How much is global gross primary production of the terrestrial biosphere?

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Global terrestrial GPP

- Gross primary production, GPP, is the largest flux in terrestrial carbon cycle, can not be measured directly.
- Current estimates vary widely:

By modeling. Beer et al. (2010):107– 139Gt C $year^{-1}$

From NPP. Piao et al. (2010):100– 157 Gt C $year^{-1}$

$CO^{16}O^{18}$. Welp et al.(2011):150– 175 Gt C $year^{-1}$

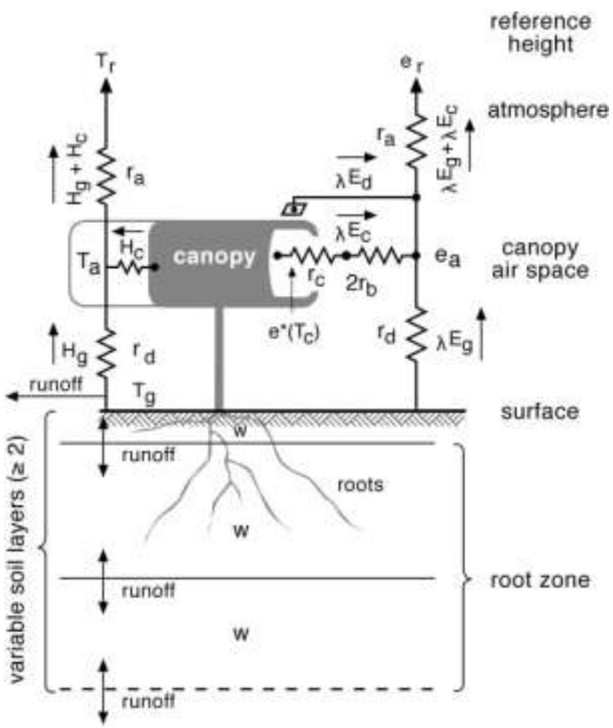
Issues with various estimates

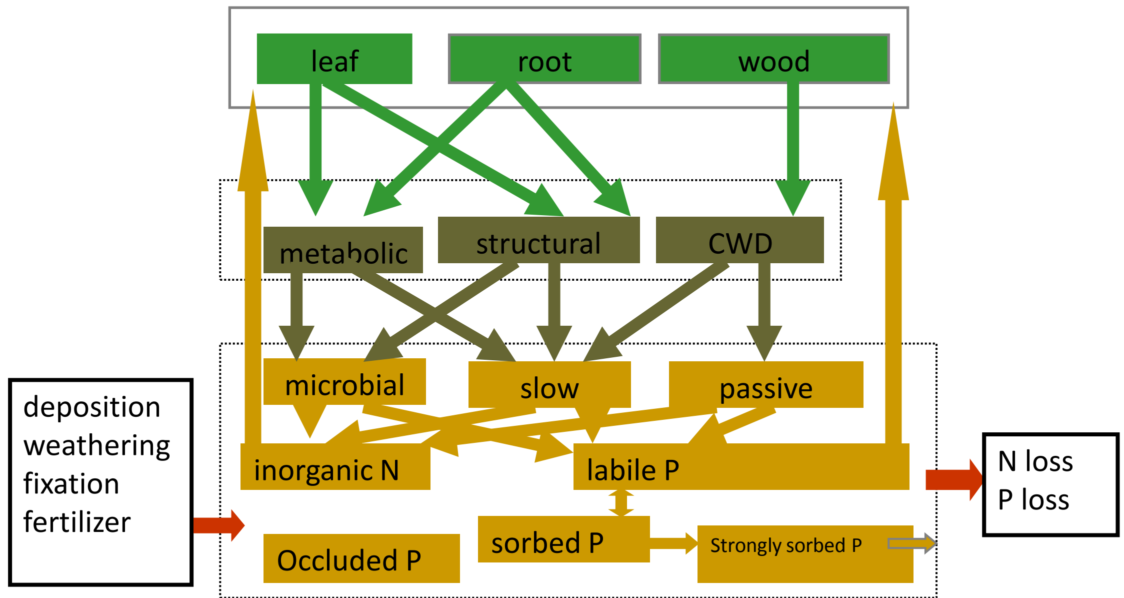
- Modeling
  - accuracy depends on calibration data
  - Observations are very sparse for some regions
  - Issues with nighttime flux measurements
- NPP/GPP ratio
  - Depending how good estimates of NPP are
  - the ratio quite variable, quite low under P limiting
- Isotope method
  - some unverified assumptions.
- Global C4 fraction may be underestimated.

Another modeling approach

- water and carbon are strongly coupled, and much of our present knowledge is captured in the Australian community land surface model (CABLE).
- Two questions:
  – How can we use CABLE to predict global GPP subject to the constraints of the “observed” global latent heat fluxes, global LAI and prior information about CABLE parameters?
  – What is the uncertainty of the predicted GPP?

The CABLE model

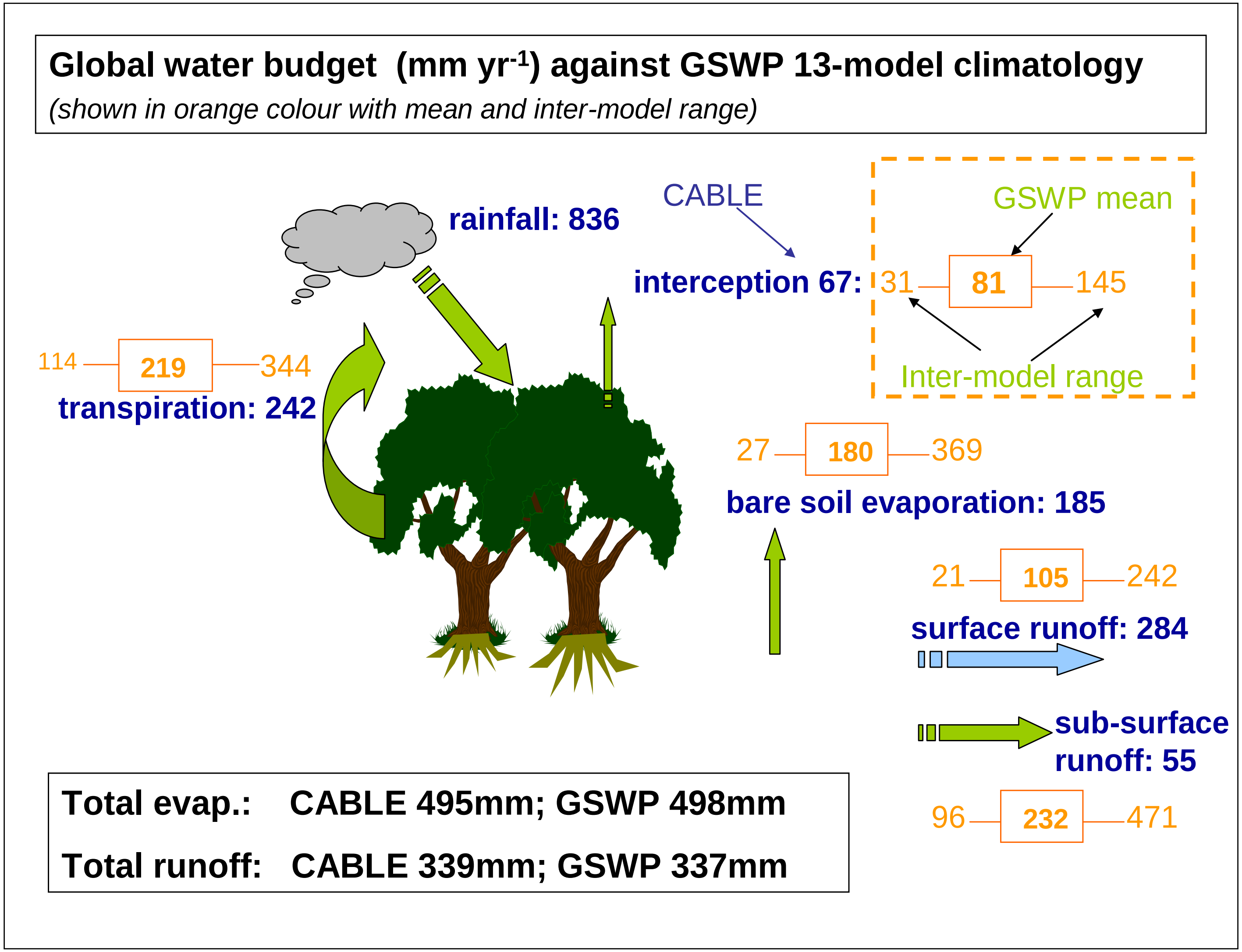




Biophysics

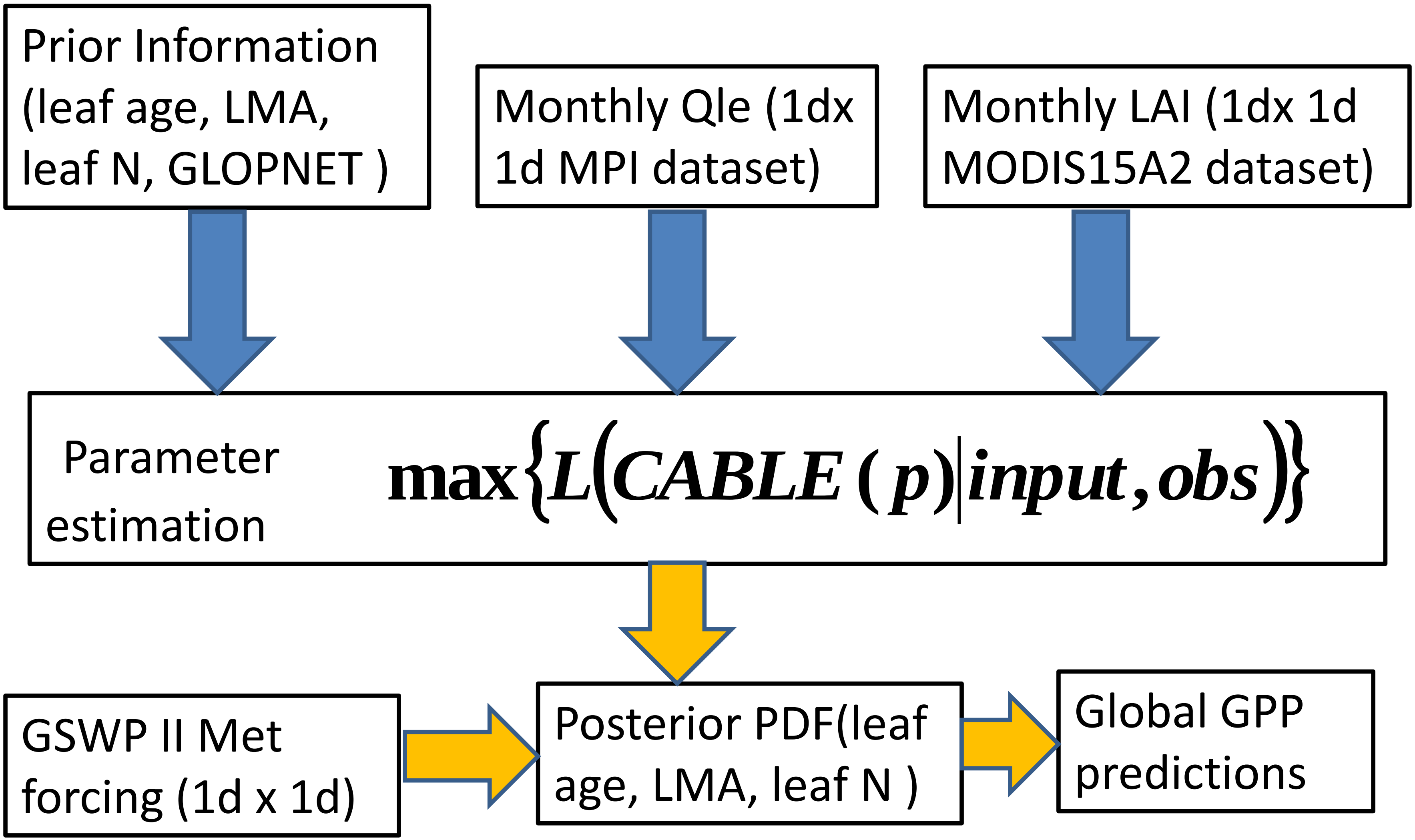
Biogeochemistry (C, N, P) = CABLE

Global water budget by default CABLE



From: Zhang et al. 2012

A Bayesian inversion



Why those three leaf parameters?

- H_2O and C fluxes depends on two variables:
  - **Canopy LAI**: total area of water and C fluxes

    LAI = f_1(*leaf age*, *leaf mass per area*, NPP, a_{leaf})
  - **Leaf nitrogen**: affecting the rate of water/carbon fluxes per unit LAI.

    V_{cmax}=f_2(*leaf N%*)
- Three parameters are optimized using PEST
- why three? (only learnt new PEST last week)

The uncertainty of model predictions (linear theory)

$$\hat{\boldsymbol{F}}_{gpp} = \boldsymbol{y}^T \hat{\boldsymbol{p}}$$

$$\boldsymbol{\sigma}_{GPP}^2 = \underbrace{\boldsymbol{y}^T (\boldsymbol{I} - \boldsymbol{R}) \boldsymbol{C}(\boldsymbol{p}) (\boldsymbol{I} - \boldsymbol{R})^T \boldsymbol{y}}_{model\ structure\ error} + \underbrace{\boldsymbol{y}^T \boldsymbol{G} \boldsymbol{C}(\boldsymbol{\varepsilon}) \boldsymbol{G}^T \boldsymbol{y}}_{model-obs\ mismatch}$$

R: model resolution matrix

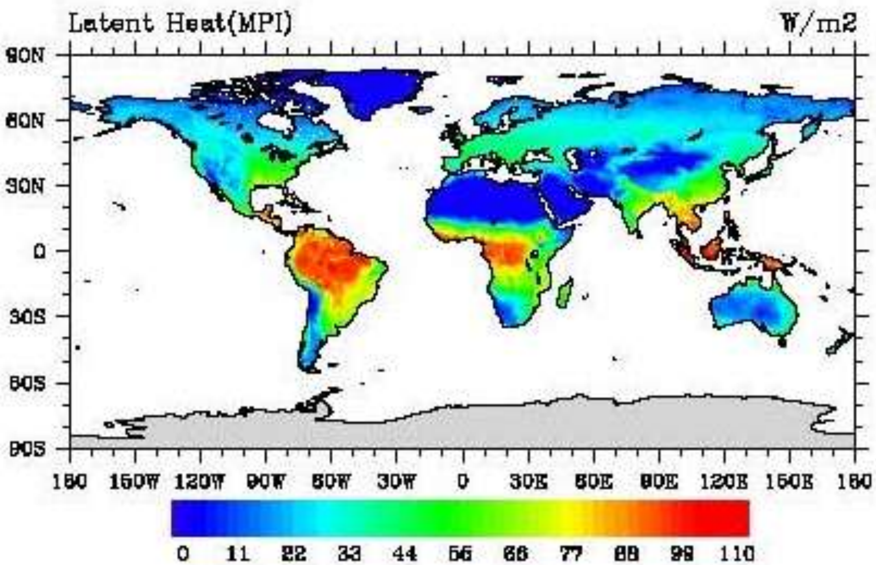
I: identity matrix

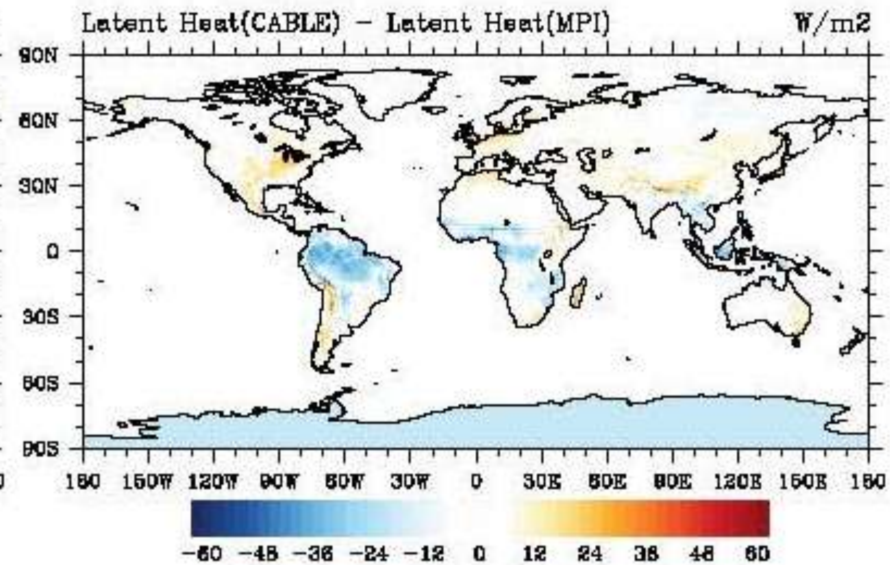
C(***p***): parameter covariance matrix

G: parameter solution matrix

C(ε): measurement error covariance matrix

Mismatch of QLE

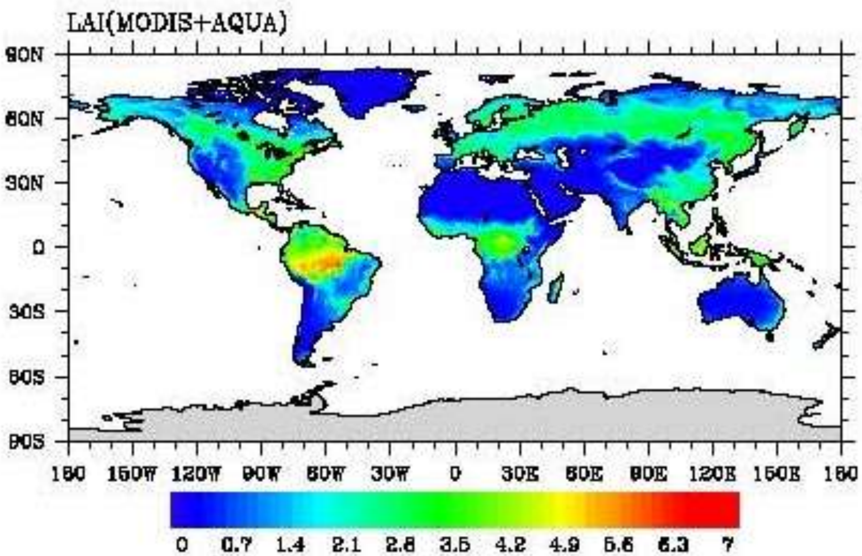


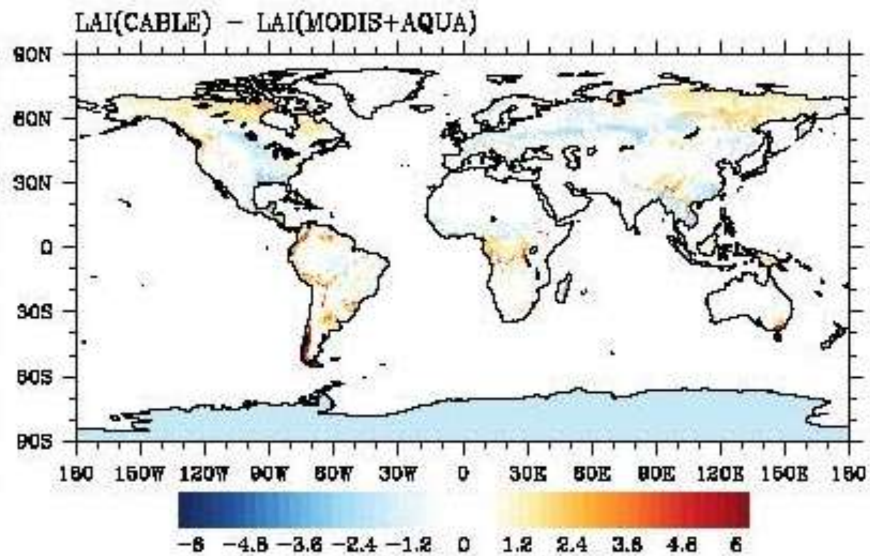


The "observed"

Mismatch

Mismatch of LAI

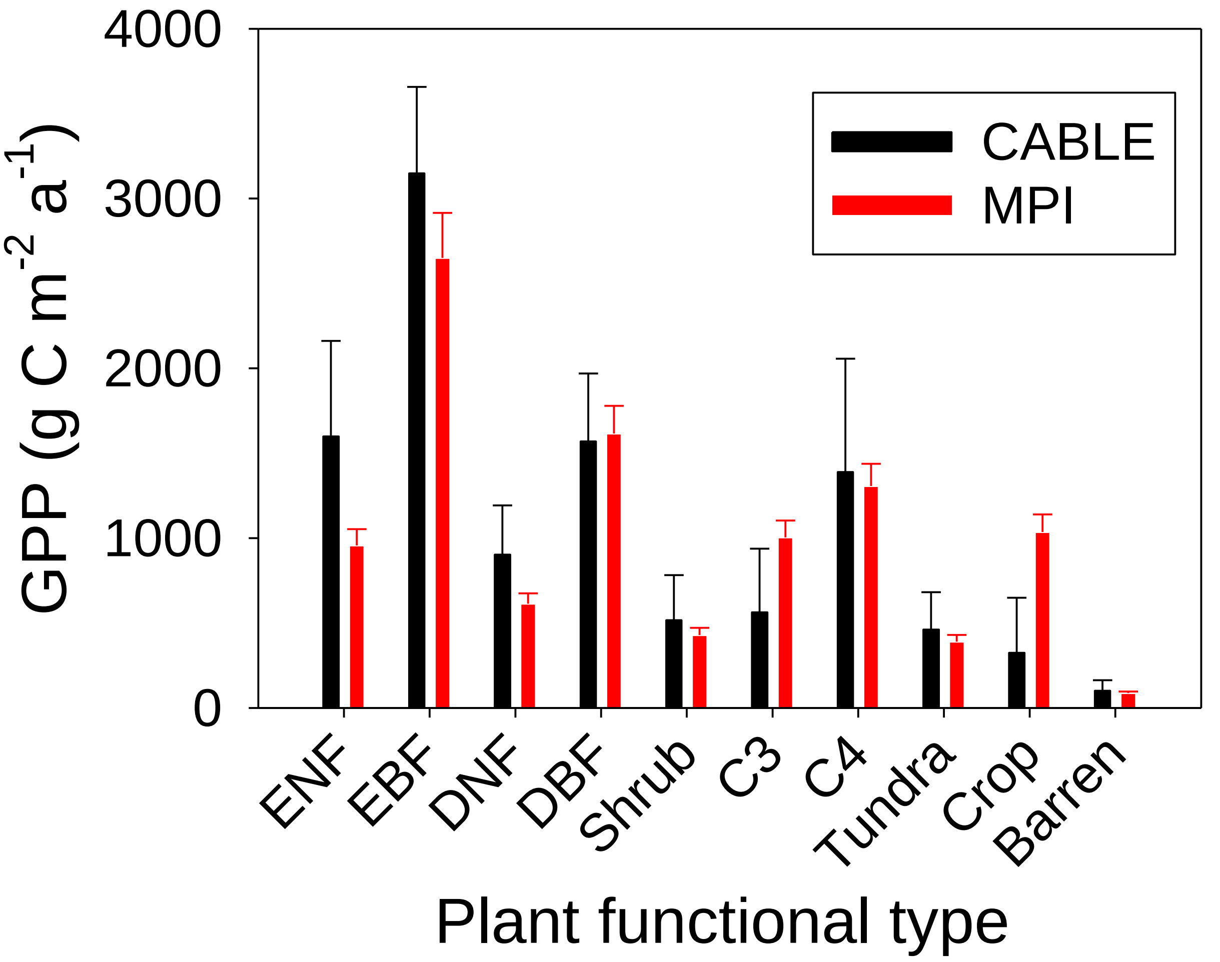




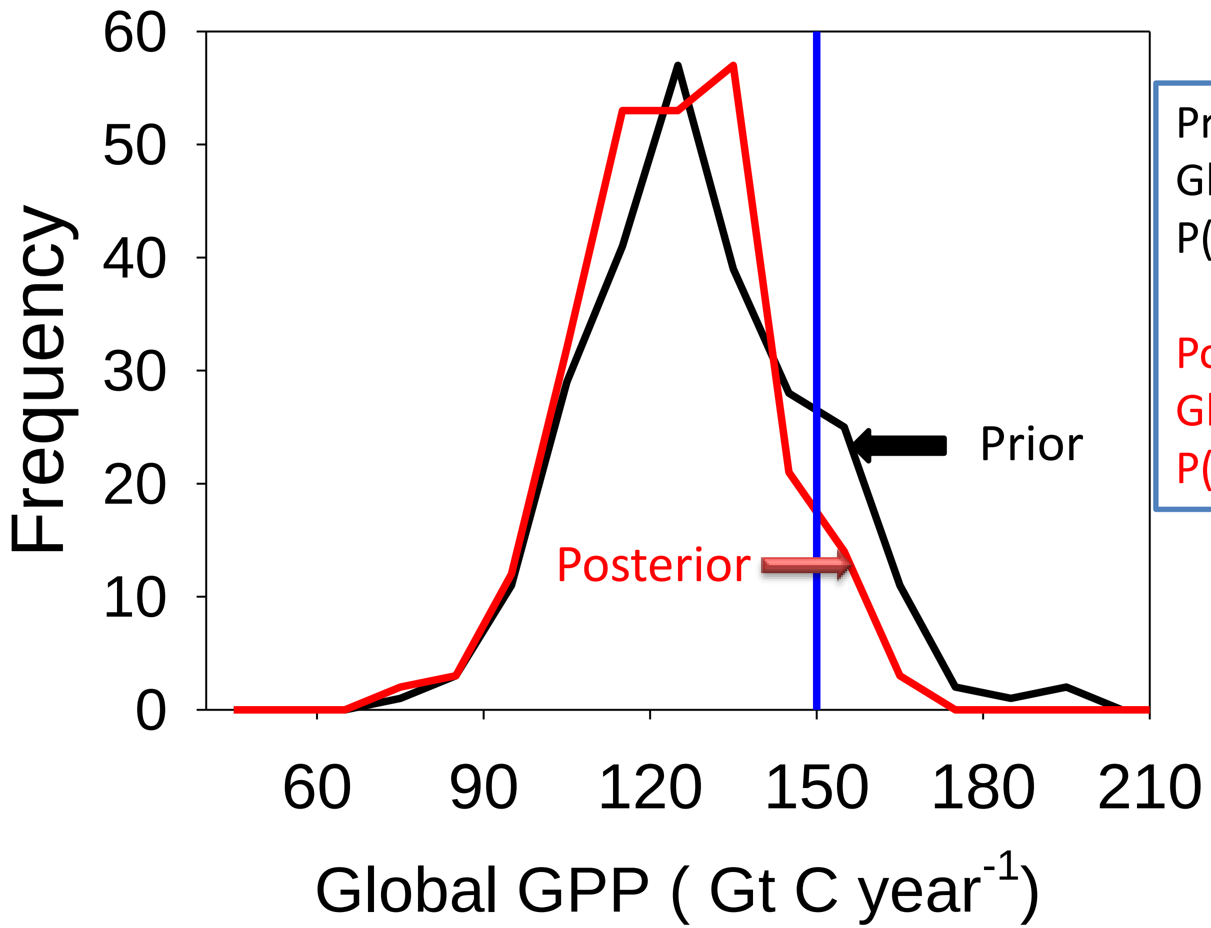
The “observed”

Mismatch

Predicted GPP after calibration



Prior and posterior GPP

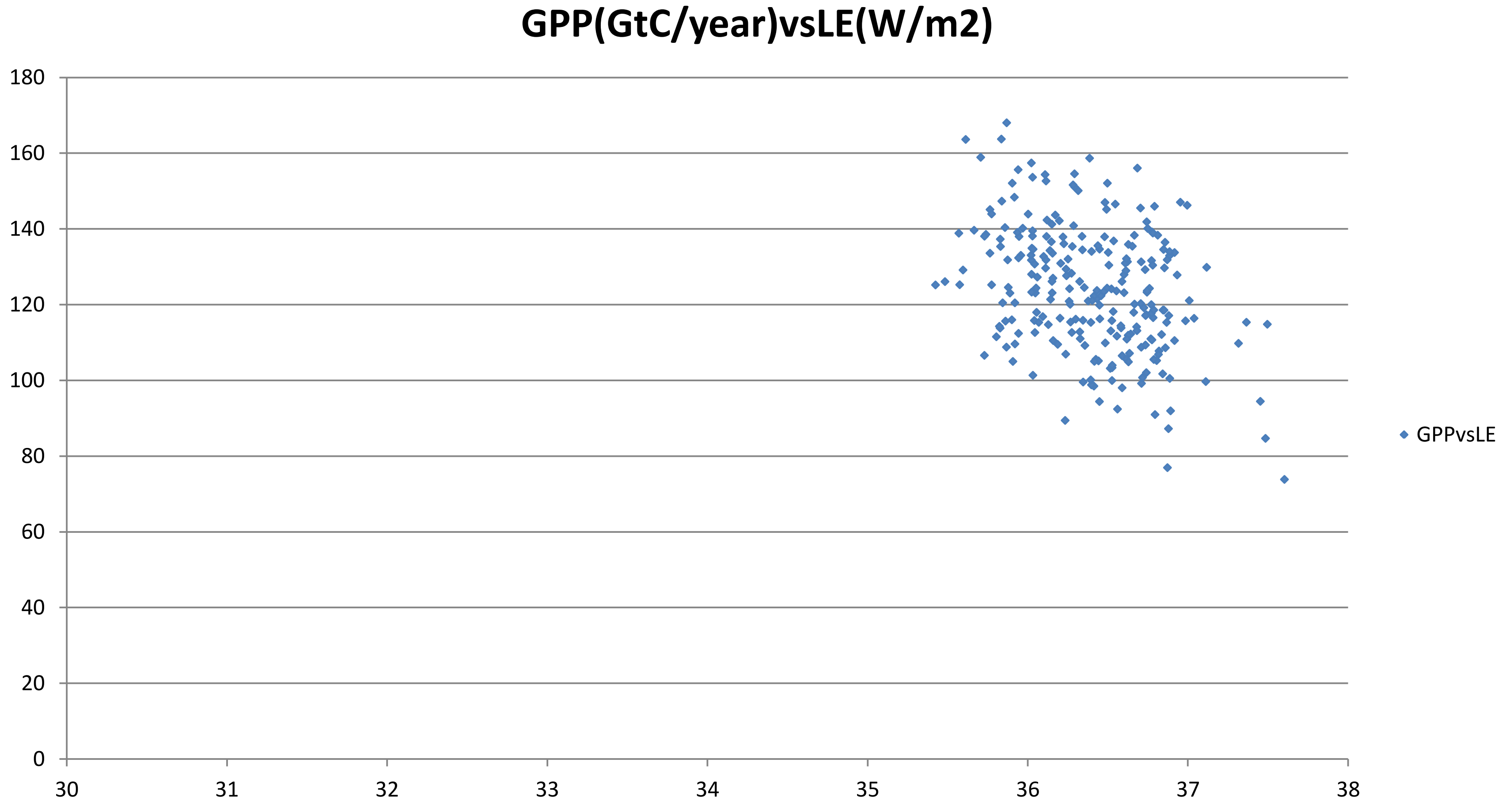


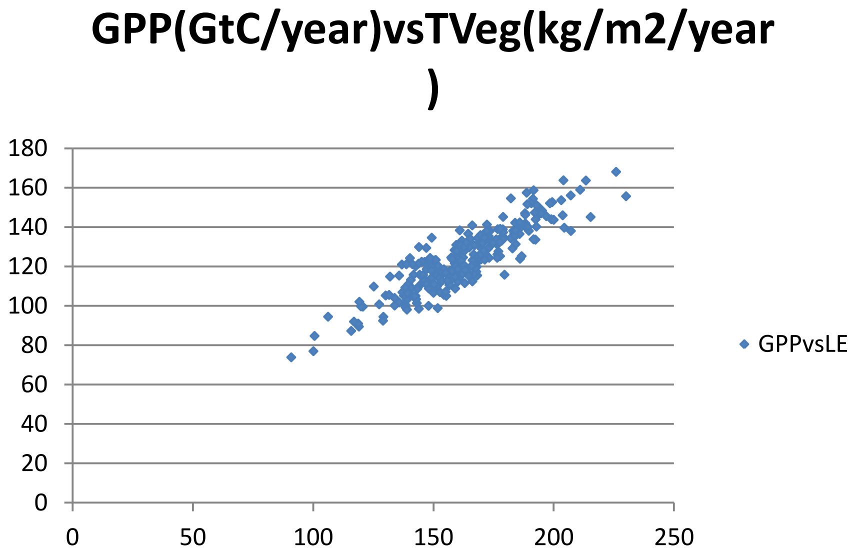
Prior
Global GPP=133±24
P(GPP>150)=0.16

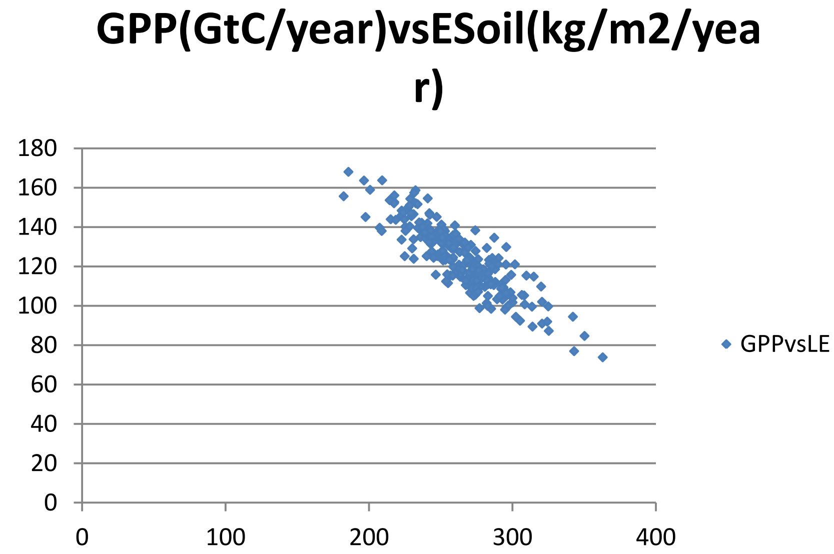
Posterior
Global GPP= 124±18
P(GPP>150)=0.08

Conclusions

- Global GPP is likely to be 124 ±Gt C year^{-1};
- The probability of global GPP being >150 Gt C year^{-1} is only 7%;
- Monthly LAI is a stronger constraint on global GPP than monthly latent heat flux;
- More independent estimates, such as NPP, runoff will be used to optimized more parameters and further refine the estimates of GPP.


GPP(GtC/year)vsLE(W/m2)
180
160
140
120
100
80
60
40
20
0
30
31
32
33
34
35
36
37
38
GPPvsLE


GPP(GtC/year)vsTVeg(kg/m2/year)
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
GPPvsLE


GPP(GtC/year)vsESoil(kg/m2/year)
180
160
140
120
100
80
60
40
20
0
0
100
200
300
400
GPPvsLE