

Observation of CO₂ efflux at Poker Flat forest fire burned site in 2005

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Abstract

Forest fire gives tremendous changes to surface conditions. In order to clarify the difference in soil respiration and its response to weather and soil conditions between burned and unburned, measurement using chambers were carried out in the summer of 2005. Together with the respiration measurement, chamber and soil temperatures and soil moisture as well as the meteorological conditions were observed.

CO₂ efflux from ground surface showed a clear diurnal variation at the both burned and unburned site. It was correlated well with soil temperature and the sum of net respiration in the observation period from May 13 to October 3 (143 days) became 143 gCm⁻² at burned site and 253 gCm⁻² at unburned site. The ratio of the two was 56%.

1. Introduction

Boreal forests account for about one-third of the carbon sequestered in terrestrial ecosystems. Northern boreal forests represent approximately 35% of the the world's forests and contain approximately 66% of the world's forest soil carbon pools (Oechel and Voulitis, 1997). Since boreal forests absorb atmospheric carbon dioxide and slowly decompose the litter, fibric and humic substances, the ecosystems are known as carbon sinks (Schlesinger, 1997).

Forest fire is a major disturbance in boreal forests and, as boreal forests emit higher concentrations of carbon to the atmosphere immediately after the fire, forest fires in the northern stands are well known as carbon resources (Kasisheke and Stocks, 2000).

2004 Alaskan forest fire was the largest in the area burned in the last 50 years. A 50-year record of Alaska boreal fires shows an increase of fire occurrence and area burned (French et al., 2002). In the 1990s, the average area burned in Alaska was 4 x 10² km² (Murphy et al., 2000). As of summer 2004, the total area burned in Alaska is more than 6 x 10² km² (Alaska Fire Service, <http://fire.ak.blm.gov>), clearly an extreme record. A wildfire named "Boundary fire" took place near Fairbanks in 2004, strongly burned surface soil and is predicted to influence on water circulation, permafrost degradation and vegetation recovery in the watershed.

In order to monitor the influences after the wildfire, Japan Aerospace Exploration Agency and International Arctic Research Center, University of Alaska jointly formed a program entitled "Monitoring of influence of 2004 Alaskan large forest fire on terrestrial environment" for 3 years. It is mutually established the basis for middle to long term monitoring by relating atmosphere, land surface (vegetation), permafrost and water cycles and by setting observation sites and regions the utmost.

In order to clarify the difference in net respiration and its response to weather and soil conditions between burned and unburned, measurement using light and dark chambers were carried out in the summer of 2005. Measurements of albedo, surface temperature, soil moisture and heat conductivity were also carried out in order to characterize the seasonal and inter-annual changes in these surface conditions. In this study, the preliminary results of the measurement are reported.

2. Study site and method

2.1. Observation site

The study site is located at southwest end of the burned area of “Boundary Fire” in 2004 (Fig. 1). It is located in the Poker Flat Rocket Launch Range of University of Alaska, northeast of Fairbanks, Alaska. We chose a north-facing slope (Fig. 2) for the study site because this region is in discontinuous permafrost area and the north-facing slope is expected to underlain by permafrost.

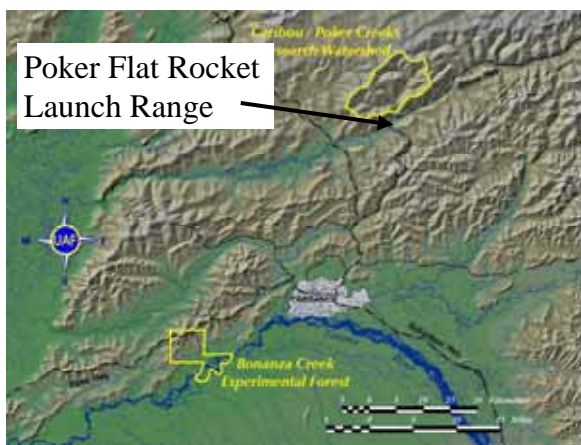


Fig. 1. Location of Poker Flat Rocket Launch Range (after <http://www.uaf.edu/water/projects/cpcrw/metdata/cpcrwmetssitemap.htm>)

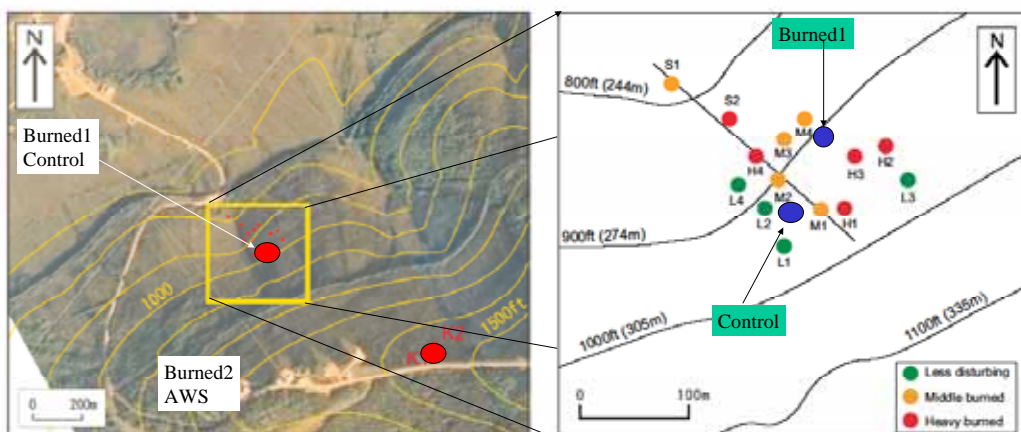


Fig.2. Location of observation site. L1-4, M1-4, S1-2 and K1-2 are the locations of plots for ecological study.



a) Burned1 in May



b) Burned2 in May



c) Burned2 in August



d) Control in May

Fig. 3 Closed chamber systems

We have chosen two burned sites and one unburned site for the measurement (Fig.2). Burned1 site (Fig.3a) locates on the slope. It was severely burned and any vegetation came back on the summer 2005. Burned2 site (Figs. 3a and 3b) is also severely burned site on the top of ridge, but the vegetation came back in August 2005 (Fig. 3c). Control site is located on the slope where sphagnum moss is dominant (Fig. 3d).

2.2. Method

In order to clarify the differences in net respiration and its response to weather and soil conditions between burned and unburned, a measurement using close/open chambers were carried out in the summer of 2005 (Fig. 3). Together with the respiration measurement, chamber and soil temperatures and soil moisture as well as the meteorological conditions (at AWS site (Fig.2) were observed.

For respiration measurement, a set of opaque and transparent chambers was used. Each chamber automatically closes and opens the lid by two timers, and the CO₂ concentration inside the chamber was measured every two minutes by an infrared CO₂ analyser (GMD20, Vaisala), and

recorded to a voltage recorder (VR-71, TandD). The chamber is closed for 15 minutes and then opened for 15 minutes. The chamber and soil temperatures were also measured every 5 minutes.

The increase rate of CO₂ concentration, dC/dt (ppms⁻¹) inside the chamber while the chamber was closed was calculated by best-fitting, and then calculated the soil (opaque chamber) and net respiration (transparent chamber), R_s (μ molm⁻²s⁻¹), by the following formula.

$$R_s = (1000/22.4) \cdot (273/(273+T_c)) \cdot dC/dt, \quad (1)$$

where T_c is the temperature inside the chamber.

We analyzed temperature response s of daily mean soil respiration calculated from half-hourly measurements using the following wellknown exponential equation:

$$R_s = a \exp(bT), \quad (2)$$

Where a and b are fitted constants and T is soil temperature (K).

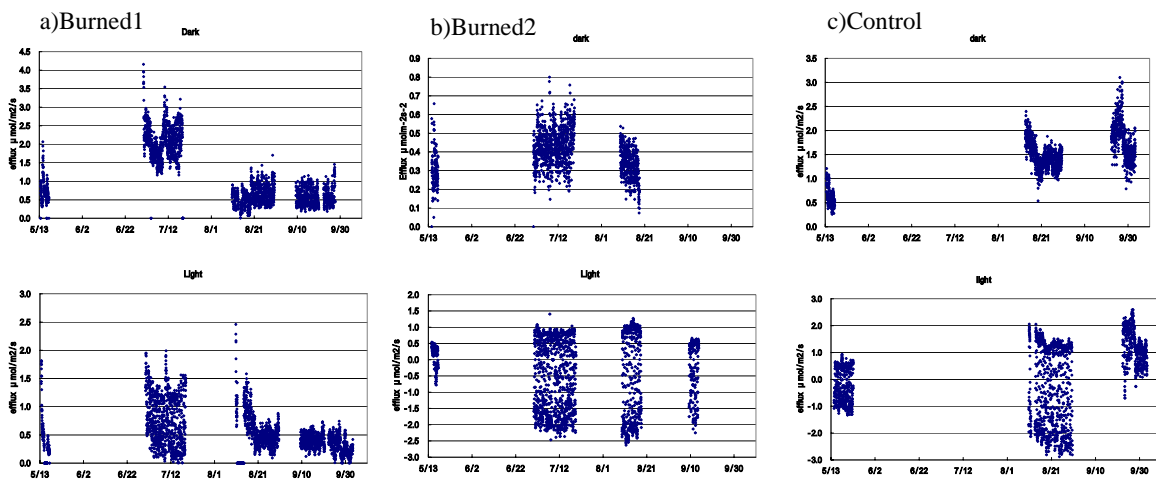


Fig. 3. The results of chamber measurement of respiration, at burned1 (a), burned2 (b) and control (c) site. Upper figures are by opaque chamber and lower figures by transparent chamber.

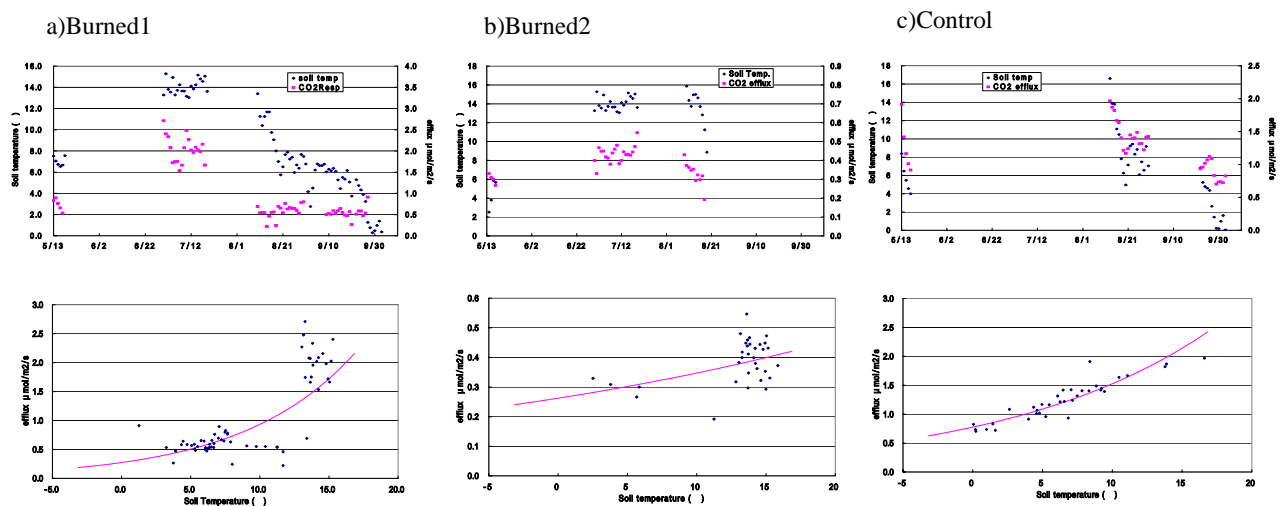


Fig. 4. Time series of soil temperature and net respiration by opaque chambers (upper) and the relationship between net temp respiration and soil temperature (lower).

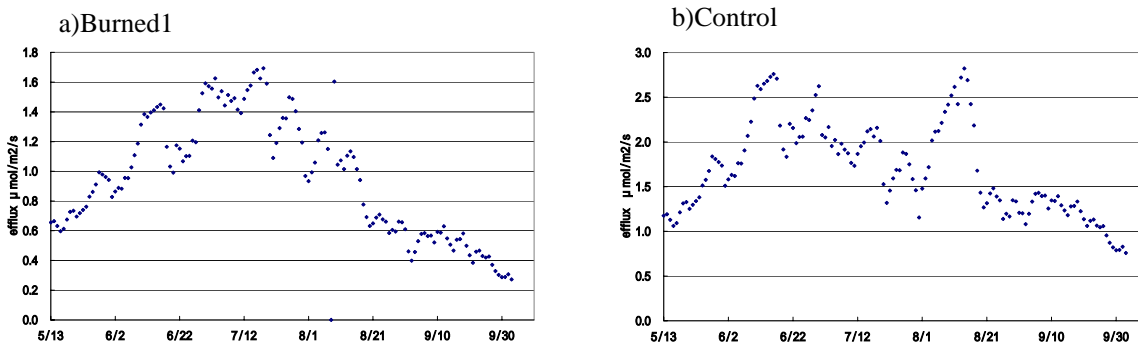


Fig. 5. Time series of net respiration calculated using the relationship between soil temperature and net respiration for a)burned1 and b)control

3. Results

3.1. Soil respiration and net respiration

Soil and net respirations were measured with an automated closed/open chamber system during summer, 2005 at two burned sites (burned1 and burned2) and unburned (control) site. Fig. 3 shows the results of respiration measurements by opaque chambers (upper figures) and transparent chambers (lower figures). No vegetation came back at Burned1 site but some vegetations grew inside the both chambers at Burned2 site. Therefore, soil respiration by opaque chamber at Burned2 site was small when compared with those at Burned1 site, and net respiration by transparent chamber at Burned1 site was never became negative due to no CO_2 assimilation. Since no moss was removed inside the opaque chamber at control site, the result of measurement by the opaque chamber at control site does not indicate respiration rate. However, the difference between the two chambers at Control site means the CO_2 assimilation rate (not shown).

3.2. Net respiration and soil temperature

Upper figures in Fig. 4 show the time series of soil temperature and net respiration by opaque chambers and lower figures in Fig. 4 show the relationship between net respiration and soil temperature calculated using Eq. 1. Soil temperature at Burned1 and Burned2 became as high as 16°C but at Control site soil temperature varied between 6°C and 10°C . However, net respiration at Burned1 and Burned2 was smaller when compared with those at Control site. It must be due to the difference in the difference in biomass between the burned and unburned sites.

The relationship between net respiration and soil temperature was obtained by using Eq. 2. As mentioned above, some plants were grown inside the opaque chamber at Burned2 site, the correlation coefficient of the two was not good, whereas the relationships at Burned1 and Control site were good.

Figure 5 shows time series of net respiration calculated using the relationship between soil temperature and net respiration for burned1 (left) and control (right). The general trend of the seasonal variation of respiration is the same at the both site. However, the net respiration become the largest at the middle of July at Burned1 site and at the middles of June and August at Control site. The reason of these differences is not clear, but it is possibly due to the soil temperature and soil moisture difference.

The sum of net respiration in the observation period from May 13 to October 3 (143 days) becomes 143 gCm^{-2} at Burned1 and 253 gCm^{-2} at Control. The ratio of the net respiration at Burned1 to Control is 56%.

4. Conclusion

In order to clarify the differences in net respiration and its response to weather and soil conditions between burned and unburned, a measurement using close/open chambers were carried out in the summer of 2005.

1) CO_2 efflux from the surface was 143 gCm^{-2} at burned1 and 253 gCm^{-2} at control from May13 to October 3 (143 days).

2) CO_2 efflux at severely burned site was 56% of the unburned site.

5. Future problems

The further analysis is needed for the study of net respiration at burned and unburned site. They are as follows. 1) Better relationships between CO_2 efflux and soil temperature, 2) Consideration of effect of soil moisture to CO_2 efflux, 3) Consideration of effect of atmospheric conditions, such as air temperature and water vapor deficit, on CO_2 efflux, 4) Microbiological studies of soils, and 5) Effect of burned logs (fallen and standing) on CO_2 efflux.

References

- Oechel, W. C. and G. L. Voulitis, 1997. Climate change in northern latitudes: Alternations in ecosystem structure and function and effects on carbon sequestration, in *Global Change and Arctic Terrestrial Ecosystems*, edited by W. C. Oechel et al., pp.381-401, Springer-Verlag, New York.
- Schlesinger, W. H., (ed.) 1997. *Biogeochemistry, An analysis of Global Change*, 588 pp., Academic, San Diego, Calif.
- Kasisheke, E. S. and B. J. Stocks, (Eds.) 2000. *Fire, Climate Change and Carbon Cycling in the Boreal Forest*, 461 pp., Springer-Verlag, New York.
- Murphy P.J., Mudd, J.P., Stocks, B.J., Kasischke, E.S., Barry, D., Alexander, M.E., French, N.H.F., 2000. Historical fire records in the North American Boreal Forest. In: Kasischke, E.S., Stck, B.J. (Eds.) *Fire, Climate Change, and Carbon Cycling in the Boreal Forest. Ecological Studies*, vol. 138. Springer-Verlag New York, pp. 274-288.