

An Automated Method to Monitor the Onset and Loss of Lake Ice Cover

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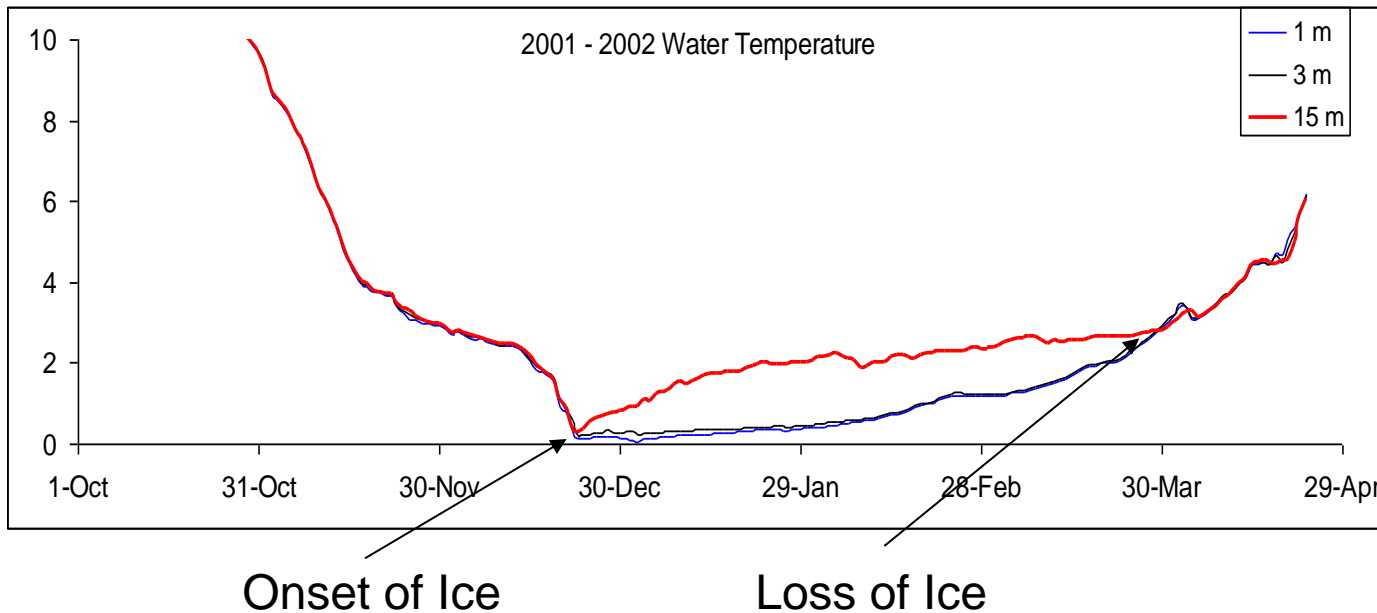
Background

- Changes in the onset, loss and duration of ice cover have been shown by numerous studies to be sensitive indicators of climate change
- Ice cover statistics rely on visual observation which, while accurate, requires a dedicated on-site observer
- Given the need to monitor the impacts of ongoing climate change it would be valuable to monitor the ice cover of more lakes, including remote lakes where no observer is present.
- We present a simple method which estimates the onset and loss of ice cover from under water temperature measurements.
- This method could be applied to a large number of lakes at low cost, and would provide consistent results between lakes.

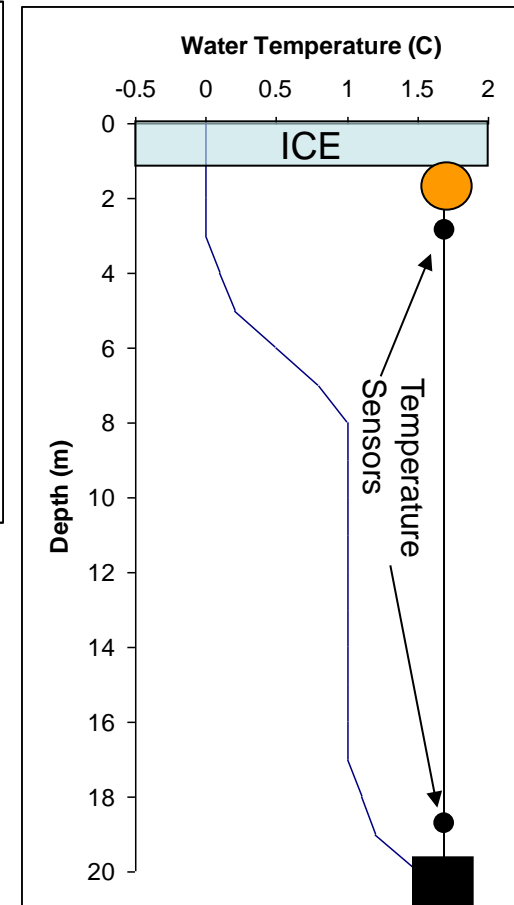
Basic Principle

1. Development of inverse temperature stratification can be used to indicate the onset of ice cover
2. Return to isothermal conditions can be used as an indication of the loss of ice cover

Lake Erken



Ice cover is assumed to exist when $(T_{15m} - T_{1m}) > 0.1 \text{ C}$



Sweden 18 years New Hampshire 1 year **GLEON Data Set**

Finland 4 years NYC reservoirs 5 years

Wisconsin 10 years

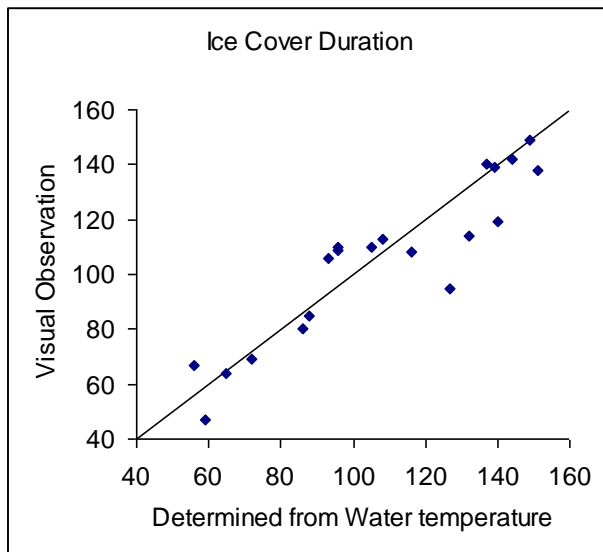
Data from Temperature Sensors

Visual Observations

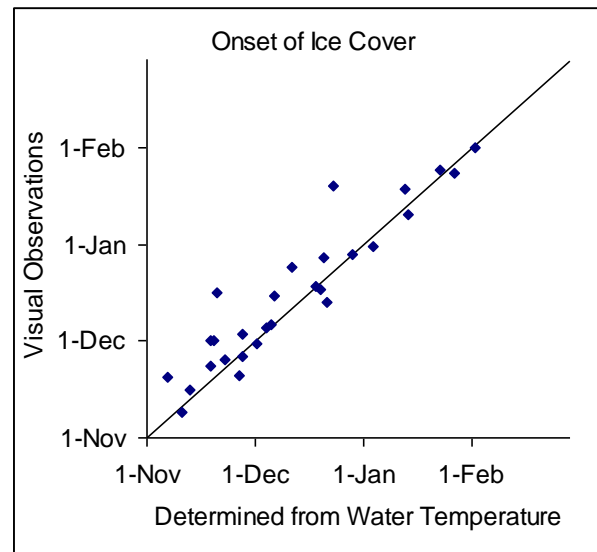
Lake	Location	Winter	Date of Onset	Date of Loss	Duration	Date of Onset	Date of Loss	Duration
Erken	Sweden	1988-1989	2-Dec-88	5-Feb-89	65	1-Dec-88	3-Feb-89	64
Erken	Sweden	1989-1990	6-Dec-89			7-Dec-89	6-Feb-90	61
Erken	Sweden	1990-1991	14-Jan-91	27-Mar-91	72	11-Jan-91	21-Mar-91	69
Erken	Sweden	1991-1992	23-Jan-92	22-Mar-92	59	25-Jan-92	12-Mar-92	47
Erken	Sweden	1992-1993		18-Mar-93		21-Feb-93	18-Mar-93	25
Erken	Sweden	1993-1994				12-Dec-93	12-Apr-94	121
Erken	Sweden	1994-1995				21-Dec-94	5-Apr-95	105
Erken	Sweden	1995-1996	29-Nov-95	16-Apr-96	139	28-Nov-95	15-Apr-96	139
Erken	Sweden	1996-1997	20-Dec-96	18-Mar-97	88	18-Dec-96	13-Mar-97	85
Erken	Sweden	1997-1998	2-Feb-97			1-Feb-97	4-Apr-98	427
Erken	Sweden	1998-1999	20-Dec-98	4-Apr-99	105	20-Dec-98	9-Apr-99	110
Erken	Sweden	1999-2000	22-Dec-99	27-Mar-00	96	29-Dec-99	16-Apr-00	109
Erken	Sweden	2000-2001	13-Jan-01	9-Apr-01	86	19-Jan-01	9-Apr-01	80
Erken	Sweden	2001-2002	23-Dec-01	29-Mar-02	96	15-Dec-01	4-Apr-02	110
Erken	Sweden	2002-2003	7-Dec-02			8-Dec-02	5-Apr-03	118
Erken	Sweden	2003-2004	30-Dec-03	1-Apr-04	93	30-Dec-03	14-Apr-04	106
Erken	Sweden	2004-2005		8-Apr-05		27-Jan-05	11-Apr-05	74
Erken	Sweden	2005-2006	4-Jan-06	22-Apr-06	108	1-Jan-06	24-Apr-06	113
Erken	Sweden	2006-2007	27-Jan-07	24-Mar-07	56	24-Jan-07	1-Apr-07	67
Pääjärvi	Finland	2000-2001	4-Jan-01	30-Apr-01	116	20-Jan-01	25-Apr-01	95
Valkea-kotinen	Finland	2002-2003		26-Apr-03		18-Oct-02	7-May-03	201
Valkea-kotinen	Finland	2003-2004	10-Nov-03			21-Nov-03	28-Apr-04	159
Valkea-kotinen	Finland	2004-2005	16-Nov-04			16-Nov-04	26-Apr-05	161
Sparkling	Wisconsin	1999-2000	8-Dec-99	7-Mar-00	90	17-Dec-99	3-Apr-00	108
Sparkling	Wisconsin	2000-2001	28-Nov-00	14-Apr-01	137	4-Dec-00	23-Apr-01	140
Sparkling	Wisconsin	2001-2002	13-Dec-01	23-Apr-02	131	26-Dec-01	19-Apr-02	114
Sparkling	Wisconsin	2002-2003	24-Nov-02	11-Apr-03	138	27-Nov-02	25-Apr-03	149
Sparkling	Wisconsin	2003-2004	23-Nov-03	9-Apr-04	138	3-Dec-03	19-Apr-04	138
Sparkling	Wisconsin	2004-2005	20-Nov-04	8-Apr-05	139	17-Dec-04	15-Apr-05	119
Sparkling	Wisconsin	2005-2006	24-Nov-05			3-Dec-05	14-Apr-06	132
Trout Bog	Wisconsin	2003-2004	12-Nov-03	20-Apr-04	160	10-Nov-03	21-Apr-04	163
Trout Bog	Wisconsin	2004-2005	23-Nov-04	12-Apr-05	140	24-Nov-04	15-Apr-05	142
Trout Bog	Wisconsin	2005-2006	28-Nov-05			22-Nov-05	13-Apr-06	142
Ashokan Reservoir	New York	2004-2005	19-Jan-05	31-Mar-05	71			
Rondout Reservoir	New York	2004-2005	16-Jan-05	9-Apr-05	83			
Rondout Reservoir	New York	2005-2006						
Rondout Reservoir	New York	2006-2007	26-Jan-07	27-Mar-07	60			
Rondout Reservoir	New York	2007-2008	4-Jan-08	22-Mar-08	78			
Lake Sunapee	New Hampshire	2007-2008	29-Nov-07	22-Apr-08	145		23-Apr-08	

Comparison of Ice cover statistics derived from Visual Observations and from Water Temperature Measurements

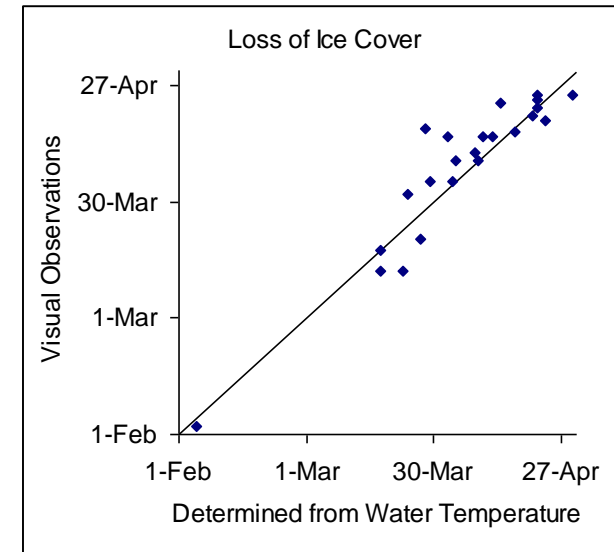
Duration of Ice Cover



Onset of Ice Cover



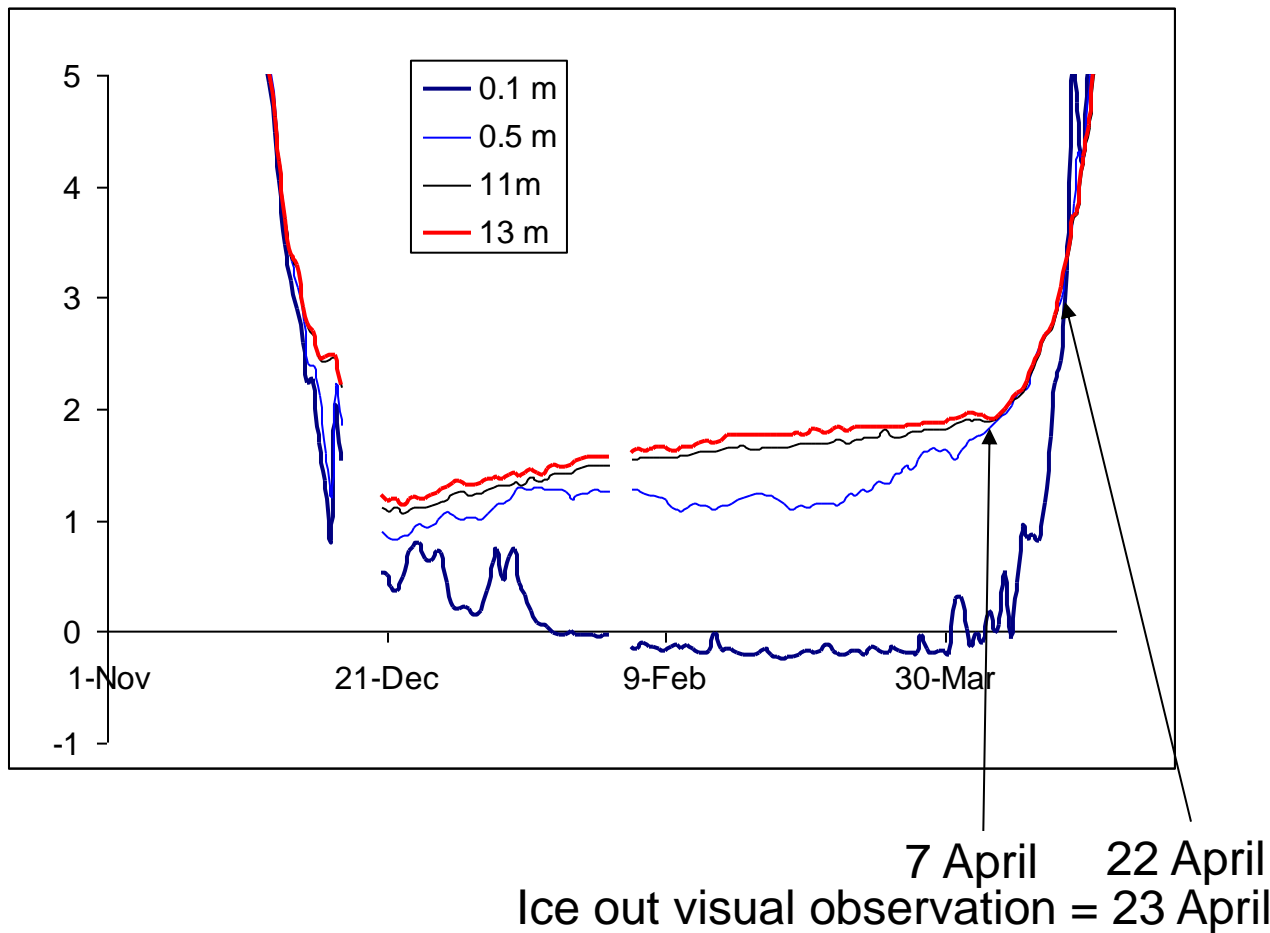
Loss of Ice Cover



Line is the 1:1 relationship

Importance of Sensor Depth on Determining Date of Ice Loss

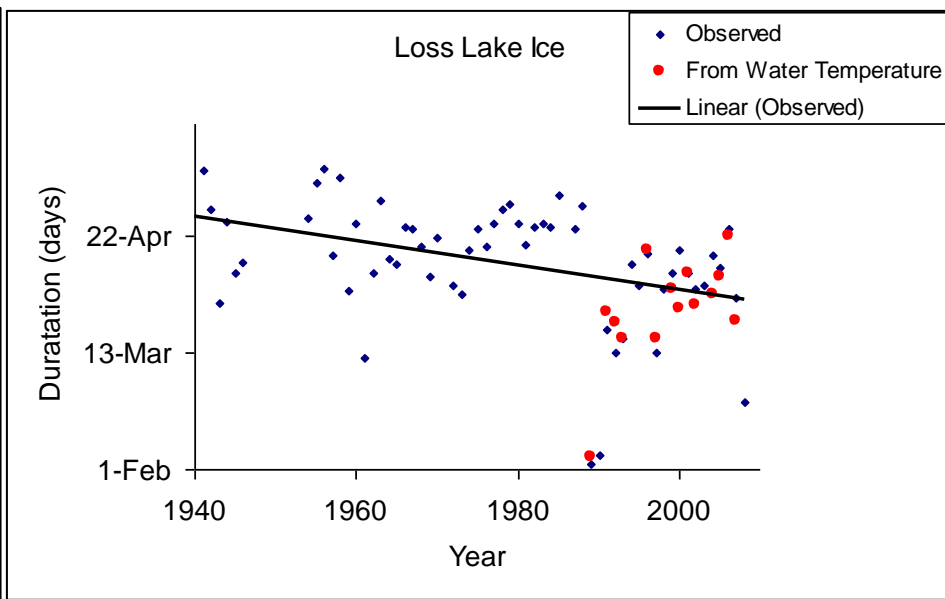
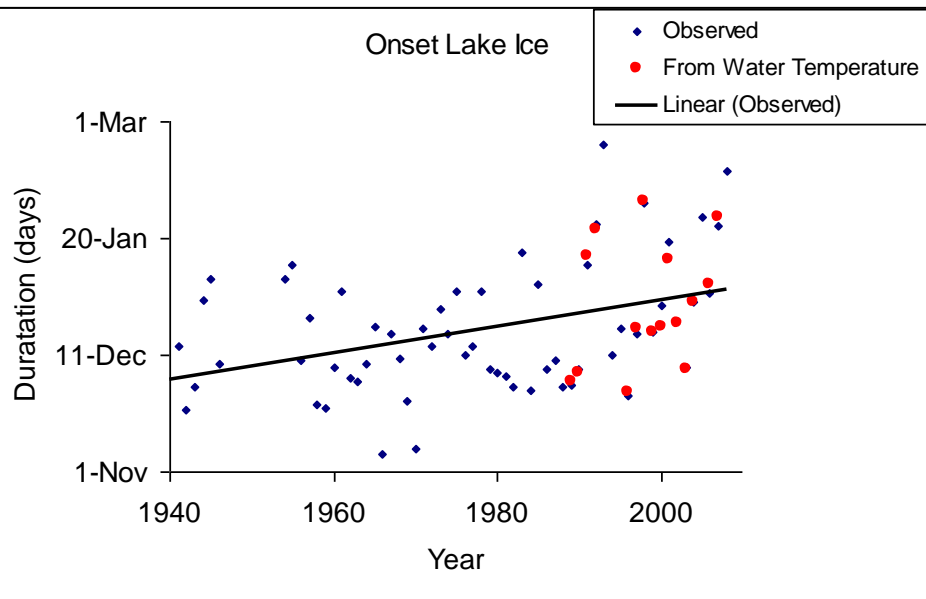
Lake Sunapee New Hampshire



There are a number of cases in the data set where the temperature method does appear to underestimate the date of ice loss. Data from Lake Sunapee suggest that in some cases the water under the ice cover could freeze before ice loss. A shallow sensor that freezes into the ice avoids this problem, even though there may be problems in maintaining such a sensor

Long Term Trend in Ice Cover – Lake Erken

Red Points determined from water temperature measurements. Water temperature derived statistics seem to show trends in ice cover as well as visual observations



Conclusions

- Monitoring of ice cover by use of underwater temperature measurements is possible
- Using a shallow sensor ie 0.1m should reduce temperature method bias towards under estimating the date of ice loss
- The method seems well suited to either permanent monitoring stations, such as Lake Erken or for use of small stand alone temperature loggers such as those used in Finland. The later loggers could allow many lakes to me monitored at low cost.