Monitoring freeze-up and break-up dates of Northern Hemisphere big lakes using passive microwave remote sensing data

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ABSTRACT

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INDEX TERMS

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MONITORING FREEZE-UP AND BREAK-UP DATES OF NORTHERN HEMISPHERE BIG LAKES USING PASSIVE MICROWAVE REMOTE SENSING DATA

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Historic freeze-up and break-up dates of lake can record the regional climate variability. Observations of lake ice from different regional or country's stations are inconsistent and their number was declined in past two decades, which makes climate change analysis difficult. This paper proposes a dynamic threshold method to derive the freeze-up and break-up dates of big lakes using passive microwave brightness temperature data. Lake ice information from 35 big lakes in Northern Hemisphere is retrieved in past three decades. These freeze-up and break-up dates were validated from 18 stations' observations. The linear correlation coefficients between observations and retrievals are 0.926 for freeze-up dates and 0.936, respectively.

Index Terms— Lake ice, freeze-up date, break-up date, passive microwave, brightness temperature

1. INTRODUCTION

Many empirical studies have shown a close correlation between lake ice's duration dates (including freeze-up and break-up dates) and air temperatures around lake regions [1]. Long series of lake-ice observations can serve as a proxy climate record, and the monitoring of freeze-up and break-up trends may provide a convenient integrated and seasonally specific index of climatic perturbations [2].

However, available observations of lake ice from field stations were decreasing due to the lacks of budgets and human resources [3]. On the other hand, the utilities of spaceborne remote sensing played a more and more important role in many operational departments [4]. Remote sensing data with high spatial resolution were used to reveal the lake ice pattern in past several decades [5]. However, the visible and near-infrared satellite data can be influenced by cloud cover and low sun elevation (even polar dark), while the revisit frequency of SAR images are relative low at present, which resulted to the low temporal resolution (about one week) of lake ice break-up and freeze-up dates[3, 5]. Though passive microwave data from spaceborne have a coarse footprint, they can provide a very high temporal revisit capability for big lakes [6, 7].

In this study, the time series passive microwave brightness temperature since 1978 were used to study the freeze-up and break-up dates of big lakes in the north Hemisphere. These dates were validated by historical observed data from field station around these lakes [8].

2. METHODOLOGY

This study explored the capabilities of passive microwave remote sensed brightness temperatures (Tbs) data in monitoring freeze-up and break-up dates of big lakes. The large differences in dielectric properties between lake water and lake ice can lead the large brightness temperatures (Tbs), while the differences in surface roughness between them can lead the large polarization differences (PDs). Based on these two physical facts, a simple dynamic threshed algorithm was used to identify the break-up and freeze-up dates. The dynamic threshed can be determined by the Tbs or PDs averaged values over the open water in summer and the ice cover in winter (See Figure 1).

3. RESULT

Totally, brightness temperature data from 1978 to 2009 were used to derive the lake ice duration on 35 big lakes in North Hemisphere (See Table 1). Though ice durations of nine lakes were increased, the shrinkage of ice duration was a common phenomenon (Figure 2).

The results have shown that duration days of lake ice in pass three decades have a significant decreasing trend in Northern Hemisphere. Furthermore, we collected the NCEP/NCAR reanalysis data to analysis the relationship between freeze-up and break-up dates of these lakes and

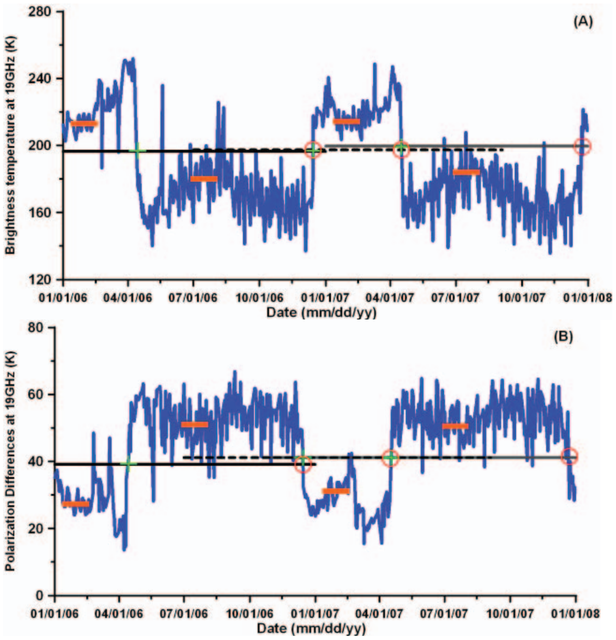

Figure 1 Examples of the dynamic threshed algorithm to monitor the freeze-up and break-up dates of lake ice over the Lake Balkhash. (A) Brightness temperature (Tbs) and (B) polarization differences (PDs).

Notes:

(1) Blue lines are time series of brightness temperature (Tbs) or polarization differences (PDs). Orange lines are averaged values of Tbs or PDs in winter or summer. Straight lines are the averaged values of Tbs or PDs in winter and summer. Green cross points are break-up or freeze-up dates which were estimated by the tandem averaged values of Tbs or PDs in winter and summer or in summer and winter. Red circle points are break-up or freeze-up dates which were estimated by the previous averaged values of Tbs or PDs in winter and summer or in summer and winter.

(2) These green cross or red circle points present dates which Tbs or PDs were greater or less than the averaged values in winter and summer within a continuous 3-5 days. Green cross points can be monitored by the algorithm when all passive microwave remote sensing data are available in a whole break-up and freeze-up period. Those red circle points can be used to estimate the coming break-up or freeze-up dates when past only past remote sensing data, namely we can estimate the lake ice break-up or freeze-up dates by current remote sensing data within 3-5 days.

monthly air temperature. The regression analysis between lake ice duration days derived from passive microwave remote sensing data and air temperature data also displayed a consistent relationship. Furthermore, the break-up dates had more significant relationship with air temperature than the freeze-up dates.

Table 1 Descriptions of 35 lakes in Northern Hemisphere

ID	Name	Lat	Lon	Country
1	Lake Uvs	50.30	92.71	Mongolia
2	Khyargas lake	49.17	93.31	Mongolia
3	Khuvsgul lake	51.11	100.52	Mongolia
4	Lake Baikal	54.32	109.01	Russia
5	Qinghai Lake	36.92	100.14	China
6	Namucuo Lake	30.67	90.53	China
7	Selincuo Lake	31.74	89.11	China
8	Lake Khanka	45.01	132.42	China and Russia
9	Balkhash Lake	46.38	74.60	Kazakhstan
10	Lake Alakol	46.12	81.75	Kazakhstan
11	Aral Aea	44.88	59.96	Uzbekistan
12	The Caspian Sea	46.07	51.30	Kazakhstan
13	Great Bear Lake	66.61	-120.83	Canada
14	Great Slave Lake	61.41	-114.51	Canada
15	Lake Athabasca	59.25	-109.43	Canada
16	Wollaston Lake	58.23	-103.30	Canada
17	Reindeer Lake	57.57	-102.15	Canada
18	Lake Winnipeg	53.53	-98.46	Canada
19	Lake Manitoba	50.47	-98.36	Canada
20	Lac La Ronge	55.10	-104.87	Canada
21	Dubawni Lake	63.11	-101.54	Canada
22	Beaufort sea	67.81	-97.62	Canada
23	Lake Nipigon	49.80	-88.36	Canada
24	Michikamau Lake	54.04	-63.97	Canada
25	Lake Melville	53.68	-59.63	Canada
26	Lac A I' Eau Claire	56.23	-74.63	Canada
27	Lac Coutaceau	53.70	-77.02	Canada
28	Nettilling Lake	66.58	-70.85	Canada
29	Amadjuak Lake	64.90	-71.22	Canada
30	Mogotoyevo Lake	69.33	160.14	Russia
31	Lake Syabero	58.67	27.48	Russia
32	Rybinsk Reservoir	58.41	38.49	Russia
33	Lake Onega	61.58	35.67	Russia
34	Ladozhskoye Lake	60.80	31.53	Russia and Finland
35	Teshekpuk Lake	70.60	-153.63	USA

4. VALIDATION

The validation data come from the global lake and river ice phenology database, which contains freeze-up and break-up dates for 748 lakes and rivers [8]. Only 19 lakes have records within the past three decades. The comparison show that a slight postpone of freeze-up and break-up dates

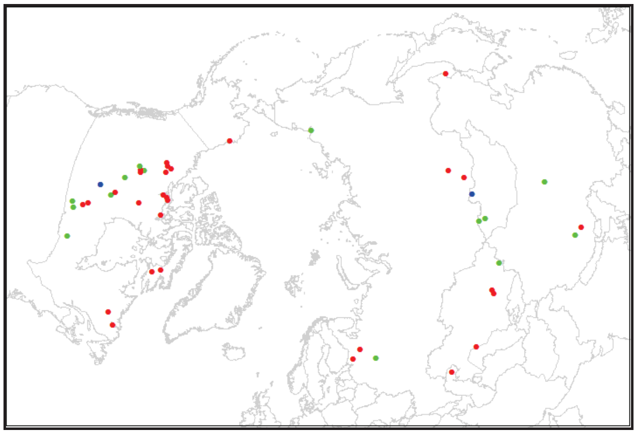

Figure 2 Lake ice duration variations of 35 lakes. Red: ice duration declines more than 5 days, Green: Ice duration varies within 5 days, and Blue: Ice duration increases more than 5 days.

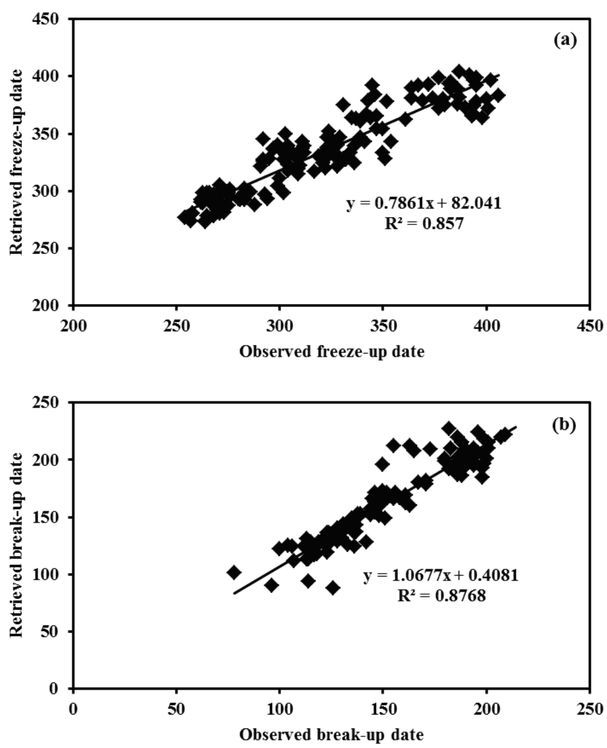

Figure 3 Comparison of freeze-up and break-up dates between observations from station and retrievals from passive microwave remote sensing data

Note: the date presents the Julian date and it means lake froze in the following year when the freeze-up date is larger than 365/366.

from passive microwave remote sensing data than observations from stations.

5. CONCLUSIONS

The freeze-up and break-up dates of big lakes can be retrieved from satellite passive microwave brightness temperature data. The lake ice duration overall decreased in Northern Hemisphere for past three decades. The freeze-up and break-up dates derived from satellite data are later than observations from stations.

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