

**Long-term monitoring of alpine ecosystems on the Tibetan Plateau
in relation to the early detection and prediction of climate warming
(Abstract of the Final Report)**

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1. Introduction

IPCC suggests that global warming and its impacts on ecosystems may be more prominent at higher altitudes and/or latitudes. The Qinghai-Tibetan plateau has the highest elevation in the world. Temperature elevation on the plateau has been reported to be greater than the surrounding areas (Liu and Zhang, 1998; Liu and Chen, 2000; Yin et al., 2000). A larger increase in temperature can result in a stronger response of ecosystem. The ecosystem response to global warming would be stronger on the Qinghai-Tibetan plateau than its surrounding lowlands. Based on the idea, we have started a long-term project to monitoring both climate changes and ecosystem variation on the plateau.

The grassland is the widest distributed ecosystem on the plateau, which covers about 63% of the total plateau surface. Most of these grassland ecosystems or the meadow ecosystems are distributed on the plateau area with elevations higher than 3000 m. If an early warming would occur at the high elevations, these alpine ecosystems are expected to respond earlier than similar ecosystems at the low elevations. Like all other grassland ecosystems, which are often considered to be ecologically fragile or vulnerable, the alpine grassland ecosystem may show a more conspicuous response to global warming than those grassland ecosystems at low elevations of the similar latitudes. However, no evidence so far has been provided to show whether the magnitude and velocity of response to temperature elevation is greater at higher elevations. There is also no information available if the alpine ecosystem is really more sensitive to temperature elevation. With high elevation and large elevation difference, the ecosystems on the Qinghai-Tibetan Plateau may provide a proper system to test the above hypothesis.

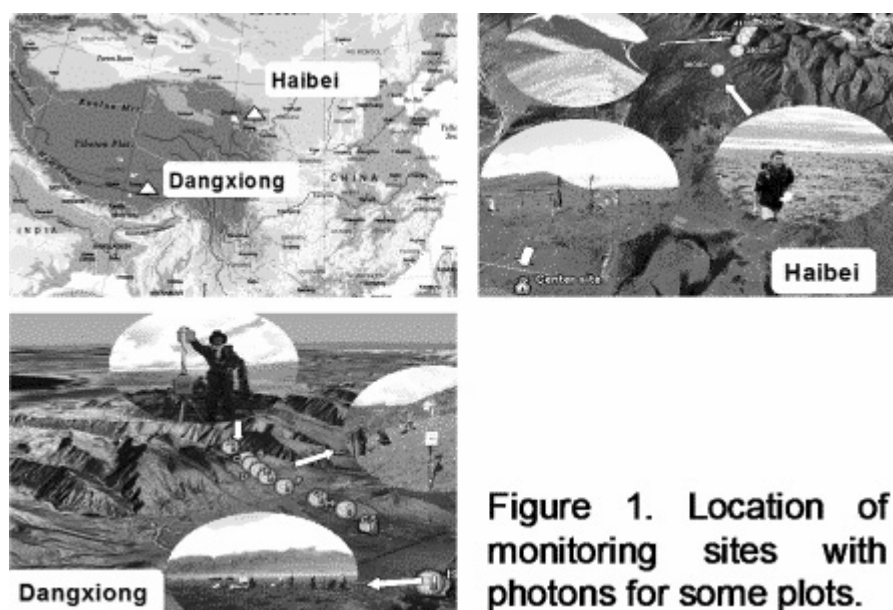


Figure 1. Location of monitoring sites with photons for some plots.

2. Research objectives

The objectives of the study are as follows:

- (1) To measure and examine climatic changes of the typical alpine ecosystems on the Qinghai-Tibetan plateau. Particular attention will be paid on the temperature changes along different altitudes through a long-term observation for two vertical transects above 1000m;
- (2) To monitor and analyze ecological responses of the alpine grassland ecosystems along different altitudes from ecological hierarchies from genetic structure and functions to ecosystem functions through long-term observations;
- (3) To develop a model aiming at the early detection and prediction of global warming using the data from meteorological observations and current monitoring.

3. Methods

Meteorological monitoring: To address current climatic changes in the typical alpine ecosystem on the Qinghai-Tibetan plateau, we have already established two meteorological observation systems along vertical transects at the center area, Dangxiong and the north-eastern area, Haibei on the plateau.

At the Haibei site (Fig. 1), we set 6 observatories with only both air and soil temperature and moisture measurements along transect from 3200 to 4400m. At the Dangxiong site (Fig. 2), we set 10 observatories from 4300m to 5500m for measuring air temperature, air moisture, soil temperature and soil water content at different depths. At both site, we have set a center meteorological observation system to monitor energy balance and all local environments. In

2007, we increased some more observation using similar monitoring system at the northern side of the Dongxiong mountain in cooperation with CAS, Chinese Academia of Science.

Ecological observation: For the second objective mentioned above, we set 5 plots at the elevations from 3600m to 4200m at the Haibei site. We also established 6 plots at each elevation from 4300m to 5300m with almost equivalent vertical distances at the Dongxiong site. These plots at different elevations were set on a vertical transect and each plots had numbers of quadrats of 1m x 1m with 2m apart from its neighboring. The species composition, vegetation cover of each quadrat, and plant phenology were monitored. In addition, to separate the effects of grazing, we set also an area enclosed for livestock grazing. In addition to the ecological investigation at community level, we have started also eco-physiological and molecular ecological monitoring and survey for three indicator species. To clarify the genetic structure of the indicator species, we collected fresh leaves from 20-30 genets of each population at different elevation. Total DNA was extracted from leaves using a modified CTAB method. One noncoding region of cpDNA [trnL (UAA) 3'exon and trnF (GAA)] was sequenced for all individuals. This year we analyzed the data obtained so far.

4. Results and discussion

Meteorological observations

Observations at 10 different altitudes from 4300m to 5540m showed that the adiabatic lapse rate for air temperature during the three years from 2005 was similar and ranged between 0.65-0.69K per 100m in the summer period. Such the lapse rate in the summer period was slightly lower than the values for coastal areas or on island mountains (Körner 2003), but was higher than the best estimate of 0.6K per 100m for the temperate zone. It is observed in the study that the adiabatic lapse rate was larger at higher than at lower latitudes, and larger in winter than in summer. Precipitation at Dangxiong however showed very large annual variation as well as seasonal pattern. Most precipitation concentrated between May and October. The large difference of seasonal pattern may have potential effect on the annual variation of productivity of the alpine grassland.

Indicator of flower status derived from in situ hyperspectral measurement in an alpine meadow on the Tibetan Plateau

Flowering status including flowering date and flower amount could reflect ecological process in assessing plant phenological response to global warming. However, little information is available so far for monitoring flowering status through remote sensing. To provide an ecological indicator for monitoring plant phenology from remotely sensed data, we conducted a field survey in an alpine meadow on the Tibetan Plateau where flower color in July is dominantly yellow due to flowering of *Halerpestes tricuspis* (Ranunculaceae). We used

flower coverage to indicate the flowering status of this species and proposed a flower index derived from in situ hyperspectral data (HFI) to estimate the flower coverage. Results demonstrate that the flower coverage of *H. tricuspis* can be estimated with high accuracy from the hyperspectral measurements. The indicating ability was further improved when the flower coverage was higher than 0.10 or the fractional coverage of soil was low or known in advance.

A simulation also shows that a quadrat or pixel with flower coverage higher than 0.066 can be detected with existence of flower by HFI if soil fraction is less than 50%. These results indicate that HFI is applicable for estimating flower coverage of this species from hyperspectral measurement. The study suggests that the hyperspectral remote sensing technique can be applied for monitoring flowering status, and therefore the technique can provide an important ecological indicator for monitoring plant phenology.

A model approach to simulate ecosystem leaf area index and ecosystem functions

In this study, the process-based ecosystem model called ORCHIDEE (ORganizing Carbon and Hydrology In Dynamic Ecosystems) was modified and calibrated to simulate ecosystem structure (leaf area index) and functions including carbon fluxes and stocks of the Qinghai-Tibetan grasslands. The parameterizations of ORCHIDEE were improved and calibrated against multiple time- and spatial-scale observations including the eddy-covariance fluxes of CO₂ above one alpine meadow site and satellite leaf area index (LAI) data collocated with the meteorological stations. After calibration, the ORCHIDEE can successfully capture the seasonal variation of net ecosystem exchange (NEE), as well as the LAI spatial distribution. The study also suggests that in response to an increase of temperature by 2°C, an NPP can increase by about 9%, but the total carbon budget turns to negative. The model results suggest that Qinghai-Tibetan grasslands may be a vulnerable ecosystem in response to temperature elevation.

Other topics in the study

The following introduction is modified from the special issue in the *Journal of Plant Ecology* by Tang et al. (2009): In addition to the major topics above, our study has some other topics with a wide range from ecosystem energy flux to molecular ecology, but all focus on the issue of climate change on the Qinghai-Tibetan Plateau. Hirota et al. (2009) and Yashiro et al. (2010), using their portable NEP (net ecosystem production) measuring system' specifically designed for the conditions in an alpine meadow, have attempted to clarify ecosystem CO₂ fluxes at different elevations along a vertical transect through an alpine meadow from 3600 to 4200m elevation. On the other hand, Zhang et al. (2009) focused on ecosystem CO₂ fluxes at similar elevations but at sites dominated by different *Kobresia* species under three contrasting soil water regimes. To scale-up local observations, Chen et al. (2009) tried to relate

tower-based CO₂ flux observations to remote-sensing data through measurements of light utilization efficiency. In contrast to the ecosystem observations, Shen et al. (2009) provided the first reliable field measurements of leaf photosynthesis in a warming experiment and found that despite a slight acclimation of leaf photosynthesis of *Gentiana straminea* during an 11-year experimental warming period, the consequences of this physiological acclimation for leaf carbon budgets were significant. In addition to these field observations and experiments, et al. (2010) used soils from an alpine meadow on the plateau and from a lowland grassland in Japan to study the temperature sensitivity of soil respiration and test previous speculations that alpine ecosystems may be more sensitive to global warming. Shimono et al. (2010) assessed plant species diversity as a function of elevation to provide further insights into the potential elevational shift of plant species in response to global warming. The only molecular ecological paper by Li et al. (2010) aimed to clarify the effects of past climate change and plant distribution on the plateau and increased our understanding of the phylogeography of *Potentilla fruticosa*, an alpine shrub on the Qinghai–Tibetan Plateau, by analyzing a new chloroplast DNA sequence. The molecular phylogeny and biogeography of alpine plants may provide insights into the evolutionary history and change in distribution of plant species as a function of climate in a unique ecosystem. These studies may also explain the high plant species diversity in some ecosystems on the plateau.

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(Note: Citations in the section Other topics in the study are in the special issue of *Journal of Plant Ecology* vol. 3, 2009 and vol. 3, 2010.)