Problem 2. Source partitioning

There are some very helpful programs available on the web from Don Phillips at the EPA for source partitioning by both statistical and quantitative methods. There is also an R package "simmr" that does the same thing.

Please download one of these and for answering the following questions:

http://www.epa.gov/wed/pages/models/stableIsotopes/isotopes.htm

https://cran.r-project.org/web/packages/simmr/vignettes/simmr.html

If using the Simmr, you will need R (also recommended Rstudio), and

2a) You are trying to detect the contribution of heterotrophic decomposition to total ecosystem respiration fluxes, and have measured the respiration $\Delta^{14}CO_2$ value to be +118‰ (SD±10, n=4). From your lab incubations of soil and plant respiration at your site, you found the $\Delta^{14}CO_2$ values to be +145‰ (SD±20, n=2), and +75‰ (SD±5, n=6) respectively. Please calculate the proportional contribution of heterotrophic respiration using IsoError. What would happen to your estimate if you had more replicates of your measurements? What happens if the inherent variability of your observations was larger, or smaller?

Fractions: (soil) = 61% ± 14; plant = 38% ±14
When n=10, error goes to ± 7% and the means are the same
If stdev = 10 for all pools, error goes to ± 6 (means are the same)

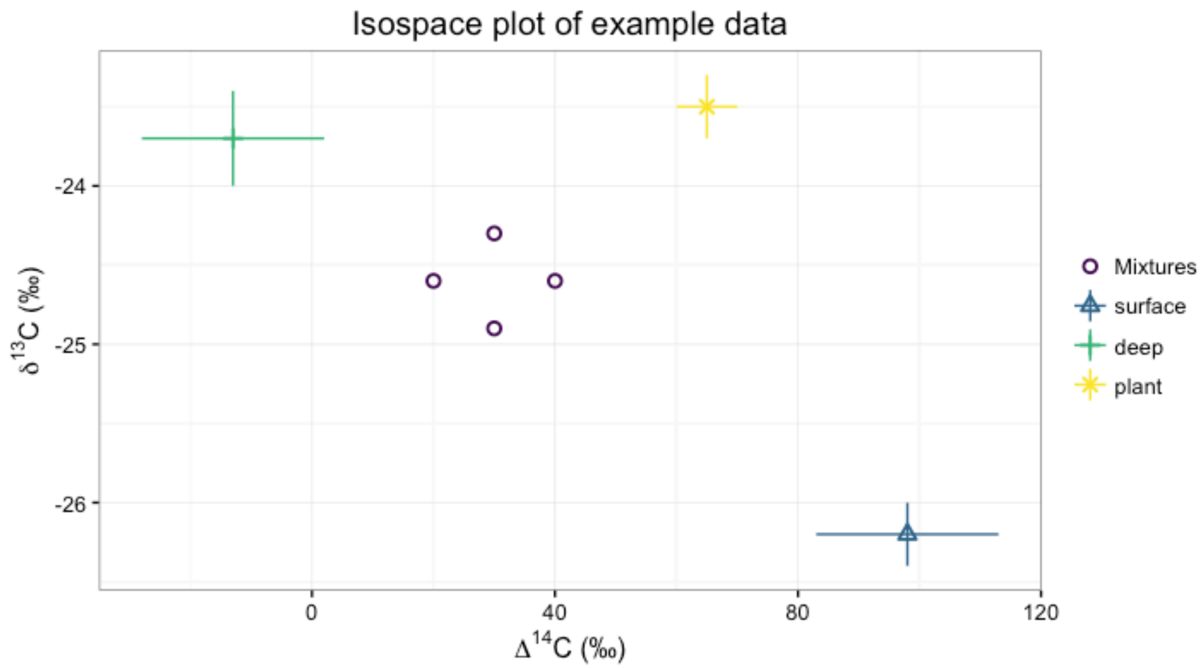
2b) Now you want to understand how the surface and deep soil each contribute individually to the total ecosystem respiration value, so you make measurements in another site and find the respiration $\Delta^{14}CO_2$ value to be +31‰ (SD±8, n=4). From your lab incubations of surface soil, deep soil, and plant respiration at your site, you found the $\Delta^{14}CO_2$ values to be +98‰ (SD±15, n=3), –13‰ (SD±15, n=3), and +65‰ (SD±5, n=4) respectively. Please calculate the statistical proportional contribution of the three components to total ecosystem respiration using IsoSource. What happens to these estimates if you had more replication, or if the inherent variability was different?

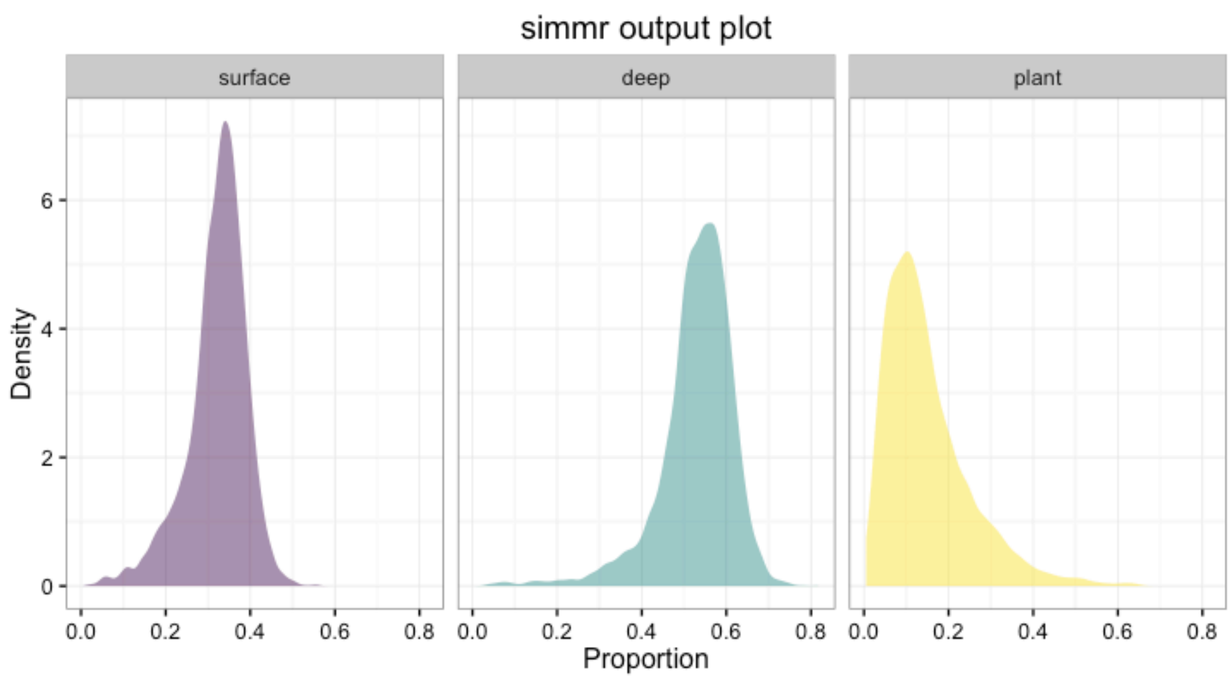
2c) Because you are left with an certain unsatisfied craving after your statistical partitioning, you decide to reanalyze your data by including $\delta^{13}CO_2$ data that you also collected from your sites. Your measurement of ecosystem respiration $\delta^{13}CO_2$ was –24.6‰ (SD±0.2, n=3). From your lab incubations of surface soil, deep soil, and plant respiration at your site, you found the $\delta^{13}CO_2$ values to be –26.2‰ (SD±0.3, n=3), –23.7‰ (SD±0.2, n=3), and –23.5‰ (SD±0.4, n=3) respectively. Please combine these measurements with those of 2b and calculate the contribution of the three components to ecosystem respiration using IsoError.

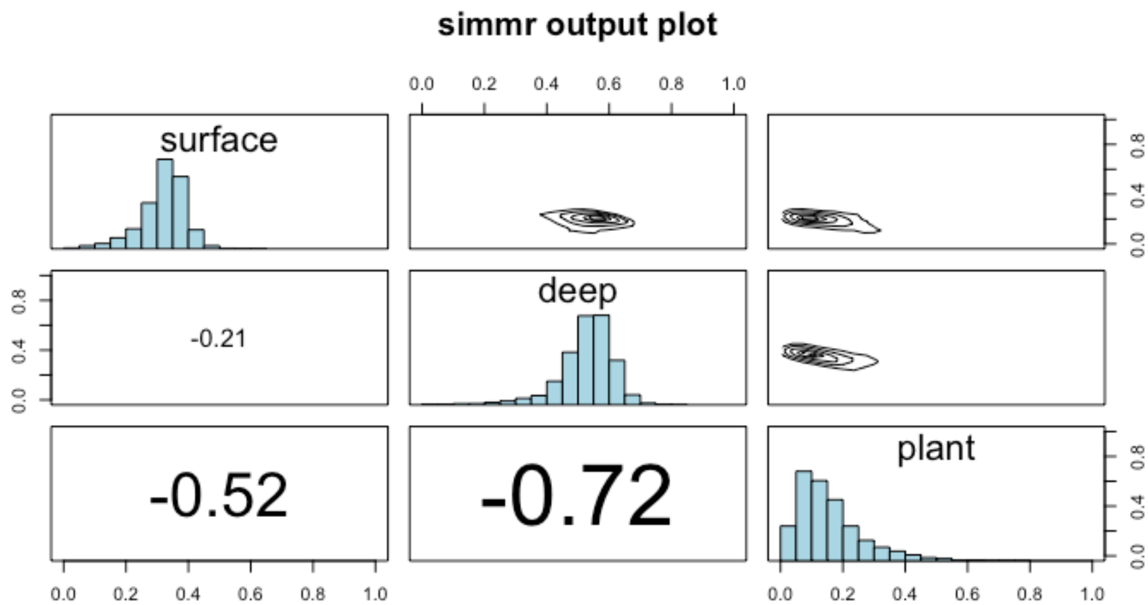
Surface 36 (±5)
Deep 59 (±9)
Plant 5 (±11)

**** This code works if you have downloaded the "jagd" program

```
install.packages('simmr')
library(simmr)

##Example Data
mix = matrix(c(20, 40, 30, 30,-24.6,-24.6,-24.9,-24.3), ncol=2, nrow=4)
colnames(mix) = c('D14C','d13C')
s_names = c("surface","deep", "plant")
s_means = matrix(c(98,-13,65, -26.2,-23.7,-23.5), ncol=2, nrow=3)
s_sds = matrix(c(15,15,5,.2,.3,.2), ncol=2, nrow=3)

#
simmr_in = simmr_load(mixtures=mix,
                    source_names=s_names,
                    source_means=s_means,
                    source_sds=s_sds)

#simmr
plot(simmr_in)
plot(simmr_in,xlab=expression(paste(Delta^14, "C (\u2030)",sep="")),
     ylab=expression(paste(delta^13, "C (\u2030)",sep="")),
     title='Isospace plot of example data')
##run the model
simmr_out = simmr_mcmc(simmr_in)
##
summary(simmr_out,type='diagnostics')
## Values should be close to 1.0 if the model is converging
summary(simmr_out,type='statistics')
## Gives the results
summary(simmr_out,type='statistics')
summary(simmr_out,type='quantiles')
plot(simmr_out,type='density')
plot(simmr_out,type='matrix')
```


Isospace plot of example data
-24
-25
-26
0
40
80
120
δ^{13}C (‰)
Δ^{14}C (‰)
Mixtures
surface
deep
plant


simmr output plot
surface
deep
plant
Density
6
4
2
0
0.0
0.2
0.4
0.6
0.8
Proportion



simmr output plot
surface
deep
plant
-0.21
-0.52
-0.72
0.0
0.2
0.4
0.6
0.8
1.0

Keeling plot problem

Isotope mixing – linear superposition of two sources
(otherwise known as the "Keeling plot")

$C_m = C_{bg} + C_{ff}$ mass balance for sum of isotopes where C = concentration in mixture (m), and sources bg (background atmosphere) and ff (fossil fuel)
$^{13}C_m = {}^{13}C_{bg} + {}^{13}C_{ff}$ mass balance for isotope (13C or 14C)
$\delta_m C_m = \delta_{bg} C_{bg} + \delta_{ff} C_{ff}$ ≈ mass balance for isotope ($\delta^{13}C$ or $\Delta^{14}C$)

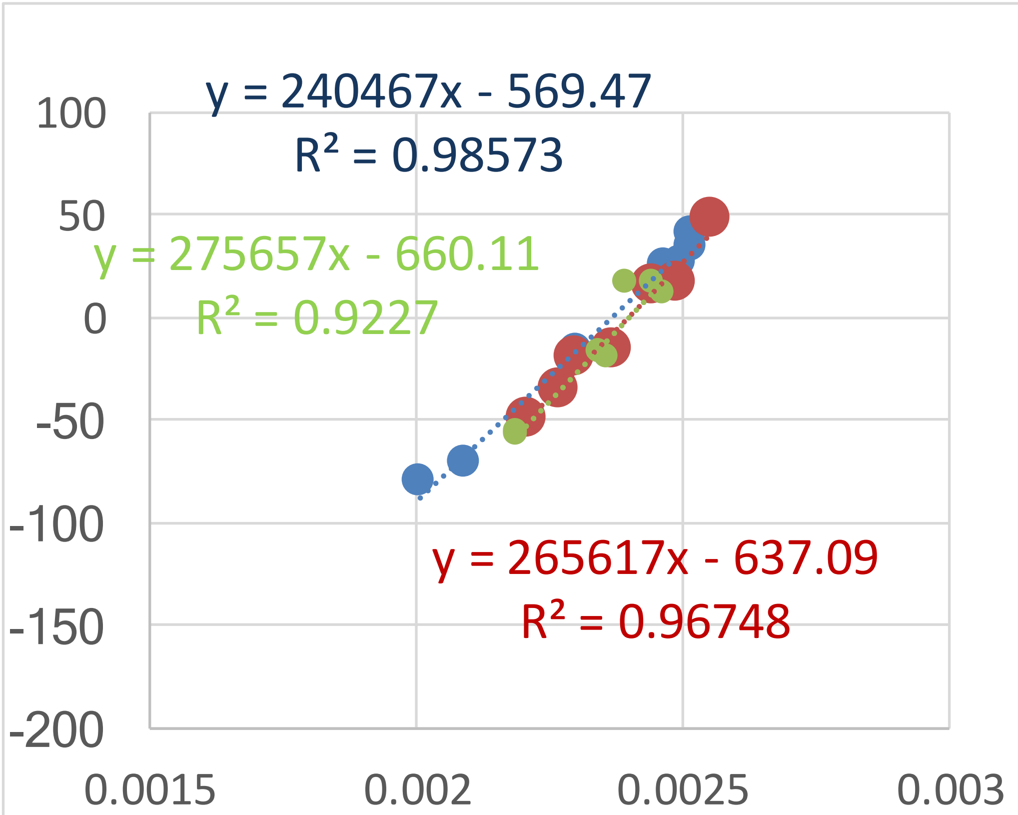
with some algebra (see the papers referenced below for the derivation)
$\delta_m = (\delta_{bg} C_{bg} - \delta_{ff} C_{bg})*(1/C_m) + \delta_{ff}$
slope intercept

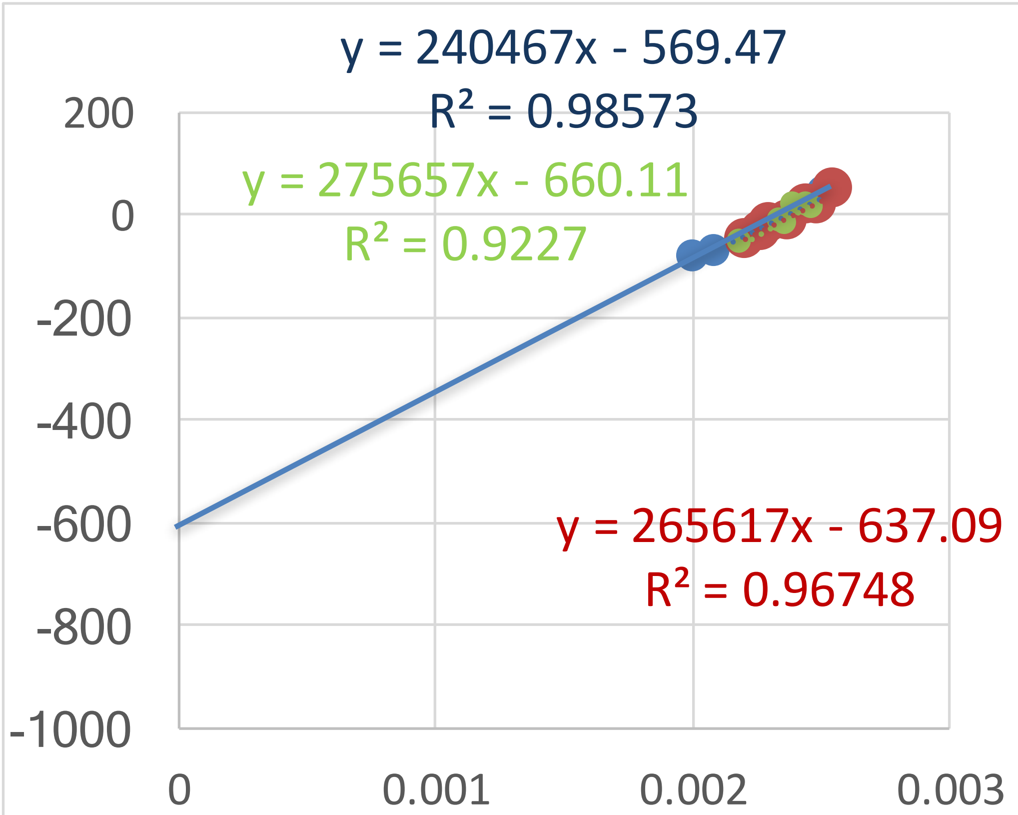
Keeling plot assumptions:
1) C_A, d_A and d_B are unchanging
2) mixing is mass-independent (turbulent, no diffusion)
3) no chemical or equilibrium reactions
4) only 2 sources A and B mix
   (above are usually met for respiration at night)
5) OR if there is a third source (C) then the relative proportions of B and C do not change, so their combined isotope ratio is the same

On the plots of the data set, the intercept is about -600‰ $\Delta^{14}C$. If we assume this is a mixture of fossil fuel carbon (-1000 ‰) and biosphere respiration (+50‰), then we can use our mixing models to estimate the fraction coming from fossil fuel:

100%*(-600‰) = X%* (-1000‰) + (100-X%)*(50‰), and solving for X

X = (-60000 -5000)/(-1000-50) = 52%


y = 240467x - 569.47
R² = 0.98573
y = 275657x - 660.11
R² = 0.9227
y = 265617x - 637.09
R² = 0.96748
100
50
0
-50
-100
-150
-200
0.0015
0.002
0.0025
0.003


y = 240467x - 569.47
R² = 0.98573
y = 275657x - 660.11
R² = 0.9227
y = 265617x - 637.09
R² = 0.96748
200
0
-200
-400
-600
-800
-1000
0
0.001
0.002
0.003