LICHENS AND CLIMATE CHANGE IN SIBERIAN ALTAI MOUNTAINS: A STEP TOWARDS LONG-TERM MONITORING SYSTEM

A START-UP PROJECT

Gregory E. Insarov

Institute of Geography
of Russian Academy of Sciences

and

Institute of Global Climate and Ecology
of Federal Service of Russia for Hydrometeorology and Environmental Monitoring
and Russian Academy of Sciences

E-mail: insarov@lichenfield.com
LICHENS REACT ON CLIMATE CHANGE

• IN TEMPERATE ZONE ARCTIC-ALPINE / BOREO-MONTANE SPECIES APPEAR TO BE DECLINING, WHILE (SUB) TROPICAL SPECIES ARE INVADING, AND THIS IS PROVED FOR EUROPE (van Herk et al., 2002)

• IN ARCTIC SOME SPECIES CAN DISAPPEAR (IPCC, 2007)

• LICHENS WERE SUCCESSFULLY USED TO MONITOR GLOBAL WARMING IN THE CENTRAL NEGEV HIGHLANDS (Insarov et al., 2002)
Why Lichens? 1. Lichens are sensitive to climate change due to:

(1) symbiotic nature (a lichen results from the symbiotic relationship of a fungus and an algae which must be in metabolic equilibrium)

(2) large absorption surface (for the uptake of substances from precipitation or ambient water)

(3) high water absorbability

(4) long vegetative period
Why Lichens? 2. Under given conditions, the cover and species composition of lichens are stable due to:

- (1) relatively independent from other organisms (they are seldom involved into food webs)
- (2) low reproductive rate
- (3) low growth rate
- (4) longevity
STUDY AREAS:
1- KATUNSKY STATE BIOSPHERE RESERVE
2 and 3 – BELUKHA NATURE PARK

Black squares indicate meteorological stations in the region:
KATAANDA, 949 m
AK-KEM, 2056 m
KARA-TUREK, 2596 m
1. HISTORY

- Established: 25.06.1991
- Part of the Natural Site “Golden Mountains of Altai” Inscribed on the World Heritage List: since 1998
- UNESCO Biosphere Reserve status: since 2000
2. TERRITORY & CLIMATE

- Location: Central Altai, Katun Ridge and Listvyaga Ridge
- Area: 151,664 ha
- Buffer zone area: 57,515 ha
- Altitude: 1300 - 3280 m above sea level
- Average January temperature in high mountains: -15 – - 17 °C
- Average July temperature in high mountains: +4 – +6°C
- Yearly precipitation: c. 500 mm in values and 1000-1500 mm on watersheds
- Timber line position: ~2000 m above sea level
Established: 10.06.1997
Area: 131, 337 ha
Part of the Natural Site “Golden Mountains of Altai” Inscribed on the World Heritage List: since 1998
Belukha Peak, 4506 m a.s.l. is the highest peak in Siberia
Mean summer air temperature and total annual precipitation at Kara-Turek meteorological station, 2600 m a.s.l.

The increase of summer mean temperature at Kara-Turek station is $0.0083 \, ^\circ\text{C} \, \text{yr}^{-1}$, at Ak-Kem station it is c. $0.013 \, ^\circ\text{C} \, \text{yr}^{-1}$.

Increase of annual precipitation at Kara-Turek station is $3.2 \, \text{mm} \, \text{yr}^{-1}$.

Source: Aizen, 2008.

The global average surface temperature has increased over the last 50 years for $0.013 \, ^\circ\text{C} \, \text{yr}^{-1}$ (IPCC AR4, 2007), precipitation trend in the
TEMPERATURE RECONSTRUCTIONS FROM PALEO DATA IN SIBERIAN ALTAI

Annual values (gray lines) and 100-year lowpass filtered (colored lines) temperature anomalies reconstructed from the Belukha ice core δ¹⁸O record (March-November T; red; Eichler et al., submitted), the Lake Teletskoye sediment geochemistry (annual T; green; Kalugin et al., 2007), and the tree ring width chronology for Larix sibirica at the upper timberline in the SE Altai (June-July T; blue; Ovtchinnikov et al., 2000).

Periods of low solar activity are indicated by yellow bars (W = Wolf, S = Sporer, M = Maunder, D = Dalton and G = Gleissberg minima).

Source: M. Schwikowski et al., 2009.
OBJECTIVES

• To define how a change in lichen communities in Siberian Altai mountains caused by an alteration of climate can be detected

• To provide baseline against which these changes can be measured
METHODOLOGY

- Selection of monitoring sites in protected areas to minimize influence of other than target factors

- Sampling within as narrow ecological stratum as possible to reduce influence of other than target factors. In Katunsky BR and in Belukha Nature Park sampling will be on stable plane metamorphized slate rocks

- Selection of rocks without a priori information on lichen presence/abundance
  - Line-intercept method for lichen measurement and digital photography

- Altitudinal gradient study to estimate lichen species sensitivity to climatic factors. In Katunsky BR altitude gradient will be 1500 - 2600 m above sea level, in Belukha Nature Park it will be 2400-3000 m a.s.l.

- Construction of Trend Detection Index (TDI) to ensure maximum ability to detect target factor's trend. TDI is based on both lichen species cover and sensitivity estimates
SAMPLING PLOT AT THE VALLEY BOTTOM

Katun Biosphere Reserve, Altai Mountains, Russia
SAMPLING PLOT AT THE LOCAL SUMMIT
LICHENS ON THE ROCK
CHOICE OF SAMPLING UNIT SHAPE: HOW TO GET THE MOST ACCURATE ESTIMATE OF LICHEN COVER IF TIME IS PRE-ASSIGNED?

<table>
<thead>
<tr>
<th>What is the best?</th>
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<td><img src="image" alt="Sampling Units" /></td>
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UNDER CONDITION:

VARIANCE

\[ D(\Omega) = \frac{1}{n} \left[ n\sigma^2 + 2\sigma^2 \sum_{i<j} K(d_{ij}) \right] \]

REACHES MINIMUM FOR

\[ \Omega = \begin{bmatrix} \square & \square & \square & \square & \square & \square & \square & \square & \square \end{bmatrix} \]
USE OF LINE-INTERCEPT METHOD TO MONITOR EPIPHYTIC LICHENS

Measuring Thallus
LINEAR INDICES OF LICHEN COMMUNITY STATE

\[ I = w_1 a_1 + w_2 a_2 + ... + w_K a_K, \]

- \( a_i \) - cover of \( i \)-th lichen species,
- \( w_i \) - coefficients.

1. When \( w_i = 1 \), \( w_1 = ... = w_{i-1} = w_{i+1} = ... = w_K = 0 \),
   \( I \) gives the cover of the species \( i \).
2. When \( w_i = 1 \) for all \( i, 1 \leq i \leq K \),
   \( I \) yields the overall species cover.
3. When \( w_i \) is the sensitivity to air pollution for the lichen species \( i \) belonging to a certain "poleotolerance class" \( I \) is called the Index of Poleotolerance.
4. When \( w_i \) is the mean number of other lichen species encountered in combination with the species \( i \) within the studied area \( I \) is the Index of Atmospheric Purity.

TREND DETECTION INDEX

Coefficients \( w_k \) to be chosen so as to ensure maximal resolution of the TDI:
- signal/noise = maximum \( \Rightarrow w_k \) is function of:
  1. lichen species sensitivity estimates
  2. their SD estimates
  3. interplot and intraplot variability of lichen cover
LICHEN SPECIES FOUND IN COURSE OF PRELIMINARY STUDY IN THE IOLDO RIVER BASIN. SPECIES WERE IDENTIFIED BY EVGENY DAVYDOV

Aspicilia cinerea (L.) Kürb.
Baeomyces rufus (Huds.) Rebent.
Buellia disciformis (Fr.) Mudd
Candelariella vitellina (Hoffm.) Mäll. Arg.
Carbonia vorticosa (Flörke) Hertel
Cladonia amaurocracea (Flörke) Schä.
Cladonia arbuscula (Wallr.) Flot.
Cladonia borealis S. Stenroos
Cladonia botrytes (K. G. Hagen) Willd.
Cladonia cariosa (Ach.) Spreng.
Cladonia chlorophacea (Flörke ex Sommerf.) Spreng.
Cladonia coccifera (L.) Willd.
Cladonia coniocraea (Flörke) Spreng.
Cladonia cornuta (L.) Hoffm.
Cladonia deformis (L.) Hoffm.
Cladonia fimbriata (L.) Fr.
Cladonia furcata (Huds.) Schrad.
Cladonia gracilis (L.) Willd.
Cladonia macilenta Hoffm.
Cladonia macroceras (Delise) Hav.
Cladonia ochrochlora Flörke
Cladonia pleurota (Flörke) Schä.
Cladonia pocillum (Ach.) Grognot
Cladonia pyxidata (L.) Hoffm.
Cladonia rangiferina (L.) F. H. Wigg.
Cladonia rei Schä.
Cladonia stellaris (Opiz) Pouzar & Vmzda
Cladonia subulata (L.) F. H. Wigg.
Cladonia symphycarpa (Flörke) Fr.
Dimelaena oreina (Ach.) Norman
Heteroderma speciosa (Wulfen) Trevis.
Hypogymnia austerodes (Nyl.) Radn.
Hypogymnia bitteri (Lynge) Ahti
Hypogymnia farinacea Zopf
Hypogymnia physodes (L.) Nyl.
Hypogymnia subobscura (Vain.) Poelt
Hypogymnia tubulosa (Schä.) Hav.
Icmadophila ericetorum (L.) Zahlbr.
Immersaria cupreoatra (Nyl.) Calat. & Rambold (= Bellemereae cupreoatra)
Imshaugia aleurites (Ach.) S. L. F. Mey.
Lasallia pensylvanica (Hoffm.) Llano
Lasallia rossica Dombr.
Lecanora albella (Pers.) Ach.
Lecanora baicalensis Zahlbr.
Lecanora bicincta Ramond
Lecanora campestris (Schä.) Hue
Lecanora muralis (Schreb.) Rabenh.
Lecanora polytropa (Hoffm.) Rabenh.
Lecanora varia (Hoffm.) Ach.
Lecidea atrobrunnea (Ramond ex Lam. & DC.) Schä.
Lecidea lapicida (Ach.) Ach.
Lecidella carpathica Kürb.
Lecidella elaeochroma (Ach.) M. Choisy
Lecidella euphorea (Flörke) Hertel
Leptogium saturninum (Dicks.) Nyl.
Lobaria pulmonaria (L.) Hoffm.
Lobaria scrobiculata (Scop.) DC.
Melanelia tominii (Oxner) Essl.
Melanelia subaurifera (Nyl.) O. Blanco & al. (=Melanelia subaurifera)
Melanohalea exasperatula (Nyl.) O. Blanco & al. (=Melanelia exasperatula)
Melanohalea olivacea (L.) O. Blanco & al. (=Melanelia olivacea)
Nephroma bellum (Spreng.) Tuck. Nephroma helveticae Ach
LICHEN SPECIES FOUND IN COURSE OF PRELIMENARY STUDY IN THE IOLDO RIVER BASIN. SPECIES WERE IDENTIFIED BY EVGENY DAVYDOV (end)

Nephroma helveticum Ach.
Nephroma parile (Ach.) Ach.
Nephroma resupinatum (L.) Ach.
Parmelia omphalodes (L.) Ach.
Parmelia saxatilis (L.) Ach.
Parmeliopsis ambigua (Wulfen) Nyl.
Peltigera aphthosa (L.) Willd.
Peltigera canina (L.) Willd.
Peltigera collina (Ach.) Schrad.
Peltigera didactyla (With.) J. R. Laundon
Peltigera elisabethae Gyeln.
Peltigera lepidophora (Nyl. ex Vain.) Bitter
Peltigera leucophlebia (Nyl.) Gyeln.
Peltigera malacea (Ach.) Funck
Peltigera polydactylon (Neck.) Hoffm.
Peltigera praetextata (Flurke ex Sommerf.) Zopf
Peltigera rufescens (Weiss) Humb.
Peltigera scabrosa Th. Fr.
Phaeophyscia hispidula (Ach.) Essl.
Physcia caesia (Hoffm.) F. W. Meyer.
Physconia muscigena (Ach.) Poelt
Porpidia macrocarpa (DC.) Hertel & A. J. Schwab
Protoparmelia atriseda (Fr.) R. Sant. & V. Wirth
Protoparmelia badia (Hoffm.) Hafellner
Pseudoephebe pubescens (L.) M. Choisy
Rhizocarpon badioatrum (Flurke ex Spreng.) Th. Fr.
Rhizocarpon disporum (Nageli ex Hepp) Müll. Arg.
Rhizocarpon eupetraeoides (Nyl.) Blomb. & Forssell
Rhizocarpon geographicum (L.) DC.

*Rhizocarpon lecanorinum Anders
Rhizocarpon macrosporum Røsånen
Rhizocarpon norvegicum Røsånen
Rhizocarpon saanalaense Røsånen
Rhizocarpon subgeminatum Eitner
Rhizoplaca chryssoleuca (Sm.) Zopf
Rhizoplaca melanopophalma (DC.) Leuckert & Poelt
Rhizoplaca peltata (Ramond) Leuckert & Poelt
*Rimularia insularis (Nyl.) Rambold & Hertel
Stereocaulon alpinum Laurer
Stereocaulon condensatum Hoffm.
Sticta limbata (Sm.) Ach.
Trapeliopsis granulosa (Hoffm.) Lumbsch
Tremolecia atrata (Ach.) Hertel
*Umbilicaria altaensis J. C. Wei & Y. M. Jiang
Umbilicaria cylindrica (L.) Delise ex Duby
Umbilicaria deusta (L.) Baumg.
Umbilicaria hirsuta (Sw. ex Westr.) Hoffm.
Umbilicaria hyperborea (Ach.) Hoffm.
Umbilicaria muehlenbergii (Ach.) Tuck.
Umbilicaria subglabra (Nyl.) Harm.
Umbilicaria torrefacta (Lightf.) Schrad.
Umbilicaria vellea (L.) Hoffm.
Vahliella leucoaphae (Vahl) P. M. Jørg. (=Pannaria leucoaphae)
Vulpicida pinastri (Scop.) J.-E. Mattssson & M. J. Lai
Xanthoparmelia conspersa (Ehrh. ex Ach.) Hale
Xanthoparmelia stenophylla (Ach.) Ahti & D. Hawksw.
Xanthoria elegans (Link) Th. Fr.
Xanthothelia papillifera (Vain.) Poelt
Xylographa parallela (Ach.: Fr.) Behlen & Desberger
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