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): 107–139 Gt 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

Global water budget (mm yr⁻¹) against GSWP 13-model climatology

(shown in orange colour with mean and inter-model range)

From: Zhang et al. 2012
A Bayesian inversion

Prior Information (leaf age, LMA, leaf N, GLOPNET)

Monthly Qle (1dx 1d MPI dataset)

Monthly LAI (1dx 1d MODIS15A2 dataset)

Parameter estimation

\[
\max \{ L(CABLE(p)|input,obs) \}
\]

GSWP II Met forcing (1d x 1d)

Posterior PDF(leaf age, LMA, leaf N)

Global GPP predictions
Why those three leaf parameters?

• H$_2$O and C fluxes depends on two variables:
  
  – **Canopy LAI**: total area of water and C fluxes
    
    $\text{LAI} = f_1(\text{leaf age}, \text{leaf mass per area}, \text{NPP}, a_{\text{leaf}})$
  
  – **Leaf nitrogen**: affecting the rate of water/carbon fluxes per unit LAI.
    
    $V_{c_{\text{max}}} = f_2(\text{leaf N%})$

• Three parameters are optimized using PEST

• why three? (only learnt new PEST last week)
The uncertainty of model predictions (linear theory)

\[ \hat{F}_{gpp} = y^T \hat{p} \]

\[ \sigma^2_{GPP} = y^T (I - R) C(p) (I - R)^T y + y^T G C(\epsilon) G^T y \]

- **\( \hat{F}_{gpp} \)**: model resolution matrix
- **\( \sigma^2_{GPP} \)**: parameter structure error
- **\( I \)**: identity matrix
- **\( C(p) \)**: parameter covariance matrix
- **\( G \)**: parameter solution matrix
- **\( C(\epsilon) \)**: measurement error covariance matrix
- **\( \hat{F} \)**: model–obs mismatch
Mismatch of QLE

The “observed”

Mismatch
Mismatch of LAI

The “observed”

Mismatch
Predicted GPP after calibration

Plant functional type

- ENF
- EBF
- DNF
- DBF
- Shrub
- C3
- C4
- Tundra
- Crop
- Barren

GPP (g C m$^{-2}$ a$^{-1}$)

- CABLE
- MPI

0
1000
2000
3000
4000

Plant functional type
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) vs LE (W/m2)