Data paper for Special Issue of Ecological Research

Photographic records of plant phenology and spring river flush timing in a river lowland ecosystem at the taiga–tundra boundary, north-eastern Siberia

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Abstract

Arctic terrestrial ecosystems near the treeline in river lowlands are vulnerable to the changing climate and seasonal extreme events, including flooding. We set up a simple camera monitoring system to record the timings and durations of the leafy period and the spring flush of river water at three observation sites (Boydom [B]: 70.64°N, 148.15°E; Kodac [K]:70.56°N, 148.26°E; Verkhny-Khatistakh [VK]:70.25°N,147.47°E) in the Indigirka lowland, in north-eastern Siberia. Time-lapse digital cameras were located at seven points across the three sites. The time intervals were 1–4 or 24 hours. The minimum and maximum monitoring periods were 2-years (July-2016 to August-2018) at B and 5-years (August-2013 to July-2018) at K. One camera documented the timings of river ice melt and open water periods from the riverbank of the Kryvaya River, one of the small tributaries of the Indigirka River. The other six cameras recorded several types of ground cover typical of the area, including larch trees (*Larix cajanderi*), shrubs (including *Salix* spp., and *Betula nana*), forbs, mosses, and graminoids in an ecosystem of sparsely forested shrublands, wetlands, and riversides. The data consists of 45,617 JPEG-format images. This dataset can be used to detect the onset and offset of the growing season and to capture the ice melt timing and water cover periods in wetlands and riversides. It may be useful in validating satellite data such as the vegetation remote sensing index for remote and little-known areas. These data may contribute to the study of the role of high-latitude ecosystems in global climate changes.

Key words: Tundra, Digital camera, Wetland, Ground-truth, Plant phenology

1. INTRODUCTION

Growth patterns of Arctic terrestrial ecosystems are changing because they are affected by the changing climate (Buntgen *et al.,* 2015). These changes may cause large uncertainties in carbon uptake/release in the carbon cycle and climate feedbacks. Increasing land-surface carbon uptake in the warmer arctic summer has been shown through both direct observations and earth system models (Ciais et al., 2013; Forkel et al., 2016). Increased uptake will lead to negative feedback to climate warming, though missing information about carbon release processes leads to uncertainty about these effects (Ciais *et al.,* 2013). Shifting phenological events, such as earlier snow melt and start of the growing season, with rising temperature may enhance annual net carbon uptake, although risk of frost damage, enhanced respiration, and phenological mismatch may inhibit growth, carbon fixation, and reproduction in tundra ecosystems (Cooper *et al*., 2014). In this way, phenology is key in studying the function of Arctic terrestrial ecosystems and assessing climate change. Spring ice break-up and water flush timing in rivers, expected to change under climate warming, are significant abiotic hydrology factors disturbing vegetation and delivering nutrients to riparian ecosystems at high latitudes (Nilsson *et al*, 2013; Prowse *et al*., 2006; Scrimgeour, *et al*., 1994). Therefore, monitoring the vegetation and the river at seasonal and annual time scales is important in understanding changing ecosystems.

Digital time-lapse cameras are widely used tools in monitoring plant phenology, including leaf opening, leaf senescence, flowering, and leaf falling, to determine the processes and drivers of ecosystem change. These cameras are set at intervals of one to a few hours and mounted on monopods to target a stand (Anderson *et al.*, 2016), on towers to target the canopy (Nagai *et al.,* 2011), or on mountain lodges to target the landscape (Ide & Oguma 2013). Most camera sensors are sensitive to visible wavelengths (350–700 nm) and the wavelengths captured are recorded as red, green, and blue (RGB) values (Brown *et al.,* 2016). Vegetation indices (e.g., the green-red vegetation index) (Motohka *et al.,* 2010) can be used to extract phenological information from photographic records. Various photograph databases have been established and are being developed via open-access monitoring networks (Brown *et al.,* 2016; Moore *et al.,* 2016; Nagai *et al.,* 2018; Nasahara & Nagai 2015; Richardson *et al.,* 2018a; Wingate *et al.,* 2015). URLs of monitoring networks are as follows: Phenological Eyes Network: http://www.pheno-eye.org/; European Phenology Camera Network: http://european-webcam-network.net/; PhenoCam: http://explore.phenocam.us/; e-phenology: http://www.recod.ic.unicamp.br/ephenology/; Australian Phenocam Network: https://phenocam.org.au/.

Datasets of digital camera images provide useful on-the-ground information for calibrating, validating, and interpreting satellite time-series analyses (Kobayashi *et al.,* 2016; Nagai *et al.,* 2014; Richardson *et al.,* 2018b), and therefore they should cover widespread areas on a global scale. Existing databases cover much of the world, but only a few datasets have been from the Arctic. Phenology monitoring has been performed in Svalbard (Anderson *et al.*, 2016), Greenland (Westergaard-Nielsen *et al.,* 2017) and Alaska (Andresen *et al.*, 2018; Kobayashi *et al.,* 2016; Sugiura *et al*., 2013), but has not yet covered the rest of the Arctic.

Here, we describe an archive of seasonal images taken by seven time-lapse digital cameras, starting in 2013, of a river in the Indigirka lowland in north-eastern Siberia. At the Kodac site, or site “K” (70.56°N, 148.26°E), integrative studies have been conducted (Fan *et al.*, 2018; Iwahana *et al.*, 2014; Liang *et al.*, 2014; Morozumi *et al.*, 2019a; Morozumi *et al.*, 2019b; Shingubara *et al.*, 2019; Tei *et al.*, 2017a; Tei *et al.*, 2017b). Information about some of the environmental factors at the study site are archived at the ADS database (https://ads.nipr.ac.jp/). The time-lapse camera images were previously examined to link the seasonal patterns of river water, plant physiological condition, and river water chemistry (Fan *et al.*, 2018; Morozumi *et al.*, 2019a). Our dataset can provide unique information on quantitative phenological variables such as leaf opening, leaf falling, and flowering, and environmental variables including snowmelt timing and spring water flush timing of this river in eastern Siberia. This dataset can be used to complete further studies across ecosystem types using data from other phenology databases or to fill the gaps in calibration and variation for satellite data analysis at circumarctic scales.

2 DATA DESCRIPTION

2.1 Identifier

ERDP-2020-02

2.2 Contributor

A Dataset owner

Atsuko Sugimoto, Trofim Maximov, Tomoki Morozumi, Shin Nagai, Hideki Kobayashi, Shunsuke Tei, Shinya Takano, Ruslan Shakhmatov, Rikie Suzuki

B Dataset creator

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2.3 Projects

A Title

1. GRENE Arctic Climate Change Research Project
2. Belmont forum 2014 CRA COPERA project

B Personnel

1. Atsuko Sugimoto
2. Atsuko Sugimoto

C Funding

1. Ministry of Education, Culture, Sports, Science, and Technology (MEXT)

2. Japan Science and Technology Agency (JST)

2.4 Geological coverage

Geological coverage is shown in Table 1.

2.5 Temporal coverage

Temporal coverage of the data is shown in Table 2 and the Supporting Information.

2.6 Methods

A Study site

The study site was located in the Indigirka river lowland close to Chokurdakh (70.6°N 147.9°E), Republic of Sakha (Yakutia), Russia. A research collaboration between Hokkaido University and the Institute for Biological Problems of the Cryolithozone Siberian Branch of the Russian Academy of Sciences (IBPC SB RAS) began ecological and biogeochemical observation of the forested tundra in 2011, under the GRENE Arctic Research Project. The only tree species is Siberian larch (*Larix cajanderi*; syn *L. gmelinii*). The dominant shrubs are dwarf birch (*Betula nana*), alder (*Alnus fruticosa; syn Deschekia fruticosa*), and willows (*Salix boganidensis, S. alaxensis, S. richardsonii, S. glauca, S. pulchra, etc.*). In the local area (10 km scale), 60 vascular and 11 moss species grow. Sedge-dominant wetland is also the dominant land-cover type, covering more than 20% of the landscape. Larch tree density is less than 6% in the local area, with 341 trees ha^{-1} in the 100 × 100 m forested site (K) (Liang *et al.*, 2014). The vegetation and dominant species at the site were described in detail in Morozumi *et al.*, 2019b. Plant species in the view of the cameras are described in the Supporting Information, which was uploaded separately from this file.

B Data recorded by time-lapse cameras

The photographic images were captured by low-cost commercial time-lapse cameras (GardenWatchCam, Brinno, Taipei, Taiwan). We used lithium AA batteries to keep the cameras running for more than a year under low-temperature conditions. The picture format was AVI at 1280 × 720 pixels. The cameras' dark mode omitted images at night and during the polar-night season, although dark mode was turned off during a few observation periods. Each camera was set on a tree or an iron pole, and the view angles and the recorded image quality (e.g., lens haze) were sometimes unstable because of strong winds and low temperatures. Observation time stamps were automatically recorded in the footer of the image (e.g., GARDENWATCHCAM V.1.0 YYYY/MM/DD HH:MM:SS). Machine time was recorded in fixed time offset (UTC+0900; YAKT from 2014 to 2019) for stable time stamp identifier of descriptive purposes, because local time in Chokurdakh had been changed from UTC+1200 (MAGT) to UTC+1100 (SRET) at 2014 during the observation periods. Therefore, shift of time zone in 2014 is ignorable for temporal analysis of the dataset. We considered that the error of time stamp was less than ±1 hour when we manually checked the time stamp of logger on GardenWatchCam in every summer in the field.

C Data processing

The recorded data were reprocessed into a single JPEG format from the original AVI file format. The open-image software FFMPEG (FFmpeg Developers, 2016) was used to separate the movie files into a series of JPEG images. Program settings on FFMPEG were -q:v 1 and scale = 1280:1040 for quality image output. Output files were renamed as the recorded date and time for each image using a command prompt in Windows 10 (Microsoft, Redmond, WA). For the file names, recorded times were simplified to ignore minutes, and, therefore, the timestamp of the file name differed from the original sampling time within ±1 hour.

The data files in klk2016 and klk2017 were modified to correct the incorrect time stamps on the image footer. The corrected time stamp was inserted as a graphic of upper 110-pixel width of the original image using Interactive Data Language (IDL) (Harris Geospatial Solutions, Boulder, Colorado). The correction time was obtained from the saved date and the start date recorded when the logger USB was connected to the PC in the field.

2.7 Data structure

A Data files

There are 45,617 images in total, accounting for approximately 6.5 GB. The image files are ordered by date and stored in a directory for each Camera ID, with a subfolder for each observed year (Table 3).

The data files are named in the format of "gwc_2016_208_1800_0900_CKH_KLK_h.jpg". The notation of "gwc" means GardenWatchCam system, 2016 is the recorded calendar year, 208 is the day of year (DOY), 1800 is identifier of machine time (HH:MM), 0900 is offset of Universal Coordinated Time, CKH is an identifier of this dataset and is the name of the central town in the region (Chokurdakh), KLK is the Camera ID, and h is the angle of view (h: horizontal view; d: downward view). In this example, machine time at 18:00 corresponds to universal time (UTC + 0) at 09:00. A simple readme file is in the Supporting Information.

The data files in KLK2016 and KLK2017 were recorded with incorrect time stamps;

corrected time stamps with a small margin of error (±1 hour) were inserted into those images and file names (see Methods).

B File format

The data files were saved in JPEG format.

2.8 Accessibility

A License

B Location of storage

https://ads.nipr.ac.jp/dataset/A20200225-001

SUPPORTING INFORMATION

The Supporting Information file (Supporting Information.docx) is uploaded separately from the main text.

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Table 1. Location of cameras and landscape type, latitude, longitude, elevation, and azimuth angle.

Site name	Camera ID	Type	Latitude (N)	Longitude (E)	Elevation (m a.s.l)	Azimuth angle[*1]
B	B	Wetland	70.63795	148.1548	5	SW
K	KDF	Shrubland	70.56288	148.265	5	- [*2]
K	KLK	Wetland (look down)/Larch tree branch	70.56526	148.2603	5	NW
K	KLF	Wetland (look down)	70.56266	148.267	5	- [*2]
K	KR	Shrubland (riverbank)/Larch tree	70.56318	148.26368	5	SW
K	KSN	Wetland	70.56361	148.2685	5	NE
VK	VK	Shrubland/Larch tree	70.24838	147.46754	10	N

*1 Direction of horizontal view from camera

*2 Downward view

Table 2. Start and end dates of the recording, no-data period, and interval time of the data.

Camera ID (site)	Start YYYY/MM/DD (DOY)	End YYYY/MM/DD (DOY)	no-data period YYYY E:early L:late	Interval hours (year used)
B	2016/07/27 (209)	2018/08/02 (214)	-	3
KDF	2013/08/03 (215)	2016/08/12 (226)	2014E	3
KLK	2016/07/26 (208)	2018/08/03 (215)	-	4(2017), 1(2018)
KLF	2013/08/03 (215)	2016/09/24 (268)	2014L-2015E	3
KR	2013/08/03 (215)	2017/07/26 (207)	-	3
KSN	2013/08/03 (215)	2018/07/16 (197)	2016L-2017E	3
VK	2013/08/02 (214)	2018/07/25 (206)	2014L-2017E	3(2013-2014) 24(2016-2018)

Table 3. Directory of Camera-ID, Subfolder ID, Year, and the number of image files in each folder.

CameraID	SubfolderID	Year	Number of image files
	total		45617
B	**B2016**	2016	1256
	B2017	2017	2647
	B2018	2018	1685
KDF	KDF**2013**	2013	1205
	KDF**2014**	2014	1589
	KDF**2015**	2015	1850
	KDF**2016**	2016	1331
KLK	KLK**2016**	2016	950
	KLK**2017**	2017	3270
	KLK**2018**	2018	3894
KLF	KLF**2013**	2013	1205
	KLF**2014**	2014	1663
	KLF**2015**	2015	734
	KLF**2016**	2016	1454
KR	KR**2013**	2013	1205
	KR**2014**	2014	2316
	KR**2015**	2015	1929

	KR**2016**	2016	1934
	KR**2017**	2017	1236
KSN	KSN**2013**	2013	1206
	KSN**2014**	2014	2325
	KSN**2015**	2015	1914
	KSN**2016**	2016	1203
	KSN**2017**	2017	1245
	KSN**2018**	2018	1555
VK	VK**2013**	2013	1212
	VK**2014**	2014	1245
	VK**2017**	2017	153
	VK**2018**	2018	206