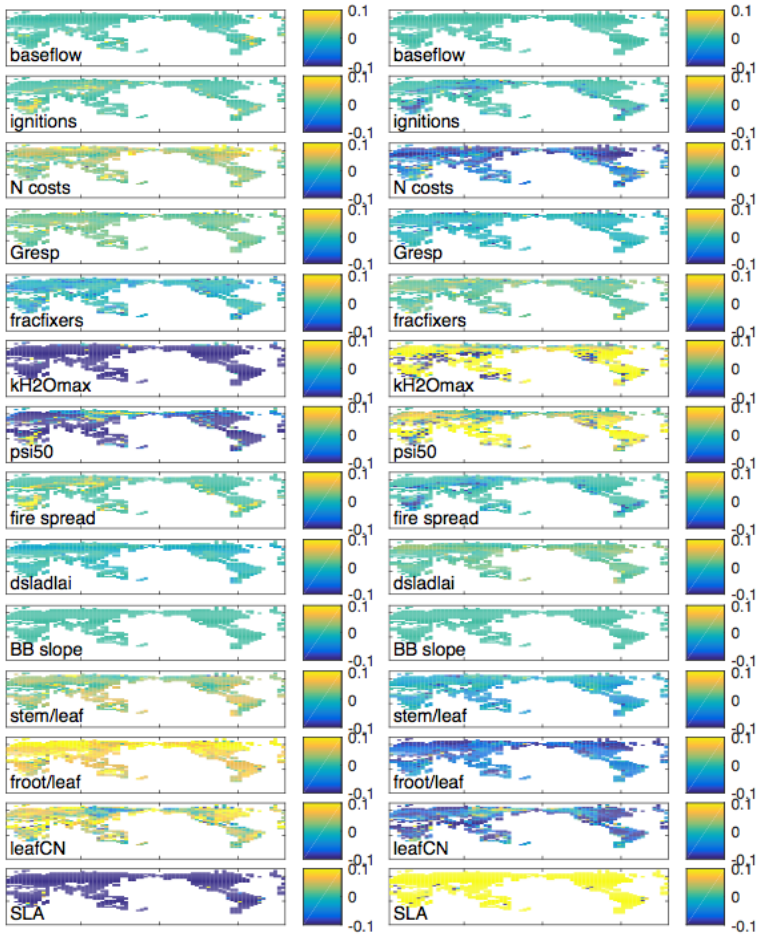
LAI, RELATIVE TO DEFAULT

- Some of the chosen parameters had little impact

- New parameters identified with important influence

-Defaults altered in line with new data

-Model baseline code changed between runtime (bug fixes, hydraulics code, respiration model correction, etc.)



Take home messages

-New philosophical frameworks are needed for understanding our confidence in complex models

-We are trialling one parameterization framework (there are others), and this represents a major departure from the normal course of ESM component development

-This is not a trivial problem. Further efforts will be appropriate even post CLM5 release.

THANK YOU!