Lake ice cover and surface water temperature III: *Numerical modelling*

Claude Duguay
University of Waterloo (Canada)

Earth Observation Summer School
ESA-ESRIN, Frascati, Italy (4-14 August 2014)
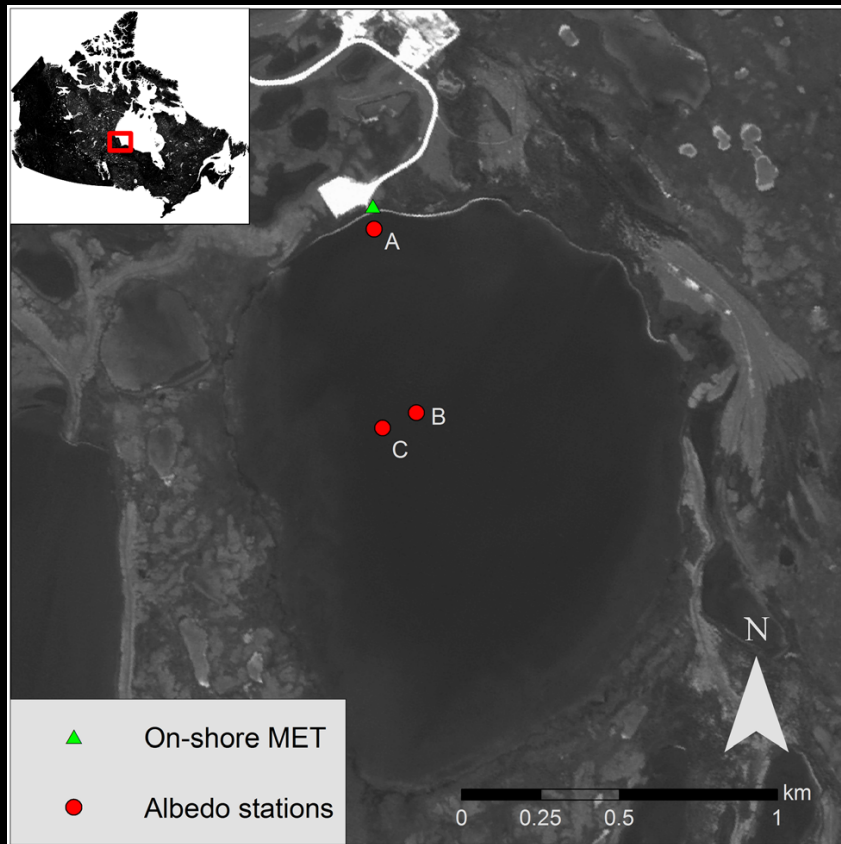Lecture 3: Wednesday, 6 August (12:30-13:30)

Content

1. Evaluation of 1-D lake models with remote sensing

2. Case study: FLake model and remote sensing in numerical weather prediction (NWP)

3. Case study: CLIMo to study the response of lake ice to contemporary and future climate conditions

Evaluation of lake models with remote sensing
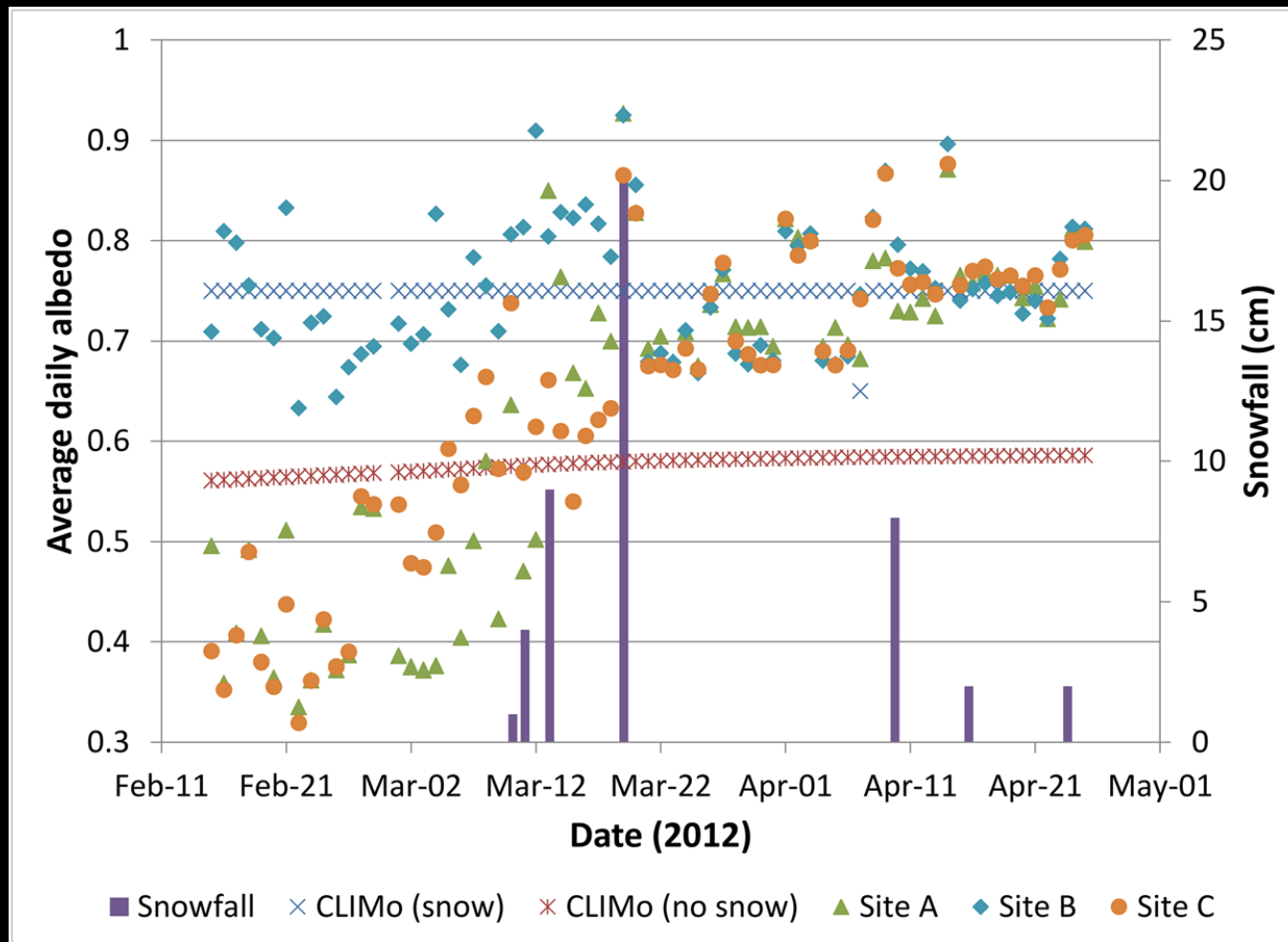## Snow/ice albedo (Lake ice model - CLIMo)

Malcolm Ramsay Lake, Churchill

Variable snow depth and ice types at 3 stations
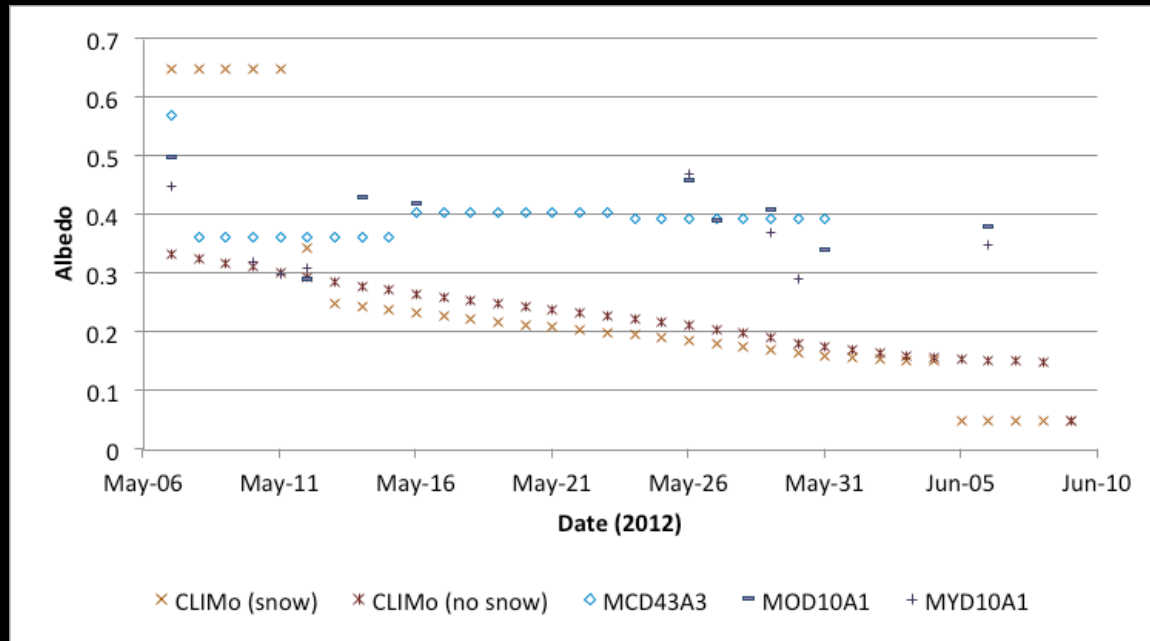
Evaluation of lake models with remote sensing
Snow/ice albedo (CLIMo vs in situ)

Svacina *et al.* (2014a)

Evaluation of lake models with remote sensing
Snow/ice albedo (CLIMo vs MODIS)

Break-up period

Model version	Statistic	MOD10A1	MYD10A1	MCD43A3
CLIMo (snow)	RMSD	0.12	0.10	0.11
	MAD	0.09	0.08	0.09
	MD*	-0.09	-0.07	-0.09
CLIMo (no snow)	RMSD	0.11	0.12	0.09
	MAD	0.10	0.11	0.08
	MD*	0.08	0.10	0.08

Svacina *et al.* (2014b)

Evaluation of lake models with remote sensing

Modelled LST vs. MODIS
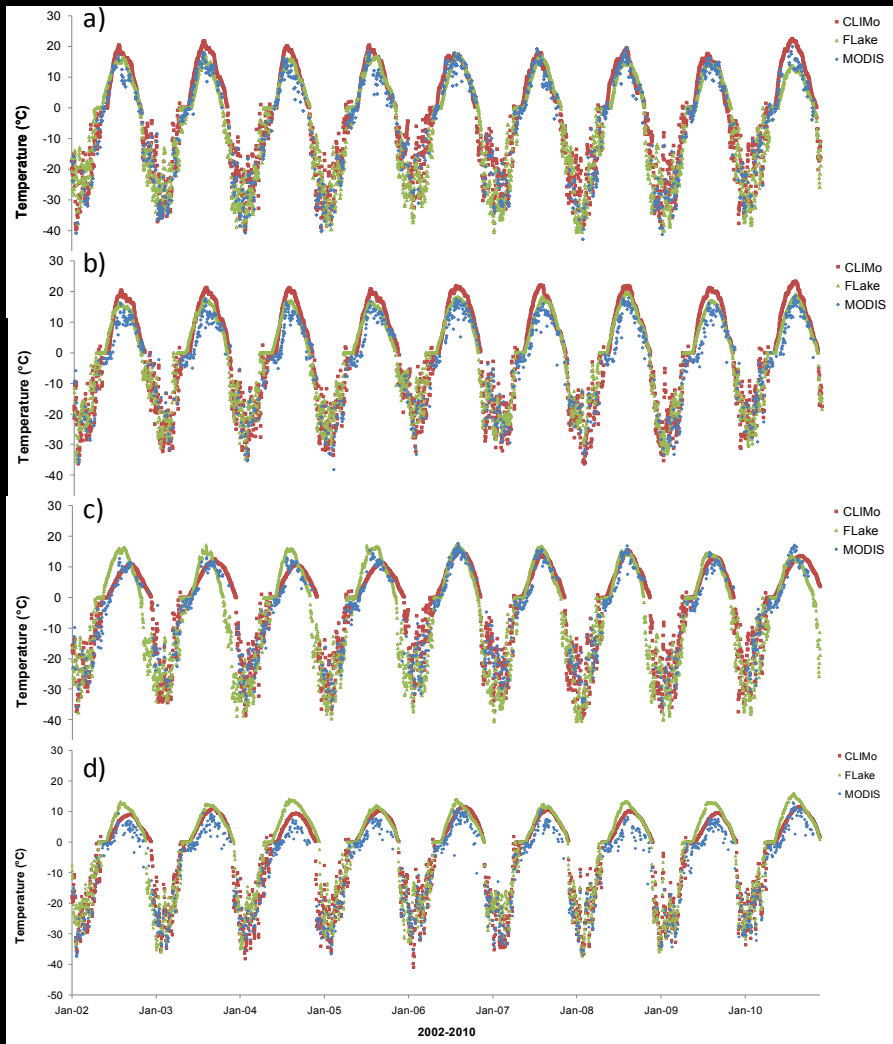
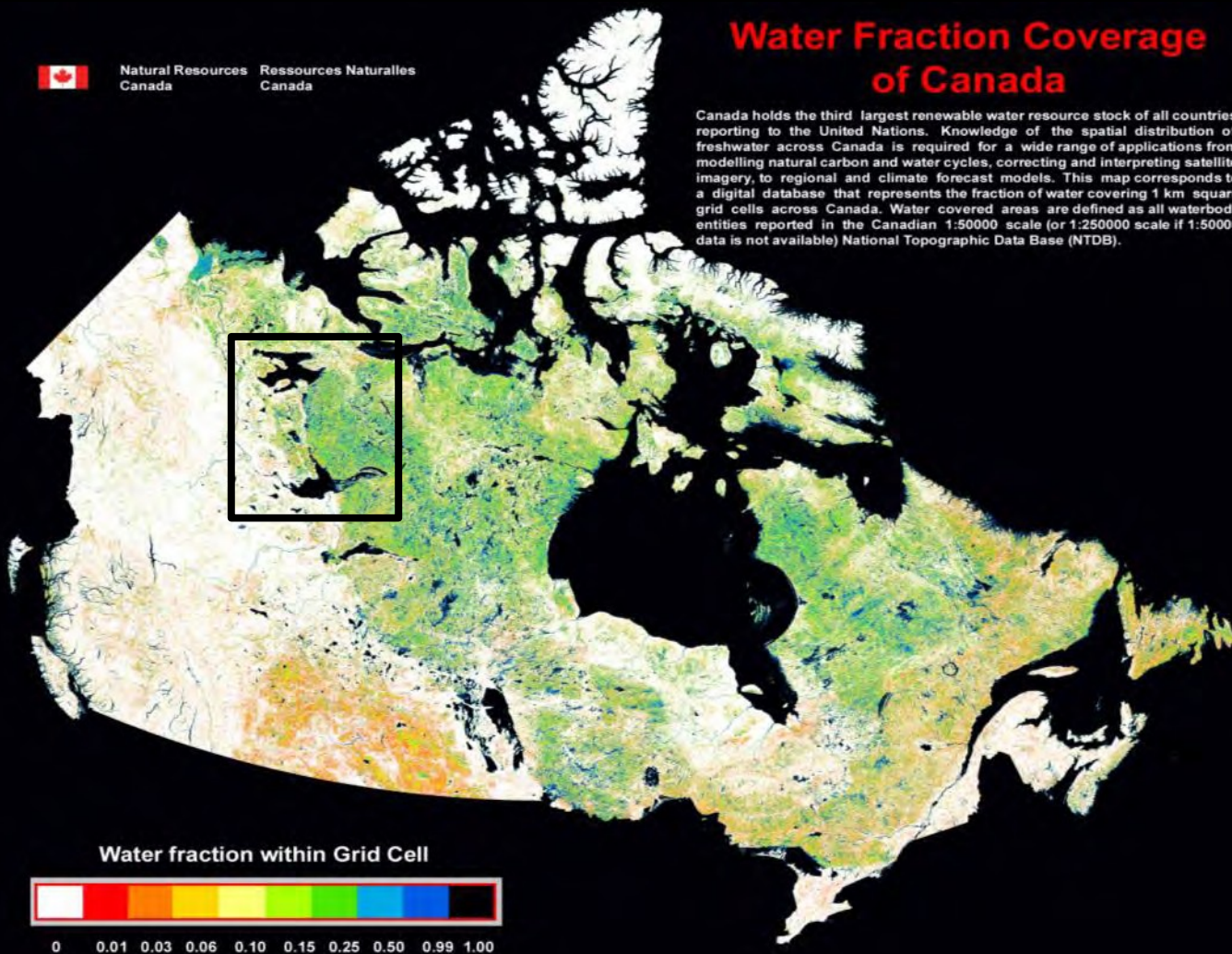Comparison of modelled lake surface temperature from CLIMo and FLake with MODIS-derived LST during full year (open water and ice seasons) for 2002-2010
(a) Yellowknife (Back Bay),
(b) Hay River,
(c) GSL (Main Basin),
(d) GBL (Deline)

CLIMo: Canadian Lake Ice Model
FLake: Freshwater Lake Model

Kheyrollah Pour *et al.* (2012)

Evaluation of lake models with remote sensing

Modelled LST vs. MODIS (GBL and GSL)

Water Fraction Coverage of Canada

Canada holds the third largest renewable water resource stock of all countries reporting to the United Nations. Knowledge of the spatial distribution of freshwater across Canada is required for a wide range of applications from modelling natural carbon and water cycles, correcting and interpreting satellite imagery, to regional and climate forecast models. This map corresponds to a digital database that represents the fraction of water covering 1 km square grid cells across Canada. Water covered areas are defined as all waterbody entities reported in the Canadian 1:50000 scale (or 1:250000 scale if 1:50000 data is not available) National Topographic Data Base (NTDB).

Natural Resources Canada   Ressources Naturalles Canada

Water fraction within Grid Cell

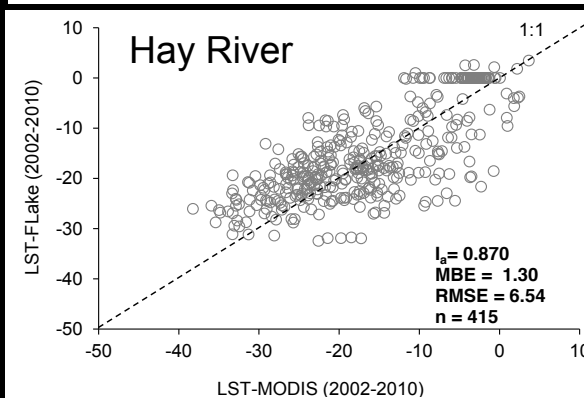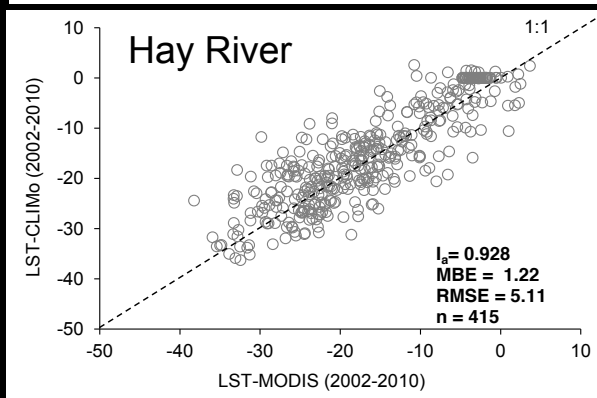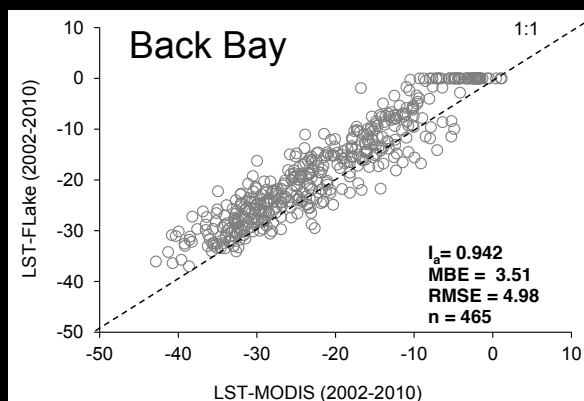0   0.01   0.03   0.06   0.10   0.15   0.25   0.50   0.99   1.00

Evaluation of lake models with remote sensing
Modelled LST vs. MODIS

CLIMo

FLake*

**MODIS LST
vs
1-D lake models**

Comparison for 2 sites
at Great Slave Lake

Ice growth period

* FLake used as lake parameterization scheme in NWP and RCM

Kheyrollah Pour *et al.* (2012)

Evaluation of lake models with remote sensing
Modelled LST vs. MODIS

Table 2. Comparison of observed and simulated LST for Yellowknife (Back Bay), Hay River, GSL (Main Basin) and GBL (Deline) (2002–2010)

	Back Bay		Hay River		GSL(Main Basin)		GBL (Deline)	
	CLIMo	FLake	CLIMo	FLake	CLIMo	FLake	CLIMo	FLake
Full year								
I_a	0.984	0.974	0.956	0.935	0.981	0.975	0.975	0.960
MBE	2.26	4.63	4.25	4.83	0.94	3.35	2.77	4.76
RMSE	4.30	5.64	6.27	7.64	3.93	4.63	4.45	5.82
Open water season								
I_a	0.860	0.719	0.712	0.600	0.922	0.809	0.739	0.569
MBE	3.10	6.02	5.70	7.03	0.96	4.16	3.49	6.61
RMSE	4.20	6.47	6.86	8.43	2.78	4.53	4.06	6.95
Ice cover season								
I_a	0.948	0.942	0.928	0.870	0.924	0.932	0.923	0.936
MBE	1.40	3.51	1.22	1.30	0.35	2.36	1.97	2.95
RMSE	4.71	4.98	5.11	6.54	5.14	4.79	5.01	4.64

Kheyrollah Pour *et al.* (2012)

Case study: FLake model and remote sensing in numerical weather prediction (NWP)

Assimilation of MODIS LSWT observations in HIRLAM
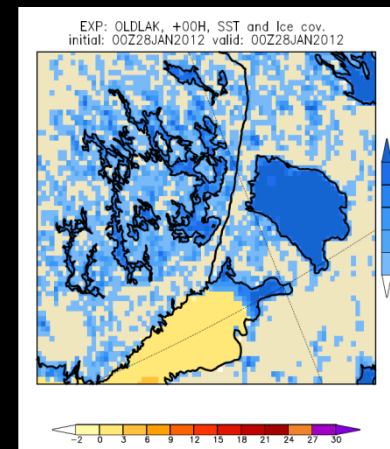
See Monday's animation

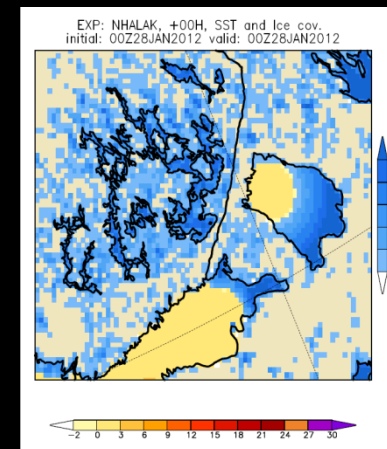70 pixels over 41 lakes are chosen for LSWT from AATSR and MODIS
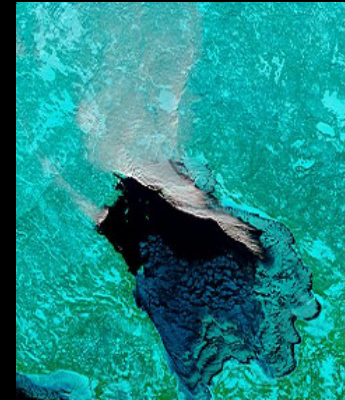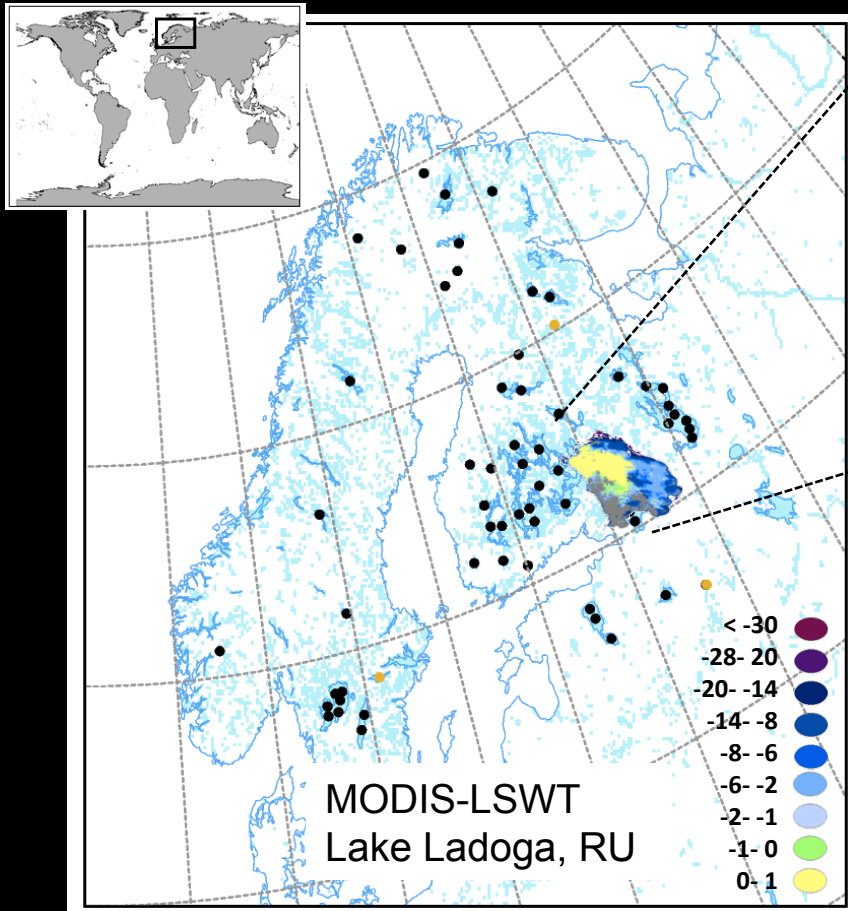
MODIS visible image
28 January 2012
Lake Ladoga, RU

MODIS-LSWT
Lake Ladoga, RU

< -30	
-28- 20	
-20- -14	
-14- -8	
-8- -6	
-6- -2	
-2- -1	
-1- 0	
0- 1	

Analyzed ice cover without assimilation

Analyzed ice cover with assimilation

EXP: OLDLAK, +00H, SST and Ice cov.
initial: 00Z28JAN2012 valid: 00Z28JAN2012

EXP: NHALAK, +00H, SST and Ice cov.
initial: 00Z28JAN2012 valid: 00Z28JAN2012

Assimilation of MODIS LSWT observations in HIRLAM

Eerola, K., L. Rontu, E. Kourzeneva, H. Kheyrollah Pour, and C.R. Duguay. Impact of partly ice-free Lake Ladoga on temperature and cloudiness in an anticyclonic winter situation - a case study using HIRLAM model. *Tellus A*.

- In experiments with realistic Lake Ladoga surface conditions, HIRLAM forecast model was able to predict cloud formation and its movement as well as 2-m height temperature variations in a realistic way.

    - The effect of large lakes on local weather can be predicted by using HIRLAM if the lake surface state is known.

    - Results encourage work to describe the lake surface state better in NWP models, both via data assimilation of satellite observations and by developing lake parameterizations, eventually combining these components into a single unified system.

Case study: CLIMo to study the response of lake ice to contemporary and future climate conditions

Canadian Lake Ice Model (CLIMo)

INPUT

OUTPUT

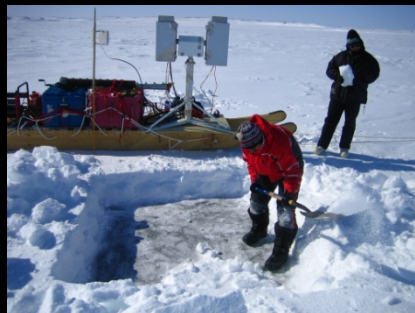Air Temperature

Relative Humidity

Wind Speed

Cloud Cover

Snow Accumulation

Lake depth (m)
Snow density (kg m^{-3})

CLIMo
0% and 100 % snow scenarios

Energy Balance Components

On-ice Snow Depth

Annual Freeze-up/ Break-up

Ice Thickness (Snow/Black Ice)

Temperature Profile (Snow/Ice)

Duguay *et al.* (2003)

Modelling of Lake Ice

CLIMo for single lake

Malcolm Ramsay Lakes, Churchill, MB