Effects of nitrogen fertilization on forest soil organic matter

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Think about this…

The amount of carbon currently stored in soils (1580 Gt), is about twice the amount in the atmosphere (750 Gt) (Johnson and Curtis 2000).

Significance of Project for Global Climate Change

•Nitrogen additions through pollution and commercial applications of fertilizers such as urea and ammonium nitrate.

How is nitrogen affecting the earth?

•Could it stabilize carbon in soil? Create a carbon sink? Or the reverse?

•What would this mean for the future of greenhouse gases like CO_2?

Goals of the Project

- Assess the effects of long-term N fertilization on radiocarbon abundance in soil carbon reservoirs.

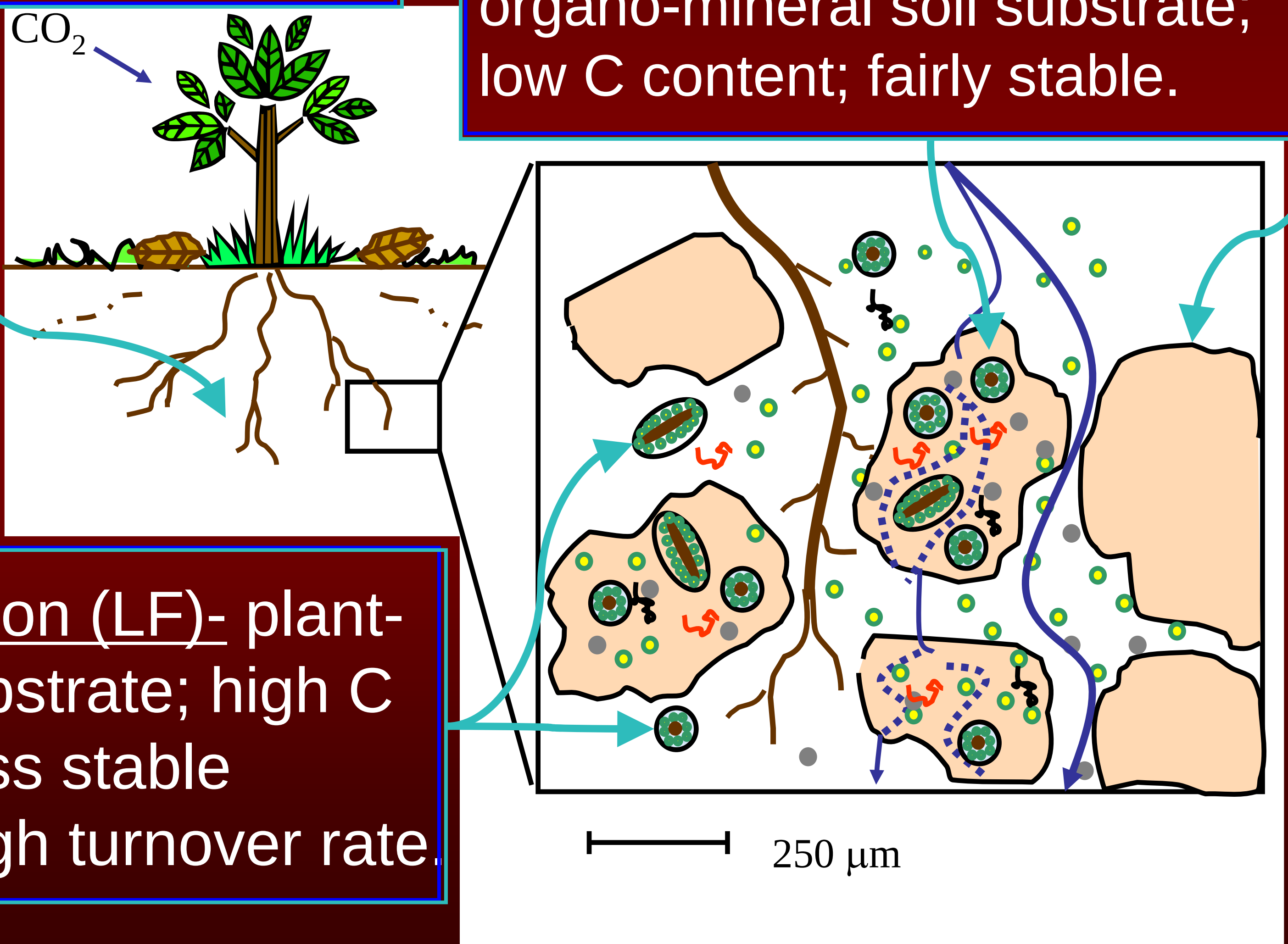
- Assess the effects of laboratory incubation on radiocarbon abundance in different soil carbon reservoirs.

- Use potential changes in radiocarbon abundance in the soil carbon pools as indices of the rate of carbon turnover.

But first, Soils 101…

Whole Soil (WS)- original soil sample; no density separation.

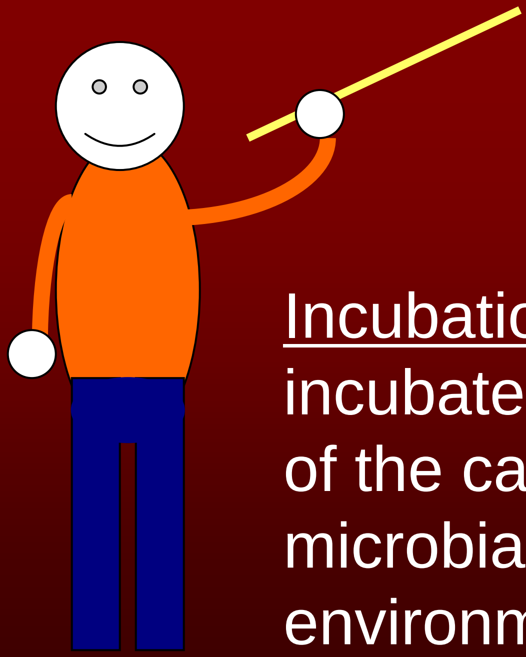
Heavy Fraction (HF)- high density, organo-mineral soil substrate; low C content; fairly stable.



Light Fraction (LF)- plant-like soil substrate; high C content; less stable fraction, high turnover rate.

Soils 101

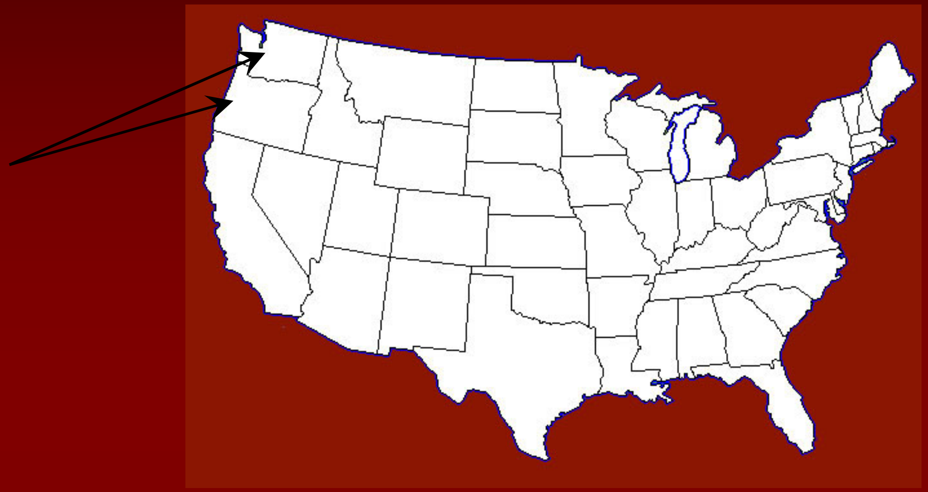
<u>Residence time</u> -time period a C atom remains in a single carbon pool (important because 14C is incorporated into soil fractions at different rates).



<u>Incubation</u>-in this project, soils and fractions were incubated to assess the relative stability
of the carbon in the substrates by measuring the microbial respiration (CO2 gas emitted) under controlled environmental conditions.

Project History

•Soil samples were collected from seven forested sites in Western Oregon and Washington in 1996.



•Each sampling site contained a no-treatment control and nitrogen-fertilized plots.

•Samples were separated into LF and HF using a density fractionation method (Swanston et al 2001) and incubated for 300 days.

Conclusions from previous studies in this project

- Johnson and Curtis (2000)-Soil C and N increases with fertilization and presence of N-fixing vegetation.

- Homann et al (2001)-Fertilization has no effect on concentration of Light Fraction and Heavy Fraction.

- Swanston et al (2002)-Recalcitrance of Heavy Fraction vs Light Fraction is similar. Accessibility and interactions are possible reasons for differences in substrate turnover rates in Whole Soil.

- Swanston et al (2003)-Cumulative respiration decreased in all substrates with added N. Long-term application of N stabilized C in Whole Soil and density fractions.

Where do we go from here? –My Role

In continuation of studies made by Swanston et al., the calculation of 14C abundance for samples collected by his group aims to further elucidate the nature and interactions of C and N in whole soil and density fractions when nitrogen is added.

More Terms!

Graphitization-chemical transformation of C contained in samples into graphite.

(AMS)- instrument that estimates radiocarbon abundance by counting radiocarbon atoms sputtered from graphite samples.

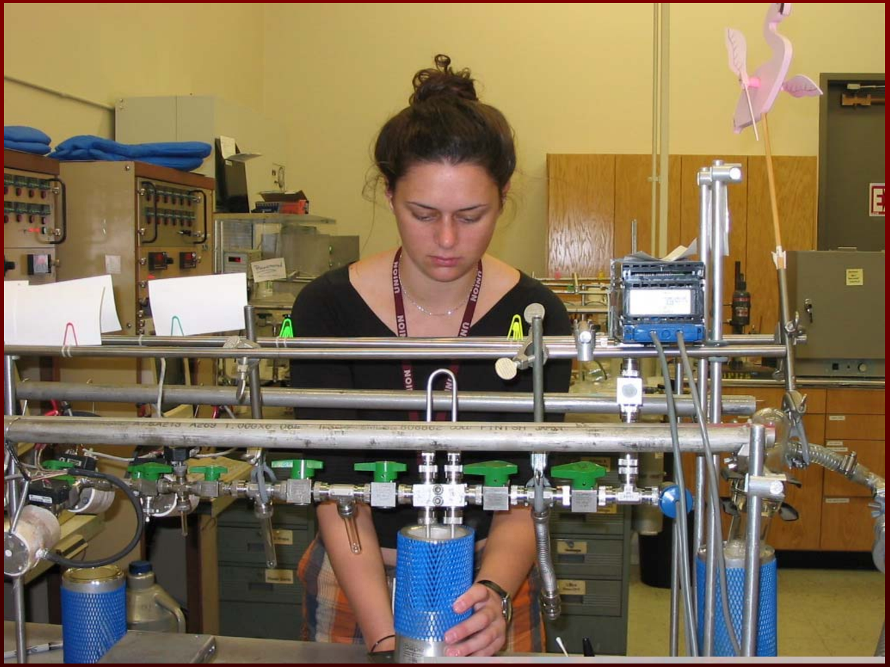
Methods

•Samples were oven-dried.

•Weighed samples were graphitized and pounded into targets.

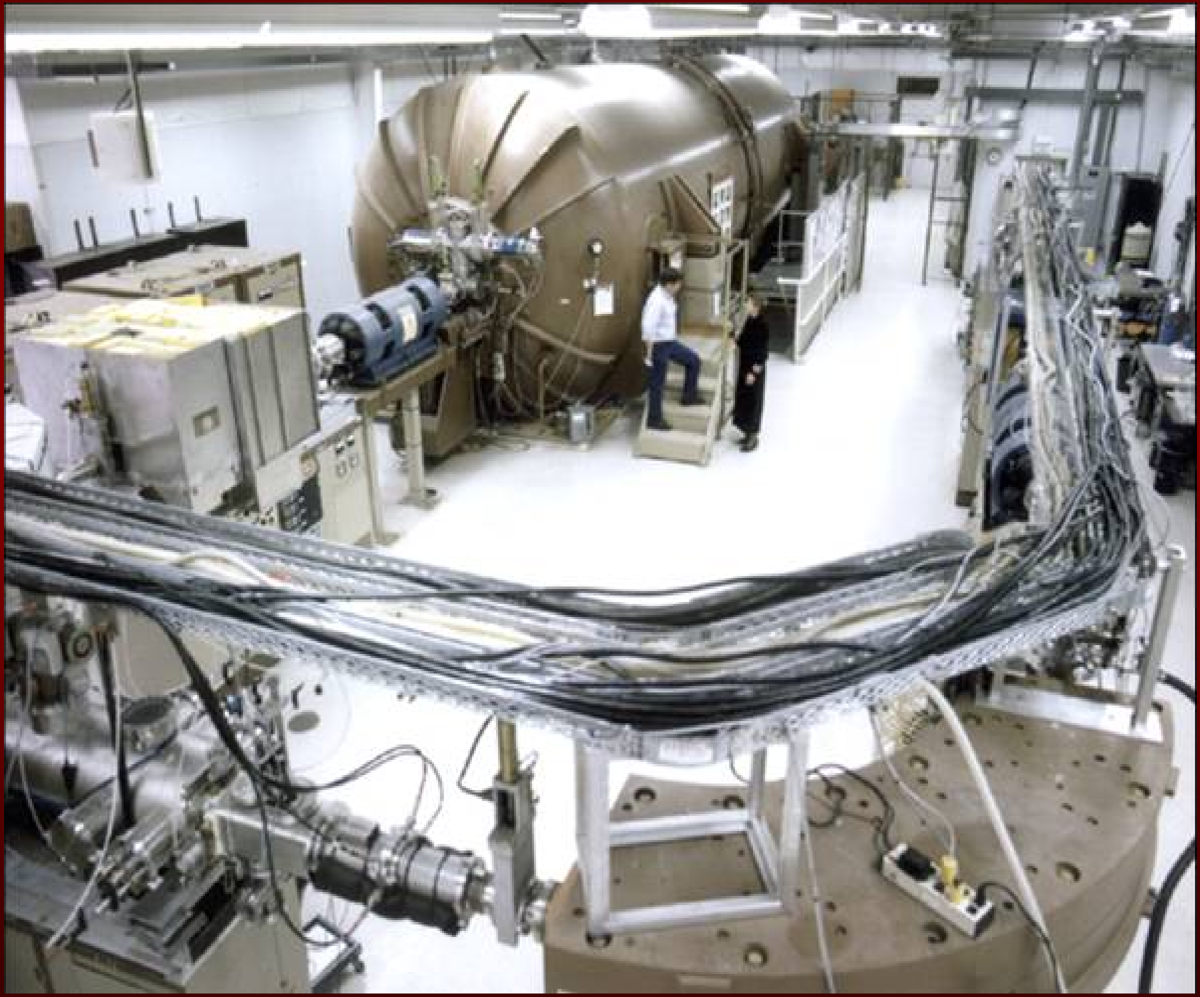
<u>Graphitization</u>

Solid samples converted to CO_2 gas by combustion at 900oC.
CO_2 gas from samples undergoes reduction in presence of H_2.
Reduced C atoms bind to FE catalyst.
O_2 and H_2 form water vapor.
$MgClO_4$ attracts and traps the H_2O vapor. (Vogel 1987)



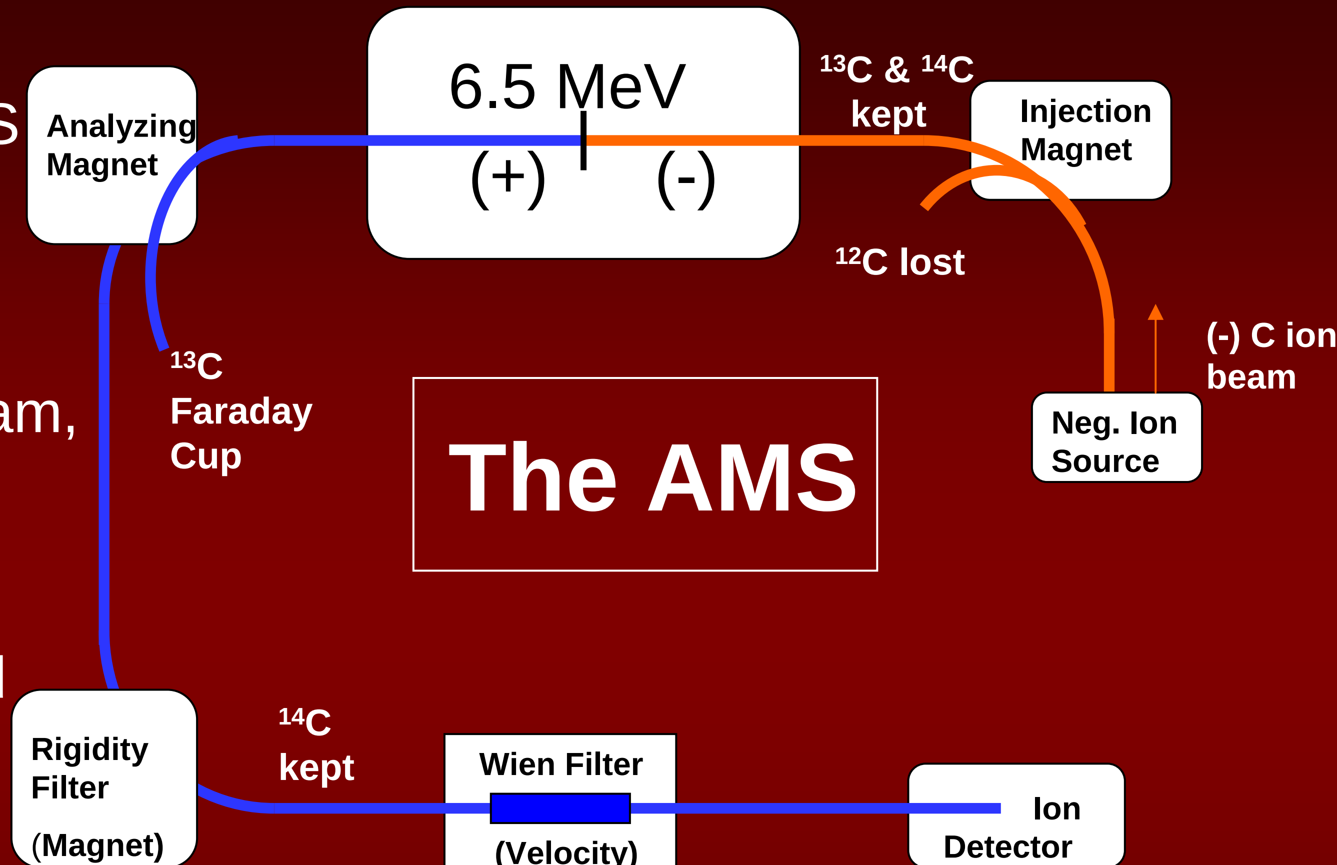
Methods

Accelerator Mass Spectrometry (AMS)



The AMS

- Samples are introduced to the AMS as graphite targets.
- The graphite is sputtered by a Cs beam, forming negative ^{12}C, ^{13}C, and ^{14}C ions.
- The ^{12}C is eliminated via the first magnet, leaving ^{13}C and ^{14}C.

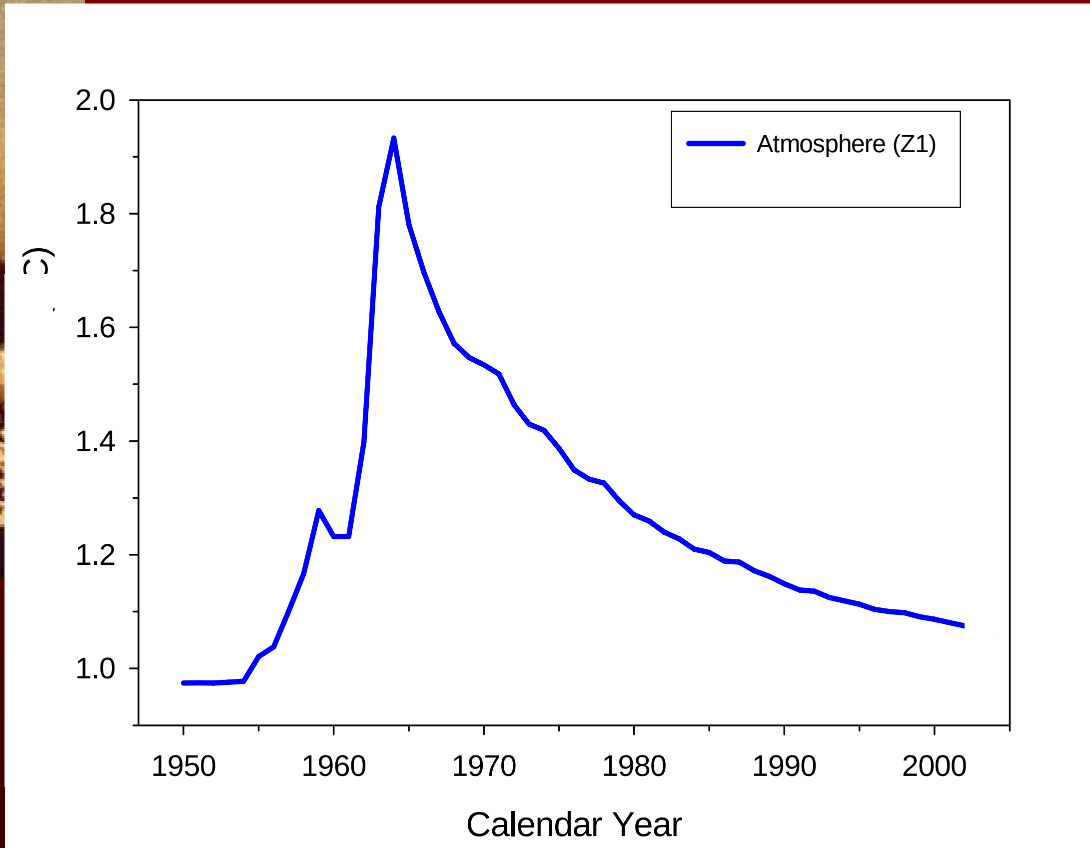


- The ^{13}C and ^{14}C are accelerated through an ion stripper at 6.5 MeV, breaking up molecules and changing the negative ions to positive ions.
- The ^{13}C is then collected in a Faraday cup after the second magnet.
- The remaining ^{14}C is counted in the detector.

An important lesson in radiocarbon dating

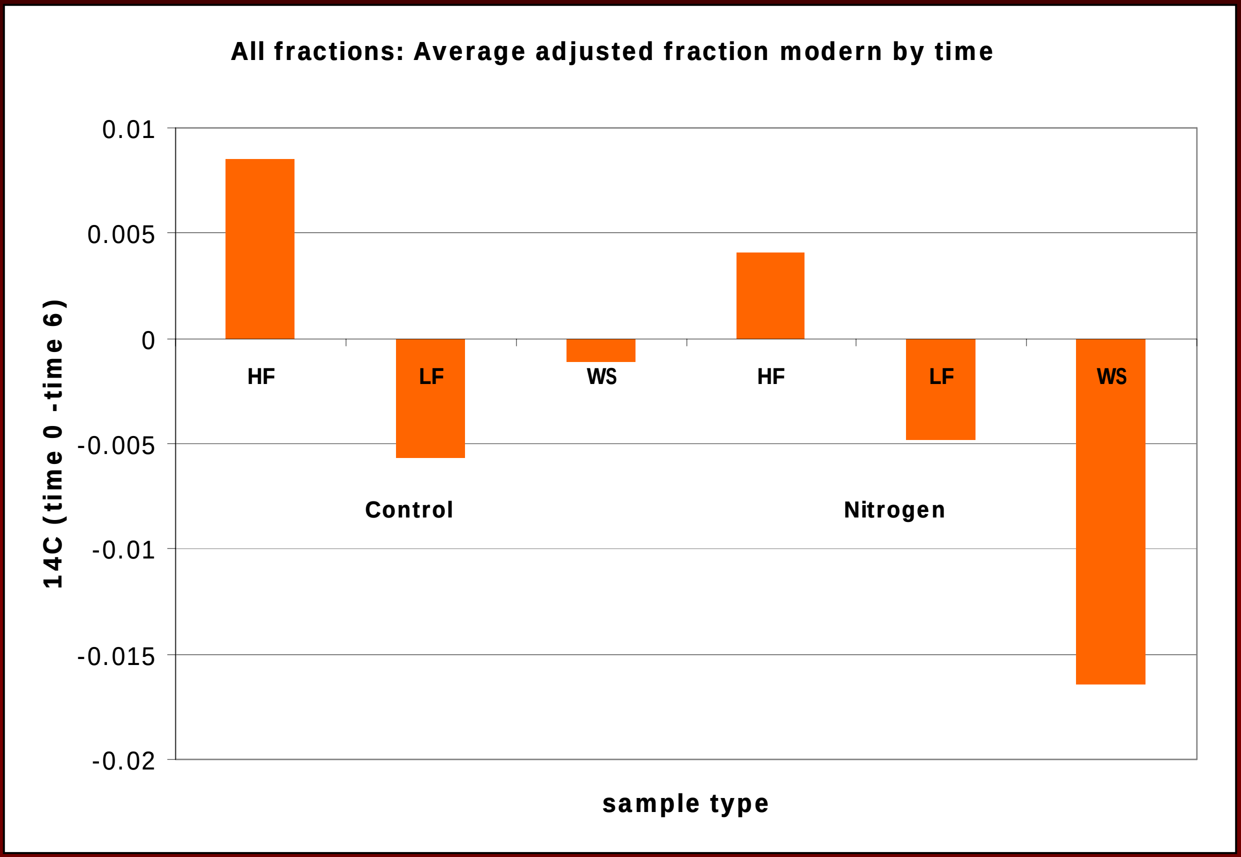
Detonation of bombs in 1950's doubled atmospheric ^{14}C, creating the 'bomb spike'.

Figure shows atmospheric ^{14}C values since 1950.



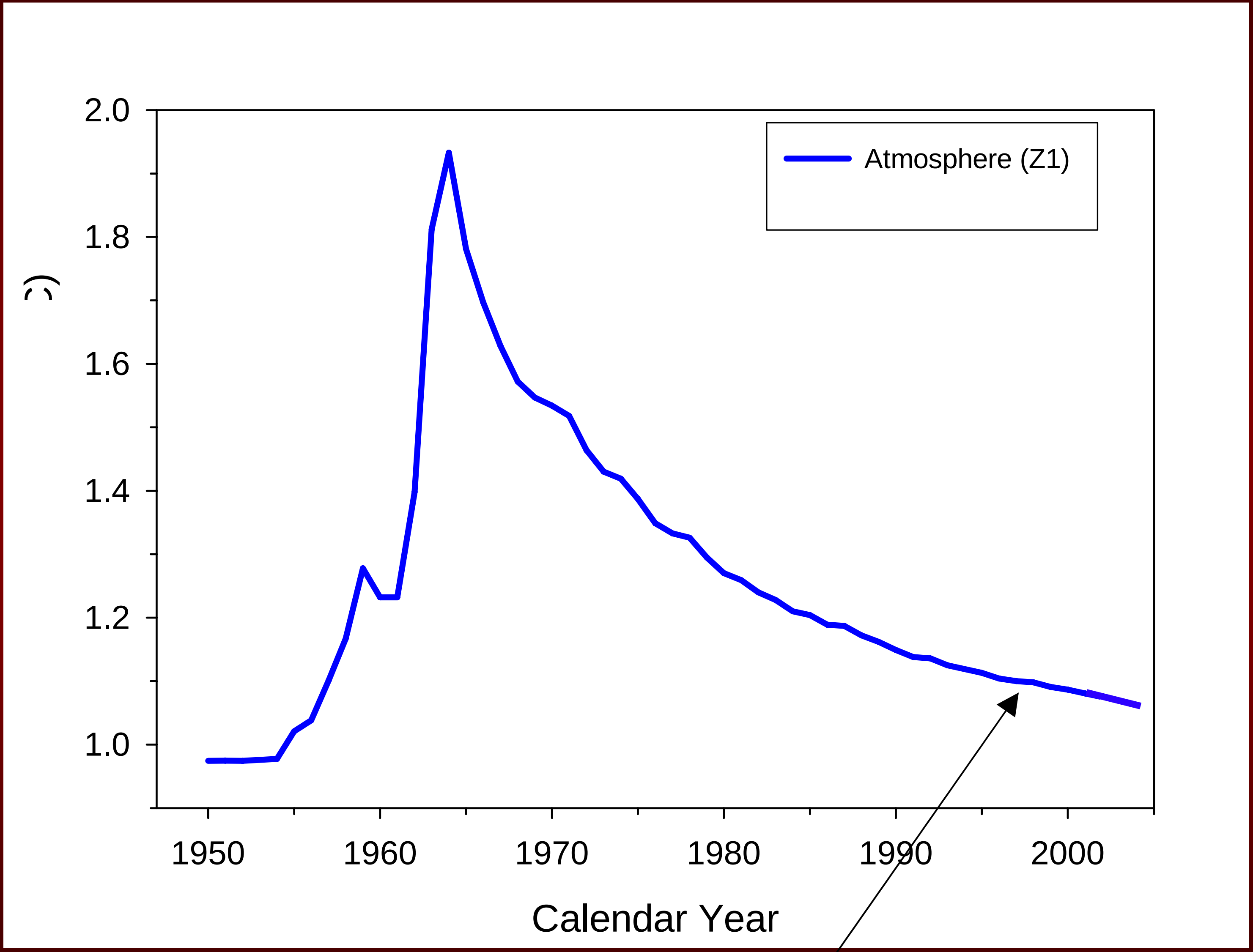
Results

Change in radiocarbon resulting from 300-day incubation.



- Negative values indicate sample released younger radiocarbon during incubation period, and vice versa for positive values, but its not that simple...
- Scale on y-axis is very small, indicating that the average changes are marginal at best, though strong in some soils.

Back to the bomb curve…



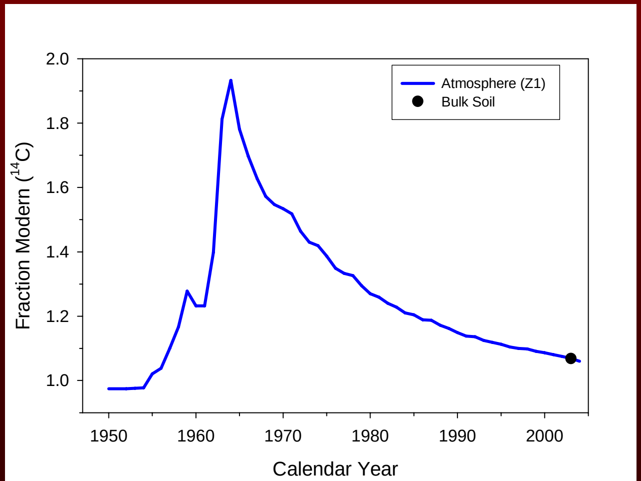
At time of sampling, we were here, around 1.10

•Bomb spike acts as a world-wide radiocarbon tracer, allowing us to differentiate soil organic matter with different carbon mean residence times, but it has two sides and can be difficult to interpret.

•If ^{14}C values are below present atmosphere, the bulk of carbon in the sample was fixed in 1950 or before.

•Values above contemporary atmosphere will have two potential ‘ages’ (from either side of bomb curve) or calculated mean residence times.

•Context of samples helps decide which mean residence time to use.

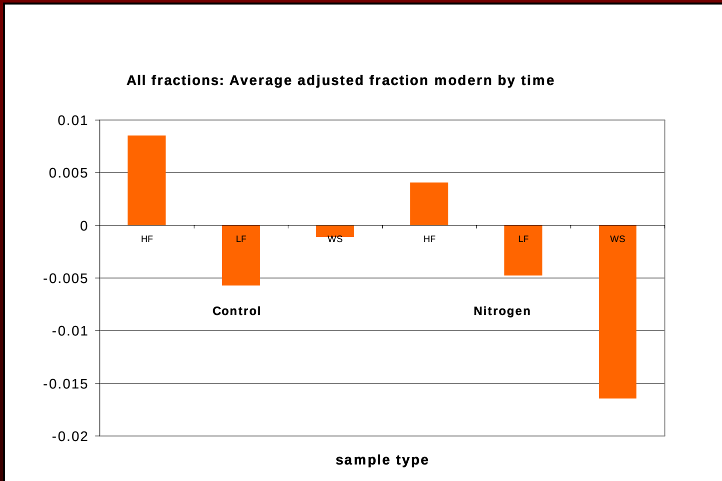


Bar graph 14C values for soil fractions do not indicate whether C was fixed before or during bomb curve; it only records increases or decreases in radiocarbon abundance.

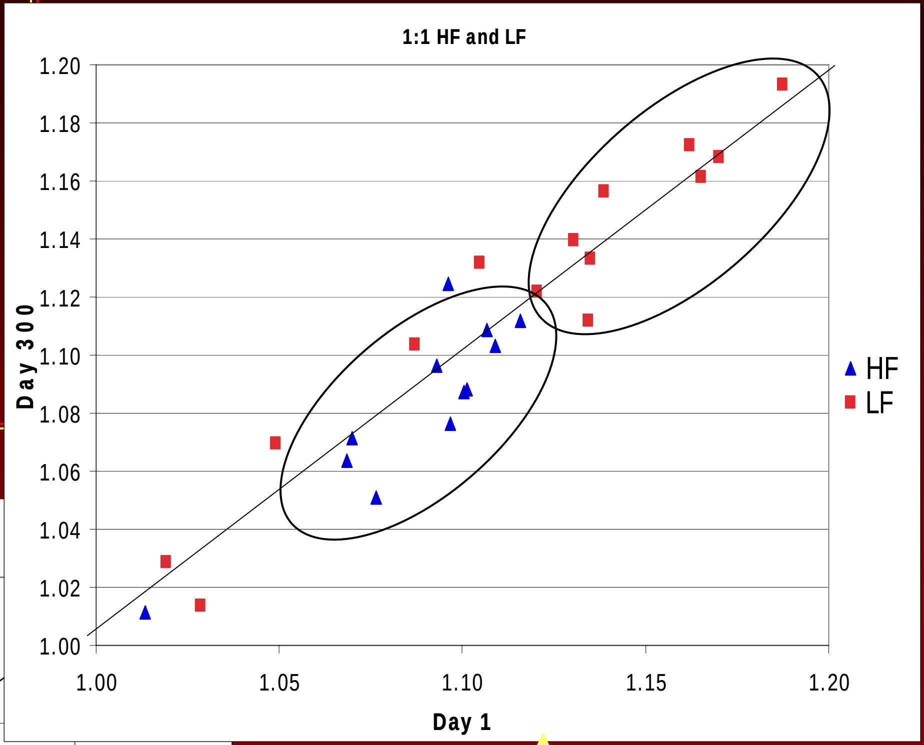
Average fraction modern values represented in the graph show HF released mostly older C during incubation, while LF released C much closer to present atmospheric values.

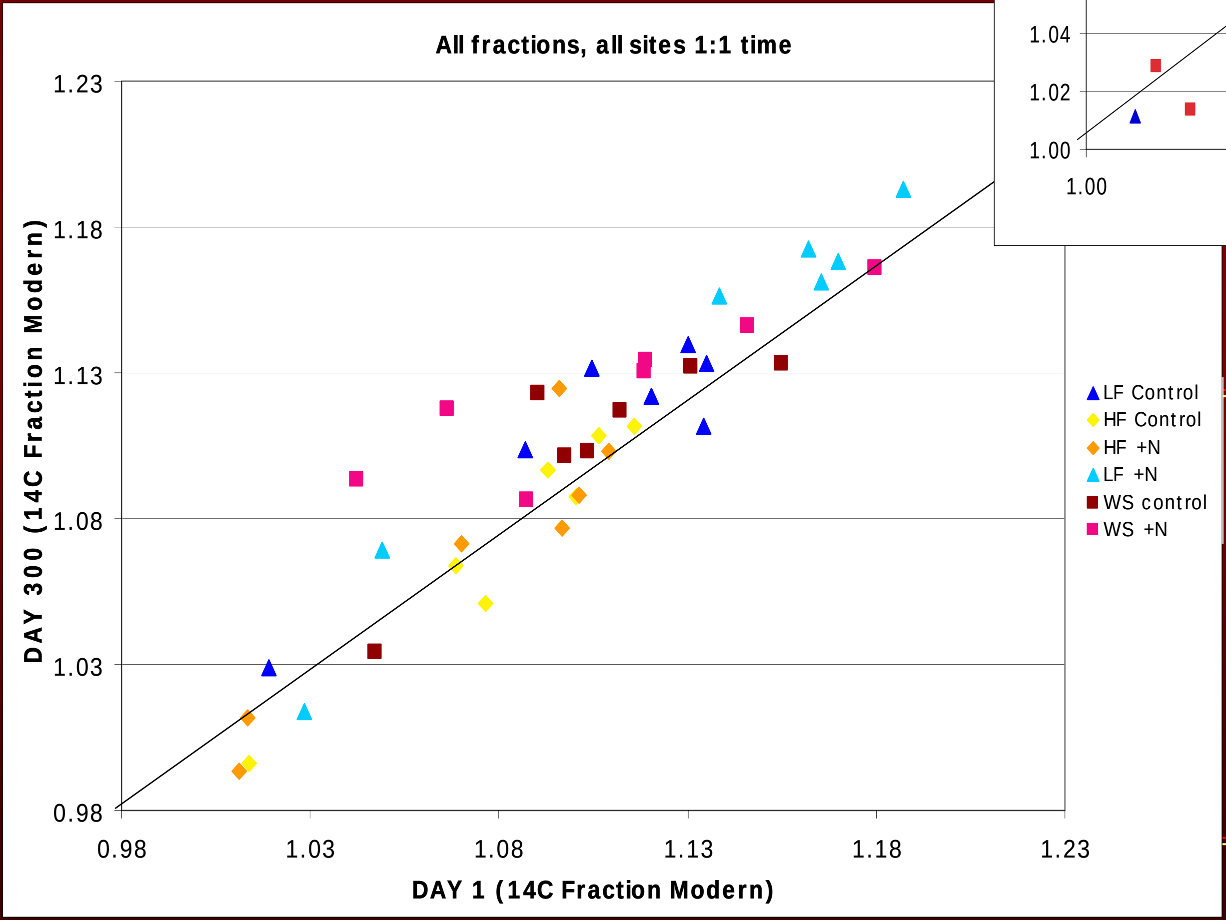
N-treated WS was least consistent in trends of 14C loss –some soils released ‘young’ and others ‘old’ C.

•Fertilized soils in general had greater variation in fraction modern - likely due to changes in both normal inputs and substrate activity.

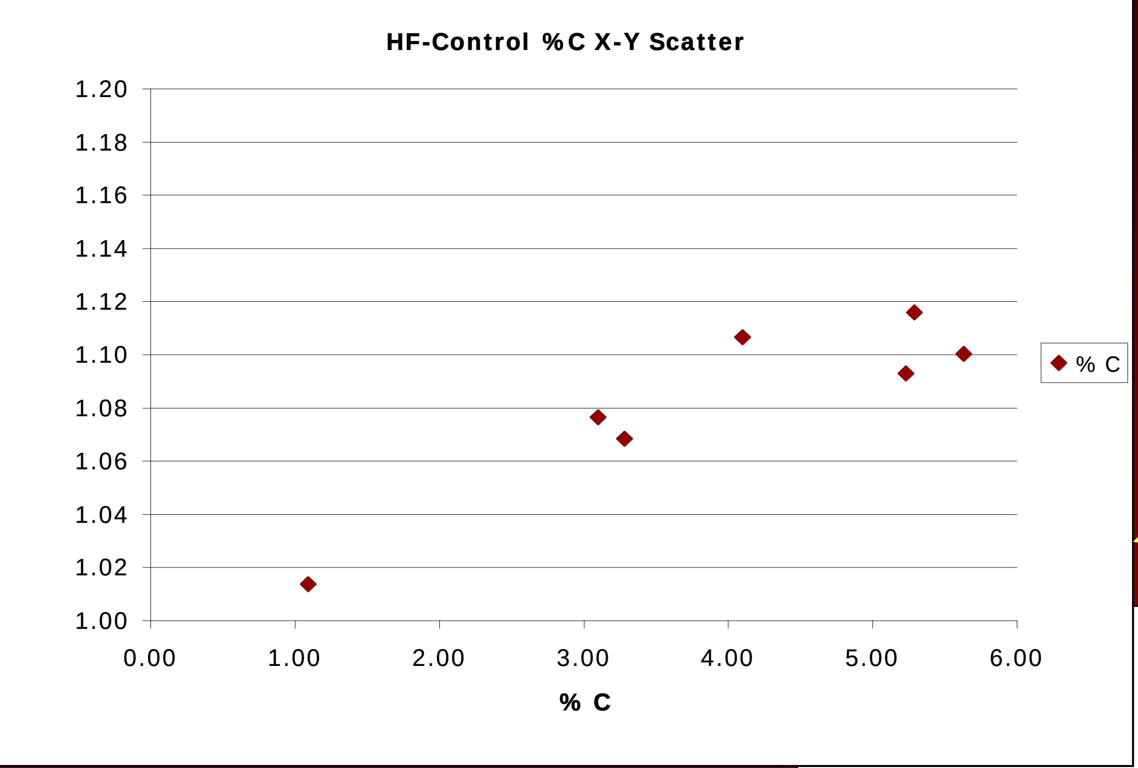


All density fractions from all sites plotted by time against one another. Points scatter around the 1:1 line.
→ The incubation did not appear to change the distribution of ^{14}C in the fractions.





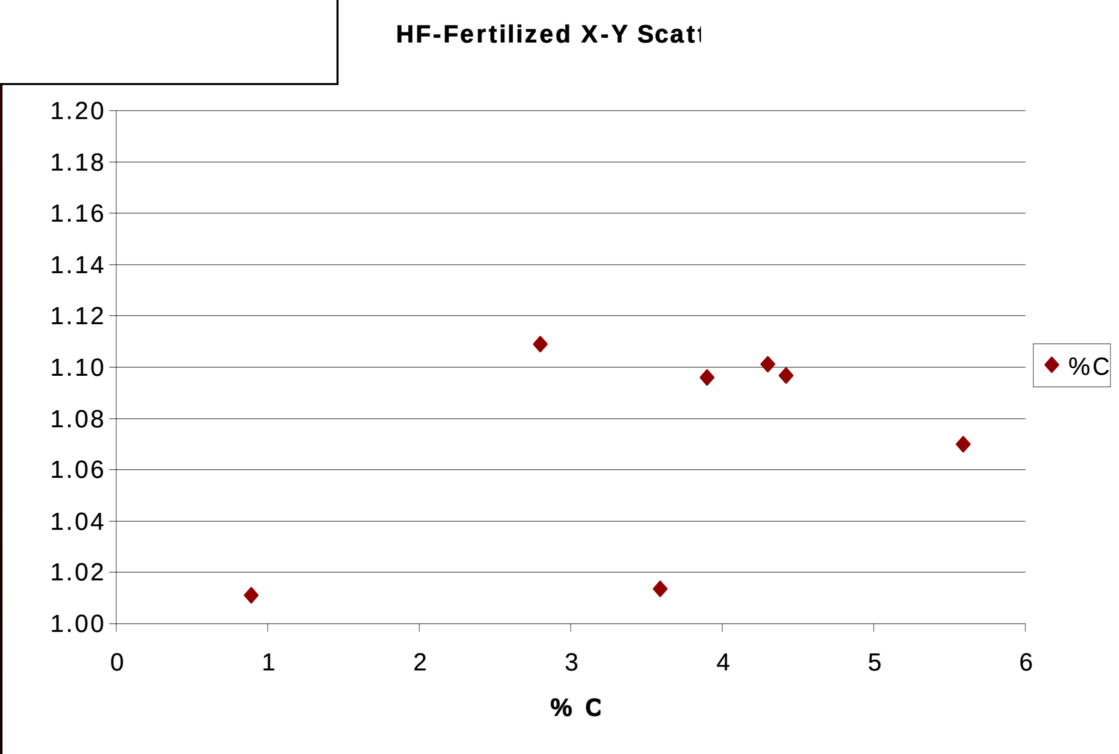
Majority of sites followed trend showing LF radiocarbon values higher than HF values.



Trend in HF control shows ^{14}C proportional to %C values.

Relationship between %C and ^{14}C is diminished in N-treated plots.

These observations were also true for %N vs ^{14}C plots.



Well, what does it all mean?

All fractions

•Incubation and treatment had marginal, if any, effect on the ^{14}C distribution in density fractions.

• Graph and statistical analysis indicate that control and N-treated soils and fractions are not different with regard to ^{14}C abundance.

•Differences in radiocarbon abundance before the incubation are likely related to quicker and slower turnover rates for LF and HF, respectively, or other structural differences between the substrates.

HF and LF

• LF 14C abundance was higher than HF abundance (split-plot ANOVA, p=0.003).

HF-14C vs %C

• Higher %C coincides with younger carbon.

•Lower %C coincides with older, more stable carbon; supported by other studies using density fractionation and radiocarbon.

•Fertilized plot indicates possible changes in substrate recalcitrance and microbial community of fraction with addition of N.

Conclusions

- Separation of fractions makes them equally susceptible to microbial decomposition.

- There was an initial difference in radiocarbon abundance between the density fractions (LF, HF); N treatment and incubation did not significantly alter this difference.

- Differences between fractions exist when incorporated in WS in the field.

Next Step

Look at site specific sources of variability, especially with regard to organo-mineral interactions.

Acknowledgements

Chris Swanston, Paula Zermeño, Dot Kurdyla, Rachel Porras, Tom Guilderson, Jeff Gaffney, and Milton Constantin

Thank you to everyone for this amazing research opportunity and the chance to work at LLNL.