ICOP 2016
XI. International Conference on Permafrost
20-24 June 2016

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

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Quantification of a full year water balance of a thermokarst lake in East Siberia based on field measurements, Lena Delta, Siberia

I. Background

Thermokarst lakes and basins are major components of the ice-rich permafrost landscapes in East Siberian coastal regions. One of the major control factors of thermokarst lake development is the local water balance. Variations in environmental and climate conditions due to climate change might have severe impacts on the water balance. Higher evapotranspiration and an increased active layer thickness could enhance the water flow and thus favor the thermal degradation of the tundra landscape.

II. Study site and methods

"Lucky Lake"

- Kurungnakh Island
- Continuous, ice-rich permafrost to about
- 400 – 600 m depth
- *Max depth:* 6 - 7 m
- *Volume:* 4 x 10^6 m^3
- *Area:* 1.25 x 10^6 m^2
- *Time:* Aug '14 - Sep '15

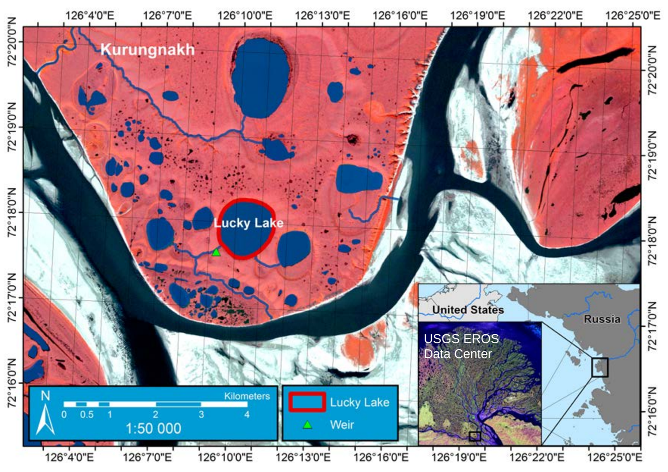
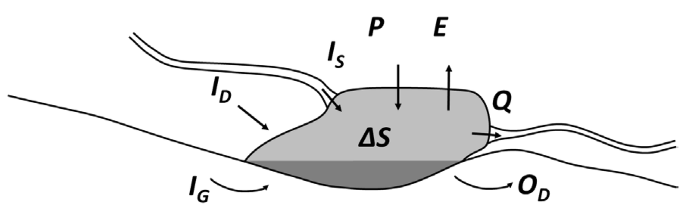


Fig. 1: Study site „Lucky Lake" in the Lena River Delta, Siberia

Parameter	Method	Raw data interval
Precipitation P	Rain gauge	½ h
Discharge Q	RBC discharge flume, radar distance sensor	10 min
Evaporation E	Climate data: u, T, RH, PA, $T_{water\ surf}$ (gradient approach)	½ h
Storage ΔS_m	Pressure sensor	1 h

Tab. 1: Overview of water balance parameter, method and raw data interval



Input Flux
P: precipitation
I_S: stream inflow
I_G: groundwater inflow
I_D: diffuse inflow

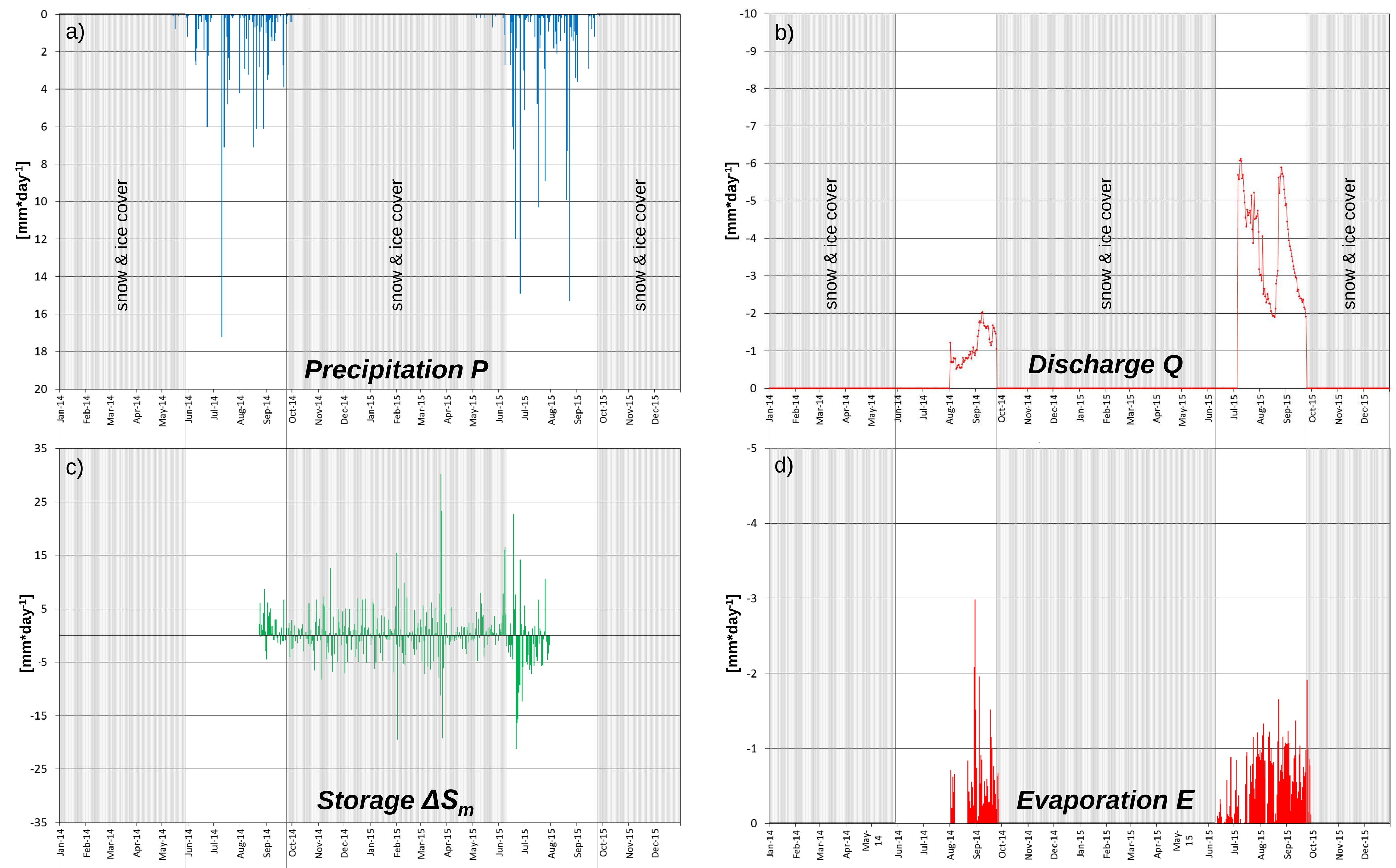
Output Flux
E: evaporation
Q: discharge
O_D: diffuse outflow
Balance
ΔS: storage (water level, WL)

Fig. 2: Lake water balance (modified after: Sharon E. Nicholson et al., 2000)

Fig. 3: "Lucky Lake"

Fig. 4: Discharge measurement station

III. Results



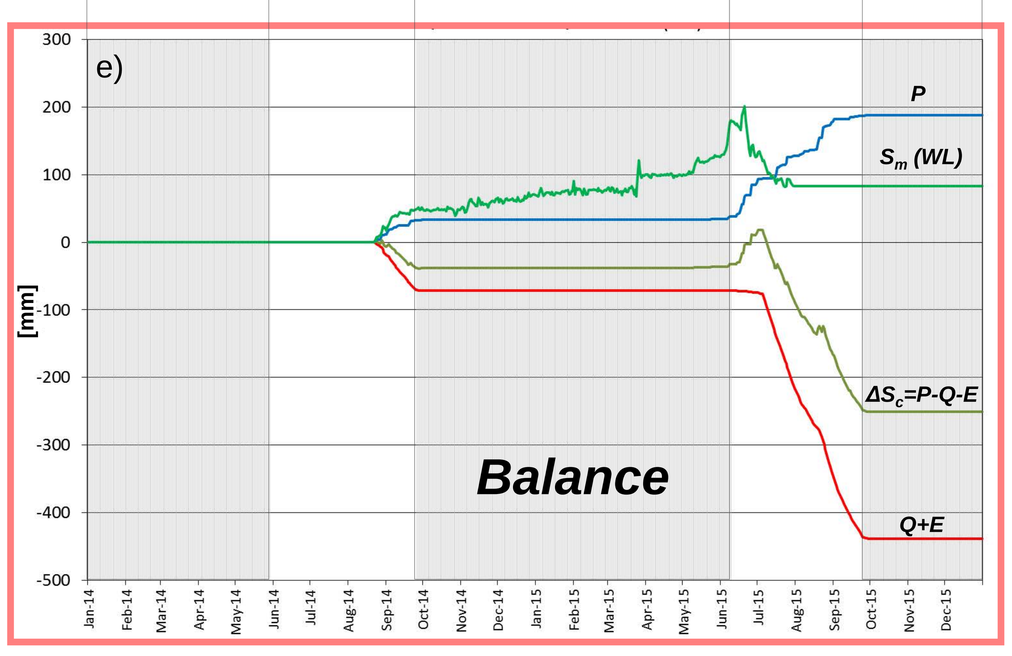


Fig. 5: a) – d) Show the measured in- and output parameters [mm*day⁻¹]; e) accumulated in- (P), output (Q + E), calculated storage (ΔS_c = P-Q-E) and measured storage (ΔS_m) [mm]; snow & ice cover period is gray shaded

Tab. 2: In- and output quantities during the snow & ice free period and winter [mm] for the lake area (1.25 x 10^6 m^2) in [mm]; and quantities for full period of measurements [mm] and [m^3]

Parameter	Snow & ice free autumn 2014 [mm]	Winter 2014/15 [mm]	Snow & ice free 2015 [mm]		Full balance: end Jul 2015 [mm]	Full balance: end Sep 2015 [mm]	Full balance: end Sep 2015 [m^3]
Precipitation P	33	0	95[1]	155	128[1]	188	235 000
Discharge Q	-46	0	-124[1,2]	-305[2]	-170[1,2]	-351[2]	-439 000[2]
Evaporation E	-25	0	-17[1]	-62	-42[1]	-87	-109 000
Storage ΔS_c (P-Q-E)	-38	0	-46[1]	-213	-84[1]	-251	-313 000
Storage ΔS_m (WL)	50	131	-98[1]		83[1]	--	(104 000)[1]

[1]till end of July '15
[2]no data in June '15

IV. Discussion

Uncertainties

- No discharge measurement in spring '15 (exceeded capacity of RBC-flume > 150 l/s) → snow melt runoff
- No measurements of stream inflow, groundwater and diffuse inflow → catchment area for P = lake area
- Snowmelt input → storage change autumn to spring ~ **130 mm**

V. Conclusion

- Autumn (Aug - Sep) high inflow from catchment
  $\Delta S = \Delta S_m - \Delta S_c \rightarrow$ ~ **90 mm**
- Winter (Oct - May) snow melt input
  $\Delta S = \Delta S_m - \Delta S_c \rightarrow$ **~ 130 mm**
- Summer (Jun - Jul) low inflow from catchment, dominated by P and high Q
  $\Delta S = \Delta S_m - \Delta S_c \rightarrow$ > **-50 mm** (no Q data in Jun)
- Full balance (11 months)
  $\Delta S = \Delta S_m - \Delta S_c \rightarrow$ **~ 170 mm** →

Important to measure:
- Inflow from catchment
- Snow melt input

References
SHARON E. NICHOLSON , XUNGANG YIN & MAMOUDOU B. BA (2000): On the feasibility of using a lake water balance model to infer rainfall: an example from Lake Victoria, Hydrological Sciences Journal, 45:1, 75-95;
Niemann S. 2014. Seewasserbilanz eines Thermokarstsees im Lena Delta, Nord-Sibirien. Master thesis, Universität Potsdam.

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