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Unexpected climate impacts on the Tibetan Plateau: Local and scientific knowledge in findings of delayed summer

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ABSTRACT

Knowledge of climate change and its impacts can facilitate adaptation efforts. However, complex system dynamics, data scarcity, and heterogeneity often generate both contradictory findings and unexpected climate change impacts. Here we present local ecological knowledge of climate and ecological change in central Tibet to support the finding of delayed summer on the Tibetan Plateau, a finding that has been subject to vigorous, ongoing debate based on Western scientific data. Tibetans who actively herd on a daily basis and are located at higher elevations were most likely to notice changes in seasonality, reported as later start of summer and green-up, and as delayed and shortened livestock milking season. Local meteorological data, indigenous observations of higher snowlines and long-term animal number data suggest that a regional warming trend, rather than land use change, may underlie the delayed phenology trends. We demonstrate that local ecological knowledge can reveal counter-intuitive outcomes and help resolve apparent contradictions through its strengths in situations of high variability, ability to integrate over a range of variables and time scales, and operation outside of Western scientific logic. This suggests local knowledge does not exist to be confirmed or disproved by Western science, but rather can also advance Western science and help contribute to its debates. It is precisely points of apparent contradiction within and between knowledge systems that are most productive for more extensive inquiry. Future research on climate change, and climate adaptation policy-making, will benefit from careful, contextual dialog with local observations, focusing on observable biophysical phenomena that are affected by temperature and precipitation and that are important to livelihoods.

1. Introduction

Knowledge of climate change and its impacts can facilitate adaptation efforts as it can guide policy makers to develop programs that reduce the adverse effects of climate change and that augment adaptive capacity (Seidl and Lexer, 2013). However, complex system dynamics, data scarcity, and differential climate changes and impacts across heterogeneous social–ecological systems can generate contradictory and unexpected findings, which can hamper adaptation efforts (Hoogstra and Schanz, 2008). The ongoing debate over spring vegetation phenological trends on the Tibetan Plateau, and the scientific disagreement over the role of climate change in driving these changes, illustrates the limitations of current scientific observations and knowledge of climate change and its impacts due to system complexity, heterogeneity and data scarcity.

Phenological changes associated with climate change have been widely documented and generally demonstrate an advancement of key events, such as green-up and flowering (Cleland et al., 2007; Rosenzweig et al., 2008). Changes in plant phenology have important implications for Earth system processes, including plant–animal interactions, hydrology, ecosystem carbon and

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energy balance, and the sustainability of livelihoods worldwide (Cleland et al., 2007; Wolkovich et al., 2012). Studies of phenology and climate change typically use satellite remote sensing (Yu et al., 2010), monitoring of atmospheric CO_2 (Keeling et al., 1996), and direct field observations of species over time (Cook et al., 2012) or under experimental climate change conditions (Arft et al., 1999; Cook et al., 2012; Dorji et al., 2013; Dunne et al., 2003). However, researchers have identified problems with these methods. For example, Wolkovich et al. (2012) examined 14 long-term, field-based observational phenology studies and 36 experimental phenology studies and found that for the same plant species, the experimental results were different in both magnitude and sign from the observational results. Moreover, the warming experiments under-predicted the timing of green-up by a factor of four compared to the long-term, observational studies. The authors attribute these mismatches to the complex interactions among multiple drivers within the long-term, field-based observations and to potential artifacts associated with the experiments. In a review of plant phenology and global change, Cleland et al. (2007) note that traditional statistical methods used to analyze ground-based studies fail to detect abrupt shifts in phenology. The authors also cite atmospheric interference and a paucity of biome-scale, ground-based, phenology data as problems associated with satellite-derived monitoring of phenology (Cleland et al., 2007). Rosenzweig et al. (2008) note that data on climate change effects on biological systems, as indicated by metrics such as phenology, are biased toward well-studied systems in North America and Europe.

Recent research about the phenology of vegetation on the important but understudied Tibetan Plateau has stirred an active and ongoing scientific debate. Through remote sensing of the Normalized Difference Vegetation Index (NDVI) from 1982 to 2006, Yu et al. (2010) found that beginning in the mid-1990s the spring phenology of the dominant meadow and steppe vegetation began to retreat, leading to a shorter growing season, despite continued warming. Statistical analysis revealed that warming spring temperatures advanced the growing season, but winter warming overwhelmed this effect, delaying spring phenology. The authors explain this phenomenon by later fulfillment of plant chilling requirements.

Three different published letters quickly challenged Yu et al.'s findings (Chen et al., 2011; Shen, 2011; Yi and Zhou, 2011). Using NDVI data from a different satellite that extended the dataset by three years and applying a different statistical analysis, Shen (2011) showed phenologic advance from 2003 to 2009 and demonstrated a link between phenology and spring, not winter, temperature for the time periods of 1998–2003 and 2003–2009. Yi and Zhou (2011) attributed the smaller NDVI values reported by Yu et al. not to delayed phenology, but to increasing atmospheric contamination in spring, as indicated by the Total Ozone Mapping Spectrometer aerosol index, which would affect the sensors' readings. Chen et al. (2011) suggested that factors other than temperature, such as grassland degradation, plant community shifts, and advances of freeze–thaw processes, could explain Yu et al.'s NDVI findings.

Subsequent work published by Piao et al. (2011) found no overall trend in green-up dates on the Tibetan Plateau from 1982 to 2006, while Shen et al. (2011) demonstrated delayed phenology over that timeframe. Both studies demonstrated an overall advancing trend from 1982 to 1999 and a delaying trend from 2000 to 2006, with high spatial variation in the results. For example, Shen et al. (2011) found overall advances in the eastern regions and delays in the central regions of the Plateau. Piao et al. (2011) found a greater magnitude of phenological changes at higher elevations, but cite 'large uncertainties' regarding change in spring phenology in Tibet. Their finding of recent decreasing spring temperatures at higher elevations further confounds the ability to generalize climate-phenology trends and relationships across Tibet (Piao et al., 2011). Both studies cite the need for more ground-based phenology studies on the Plateau. A more recent study that examined three different NDVI data products (Zhang et al., 2013) concluded that phenology has advanced over the past three decades, but questioned the quality of one of the commonly used NDVI data product (GIMMS) for the Tibetan Plateau over the measurement period used by Yu et al. (2010). There were objections to Zhang et al.'s findings based on reported trends in non-growing season NDVI (Shen et al., 2013) and decreasing snow cover trends (Wang and Chang, 2013), both of which could explain the spring increase in NDVI.

The ongoing scientific debate regarding whether plant phenology on the Tibetan Plateau is advancing or retreating (Chen et al., 2011; Shen, 2011; Shen et al., 2013; Wang and Chang, 2013; Yi and Zhou, 2011; Yu et al., 2010; Zhang et al., 2013) centers on the source, quality, and interpretation of the Normalized Difference Vegetation Index (NDVI) data derived from satellite images and neglects a crucial interlocutor in these debates: local ecological knowledge. The work reported here on Tibetan pastoralists' observations of environmental and climatic change demonstrates there is likely a warming-induced shortening of the growing season in the central Tibetan Plateau region of Nagchu Prefecture. We show how bringing local and scientific observations and knowledge into conversation is a complex and iterative process that requires understanding the cultural and livelihood contexts of indigenous peoples. Using changes in Tibetan Plateau seasonality, we demonstrate how this endeavor can be particularly illuminating in systems where climate–ecosystem relationships are complex and counterintuitive. We conclude that carefully contextualizing and evaluating findings within the strengths and limitations of both local ecological knowledge and scientific methods of observation and induction allows for new insights, particularly in understanding unexpected climate change impacts. These insights in turn can help plan for future climate change and aid in development of climate change adaptation policy, particularly at the local scale, where the effects of climate change have the most immediate impact on subsistence-based livelihoods.

2. Local ecological knowledge

Sustainability science researchers increasingly call for use of both local ecological knowledge (LEK) and Western science to help create a deeper understanding of climate change and its impacts (Alexander et al., 2011; Berkes and Berkes, 2009). A number of studies have demonstrated significant overlaps between local ecological knowledge and climate data gathered through scientific measurements (Alexander et al., 2011; Laborde et al., 2012; West and Vásquez-León, 2003). However, critical work in the social sciences informed by Science and Technology Studies and feminist standpoint epistemology suggests that sustainability science must move beyond simple comparisons, in which the role of local ecological knowledge is merely to be validated by scientific knowledge, a formulation that fails to recognize science as knowledge produced by socially situated actors (Agrawal, 1995; Alexander et al., 2011; Goldman, 2007; Goldman et al., 2011; Haraway, 1988; Harding, 1998; Turnbull, 2000). Here, we present results from complementary engagement between local ecological knowledge and Western science, which reduce overall uncertainty about climate change and its impacts. This analysis starts from the recognition that local ecological and Western scientific knowledge systems are both partial and situated; neither alone is a panacea for understanding and adapting to climate change (Agrawal, 1995; Berkes, 2007; Ostrom et al., 2007). Instead, it is necessary to search for possibilities that preserve both "liberatory elements of the enlightenment project and a wide diversity of other knowledge traditions" (Turnbull, 2000, p. 14).