Peatland Constraints on the Deglacial CO_2 Rise from Ice Cores

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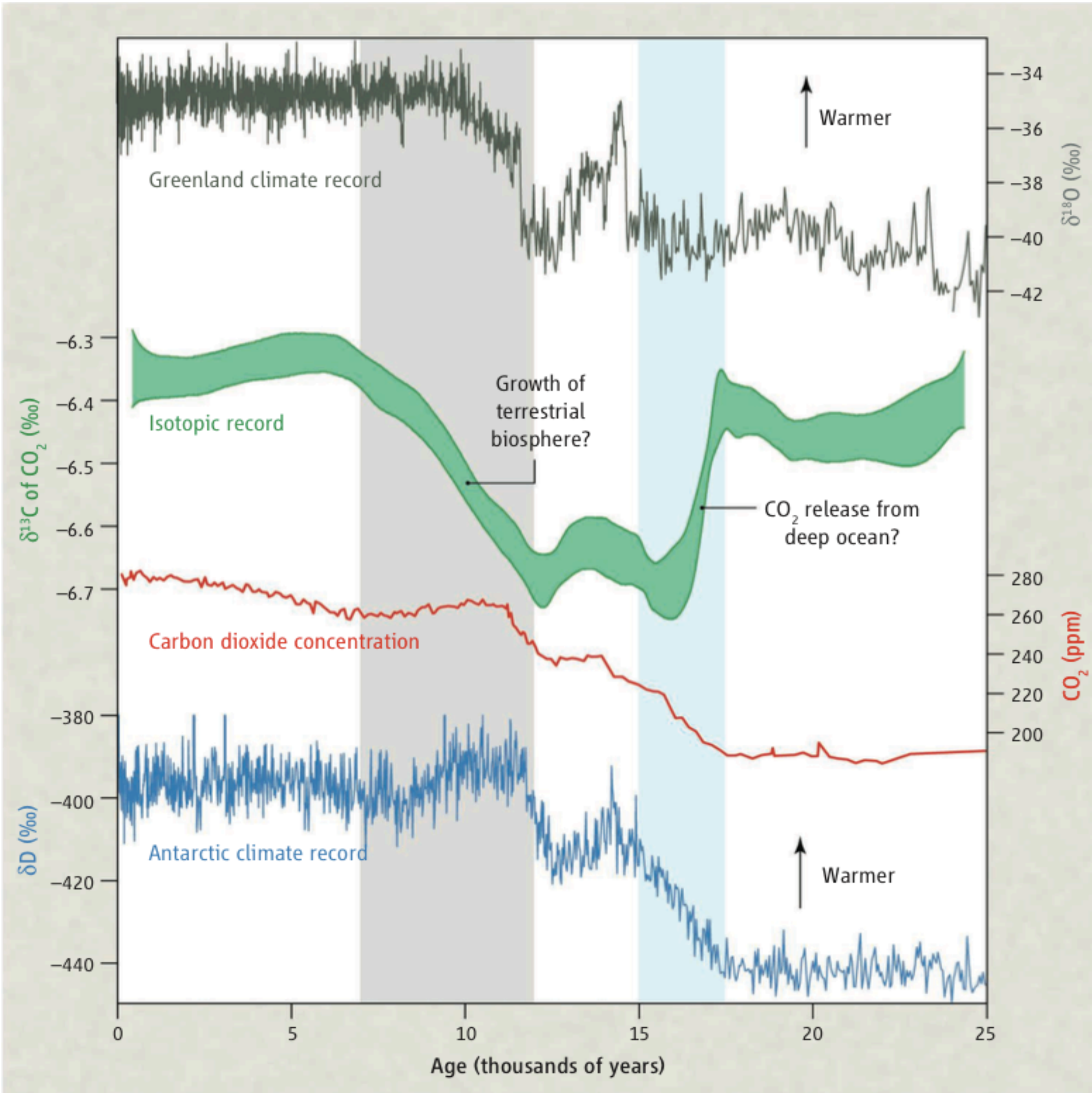
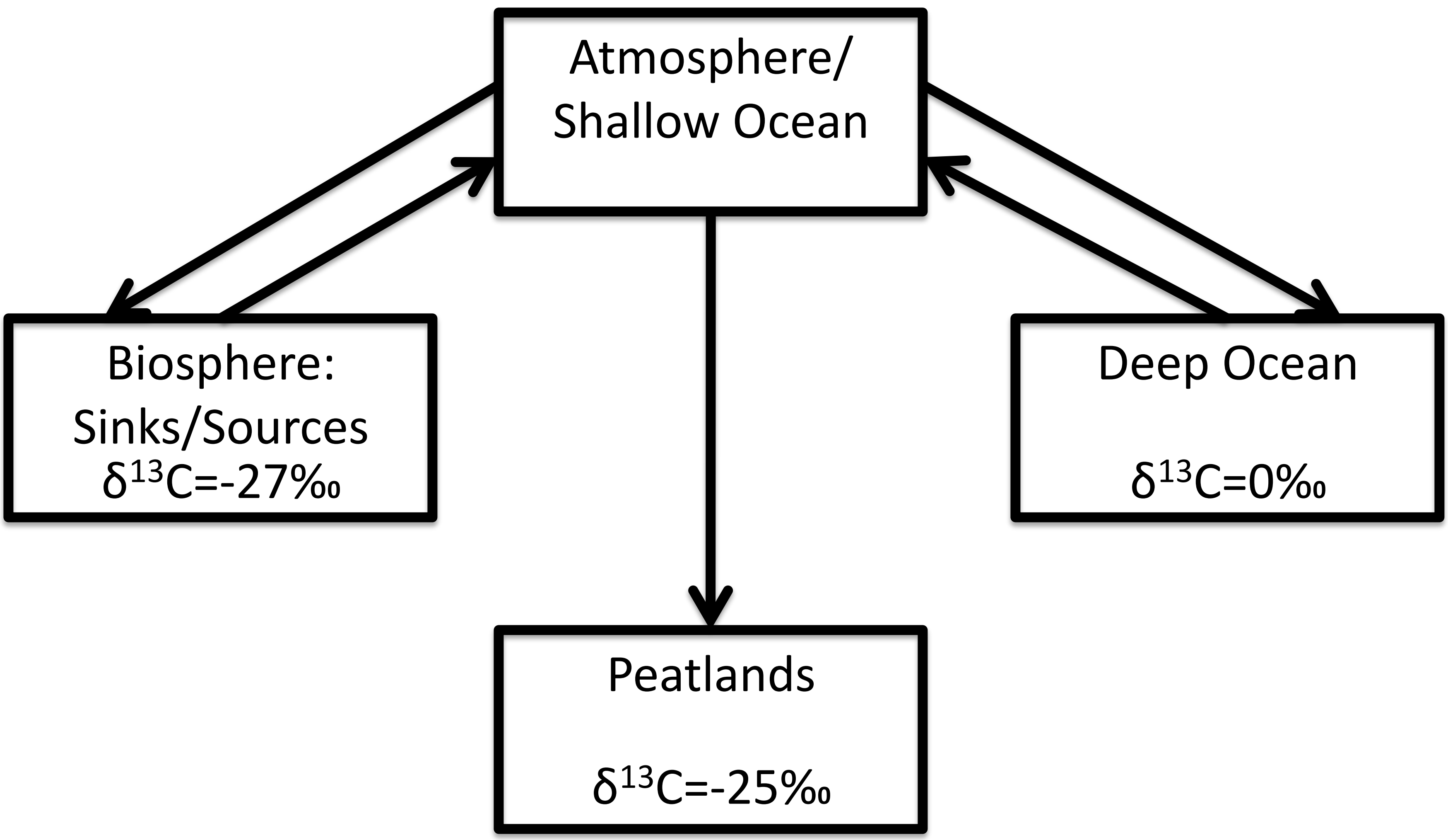


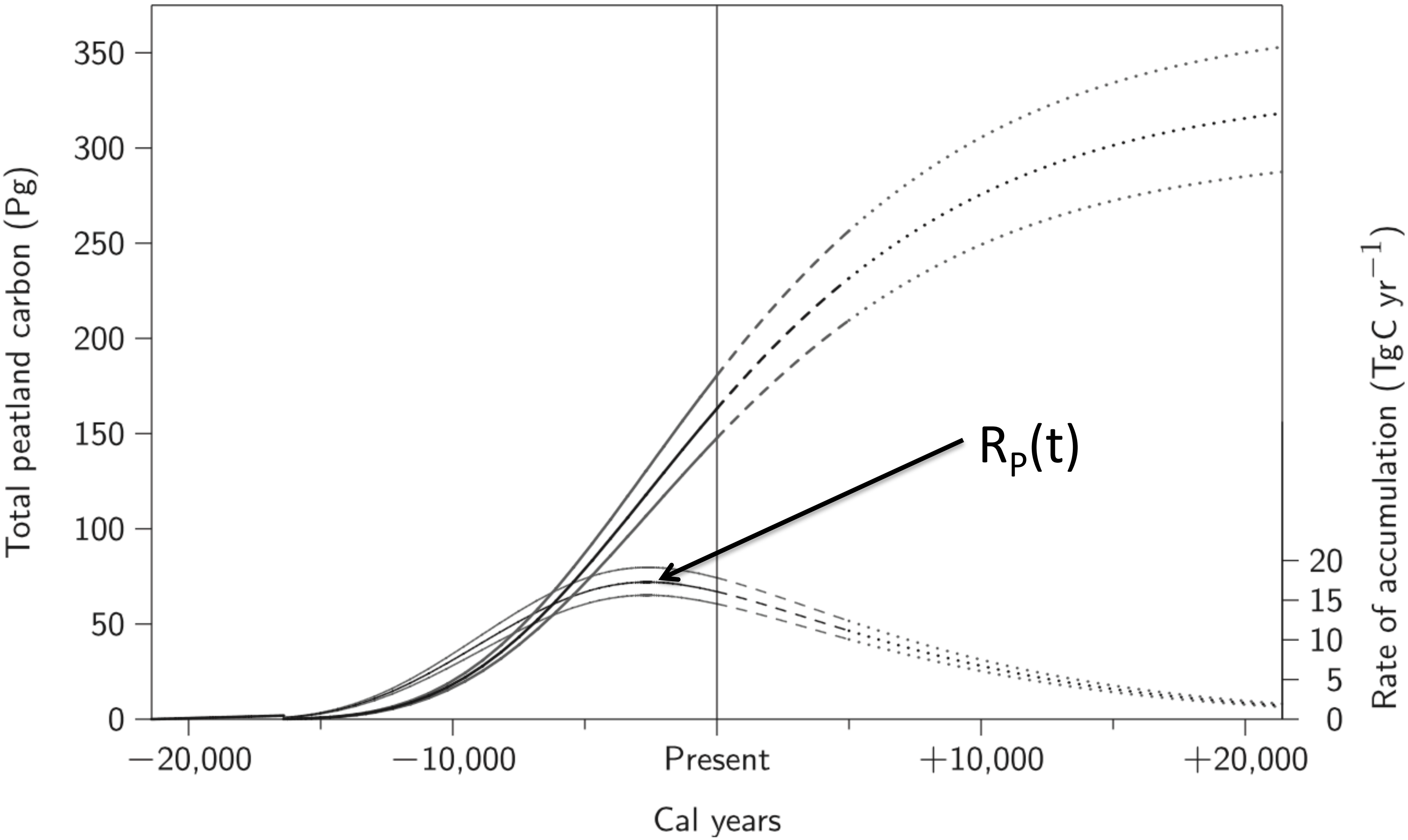
Brook, E. *Science*: **336** pg. 682-683.

Possible Factors

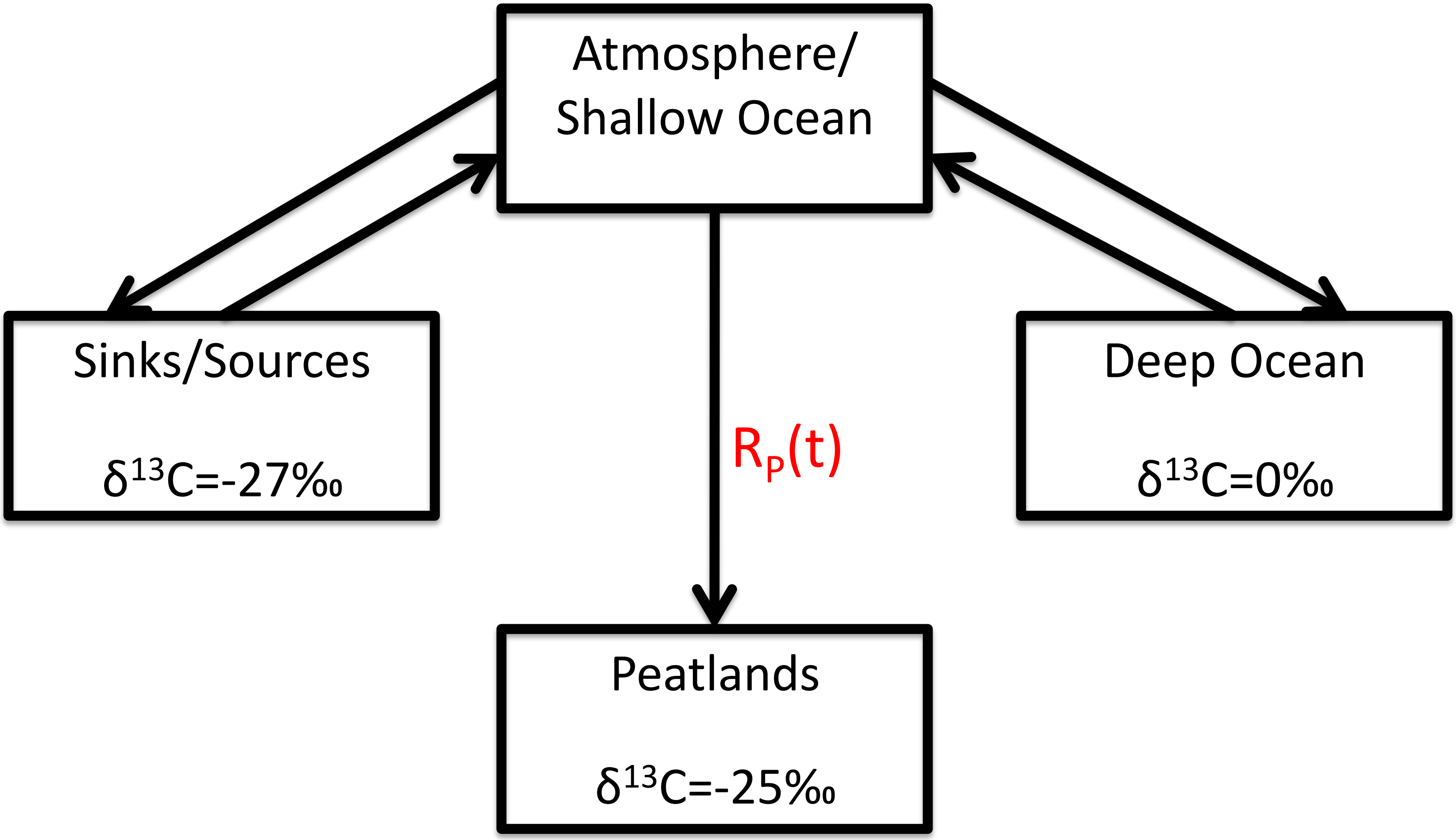
- CO_2 Sources
  - Melting dirty glaciers
  - Coastal ocean rise
  - Loss of grasslands/ forests (Sahara/ Australia)
- CO_2 Sinks
  - Peatlands
  - Lake Sediments
  - Boreal Forests
  - Coral Reefs


Atmosphere/
Shallow Ocean
Biosphere:
Sinks/Sources
δ13C=-27‰
Deep Ocean
δ13C=0‰
Peatlands
δ13C=-25‰

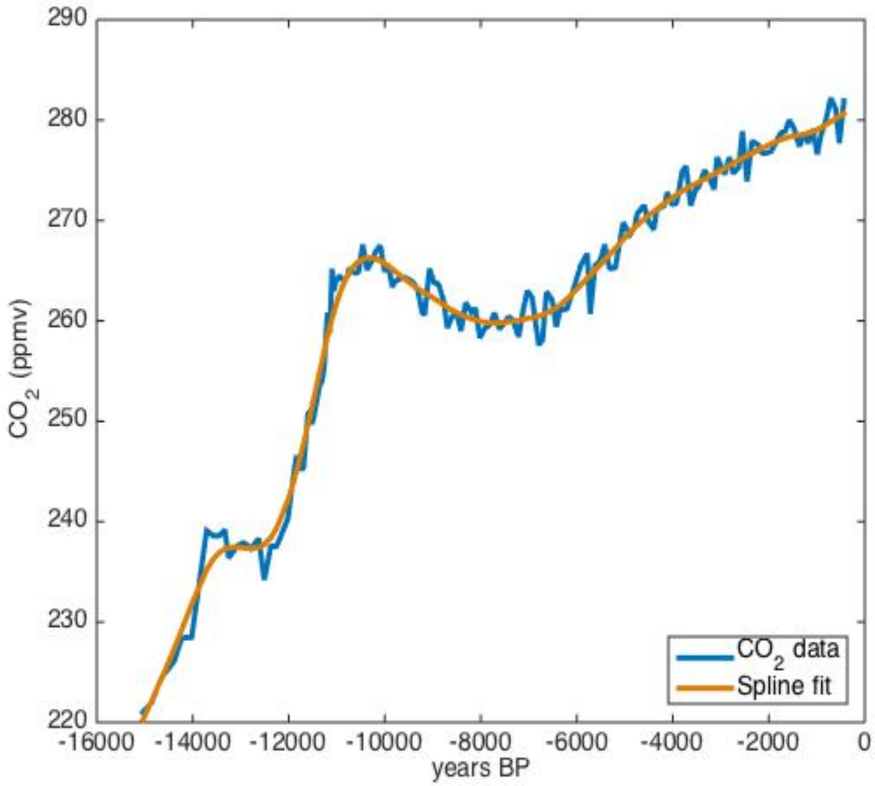
Rate of Peatland Growth

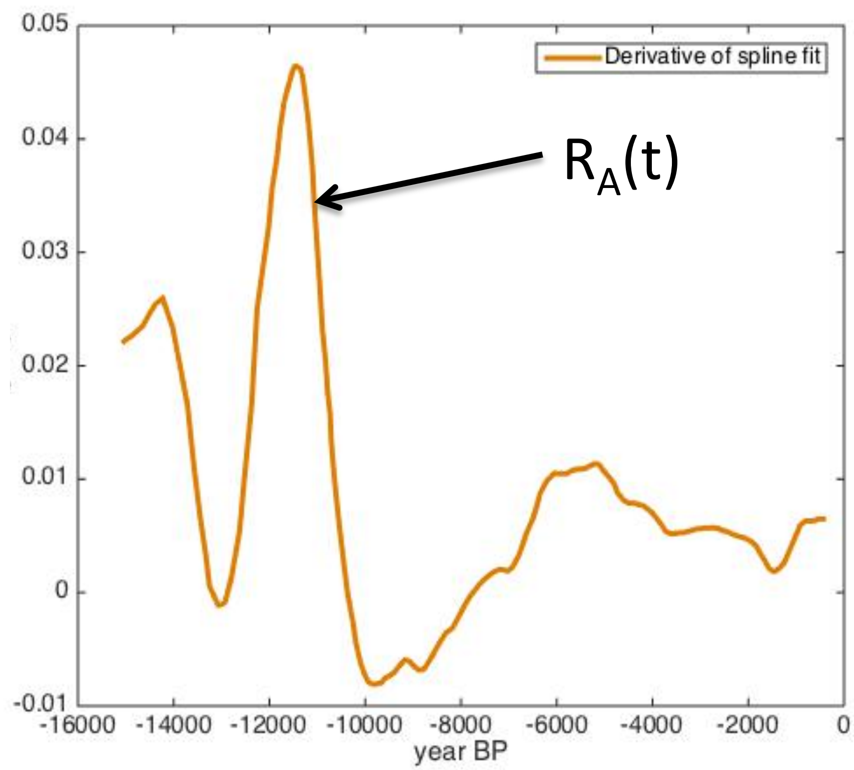


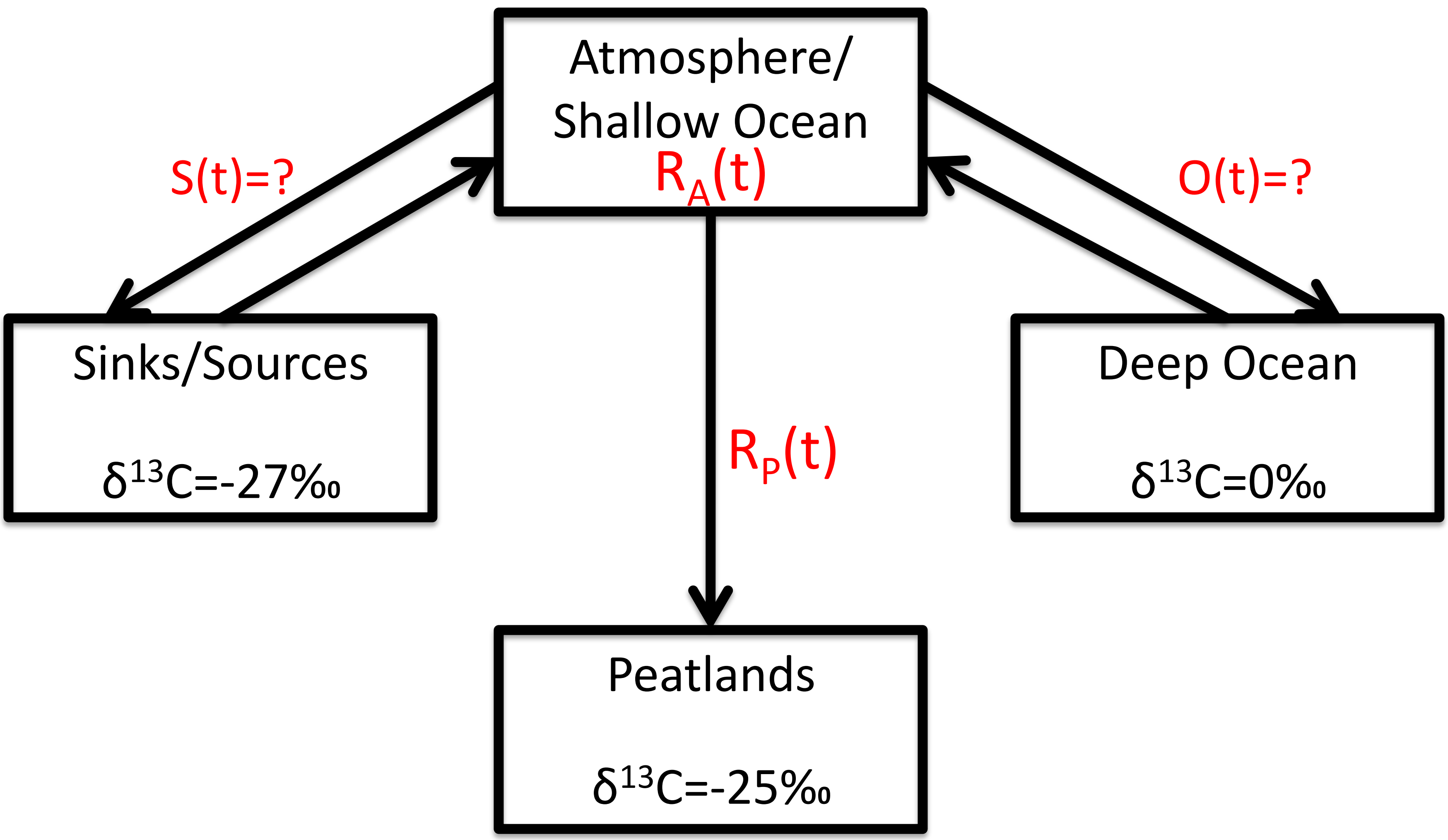
Gorham, E. et al. *Qua. Sci. Rev.*: **58** pg.77-82.


Atmosphere/
Shallow Ocean
Sinks/Sources
δ13C=-27‰
Deep Ocean
δ13C=0‰
Rp(t)
Peatlands
δ13C=-25‰

Rate of Atmospheric Carbon Change






Atmosphere/
Shallow Ocean
R_A(t)
S(t)=?
O(t)=?
Sinks/Sources
δ13C=-27‰
R_P(t)
Deep Ocean
δ13C=0‰
Peatlands
δ13C=-25‰

$$O(t) + S(t) - R_P(t) = R_A(t)$$

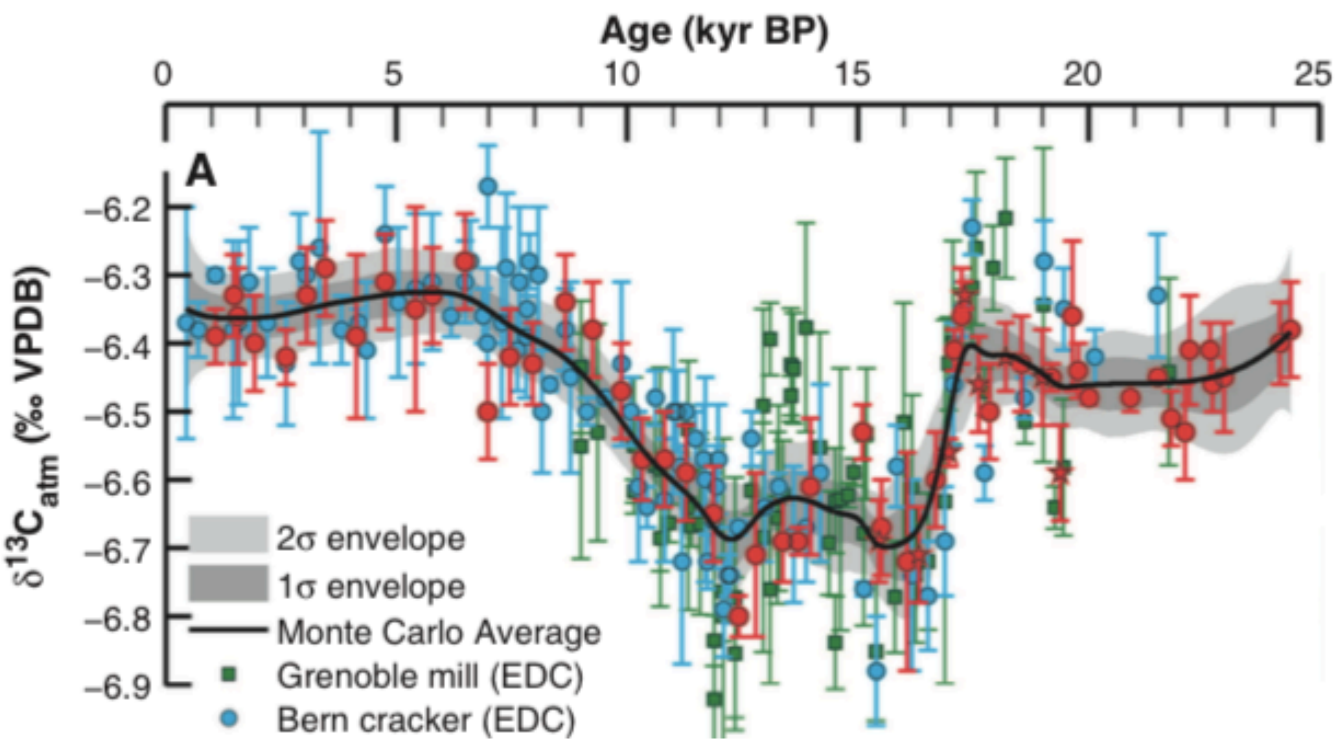
$$\Rightarrow O(t) + S(t) = R_P(t) + R_A(t)$$

Assume that the amount coming from the Deep Ocean and Biosphere is a convex combination:

$$O(t) = \alpha(t)(R_P(t) + R_A(t))$$

$$S(t) = (1 - \alpha(t))(R_P(t) + R_A(t))$$

But we really need to know the ratio of ^{13}C to ^{12}C in the atmosphere.



Schmitt, J. et al. *Science*: **336** pg. 711-713.

Some Notation

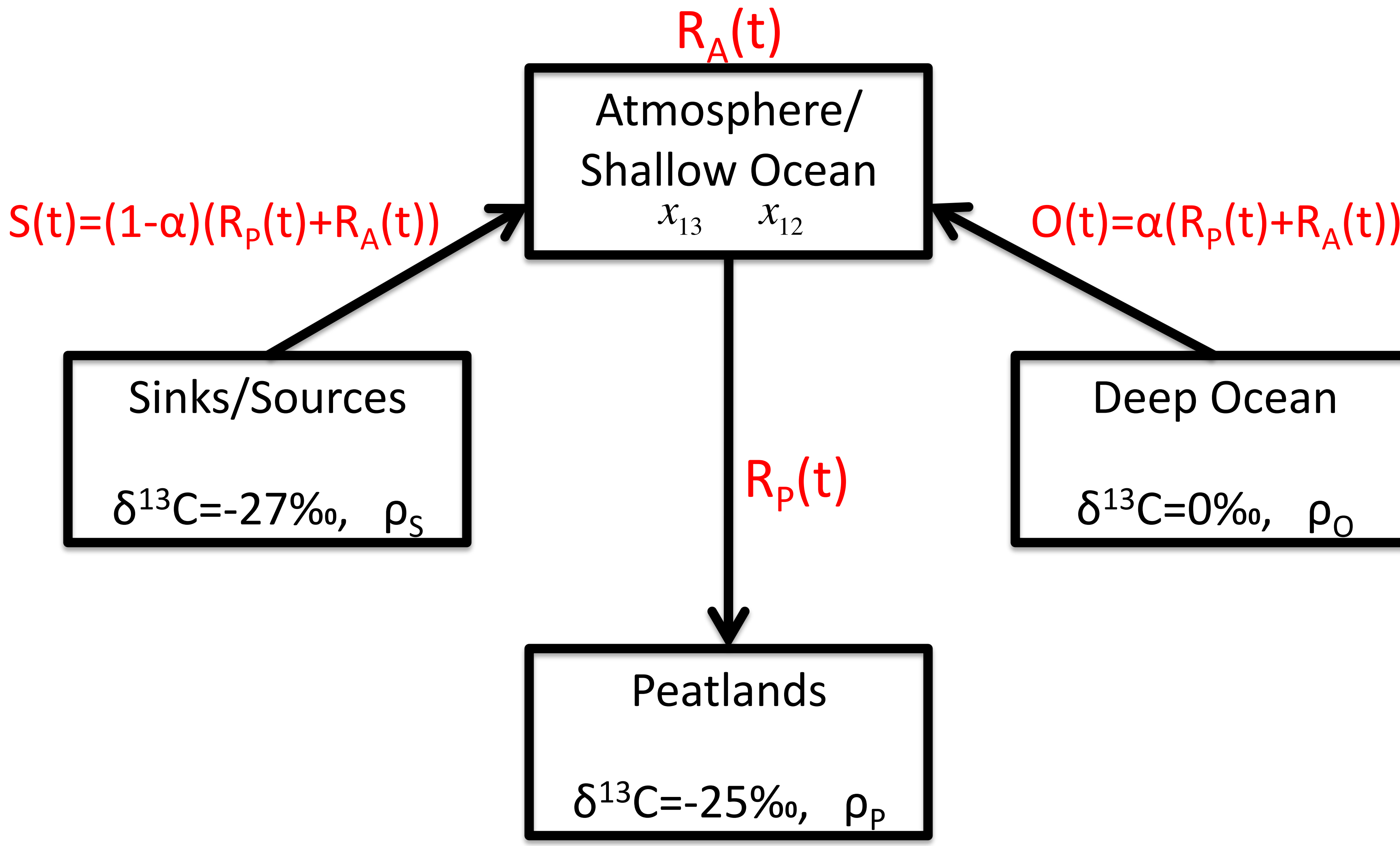
x_{13} := amount of ^{13}C in atmosphere

x_{12} := amount of ^{12}C in atmosphere

ρ_P := ratio of ^{13}C to ^{12}C in peat

ρ_O := ratio of ^{13}C to ^{12}C in the deep ocean

ρ_S := ratio of ^{13}C to ^{12}C in sinks/sources


$R_A(t)$
Atmosphere/
Shallow Ocean
x_{13} x_{12}
$S(t)=(1-\alpha)(R_P(t)+R_A(t))$
$O(t)=\alpha(R_P(t)+R_A(t))$
Sinks/Sources
$\delta^{13}C=-27‰$, ρ_S
Deep Ocean
$\delta^{13}C=0‰$, ρ_O
$R_P(t)$
Peatlands
$\delta^{13}C=-25‰$, ρ_P

"Out"

$$\omega'_{13}(t) = \frac{\rho_P}{1+\rho_P} R_P(t)$$

$$\omega'_{12}(t) = \frac{1}{1+\rho_P} R_P(t)$$

Notice that

$$\omega'_{13}(t) + \omega'_{12}(t) = R_P(t)$$

and at each $t=t_*$ we have

$$\frac{\omega'_{13}(t_*)}{\omega'_{12}(t_*)} = \rho_P$$

“In”

$$\eta'_{13}(\alpha,t) = \frac{\rho_S + \alpha(t)(\rho_O - \rho_S)}{1 + \rho_S + \alpha(t)(\rho_O - \rho_S)}(R_P(t) + R_A(t))$$

$$\eta'_{12}(\alpha,t) = \frac{1}{1 + \rho_S + \alpha(t)(\rho_O - \rho_S)}(R_P(t) + R_A(t))$$

Again

$$\eta'_{13}(\alpha,t) + \eta'_{12}(\alpha,t) = R_P(t) + R_A(t)$$

and at each t=t$_*$ we have

$$\frac{\eta'_{13}(\alpha,t_*)}{\eta'_{12}(\alpha,t_*)} = (1 - \alpha(t_*))\rho_S + \alpha(t_*)\rho_O$$

So that

$$x'_{13}(\alpha,t) = \eta'_{13}(\alpha,t) - \omega'_{13}(t)$$
$$x'_{12}(\alpha,t) = \eta'_{12}(\alpha,t) - \omega'_{12}(t)$$

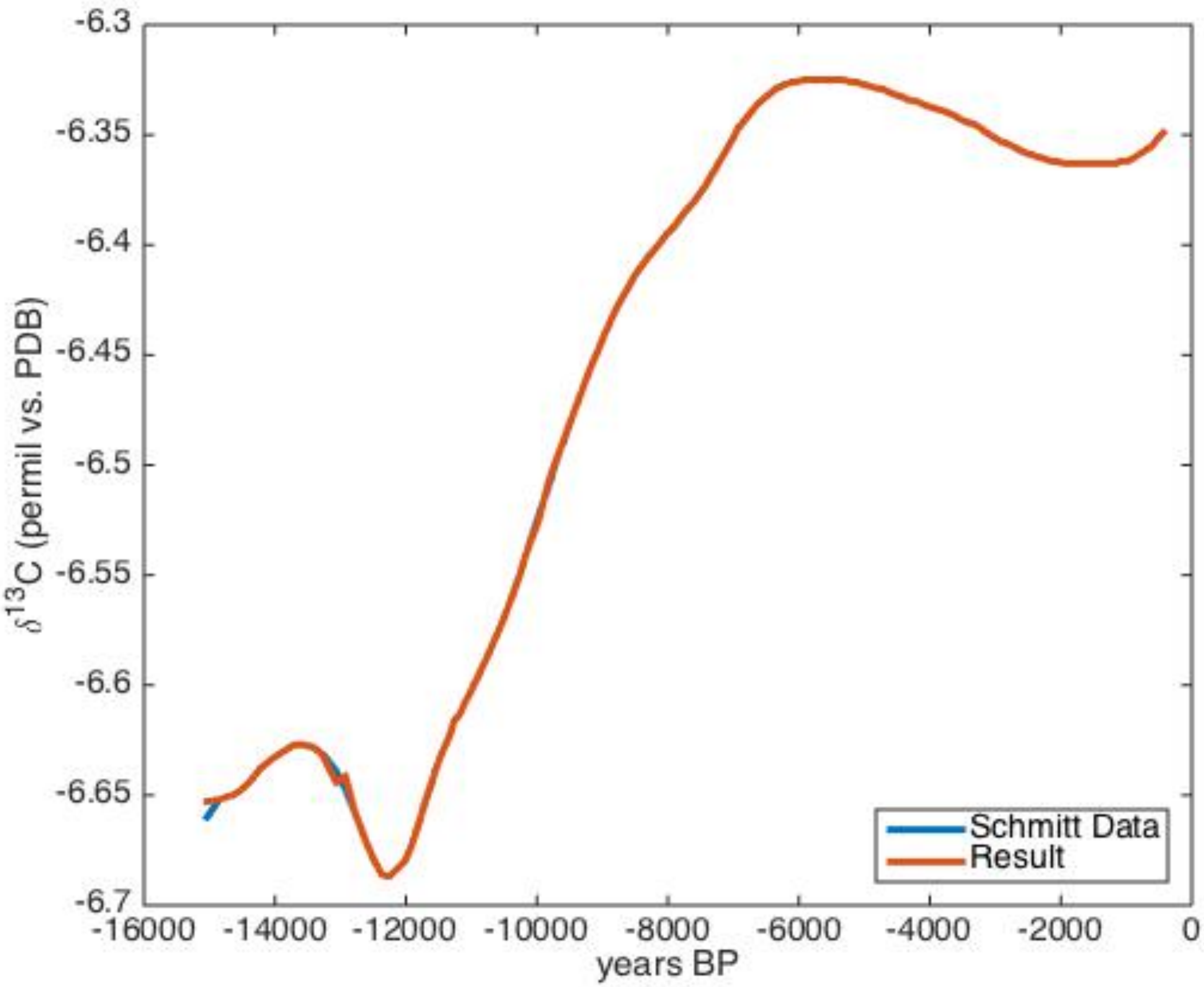
and

$$x_{13}(\alpha,t) = x_{13}(\alpha,t_0) + \int_{t_0}^{t} x'_{13}(\alpha,s)ds$$

$$x_{12}(\alpha,t) = x_{12}(\alpha,t_0) + \int_{t_0}^{t} x'_{12}(\alpha,s)ds$$

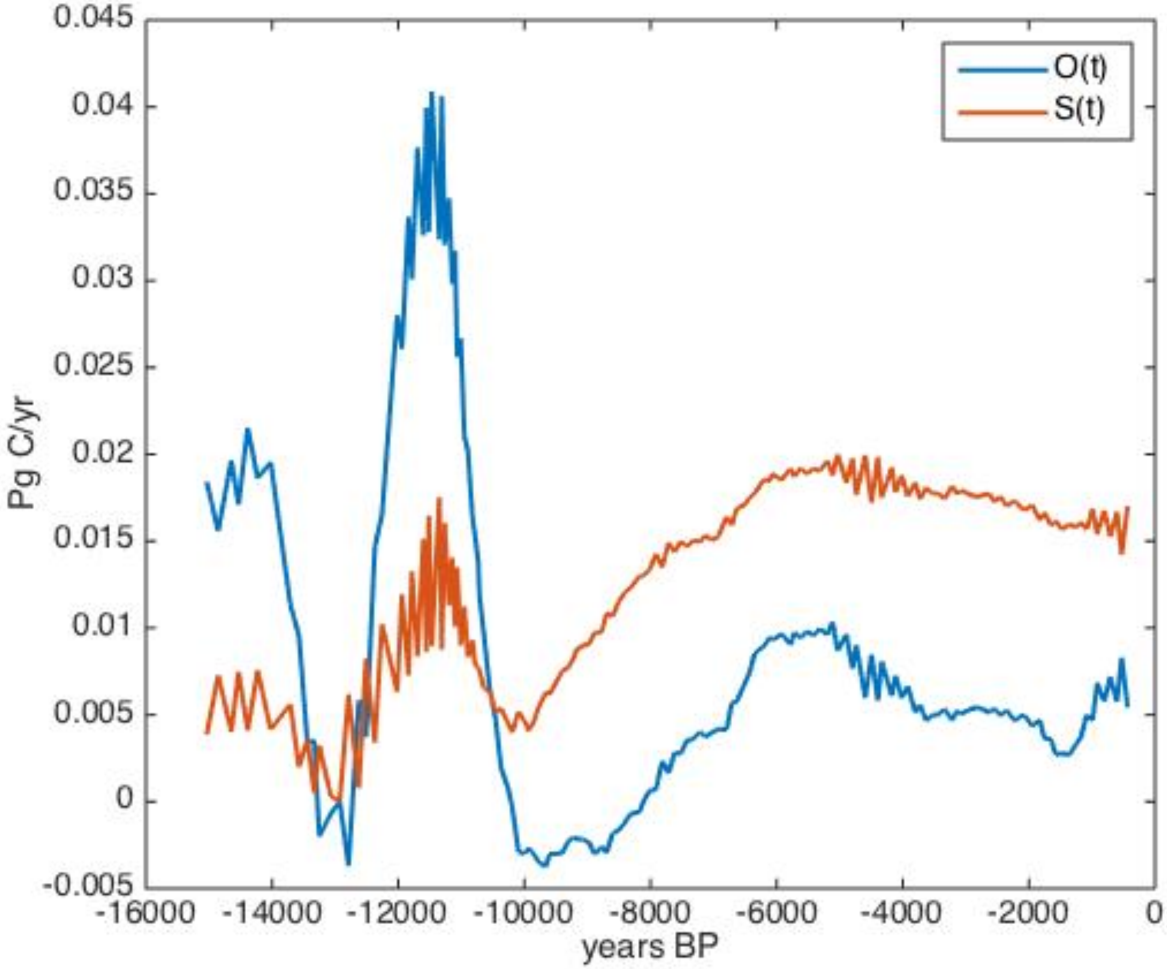
We need to find the α(t) which reproduces Schmitt's data.

Results



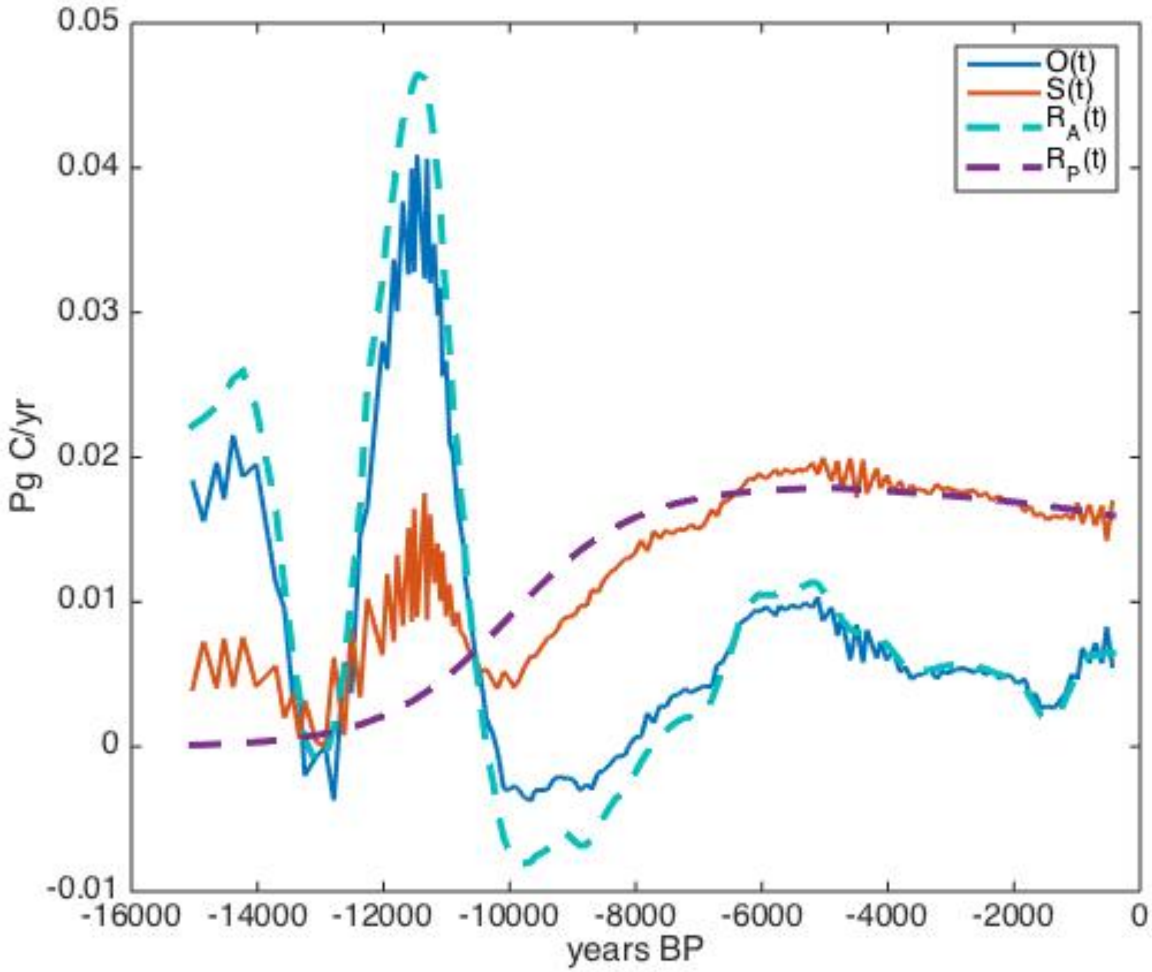
-6.3
-6.35
-6.4
-6.45
-6.5
-6.55
-6.6
-6.65
-6.7
δ13C (permil vs. PDB)
-16000
-14000
-12000
-10000
-8000
-6000
-4000
-2000
0
years BP
Schmitt Data
Result

Results



O(t)
S(t)
Pg C/yr
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-16000
-14000
-12000
-10000
-8000
-6000
-4000
-2000
0
years BP

Results


O(t)
S(t)
$R_A(t)$
$R_P(t)$
0.05
0.04
0.03
0.02
0.01
0
-0.01
Pg C/yr
-16000
-14000
-12000
-10000
-8000
-6000
-4000
-2000
0
years BP

References

- Brook, E. "The Ice Age Carbon Puzzle." *Science*: **336** pg. 682-683.
- Gorham, E. et al. "Long-term carbon sequestration in North American peatlands." *Qua. Sci. Rev.*: **58** pg.77-82.
- Schmitt, J. et al. "Carbon Isotope Constraints on the Deglacial CO_2 Rise from Ice Cores." *Science*: **336** pg. 711-713.