Lawrence Berkeley National Laboratory

ESD
EARTH SCIENCES DIVISION

Progress in developing CLM4-BeTR: a tool for incorporating and evaluating different formulations of below ground biogeochemistry

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LMWG, NCAR, Boulder, CO

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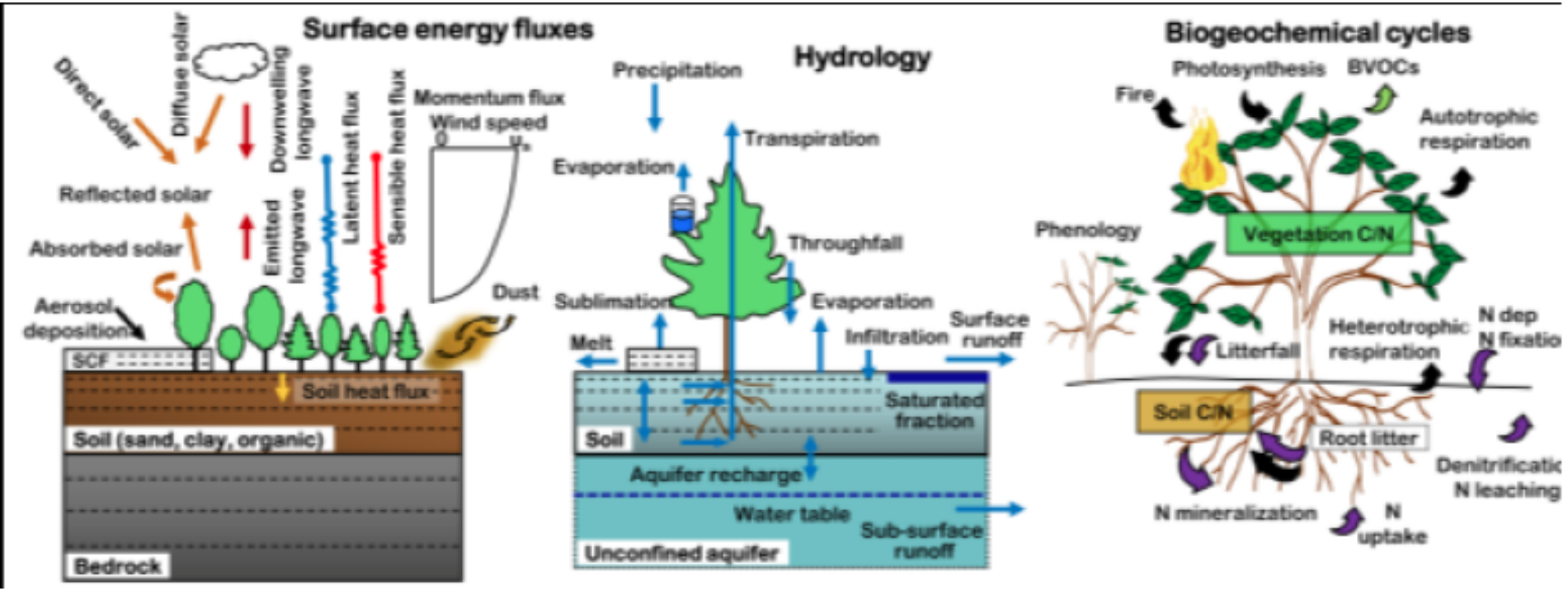
Biogeochemical Transport & Reaction in CLM4

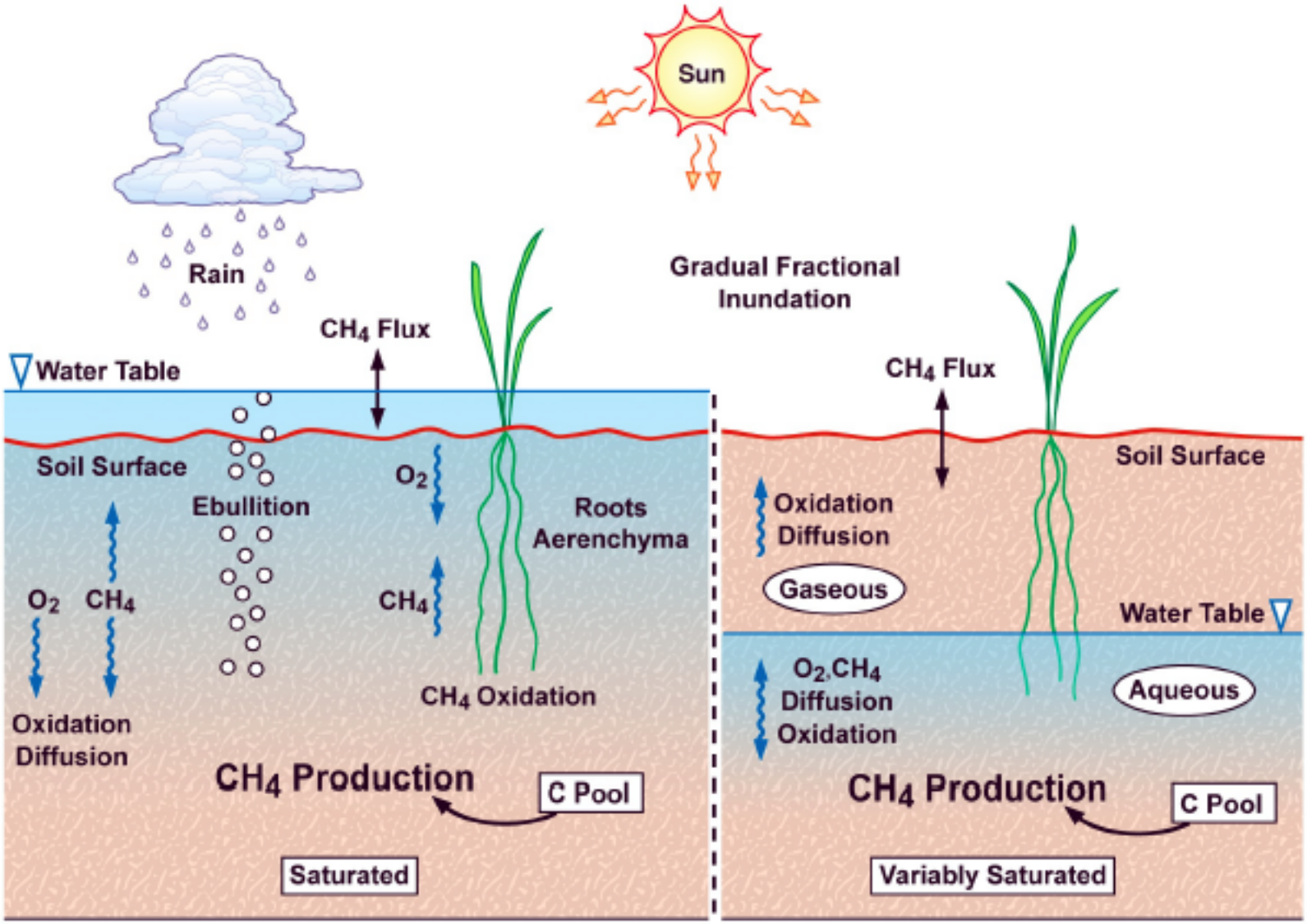
Why BeTR

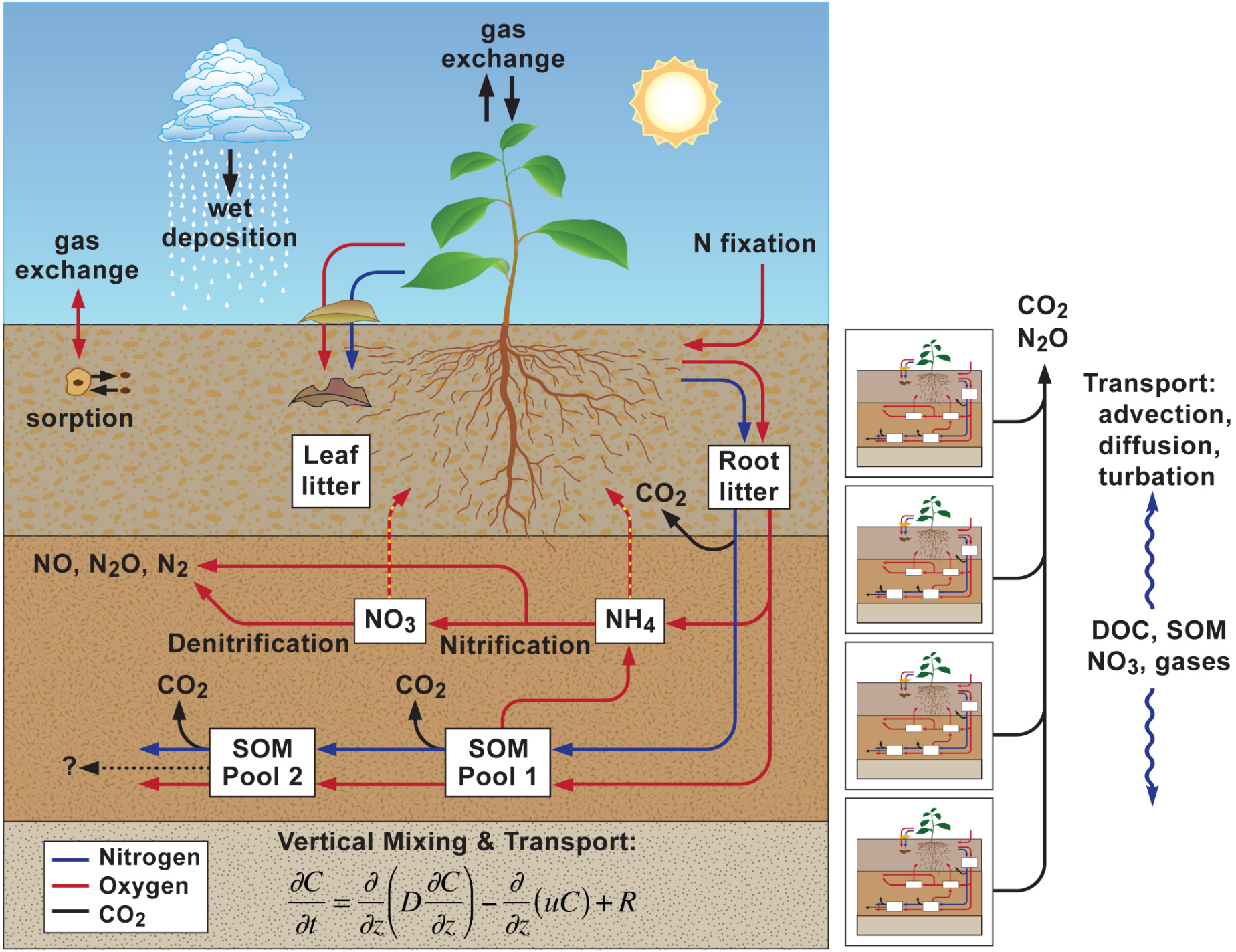


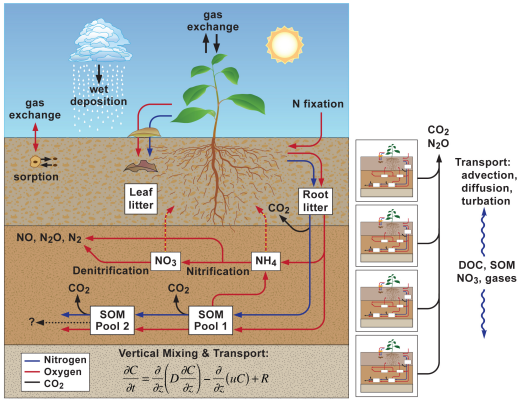
Layered | Layered | Bucket

Lawrence et al, 2010

Layered Methane Model

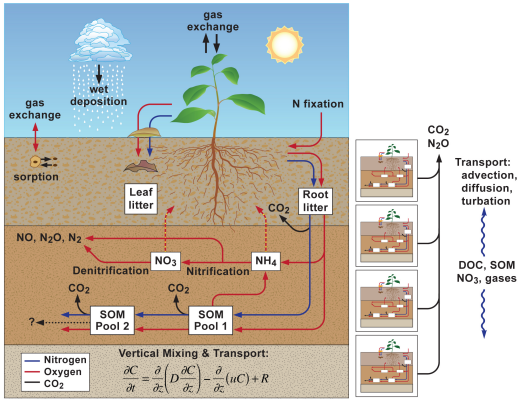



gas exchange
wet deposition
gas exchange
N fixation
sorption
Leaf litter
Root litter
CO_2
NO, N_2O, N_2
NO_3
NH_4
Denitrification
Nitrification
CO_2
CO_2
SOM Pool 2
SOM Pool 1
?
Nitrogen
Oxygen
CO_2
Vertical Mixing & Transport:
$\frac{\partial C}{\partial t} = \frac{\partial}{\partial z}\left(D\frac{\partial C}{\partial z}\right) - \frac{\partial}{\partial z}(uC) + R$
CO_2
N_2O
Transport:
advection,
diffusion,
turbation
DOC, SOM
NO_3, gases



$$\frac{\partial C_s}{\partial t} + \frac{\partial \theta C_w}{\partial t} + \frac{\partial \varepsilon C_g}{\partial t} = \frac{\partial}{\partial z}\left(D_s \frac{\partial C_s}{\partial t}\right) + \frac{\partial}{\partial z}\left(\theta D_w \frac{\partial C_w}{\partial z}\right) + \frac{\partial}{\partial z}\left(\varepsilon D_g \frac{\partial C_g}{\partial z}\right)$$

$$- \frac{\partial u_w C_w}{\partial z} - \frac{\partial u_g C_g}{\partial z} + R$$



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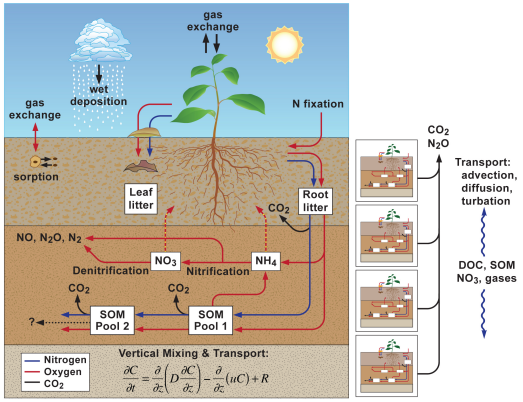
s: solid phase

g: gas phase

w: aqueous phase



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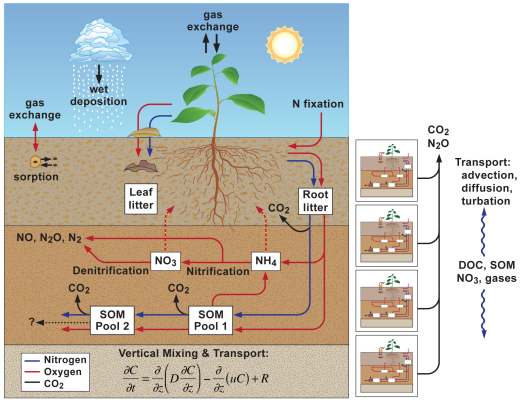
Universal transport of different chemical tracers



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Flexible biogeochemistry:
Soil-BGC .or. Soil CENTURY

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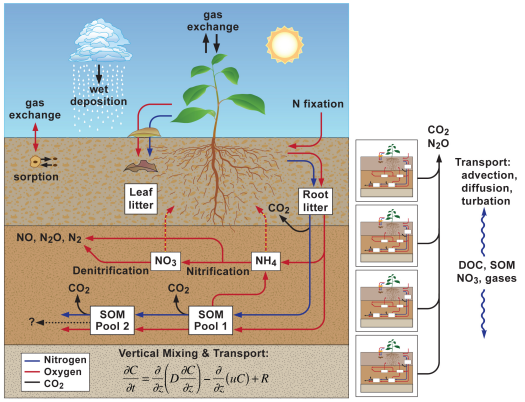

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Flexible biogeochemistry: Soil-BGC .or. Soil CENTURY

Universal transport of different chemical tracers

Simulate direct observables, e.g. soil surface flux, soil gas compositions and etc.

Tracers in the list

- CO_2X: $CO_2(g)$, $CO_2(aq)$, HCO_3^-, CO_3^{2-}
- NO_3X: $HNO_3(aq)$, NO_3^-
- NH_3X: $NH_3(g)$,$NH_3(aq)$, NH_4^+, NH_4^+(sorbed),
- O_2, Ar, CH_4, NO, N_2O, N_2

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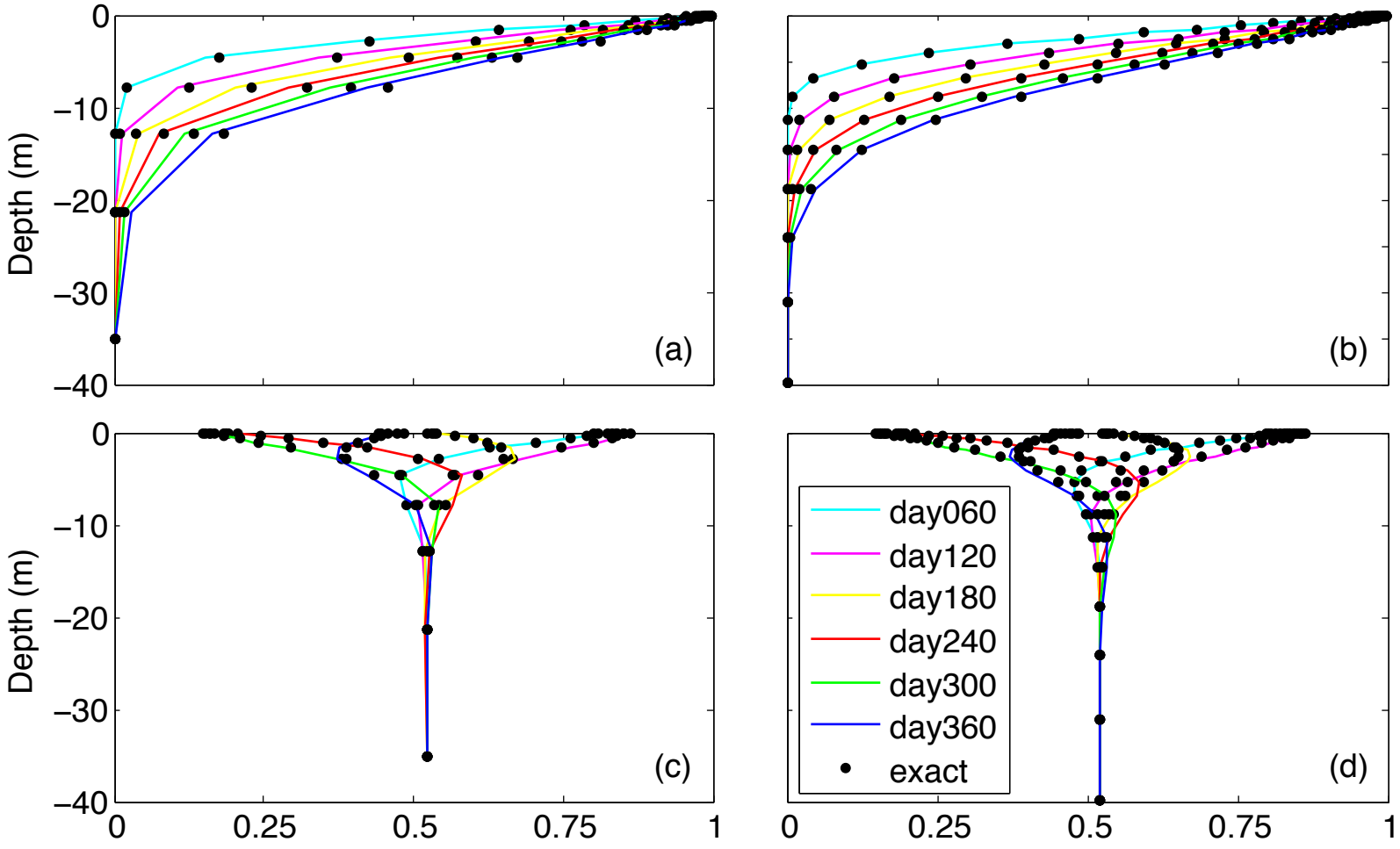
- HDO(g, l, i), $H_2{}^{18}O$(g, l, i), $H_2{}^{17}O$(g, l, i)
- $^{13}CO_2X$, $^{14}CO_2X$, $C^{18}O^{16}OX$,$C^{17}O^{16}OX$, and etc.

Flux Diagnostics

- Surface diffusive exchange
- Arenchyma/parenchyma flux
- Ebullition
- Surface runoff loss (potentially can be two-way)
- Subsurface runoff loss
- Subsurface leaching
- Root-soil exchange
- Freeze-thaw flux
- Chemical net production

Test of transport core



Expose the structural uncertainty

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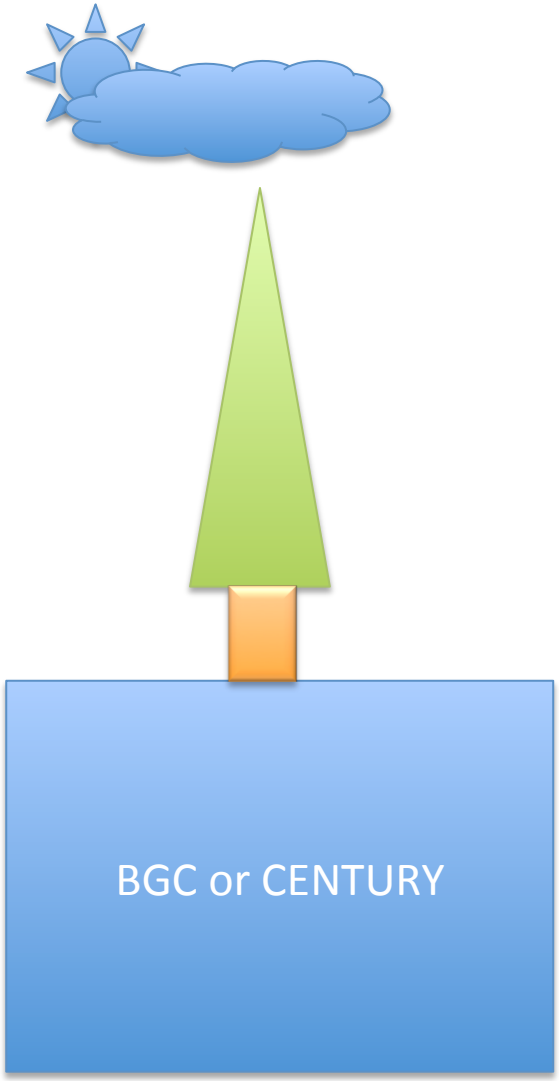

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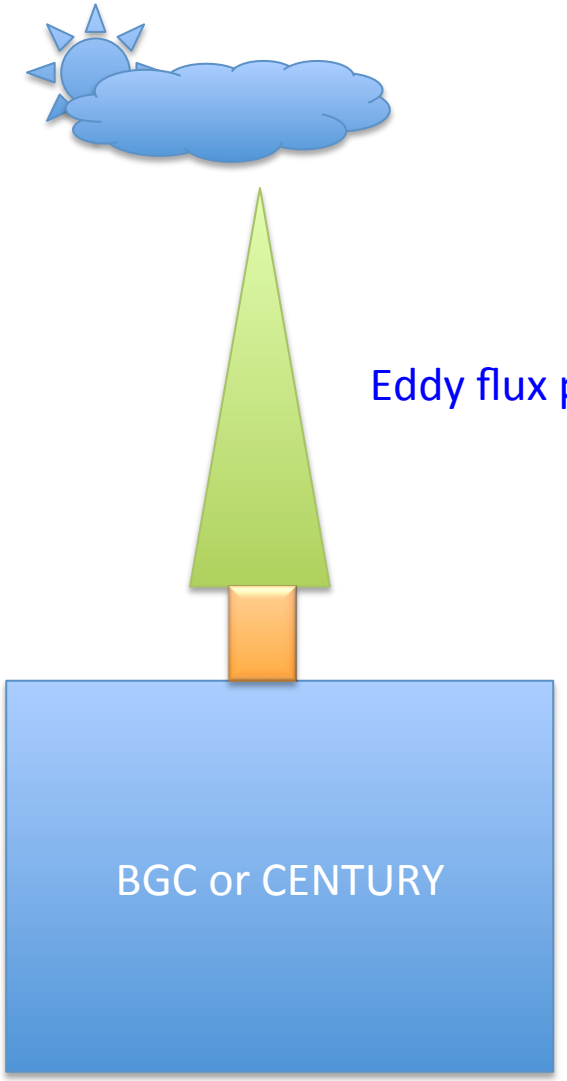

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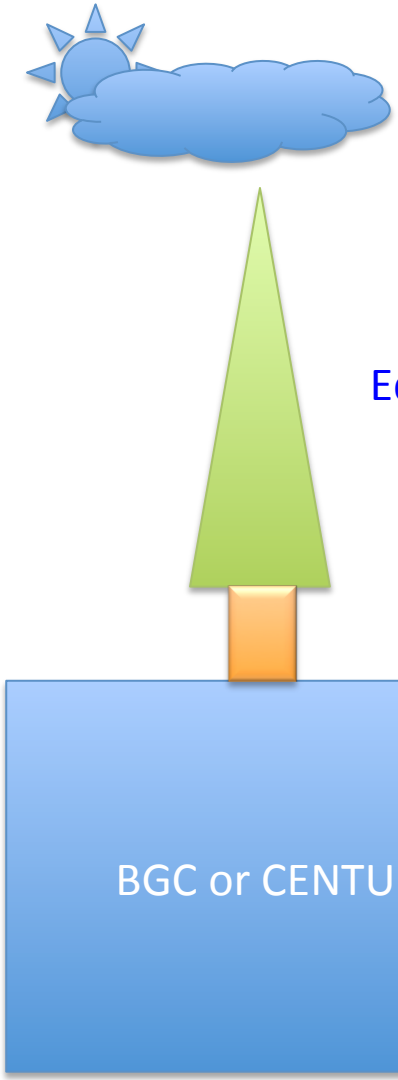
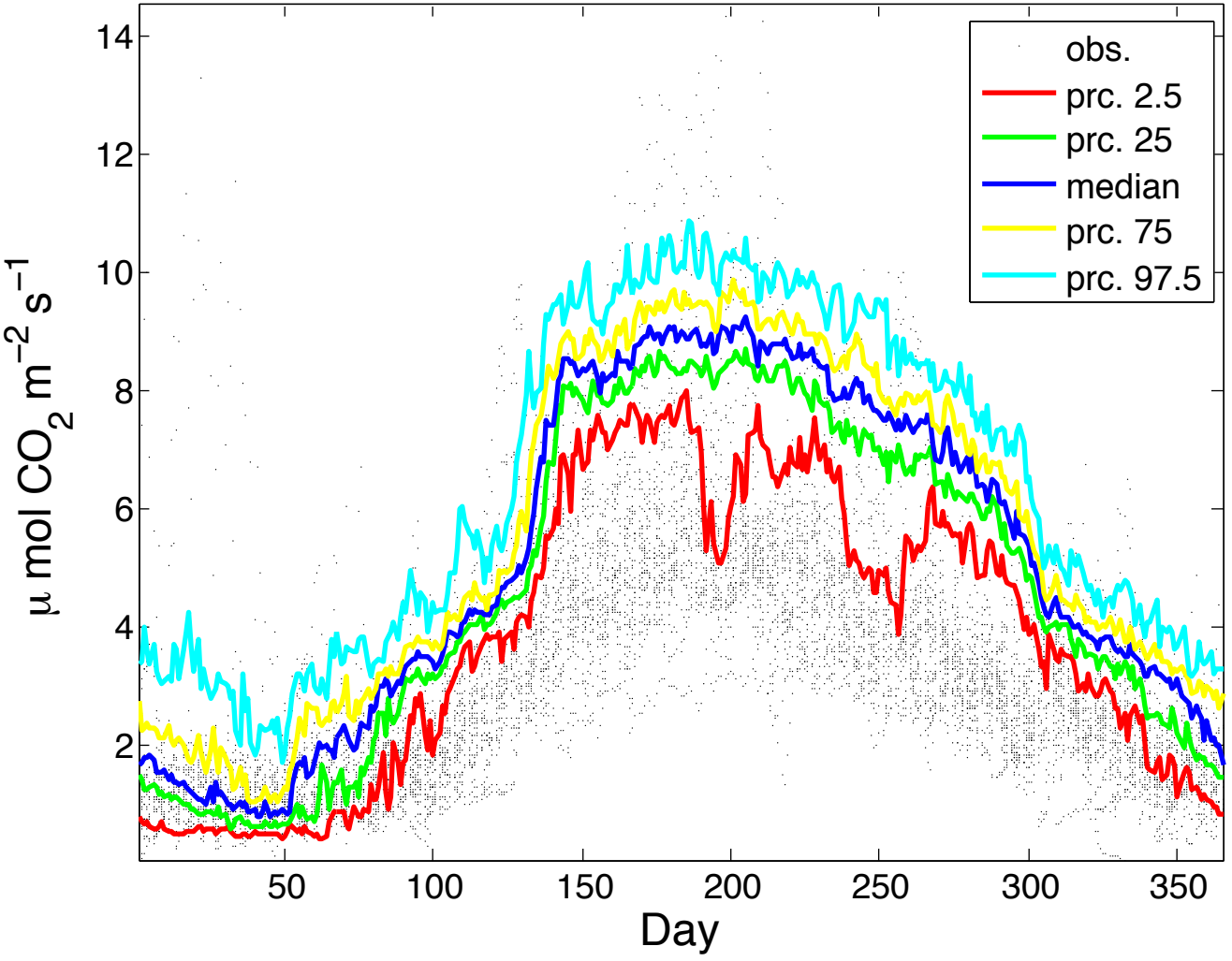


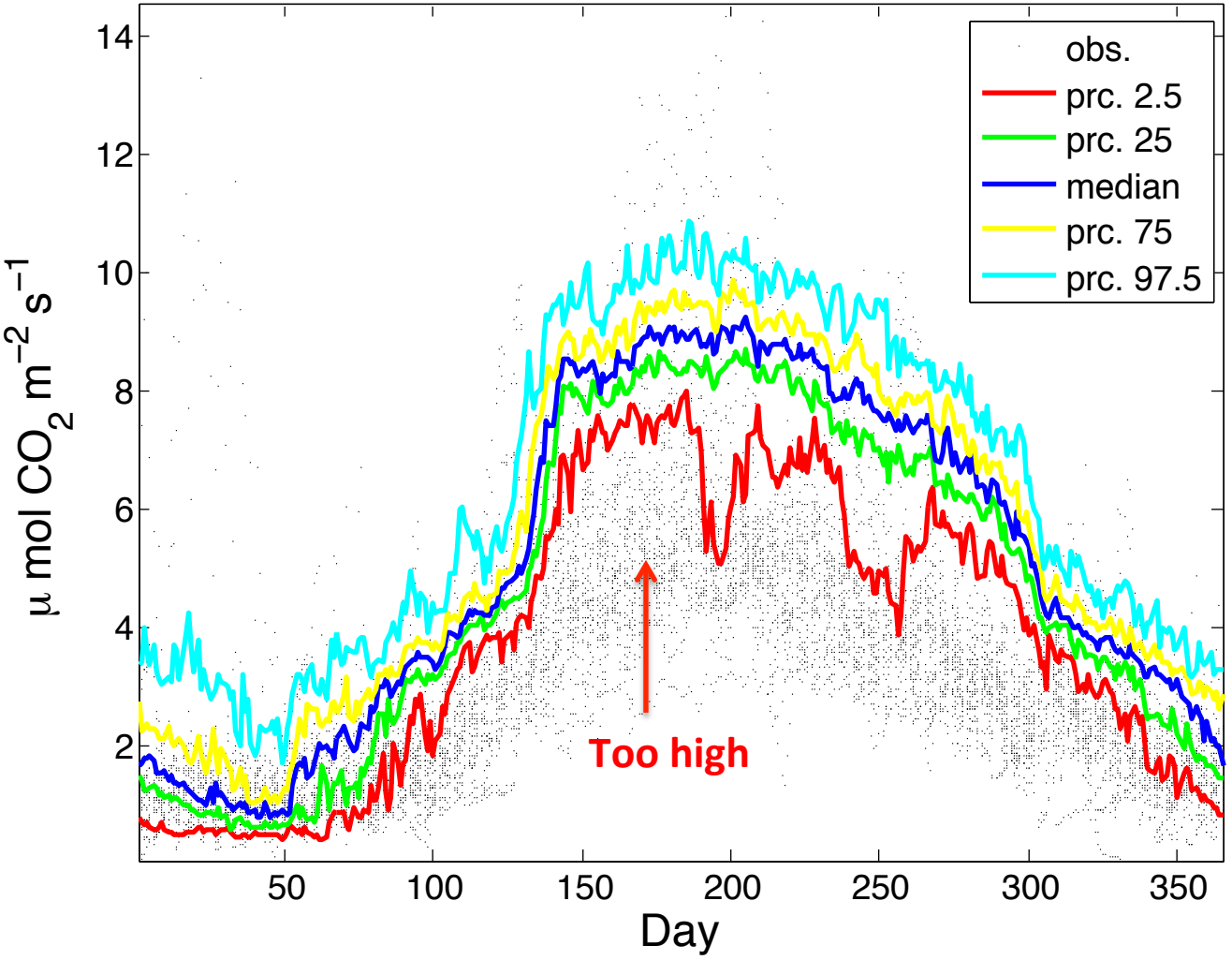
Below ground gas fluxes → gas concentrations

Below ground respiration → CO_2 fraction

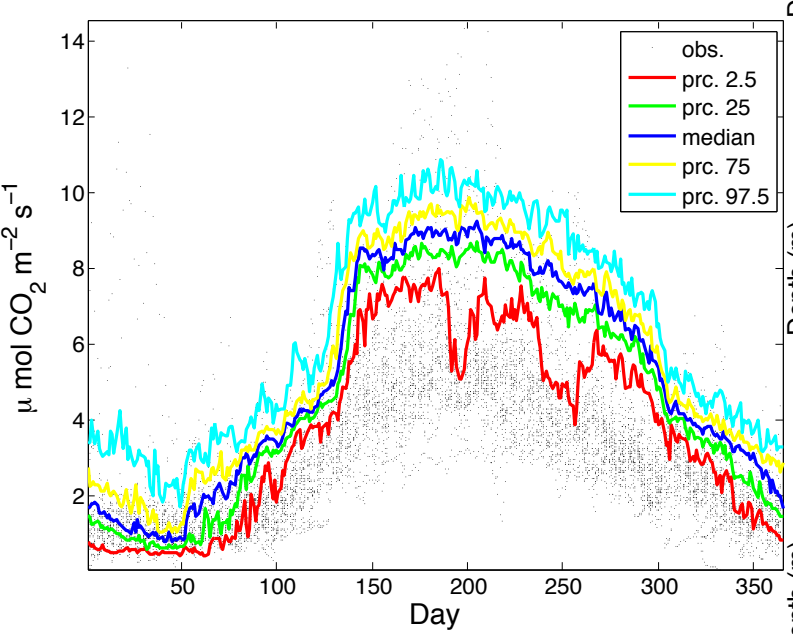
Ecosystem respiration: Veg-BGC & Soil-CENTURY



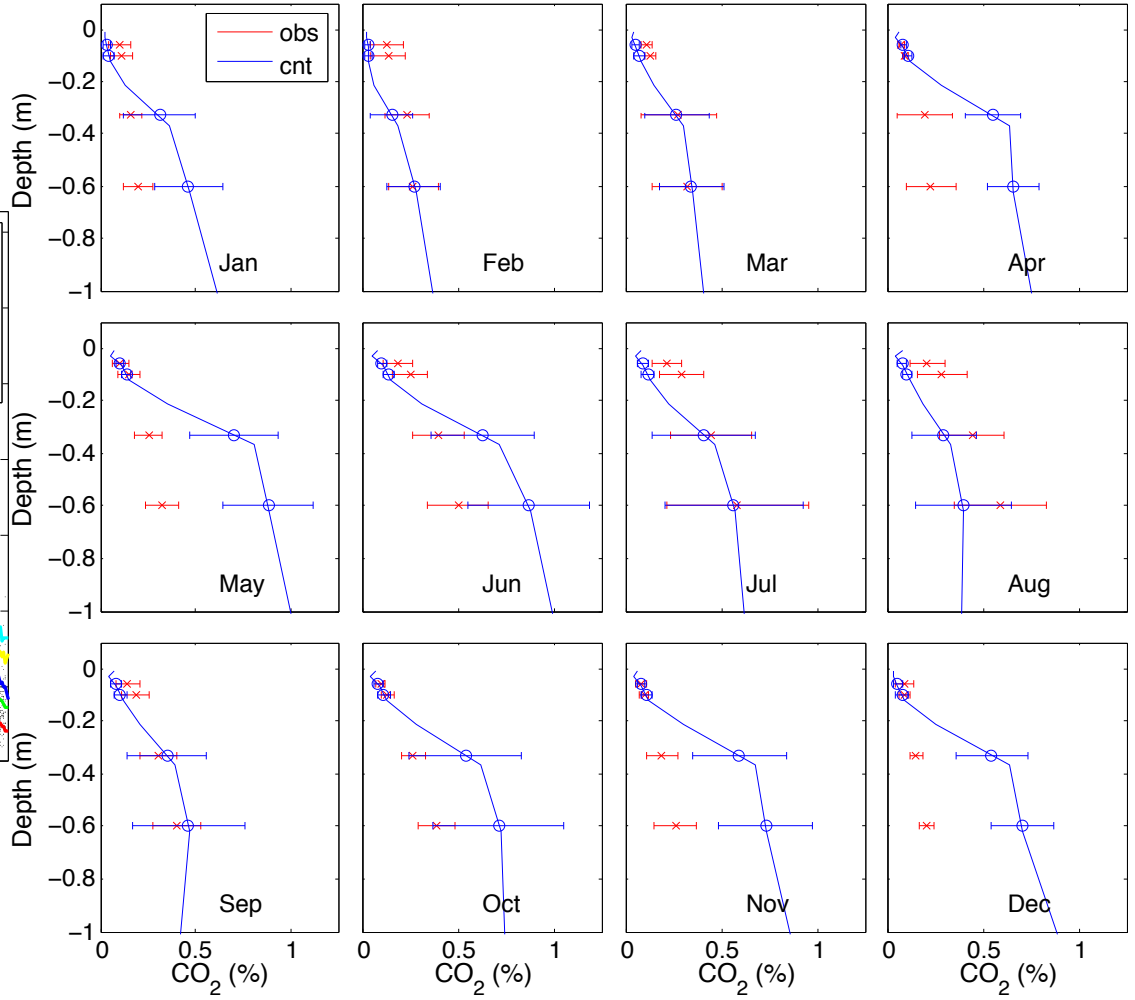
Ecosystem respiration: Veg-BGC & Soil-CENTURY



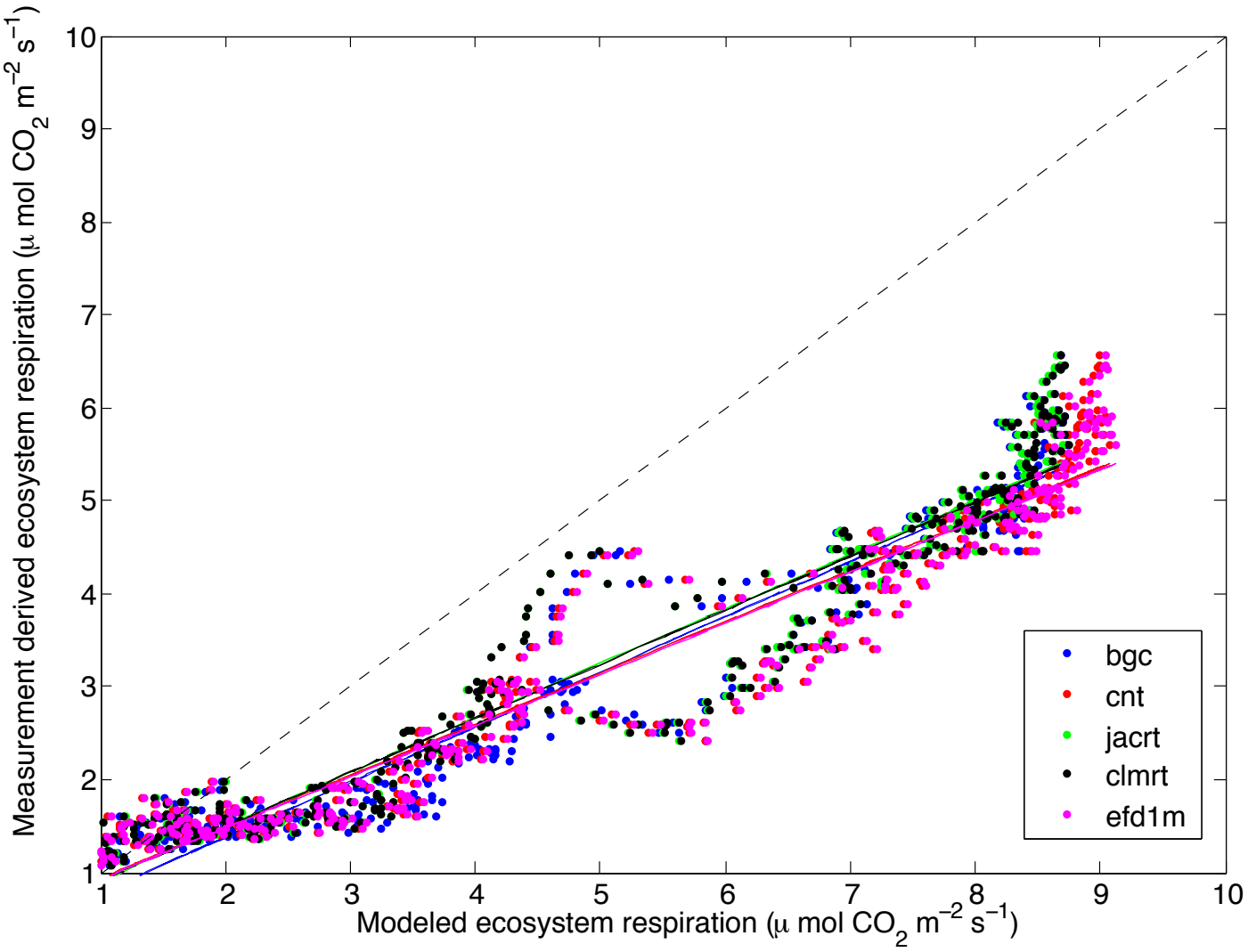
CO_2 respiration

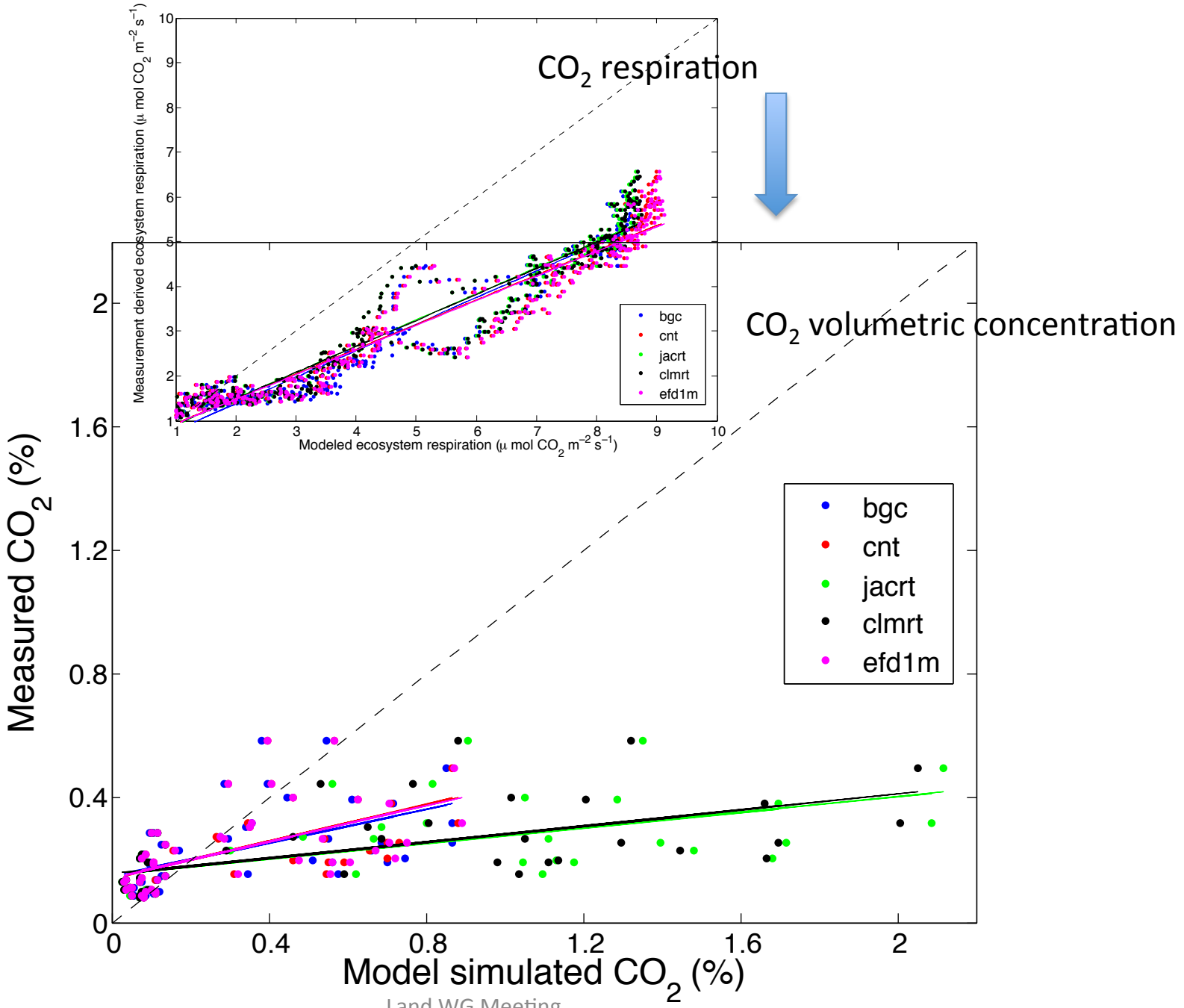


CO_2 volumetric concentration

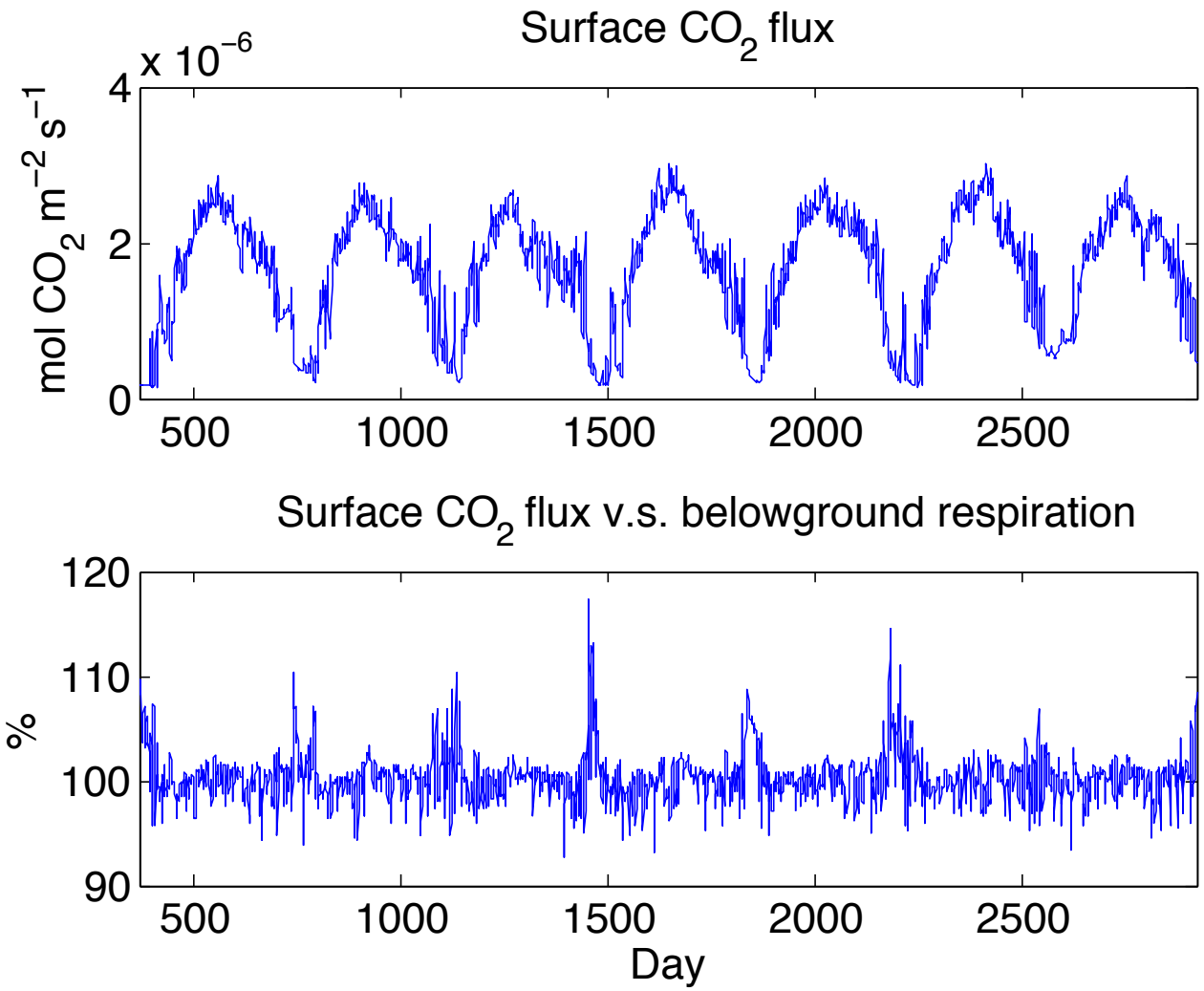


Ecosystem respiration computed by different model configurations




CO2 respiration
Measurement derived ecosystem respiration (μ mol CO2 m−2 s−1)
Modeled ecosystem respiration (μ mol CO2 m−2 s−1)
bgc
cnt
jacrt
clmrt
efd1m
CO2 volumetric concentration
Measured CO2 (%)
Model simulated CO2 (%)
0
0.4
0.8
1.2
1.6
2

Budget the underground CO_2 sources & sinks



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- Do global evaluation of the model for different gas fluxes/compositions, e.g. N_2O, NO and NH_3 gas fluxes

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- CLM4-BeTR can help understand the structural uncertainty by converting inside soil gas fluxes into measurable concentrations and surface fluxes
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- Do global evaluation of the model for different gas fluxes/compositions, e.g. N_2O, NO and NH_3 gas fluxes
- Test and evaluate it's capability for isotope transport, and nitrogen transport