Sorting out the carbon model problem

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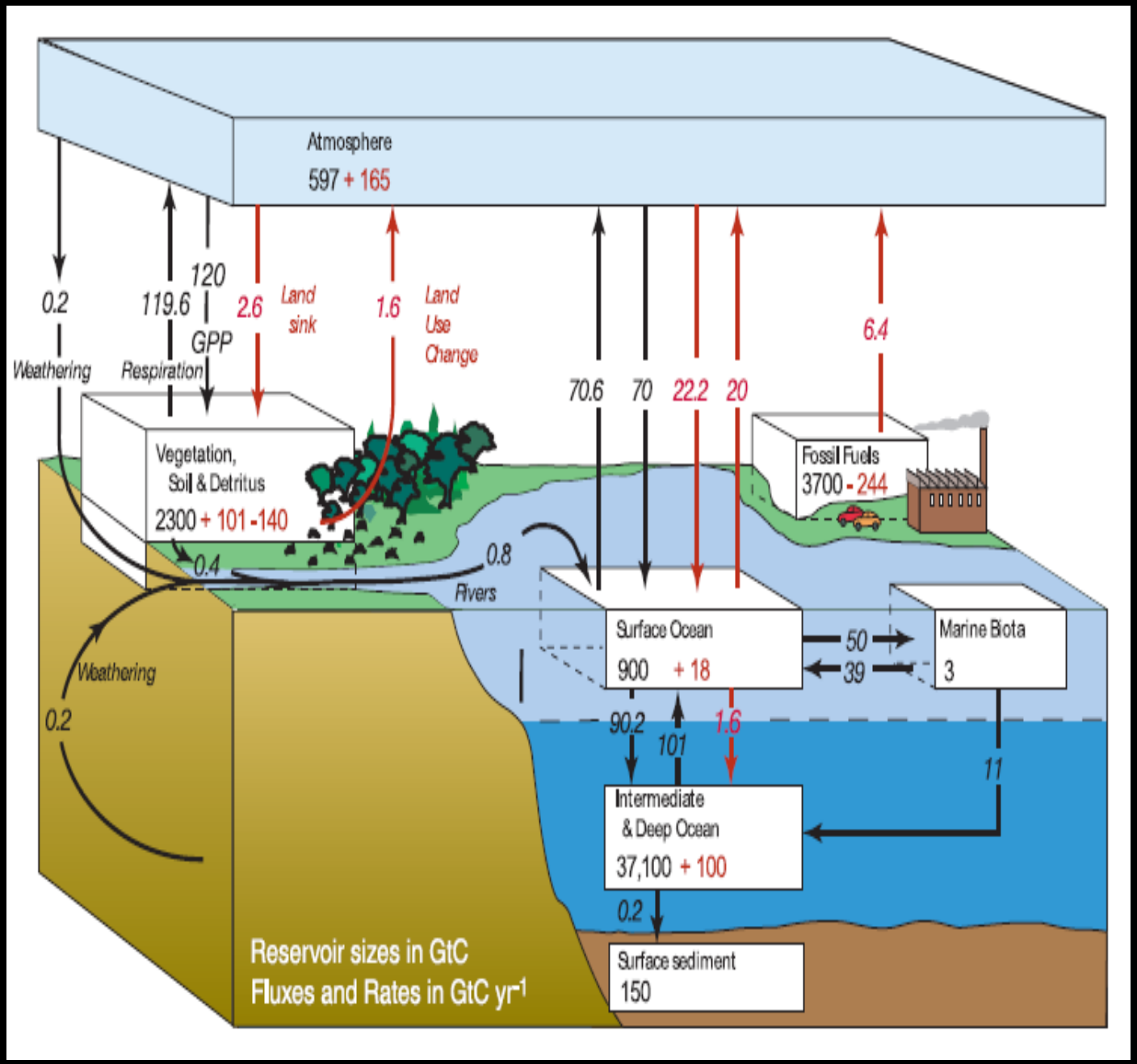
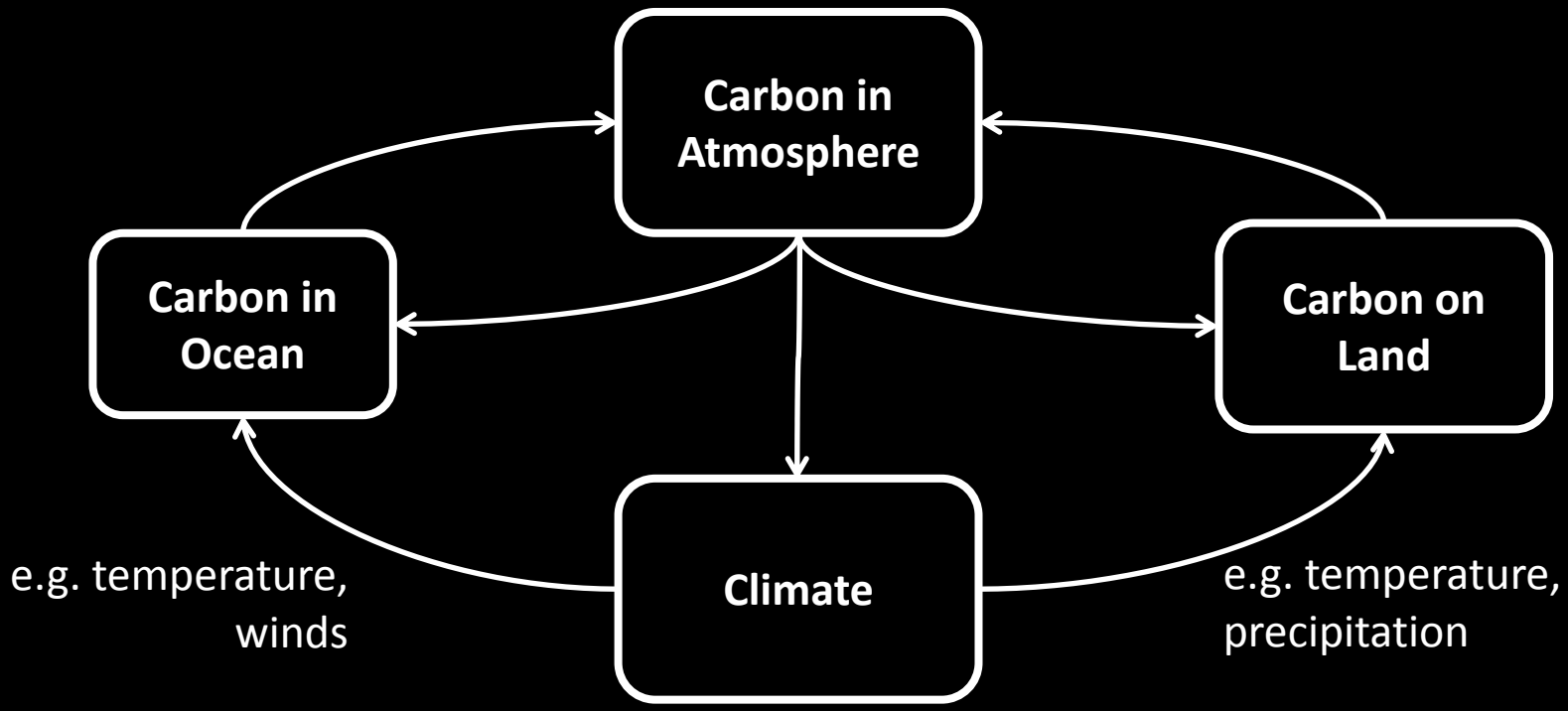
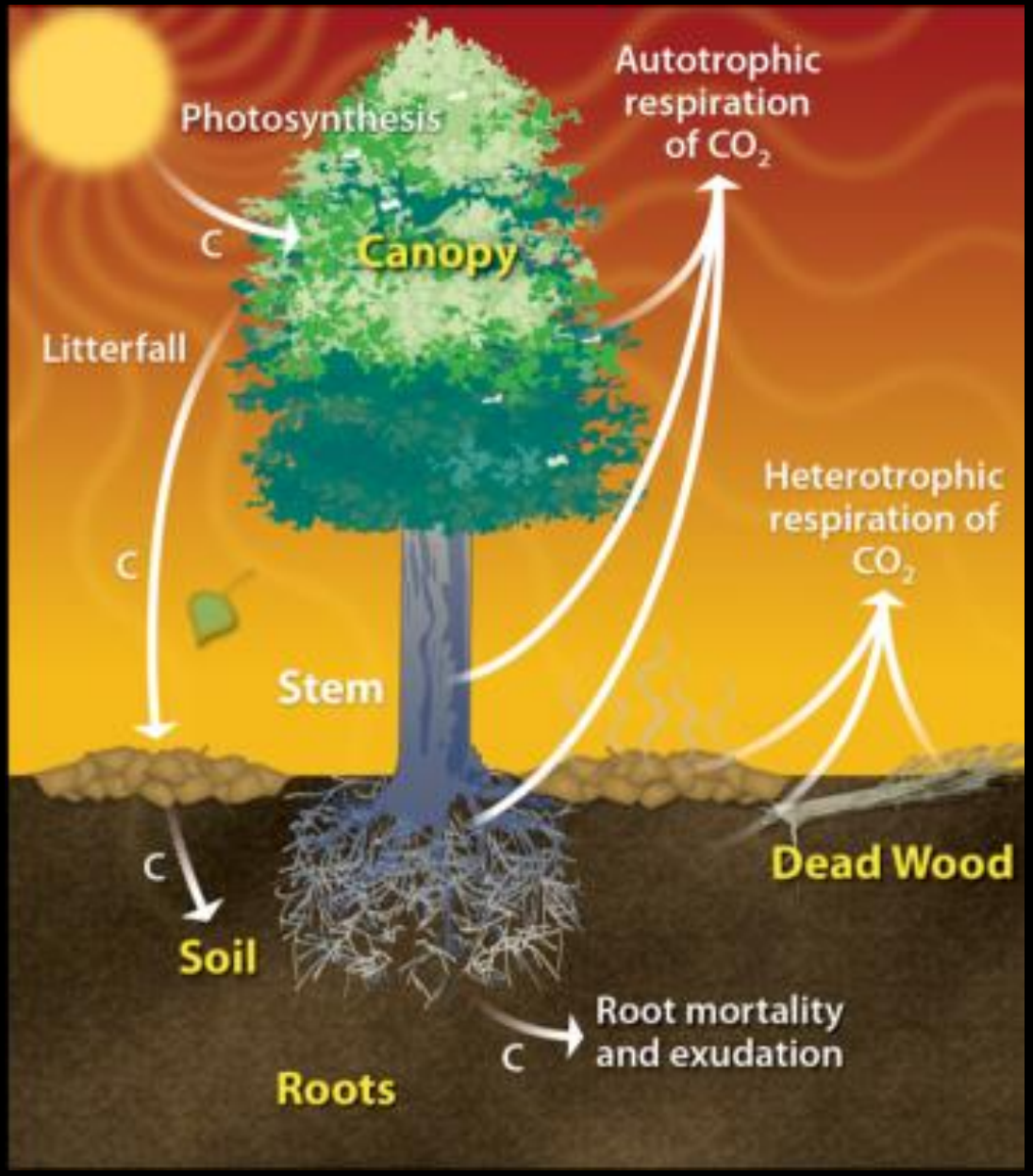
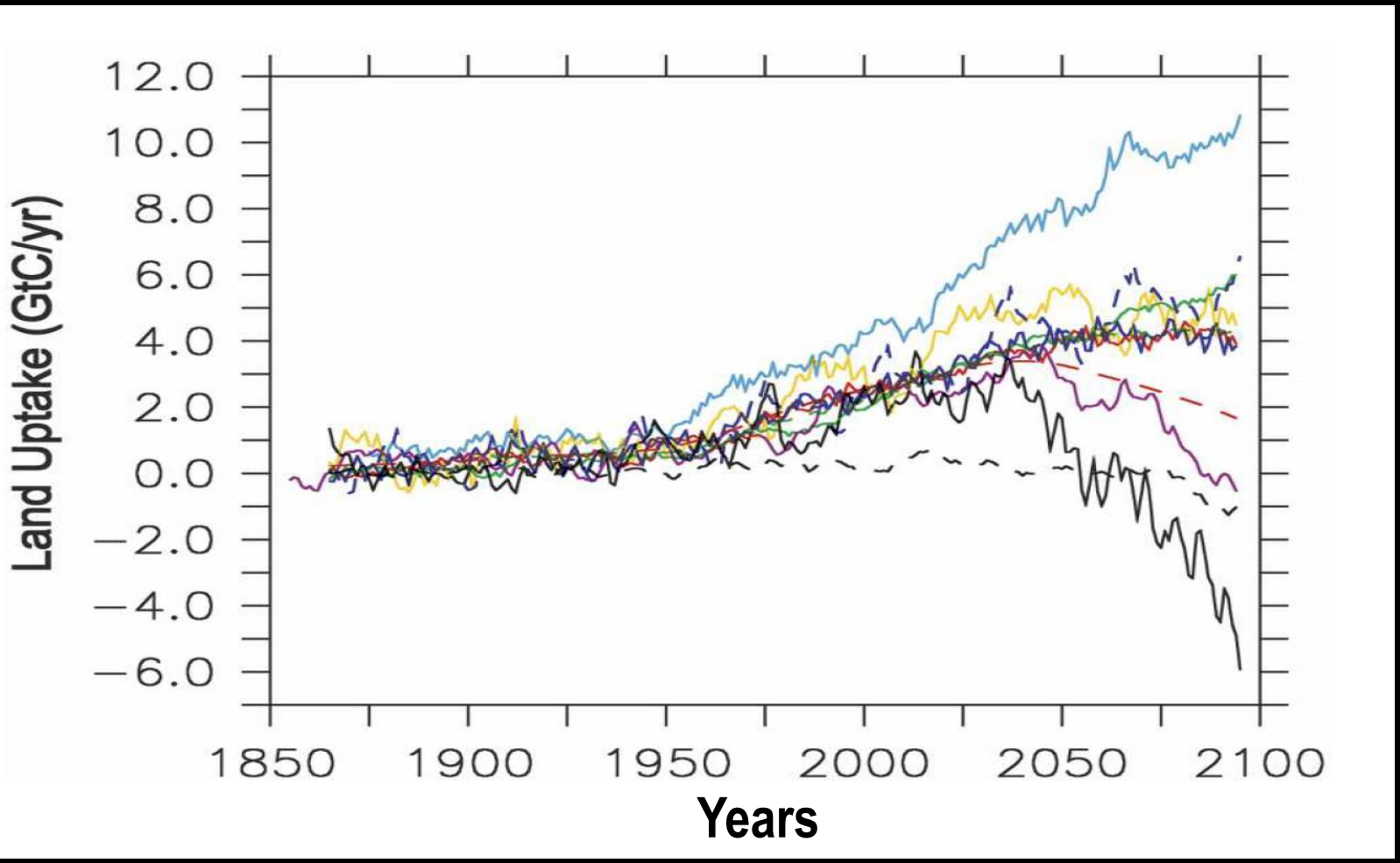
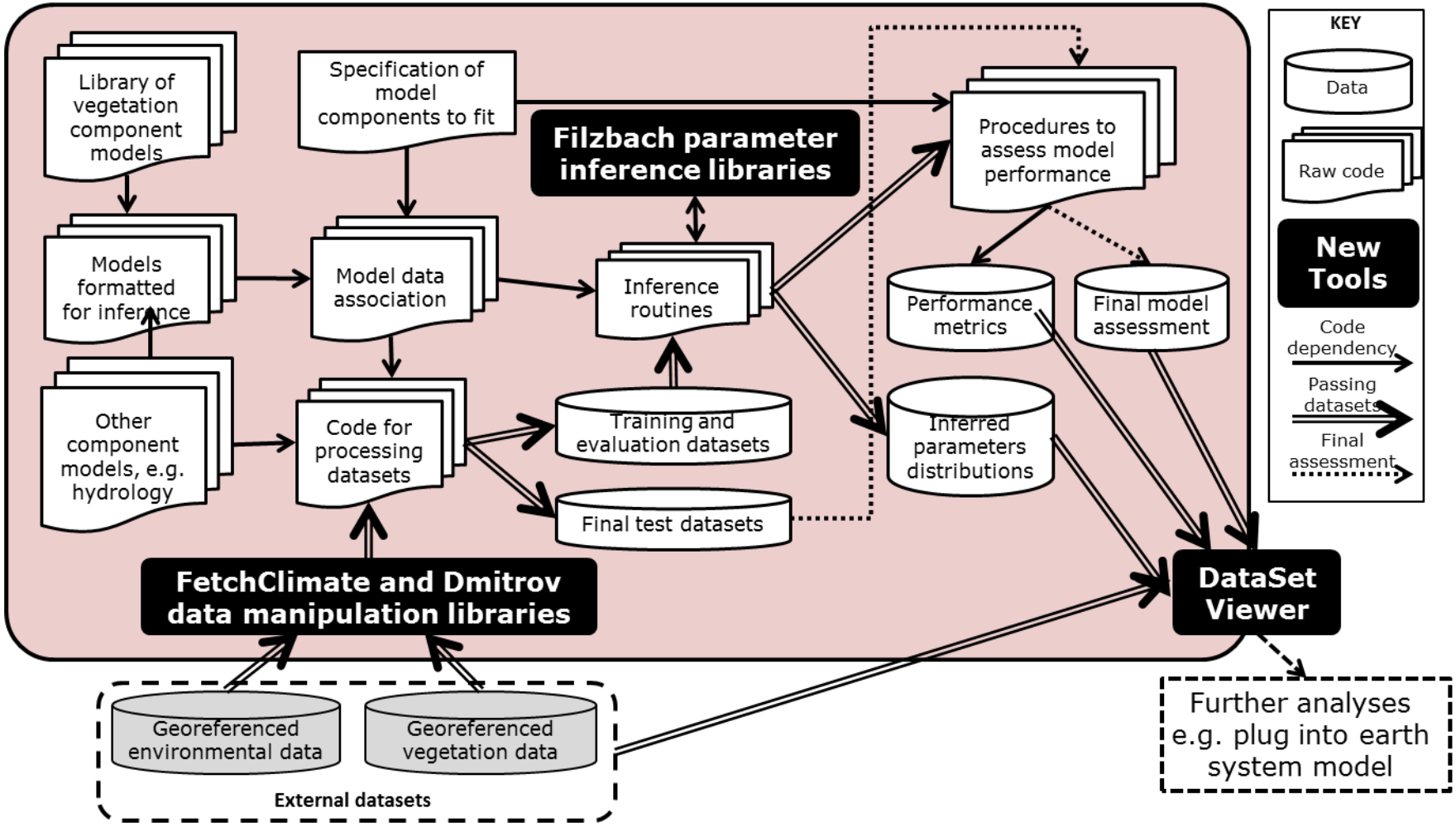
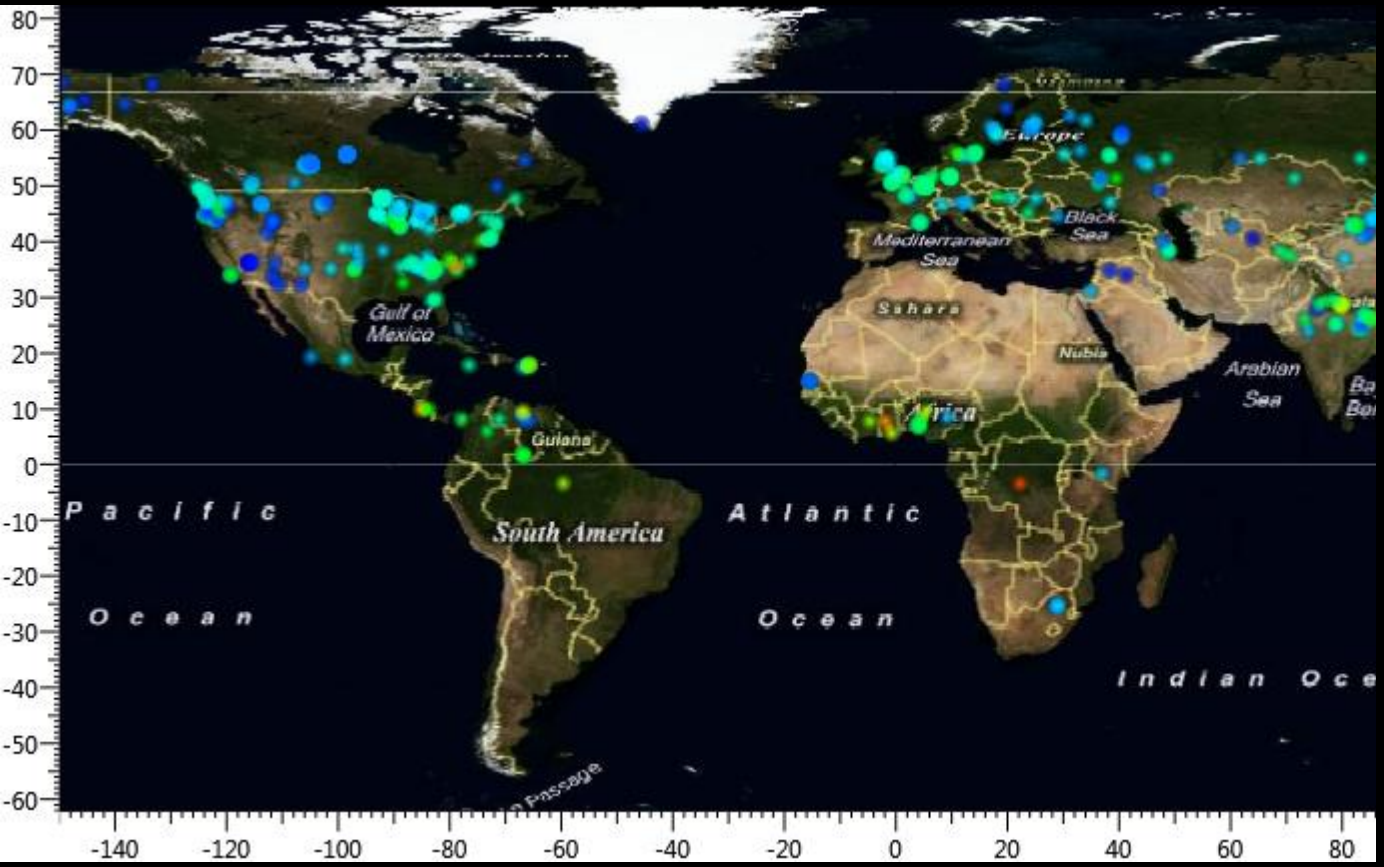

Atmosphere
597 + 165
0.2
Weathering
119.6
120
GPP
Respiration
2.6
Land sink
1.6
Land Use Change
70.6
70
22.2
20
6.4
Vegetation, Soil & Detritus
2300 + 101 -140
Fossil Fuels
3700 - 244
0.4
0.8
Rivers
Surface Ocean
900 + 18
50
39
Marine Biota
3
Weathering
0.2
90.2
101
1.6
11
Intermediate & Deep Ocean
37,100 + 100
0.2
Surface sediment
150
Reservoir sizes in GtC
Fluxes and Rates in GtC yr-1


Carbon in Atmosphere
Carbon in Ocean
Carbon on Land
Climate
e.g. temperature, winds
e.g. temperature, precipitation

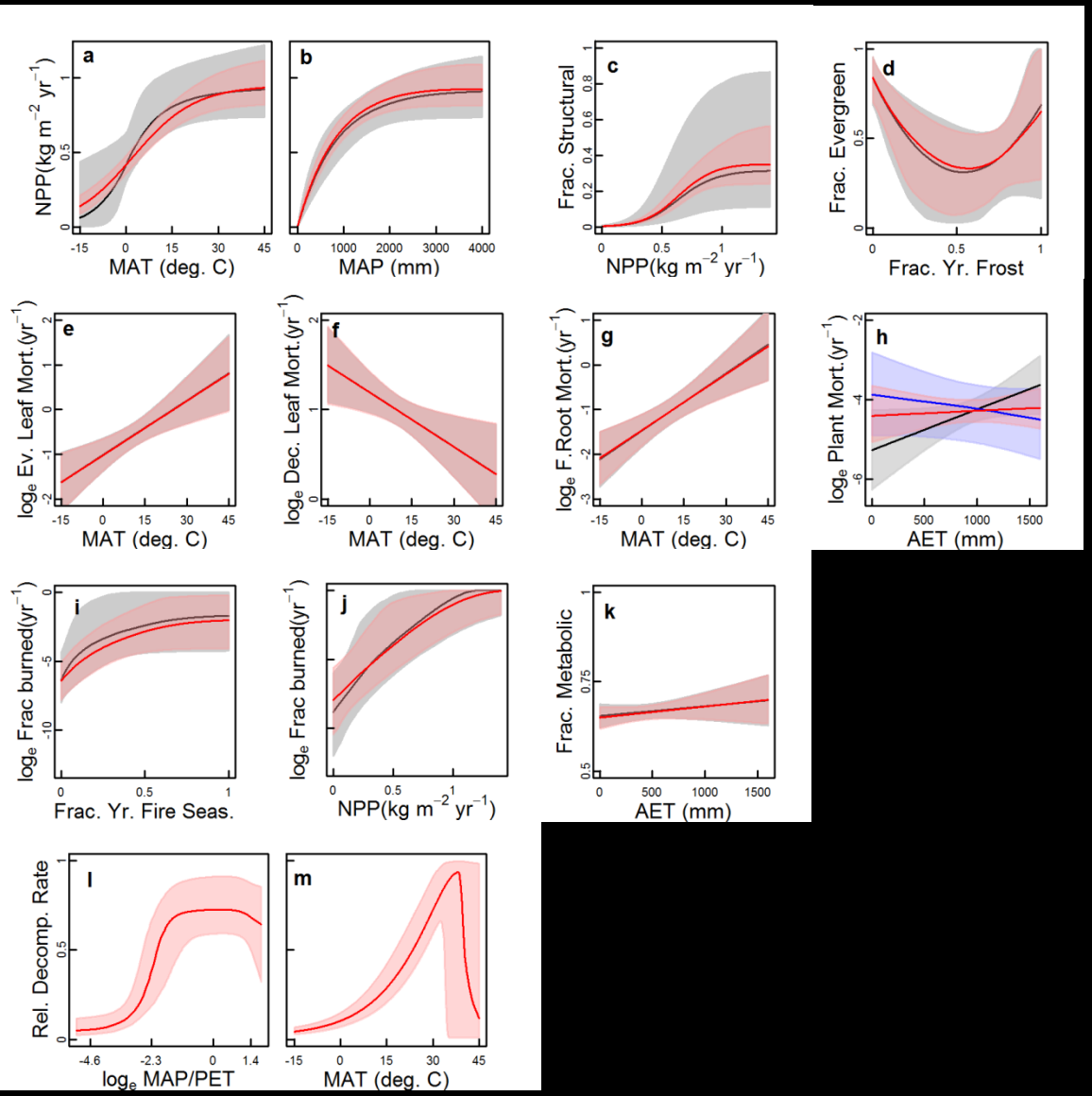

Photosynthesis
C
Canopy
Autotrophic respiration of CO_2
Litterfall
C
Heterotrophic respiration of CO_2
Stem
C
Soil
Dead Wood
Root mortality and exudation
C
Roots


Land Uptake (GtC/yr)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
−2.0
−4.0
−6.0
1850
1900
1950
2000
2050
2100
Years

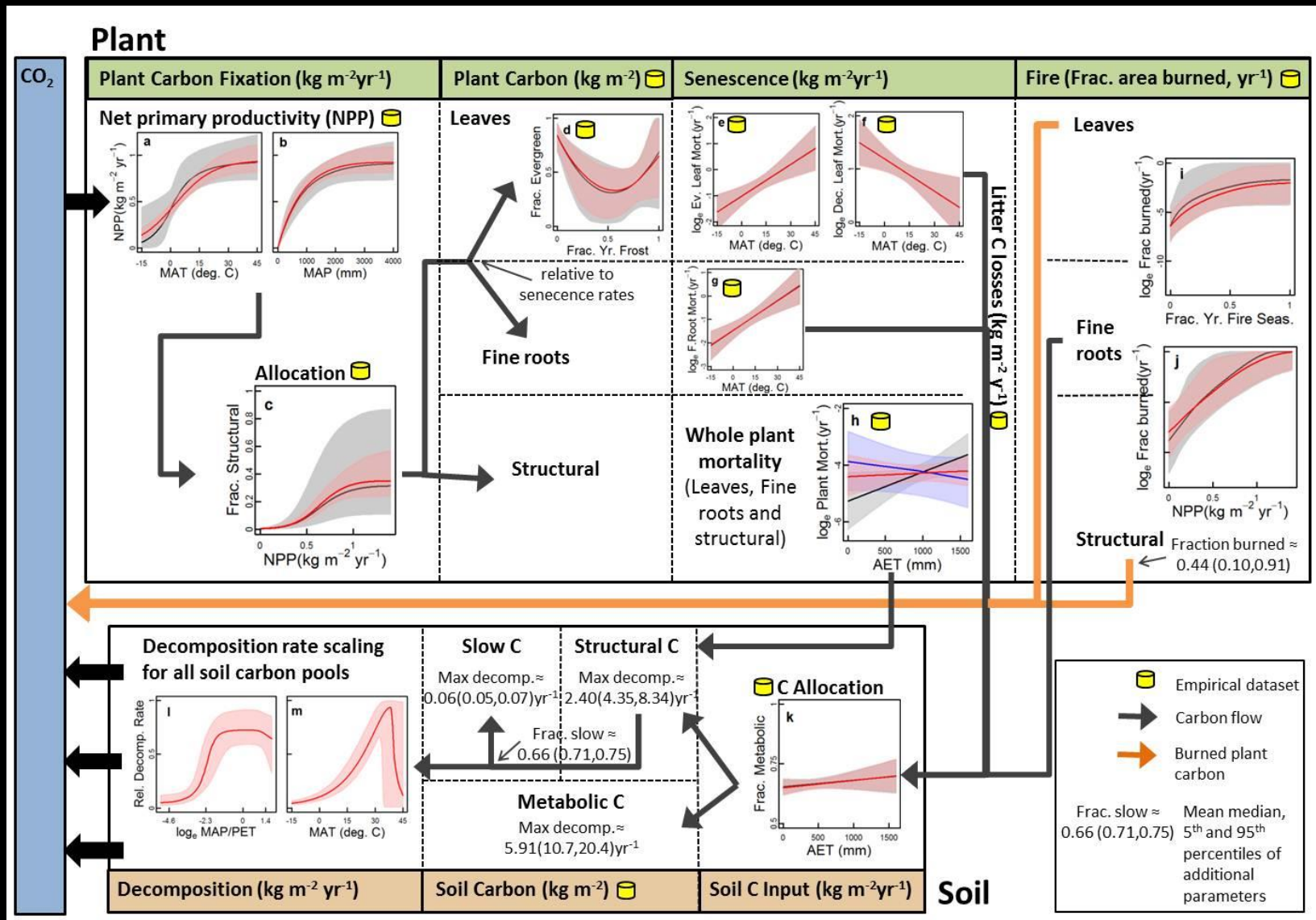

Library of vegetation component models
Specification of model components to fit
Filzbach parameter inference libraries
Procedures to assess model performance
Models formatted for inference
Model data association
Inference routines
Performance metrics
Final model assessment
Other component models, e.g. hydrology
Code for processing datasets
Training and evaluation datasets
Inferred parameters distributions
Final test datasets
FetchClimate and Dmitrov data manipulation libraries
DataSet Viewer
Georeferenced environmental data
Georeferenced vegetation data
External datasets
Further analyses e.g. plug into earth system model
KEY
Data
Raw code
New Tools
Code dependency
Passing datasets
Final assessment



Plant growth
Allocation
Plant Carbon
Phenology
Woody carbon
Leaf-fall
Root death
Plant death
Litter
Fire
Soil carbon



Plant growth
Allocation
Phenology
Leaf-fall
Root death
Plant death
Fire
Decomposition


Plant
CO2
Plant Carbon Fixation (kg m-2yr-1)
Plant Carbon (kg m-2)
Senescence (kg m-2yr-1)
Fire (Frac. area burned, yr-1)
Net primary productivity (NPP)
a
b
NPP(kg m-2 yr-1)
MAT (deg. C)
MAP (mm)
Leaves
d
Frac. Evergreen
Frac. Yr. Frost
relative to senecence rates
Fine roots
Structural
Allocation
c
Frac. Structural
NPP(kg m-2 yr-1)
e
loge Ev. Leaf Mort.(yr-1)
MAT (deg. C)
f
loge Dec. Leaf Mort.(yr-1)
MAT (deg. C)
g
loge F.Root Mort.(yr-1)
MAT (deg. C)
Litter C losses (kg m-2 yr-1)
Whole plant mortality (Leaves, Fine roots and structural)
h
loge Plant Mort.(yr-1)
AET (mm)
Leaves
i
loge Frac burned(yr-1)
Frac. Yr. Fire Seas.
Fine roots
j
loge Frac burned(yr-1)
NPP(kg m-2 yr-1)
Structural
Fraction burned ≈ 0.44 (0.10,0.91)
Decomposition rate scaling for all soil carbon pools
l
Rel. Decomp. Rate
loge MAP/PET
m
MAT (deg. C)
Slow C
Max decomp.≈ 0.06(0.05,0.07)yr-1
Structural C
Max decomp.≈ 2.40(4.35,8.34)yr-1
Frac. slow ≈ 0.66 (0.71,0.75)
Metabolic C
Max decomp.≈ 5.91(10.7,20.4)yr-1
C Allocation
k
Frac. Metabolic
AET (mm)
Empirical dataset
Carbon flow
Burned plant carbon
Frac. slow ≈ 0.66 (0.71,0.75)
Mean median, 5th and 95th percentiles of additional parameters
Decomposition (kg m-2 yr-1)
Soil Carbon (kg m-2)
Soil C Input (kg m-2yr-1)
Soil

$$\frac{dC_l}{dt} = G\left(1 - f_{max} f_s\right)\frac{\mu_l}{\mu_l + \mu_r} - \left(\mu_l + \mu_f + \mu_s\right)C_l \qquad (4a)$$

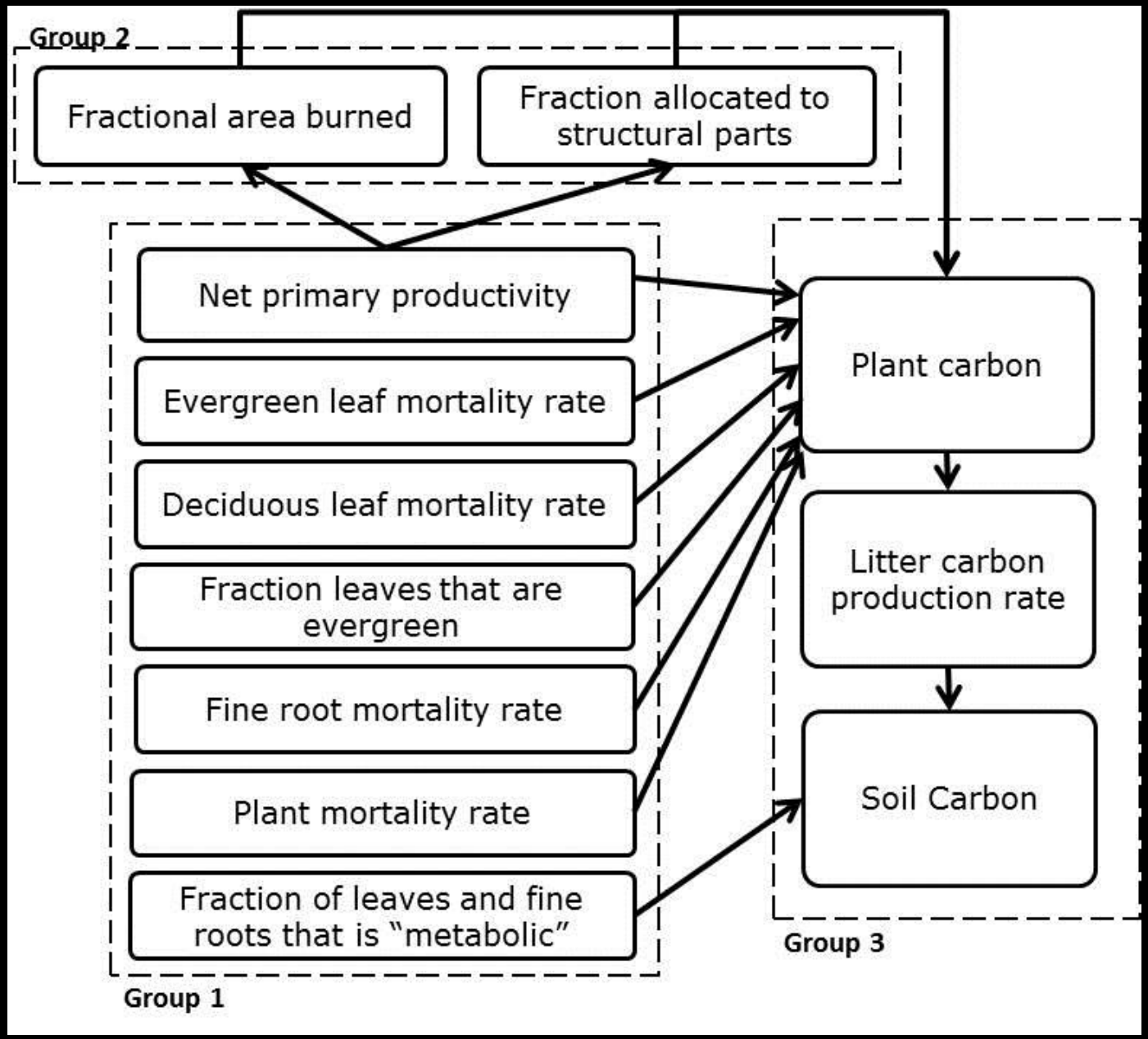
$$\frac{dC_r}{dt} = G\left(1 - f_{max} f_s\right)\frac{\mu_r}{\mu_l + \mu_r} - \left(\mu_r + \mu_f + \mu_s\right)C_r \qquad (4b)$$

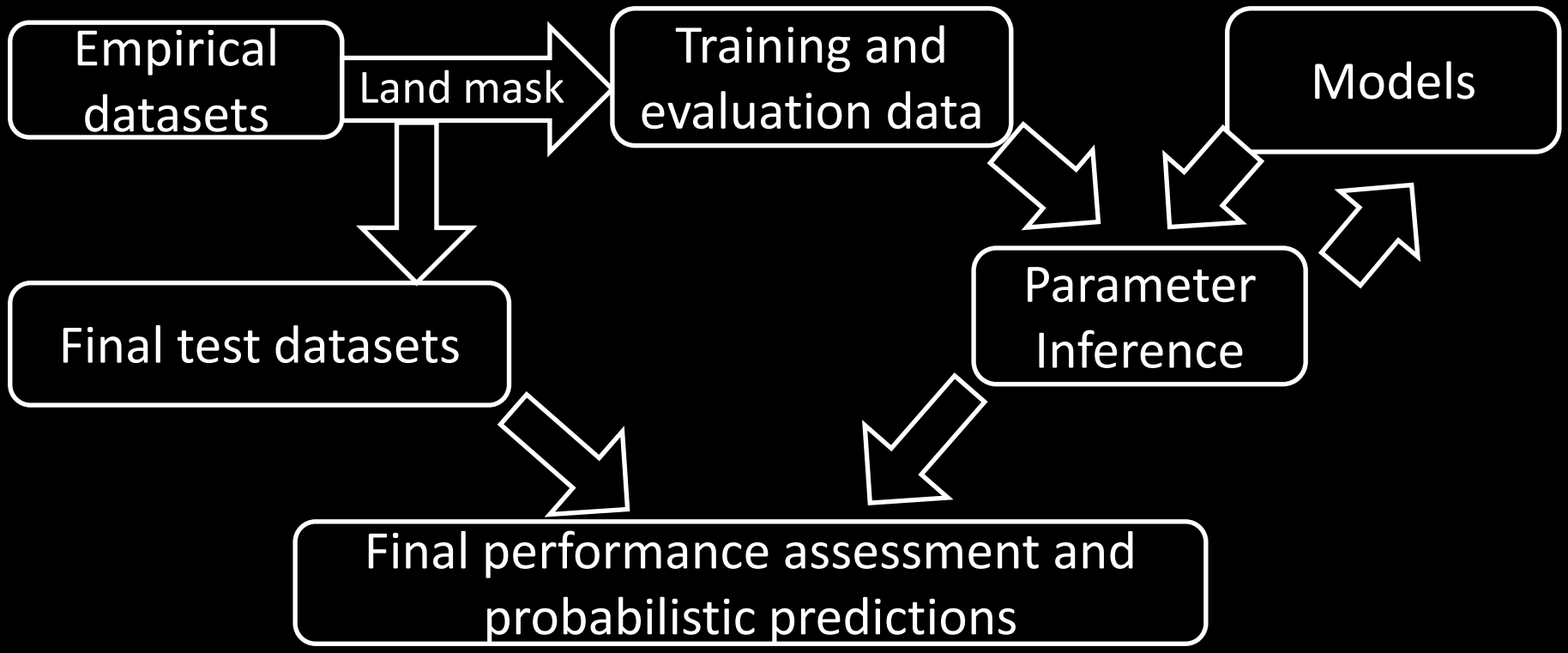
$$\frac{dC_s}{dt} = G f_{max} f_s - \left(\mu_s + S_f \mu_f\right)C_s \qquad (4c)$$

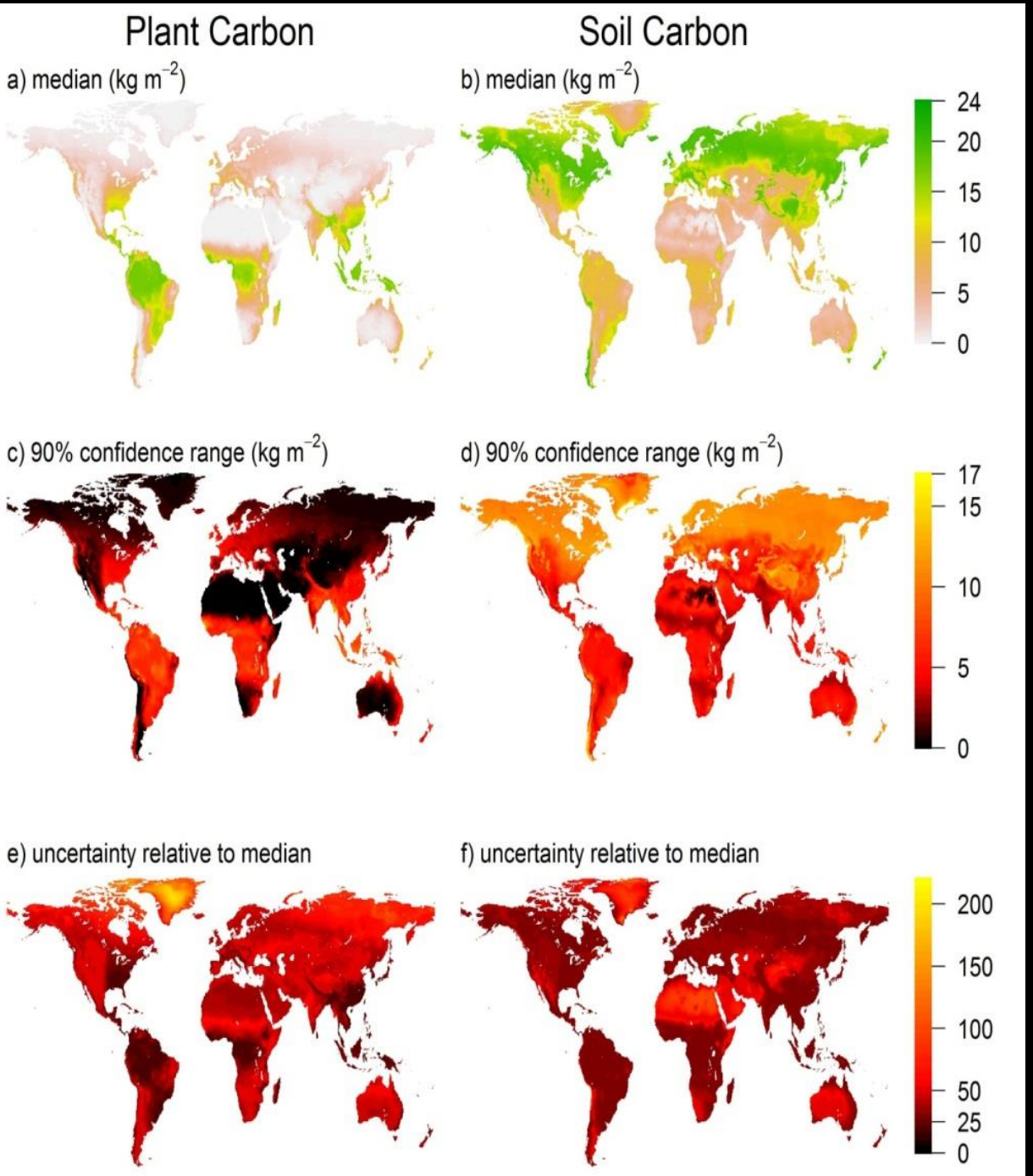
$$\frac{dC_m}{dt} = f_m\left(\left(\mu_l + \mu_s\right)C_l + \left(\mu_r + \mu_f + \mu_s\right)C_r\right) - k_m A C_m \qquad (4d)$$

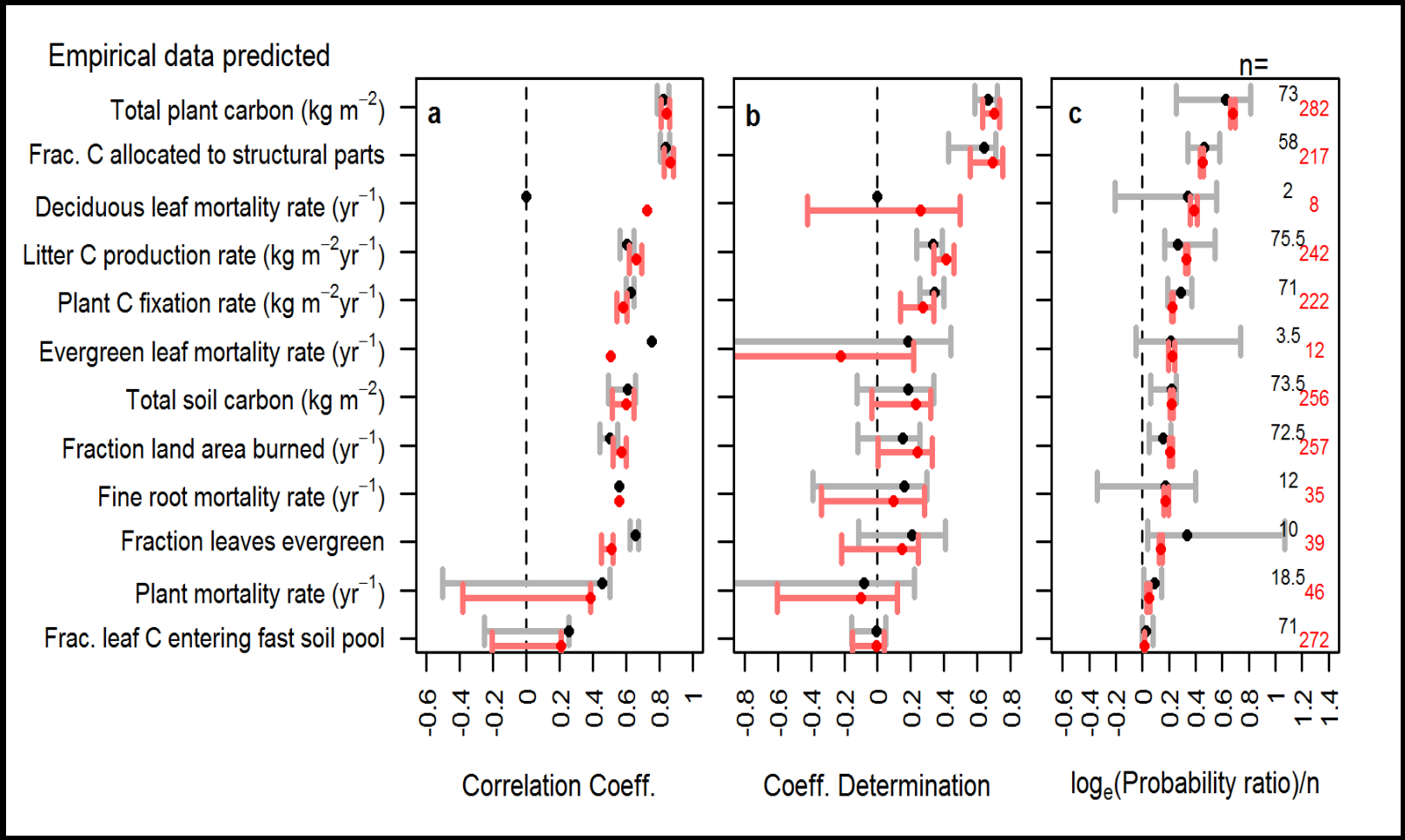
$$\frac{dC_a}{dt} = \left(1 - f_m\right)\left(\left(\mu_l + \mu_s\right)C_l + \left(\mu_r + \mu_f + \mu_s\right)C_r\right) + \mu_s C_s - k_a A C_a \qquad (4e)$$

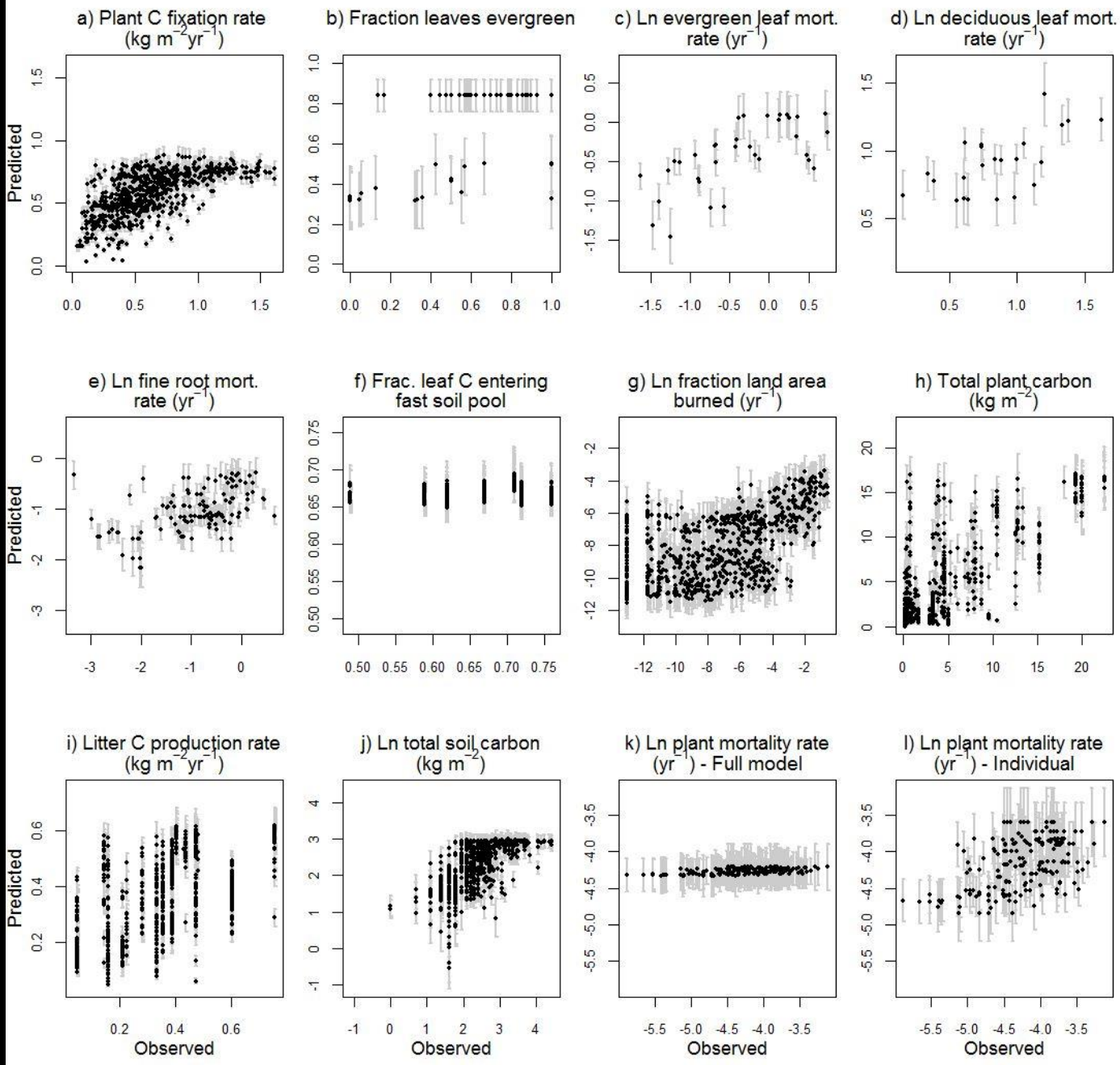
$$\frac{dC_b}{dt} = F_1 k_a A C_a - k_b A C_b \qquad (4f)$$

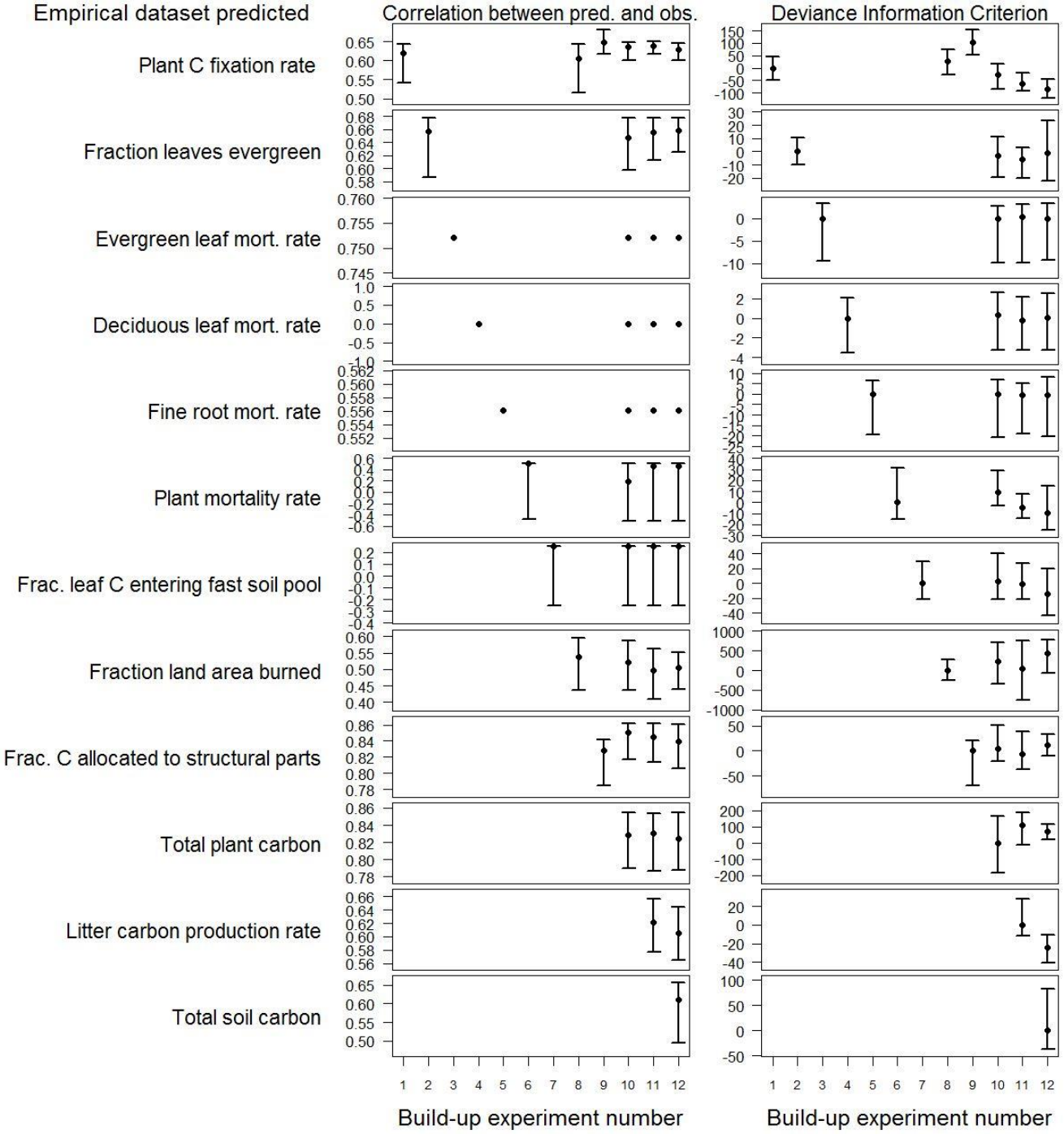

Group 2
Fractional area burned
Fraction allocated to structural parts
Net primary productivity
Evergreen leaf mortality rate
Deciduous leaf mortality rate
Fraction leaves that are evergreen
Fine root mortality rate
Plant mortality rate
Fraction of leaves and fine roots that is "metabolic"
Group 1
Plant carbon
Litter carbon production rate
Soil Carbon
Group 3

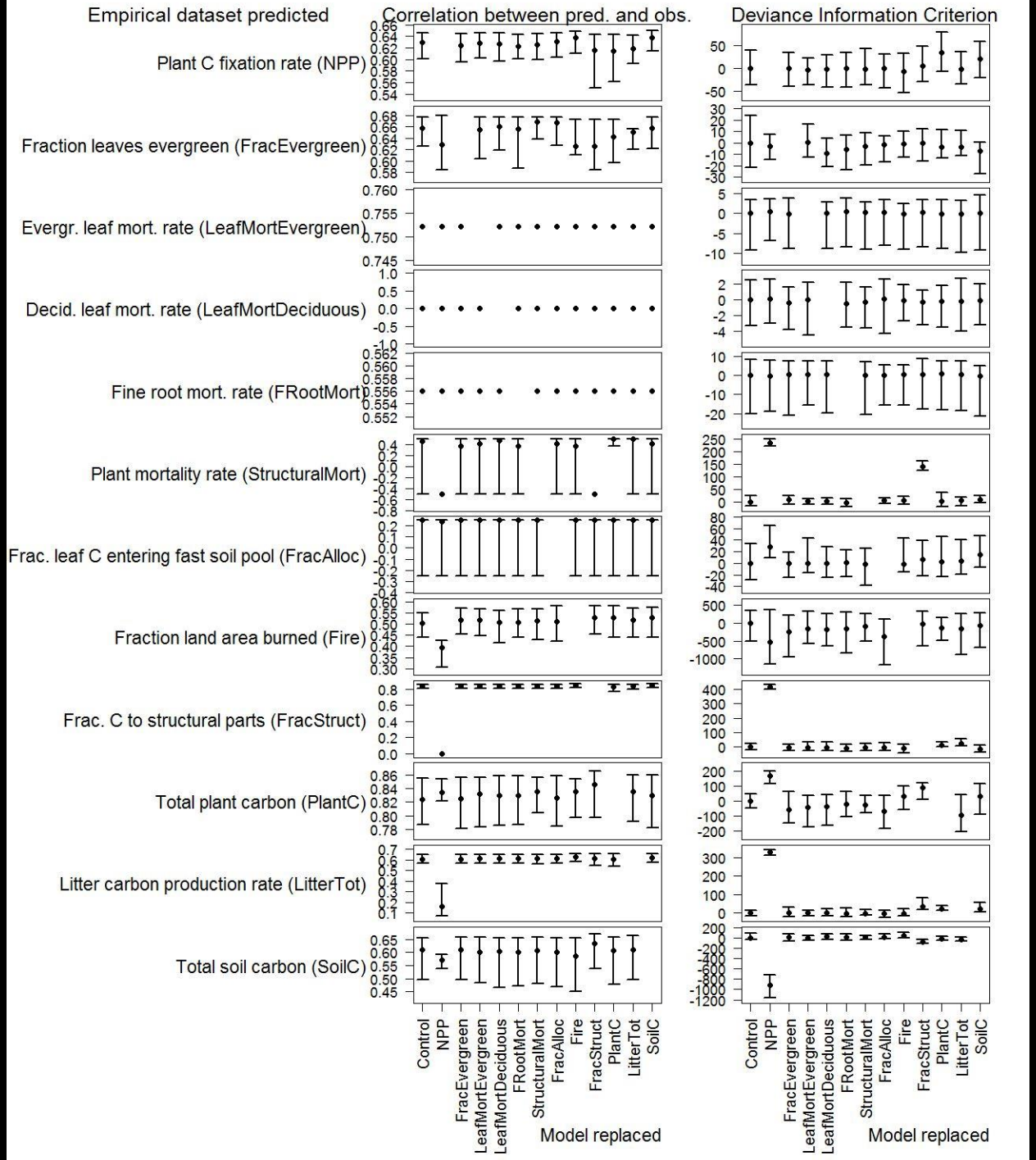

Empirical datasets
Land mask
Training and evaluation data
Models
Parameter Inference
Final test datasets
Final performance assessment and probabilistic predictions

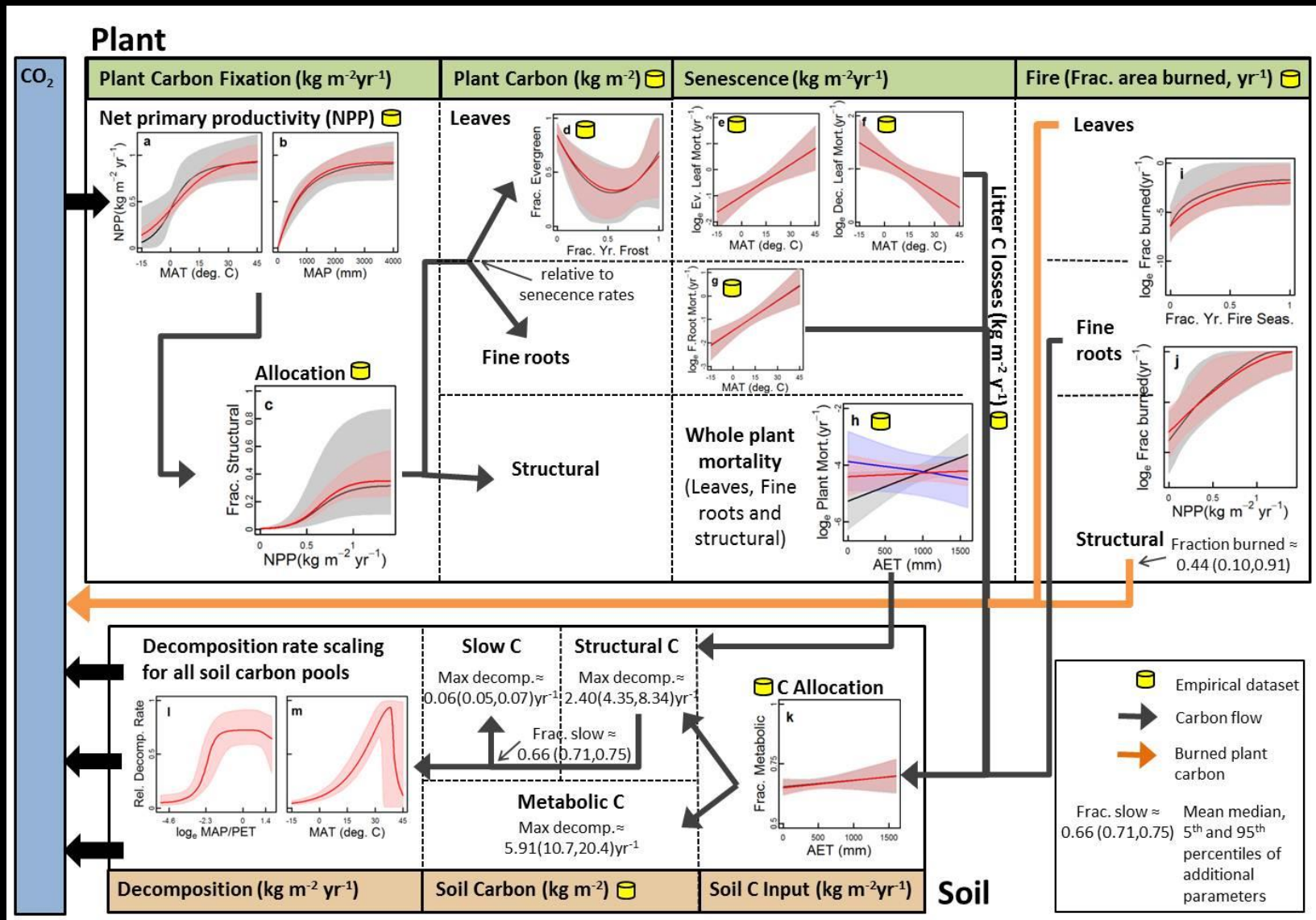

Plant Carbon
Soil Carbon
a) median (kg m^{-2})
b) median (kg m^{-2})
24
20
15
10
5
0
c) 90% confidence range (kg m^{-2})
d) 90% confidence range (kg m^{-2})
17
15
10
5
0
e) uncertainty relative to median
f) uncertainty relative to median
200
150
100
50
25
0


Empirical data predicted
Total plant carbon (kg m^{-2})
Frac. C allocated to structural parts
Deciduous leaf mortality rate (yr^{-1})
Litter C production rate (kg m^{-2}yr^{-1})
Plant C fixation rate (kg m^{-2}yr^{-1})
Evergreen leaf mortality rate (yr^{-1})
Total soil carbon (kg m^{-2})
Fraction land area burned (yr^{-1})
Fine root mortality rate (yr^{-1})
Fraction leaves evergreen
Plant mortality rate (yr^{-1})
Frac. leaf C entering fast soil pool
a
b
c
n=
73 282
58 217
2 8
75.5 242
71 222
3.5 12
73.5 256
72.5 257
12 35
10 39
18.5 46
71 272
-0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8
-0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4
Correlation Coeff.
Coeff. Determination
log$_e$(Probability ratio)/n


a) Plant C fixation rate (kg m^{-2}yr^{-1})
b) Fraction leaves evergreen
c) Ln evergreen leaf mort. rate (yr^{-1})
d) Ln deciduous leaf mort. rate (yr^{-1})
e) Ln fine root mort. rate (yr^{-1})
f) Frac. leaf C entering fast soil pool
g) Ln fraction land area burned (yr^{-1})
h) Total plant carbon (kg m^{-2})
i) Litter C production rate (kg m^{-2}yr^{-1})
j) Ln total soil carbon (kg m^{-2})
k) Ln plant mortality rate (yr^{-1}) - Full model
l) Ln plant mortality rate (yr^{-1}) - Individual
Predicted
Observed


Empirical dataset predicted
Correlation between pred. and obs.
Deviance Information Criterion
Plant C fixation rate
Fraction leaves evergreen
Evergreen leaf mort. rate
Deciduous leaf mort. rate
Fine root mort. rate
Plant mortality rate
Frac. leaf C entering fast soil pool
Fraction land area burned
Frac. C allocated to structural parts
Total plant carbon
Litter carbon production rate
Total soil carbon
1 2 3 4 5 6 7 8 9 10 11 12
Build-up experiment number
Build-up experiment number


Empirical dataset predicted
Correlation between pred. and obs.
Deviance Information Criterion
Plant C fixation rate (NPP)
Fraction leaves evergreen (FracEvergreen)
Evergr. leaf mort. rate (LeafMortEvergreen)
Decid. leaf mort. rate (LeafMortDeciduous)
Fine root mort. rate (FRootMort)
Plant mortality rate (StructuralMort)
Frac. leaf C entering fast soil pool (FracAlloc)
Fraction land area burned (Fire)
Frac. C to structural parts (FracStruct)
Total plant carbon (PlantC)
Litter carbon production rate (LitterTot)
Total soil carbon (SoilC)
Control
NPP
FracEvergreen
LeafMortEvergreen
LeafMortDeciduous
FRootMort
StructuralMort
FracAlloc
Fire
FracStruct
PlantC
LitterTot
SoilC
Model replaced
Model replaced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MAP (mm)
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relative to senecence rates
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loge F.Root Mort.(yr-1)
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Litter C losses (kg m-2 yr-1)
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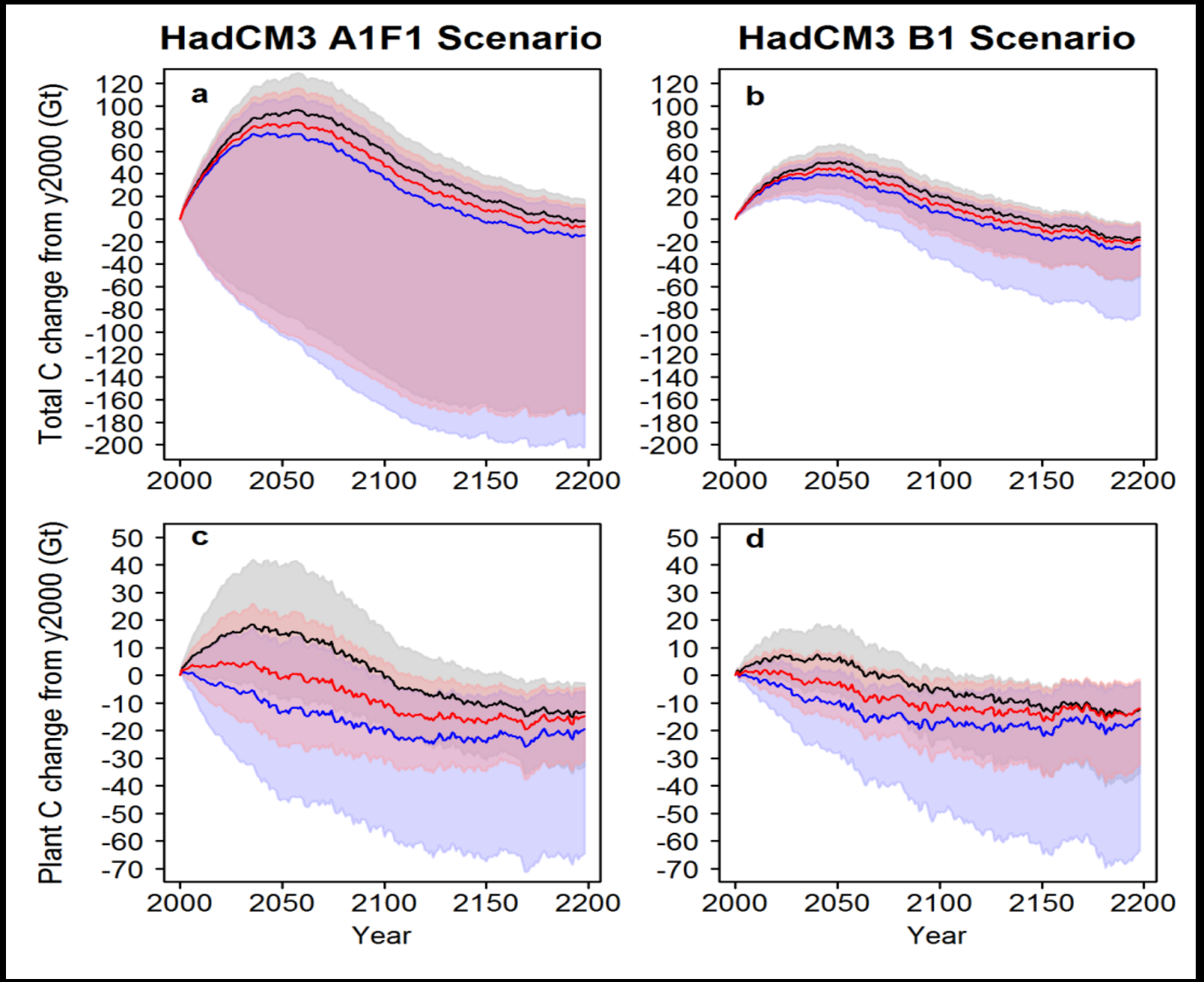
HadCM3 A1F1 Scenario
HadCM3 B1 Scenario
a
b
c
d
Total C change from y2000 (Gt)
Plant C change from y2000 (Gt)
Year
Year
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
2000
2050
2100
2150
2200