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Short communication

Response of soil respiration to short-term experimental warming and precipitation pulses over the growing season in an alpine meadow on the Northern Tibet

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ABSTRACT

A warming and precipitation pulses experiment was conducted in an alpine meadow of Tibet over the growing season (June–September) in 2013. Soil respiration (R_s) was measured biweekly from early July to early September 2013. The effect of experimental warming on R_s varied with water availability. The effect of precipitation pulses on R_s depended on pulses sizes, antecedent precipitation and soil moisture conditions. Precipitation pulses increased the temperature sensitivity of R_s, which was not affected by experimental warming. Our findings suggest that water availability regulates the response of soil respiration to warming.

The Tibetan Plateau is one of the most sensitive regions to climatic change and the alpine meadow on this Plateau is one of the most sensitive vegetation types (IPCC, 2013). For example, Fu et al., 2014b showed that the response of plant photosynthesis and biomass to climatic warming over the Tibetan Plateau was greater than that of the global average. Precipitation pulses and climatic warming can trigger series responses of soils and plants, such as ecosystem and soil respiration increases (Chen et al., 2008; Shi et al., 2006; Wu et al., 2011), soil microbial biomass and activity increases (Huxman et al., 2004; Lu et al., 2013), and plant photosynthesis and biomass increases (Fu et al., 2014b; Hao et al., 2010; Wu et al., 2011). Soil respiration (R_s) constitutes one of the largest carbon fluxes in terrestrial carbon cycle (Raich and Schlesinger, 1992; Rustad et al., 2001; Wu et al., 2011). Understanding the effects of warming and precipitation pulses on R_s is vital for predicting future changes of carbon cycle in alpine regions.

The main objectives of this study were to examine the effects of short-term experimental warming and precipitation pulses on R_s and the temperature sensitivity of R_s. Previous studies showed that precipitation pulses increased R_s and the warming effects on R_s were regulated by water availability in arid and semi-arid ecosystems (Liu et al., 2009; Munson et al., 2010). Moreover, precipitation pulse significantly increased ecosystem respiration in an alpine meadow on the Northern Tibet (Shi et al., 2006). Thus, we hypothesized that water availability regulated the response of R_s to warming and precipitation pulses could increase R_s. The effects of precipitation pulses exhibited nonlinear increases with pulse sizes (Cable et al., 2008; Huxman et al., 2004; Sponseller, 2007). Our previous study demonstrated that the correlations between R_s and soil moisture varied with water availability in an alpine meadow of Tibet (Fu et al., 2010). Therefore, we also hypothesized that the response of R_s to precipitation pulses varied with initial soil moisture condition.

The study area (30°30′N, 91°04′E) is located at the Damxung Grassland Observation Station, Tibet Autonomous Region, China. Detailed descriptions of the climate, soil and vegetation conditions can be found in our previous studies (Fu et al., 2012; Yu et al., 2014). Briefly, annual mean air temperature is 1.3 °C. Annual mean rainfall is approximate 476.8 mm. The soil is classified as sandy loam, with organic matter of 0.3–11.2% and total nitrogen of 0.03–0.49%. The vegetation is *Kobresia*-dominated alpine meadow.

In this study, nine open-top chambers (OTCs) were randomly set up in the experimental area (25 m × 50 m) in June 2013 to increase the temperature in warming treatments by trapping solar energy (Marion et al., 1997). The bottom and top diameters and the height of the OTCs were 1.45, 1.00 and 0.40 m, respectively

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(Fu et al., 2013). There was one unwarmed plot in the vicinity of each OTC. The nine warmed and unwarmed plots were assigned randomly for three levels of precipitation pulses. Precipitation pulses was provided with hand sprinklers on June 27, July 6, July 24, August 5, August 20 and September 4, 2013. Considering a 5 mm increase of precipitation may offset experimental warming-induced soil drying and daily maximum total precipitation of approximate 20 mm in the experimental area, the three precipitation levels were 0, 5 and 20 mm on each day of water addition. That is, the increases were about 0, 6 and 25% for the three levels of water addition over the whole growing season (June–September). There were a total of 18 experimental plots and six treatments: control (*C*; unwarmed plot + 0% precipitation level), warm (*W*; warmed plot + 0% precipitation level), increased precipitation at a low level (LP; unwarmed plot + 6% precipitation level), warm plus increased precipitation at a low level (*W* + LP; warmed plot + 6% precipitation level), increased precipitation at a high level (HP; unwarmed plot + 25% precipitation level) and warm plus increased precipitation at a high level (*W* + HP; warmed plot + 25% precipitation level).

We measured soil temperature (T_s) at a depth of 5 cm and soil moisture (SM) at a depth of 10 cm for all treatments during the entire study period. We measured R_s using a CO_2 flux system with a survey chamber of 20 cm in diameter (LI-8100, LI-COR Biosciences, Lincoln, NE, USA) (Fu et al., 2014a) after the application of water addition on July 6, July 24, August 5, August 20 and September 4, 2013. The SM in the experimental area was in a range from 0.04 $m^3\,m^{-3}$ to 0.30 $m^3\,m^{-3}$ over the growing season. The SM values on the five measuring occasions (Fig. 1) covered the moisture range and were divided into three ranges (i.e., <0.10 $m^3\,m^{-3}$, between 0.10 and 0.20 $m^3\,m^{-3}$, and >0.20 $m^3\,m^{-3}$). Our previous study showed that the dependence of R_s on SM changed with the three SM ranges (Fu et al., 2010). These results implied that the five measuring occasions can reflect the relationship between initial SM and the pulse effects on R_s. Before the measurement of R_s, polyvinyl chloride (PVC) collars (diameter, 20 cm; height, 5 cm) were inserted approximately 2–3 cm into the soil for all plots. The insertion of PVC collars into soil can create airtight seals between the LI-8100 survey chamber and the soil.

For a specific measuring date, repeated-measures ANOVA was used to estimate the main and interactive effects of measuring time, experimental warming and precipitation pulses on R_s,T_s and SM, respectively (Table 1). Student–Newman–Keuls multiple comparisons were performed among the three precipitation pulses, before which repeated-measures ANOVA with experimental warming and precipitation pulses as between-subject and with

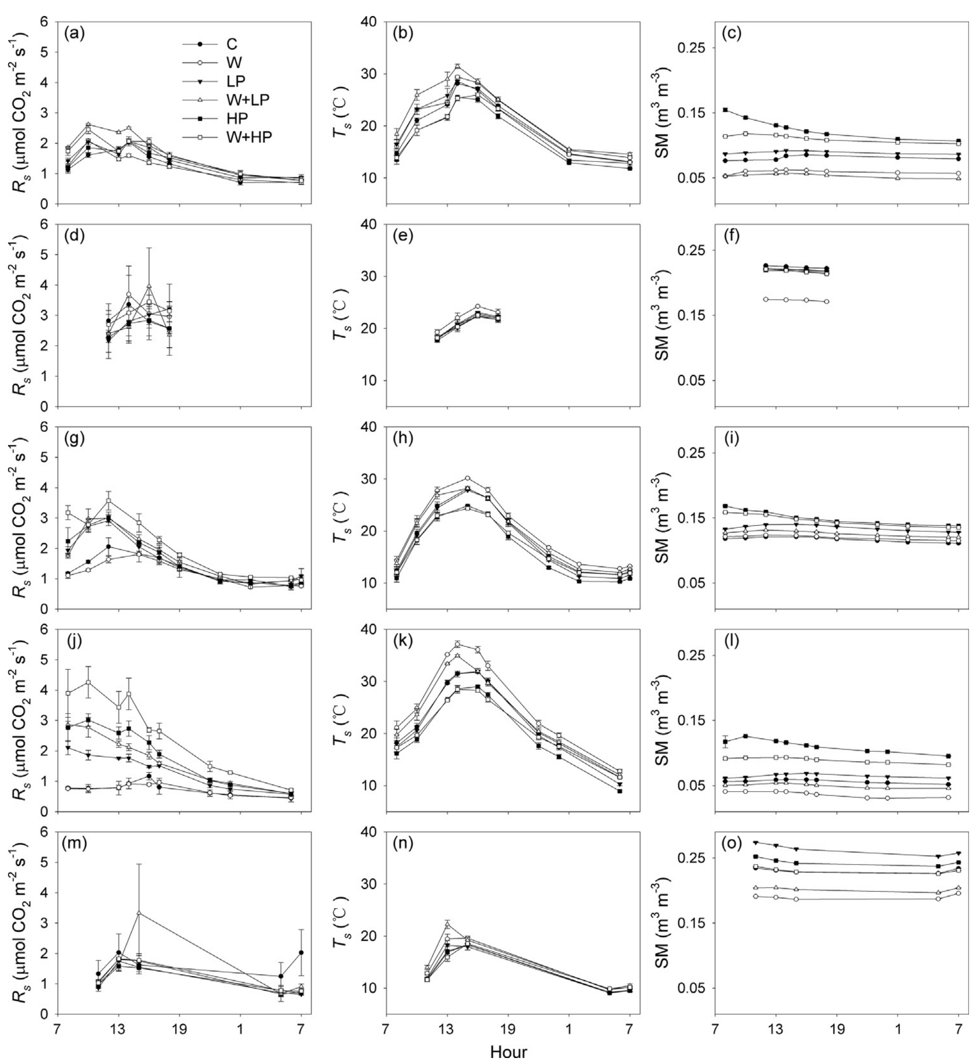

Fig. 1. Daily variation in soil respiration (R_s), soil temperature (T_s) and soil moisture (SM) on (a–c) July 6; (d–f) July 24; (g–i) August 5–6; (j–l) August 20–21 and (m–o) September 4–5. *C*: unwarmed plot + 0% precipitation level; *W*: warmed plot + 0% precipitation level; LP: unwarmed plot + 6% precipitation level; *W* + LP: warmed plot + 6% precipitation level; HP: unwarmed plot + 25% precipitation level; *W* + HP: warmed plot + 25% precipitation level.