LTER 1st Tuesday:
Resolving Soil Rh Response to Fire

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Soil Respiration

- $R_s = R_a + R_h$
  - $R_a$ operationally includes roots, rhizosphere, and mycorrhizae
  - $R_h$ includes everything else

- C balance = $f(NPP, R_h)$
  - $R_h = f(T, H_2O, Substrate)$
NPP, Rh, and C Balance
(O’Neill et al. 2003)
Fire effects on Rh?

- Increases soil temperature:
  - Remove canopy $\rightarrow$ greater insolation
  - Blackens surface $\rightarrow$ greater absorption
  - Consumes some of O horizon $\rightarrow$ less insulation

- Changes soil moisture profile
  - Warm surface $\rightarrow$ increase evaporation
  - Reduced LAI $\rightarrow$ reduced transpiration
  - Warm soils $\rightarrow$ deeper active layer

- Changes substrate
  - Fire severity $\rightarrow$ surface OM loss
  - Pulse of detritus inputs
  - Loss of root and foliar litter inputs
Fire stimulates Rh

- Lowland chronosequence near Delta & Tok, Alaska
  - Richter *et al.* 2000
  - O’Neill *et al.* 2002
- Glacial outwash underlain by shallow permafrost
Richter et al. 2000

- Rs in burned soils \( \approx 0.5 \times \) unburned soils
Lowland chronosequence

- Rs in burned soils $\approx 0.5 \times$ unburned soils
- Unburned Rh $\approx 0.2 \times$ Rs
  - Schlentner and Van Cleve 1985

![Graph showing Rs and Rh emissions](image-url)
Soil temperature in black spruce

(O’Neill et al. 2002)

Soil CO2 Flux (g CO2 m⁻² hr⁻¹)

Soil Temperature at 10 cm (°C)

Control
(P = 0.005; R² = 0.46)
Soil Temperature in black spruce
(Bergner et al. 2004)
Role of roots following fire?

(Bergner et al. 2004)
Soil moisture in black spruce

(O’Neill et al. 2002)

Soil Moisture Potential (centibars)

Soil CO₂ Flux (g CO₂ m⁻² hr⁻¹)

Burned

(P = 0.05; R² = 0.40)
Fire suppresses Rh

- Frostfire experimental wildfire in uplands near Fairbanks, Alaska
  - Valentine 2002
  - Schuur et al. 2004
- Generally well-drained rocky soils near ridge
a. Light chamber at Poker Flat

b. Dark chamber

c. Net Respiration Rate (Dark-Light)  

Kim 2006

1. 30 min. interval
2. Diurnal Variation
3. C emissions (143 days)
   * Burned: 143 g C m\(^{-2}\)
   * Control: 253 g C m\(^{-2}\)
4. Continuous measurements of CO\(_2\) flux since 2006
Partitioning Sources of Soil Respiration
Respiration Partitioning
(Schuur)

- soil respiration
- soil incubation
- atmosphere

\( \Delta^{14}C \) (‰)

% heterotrophic

CPCRW Delta Tower
Schuur & Trumbore 2006
Global Change Biology
Frostfire uplands

- Rs in burned soils $\approx 0.35 \times$ unburned soils
- Unburned Rh $\approx 0.4 \times$ Rs
  - Vogel *pers. comm.*
  - Rocky soils obviated solid Ra vs. Rh
Growing Season Soil C Emissions

Burned, removal = 188.6 g C m$^{-2}$

Unburned = 512.8 g C m$^{-2}$
Growing Season Soil C Emissions
(Schuur)

Burned, removal = 188.6 g C m\(^{-2}\)

Unburned = 512.8 g C m\(^{-2}\)

Autotrophic
215.4 g C m\(^{-2}\)

Heterotrophic
297.4 g C m\(^{-2}\)
Survey Line Fire

- Accidental ignition in May 2001 by survey crews
- Poorly drained, fine-textured soils adjacent to Tanana River
  - No rocks
PVC Root Exclosures

\[ Rs = Rh \]

\[ Rs = Ra + Rh \]
Root exclosure

- Burned vs. unburned
- @3 transects
- @10 pairs per transect
- Vascular plants clipped
Moss respiration
(O’Neill et al. 2006)
Survey Line Fire Lowlands

- Rs in burned soils \( \approx 0.4 \times \) unburned soils
- Unburned Rh \( \approx 0.5 \times \) Rs

Bar chart showing the comparison between unburned and burned soil with respect to CO\(_2\)-C emissions.
Rh poorly related to soil T

Soil Temperature (°C)

Rh (mg C m⁻² h⁻¹)
Temperature Sensitivity of Soil C Emissions (Schuur)

Temperature (°C)

Respiration (μmol CO₂ m⁻² sec⁻¹)

unburned
burned, removal
Organic layer moisture

\[ y = -1.0229x + 123.68 \quad R^2 = 0.0029 \]

\[ y = 13.389x + 71.687 \quad R^2 = 0.092 \]

\[ y = 6.9162x + 112.62 \quad R^2 = 0.0296 \]

Organic Soil Moisture (g g\(^{-1}\))

Rh (mg C m\(^{-2}\) h\(^{-1}\))

- Green squares: Control
- Red triangles: Burned
Mineral soil moisture

\[ y = -32.825x + 142.29 \quad R^2 = 0.0335 \]

\[ y = -14.394x + 103.92 \quad R^2 = 0.002 \]

\[ y = 89.566x + 90.751 \quad R^2 = 0.0335 \]

\[ y = -105.96x + 141.56 \quad R^2 = 0.0261 \]
What fuels Rh?

- Burned and unburned Rh potentials similar
  - Unburned had initially higher Rh
    - Masco MS thesis
- Root allocation $\geq 5 \times \text{ANPP}$
  - Vogel et al. in press
- Isolated O horizon lost 15% mass over 3 y
  - MRT = 20 y
  - Much faster than supposed
    - Vogel et al. in press
Substrate quality
(Masco 2005)
Substrate quality
(Masco 2005)

Day One Respiration Rate

- **Flayer**
  - Treatment $p<0.0001$
  - Temperature $p<0.0001$
  - Treatment*Temperature $p=0.0001$

- **H layer**
  - Treatment $p<0.0001$
  - Temperature $p<0.0001$
  - Treatment*Temperature $p=0.0003$

Bars represent burned vs control conditions.
Belowground allocation

• Hypothesis:
  – Recent root turnover is important source of current Rh.
  – Fire deprives microbial community of fresh detritus
  – Rh depressed until post-fire root turnover recovers
Fire impacts on Rh

Rs (mg CO₂-C m⁻² h⁻¹)

- DT
  - Unburned
  - Burned
- FF
  - Unburned
  - Burned
- SL
  - Unburned
  - Burned

Ra
Rh
Net Primary Productivity Following Fire

(Schuur)
Can old soil C be lost via soil respiration following fire?

Soil Respiration Isotopes

1999 Burn Delta Junction, AK
Schuur concluded:

Heterotrophic respiration is not significantly stimulated following fire

Respired C following fire was fixed over the past several decades

Net C loss from ecosystems to the atmosphere in the early stages of succession is a result of decreased plant uptake.
Discussion points

• Increased temperature may stimulate Rh if
  – Surface soil moisture adequate
  – Substrate quality allows
  – Fire severity mild

• Role of fire severity
  – Decreases surface OM (& substrate quality)
  – Regime shift