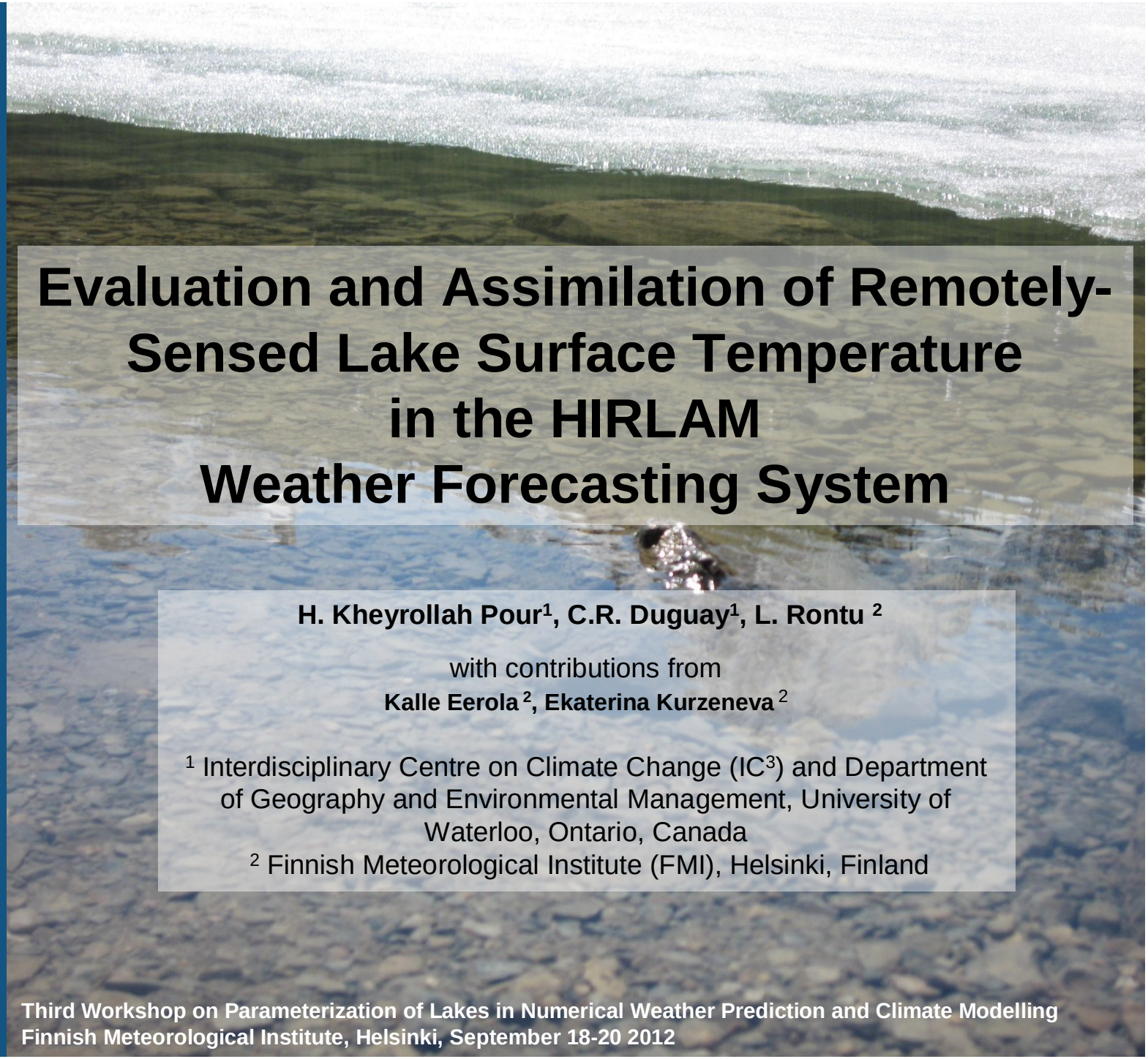

Evaluation and Assimilation of Remotely-Sensed Lake Surface Temperature in the HIRLAM Weather Forecasting System

H. Kheyrollah Pour[1], C.R. Duguay[1], L. Rontu [2]

with contributions from

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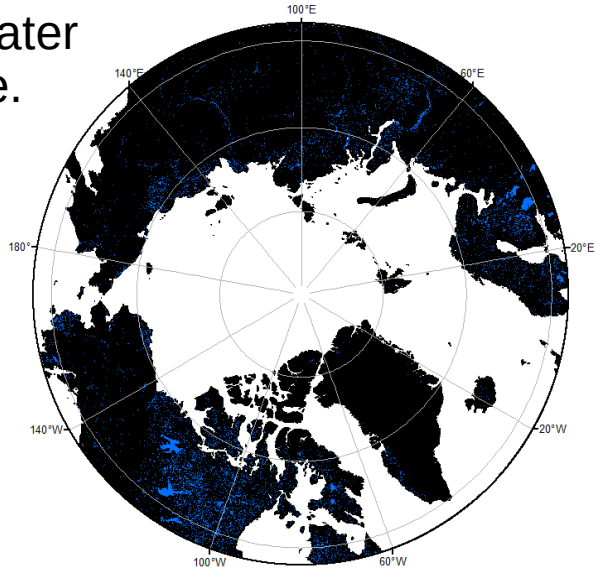
Third Workshop on Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling
Finnish Meteorological Institute, Helsinki, September 18-20 2012

Lakes in regional weather and climate

- Consideration of lake-atmosphere interactions is an important issue in climate modeling and numerical weather prediction (NWP).
- Lakes have an important role in the surface radiation balance, heat and water vapor exchanges with the atmosphere.
- The presence (or absence) of ice cover on lakes in winter has an effect on the surrounding climate.
- Earlier/later freeze-up and break-up results in ice cover duration change, and this strongly influences the radiation and energy balance.



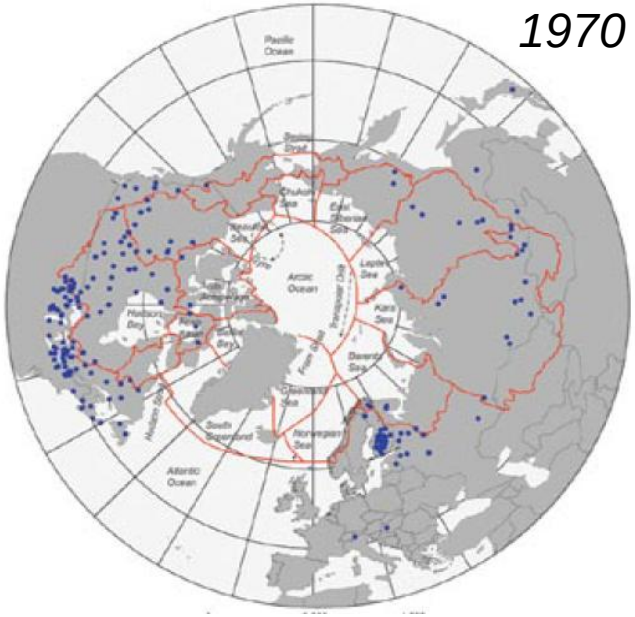
A good representation of lake ice/temperature-atmosphere interactions is necessary to improve weather forecasting and climate modelling

Objective

- To improve the objective analysis of lake surface state and forecasting (local cloud, temperature and precipitation) in the operational HIRLAM forecasting system.
  - Use *in-situ* observations (e.g. SYKE).

LWST – *In situ* measurements

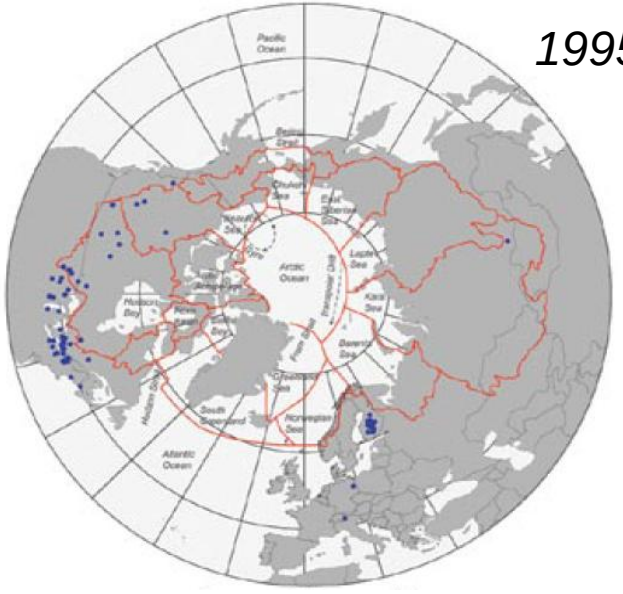
1970



Very little *in situ* data are available for the North, and many lakes are in remote regions.

The number of *in situ* sites reporting ice observations has plummeted since the 1980s.

1995



IGOS Cryosphere Theme Report (2007)

Except for a very limited number of studies, *in situ* Lake Water Surface Temperature (LWST) measurements are generally not available for northern lakes

Objective

- To improve the objective analysis of lake surface state and forecasting (local cloud, temperature and precipitation) in the operational HIRLAM forecasting system.
  - Use *in-situ* observations (e.g. SYKE).
  - Use a thermodynamical lake model(e.g. FLake).
    - FLake has shown quite realistic results in the simulation of lake freezing and provides a good background for independent analysis of LST in the operational HIRLAM.
    - Model has been found to be too sensitive during the melt period and to predict early melt.

Objective

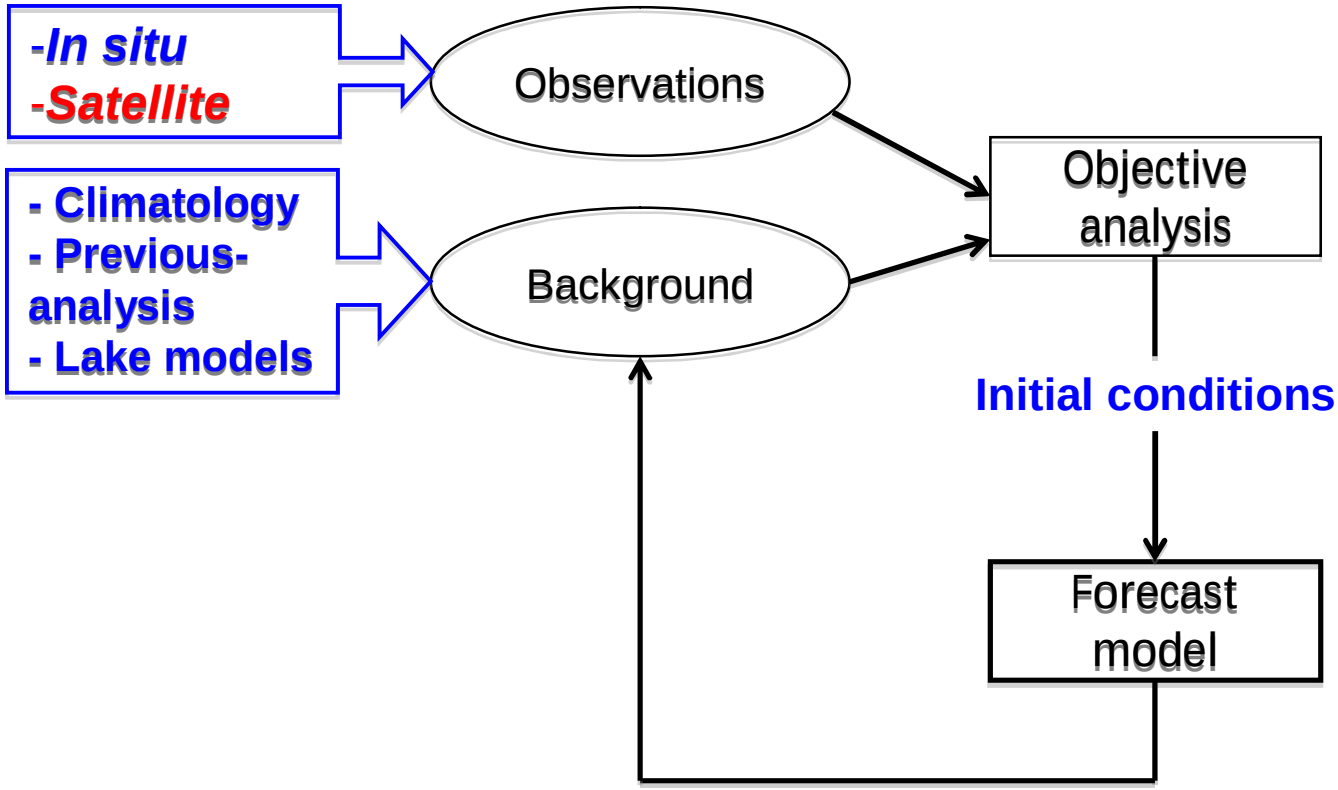
- To improve the objective analysis of lake surface state and forecasting (local cloud, temperature and precipitation) in the operational HIRLAM forecasting system.

  - Use *in-situ* observations (e.g. SYKE).
  - Use a thermodynamical lake model (e.g. FLake).
  - Use remote-sensing observations (e.g. MODIS, AATSR).

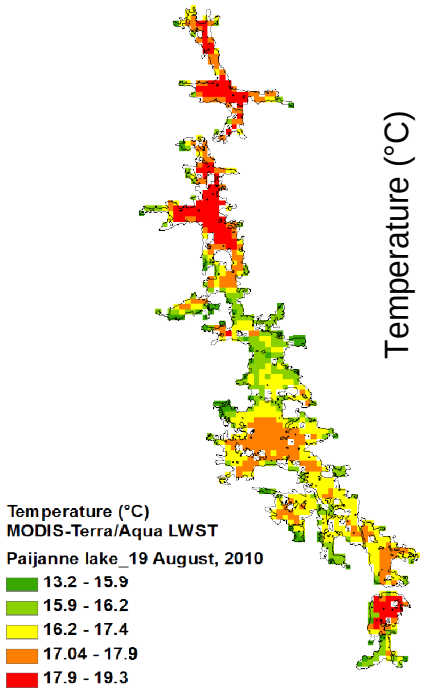
How retrieved satellite LWST observations can be used to improve weather forecasting?

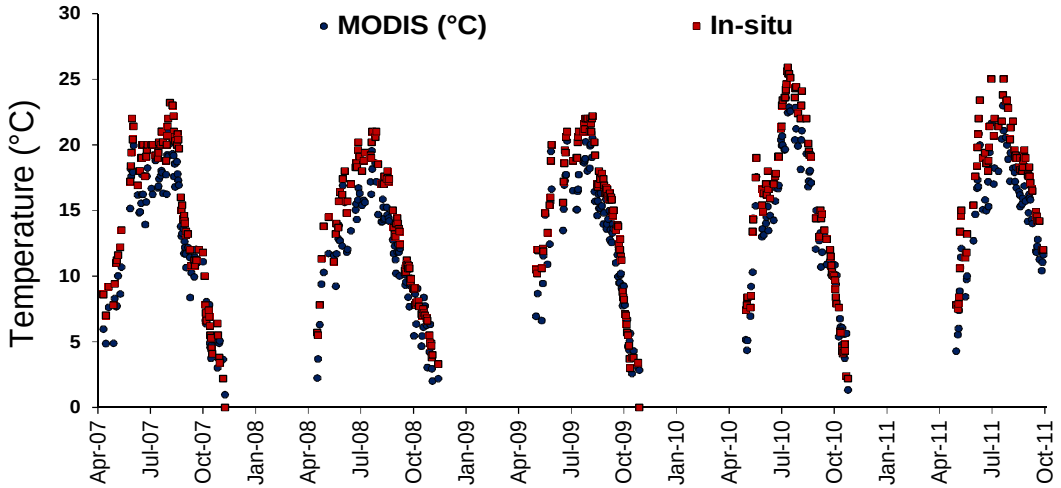
Data Assimilation

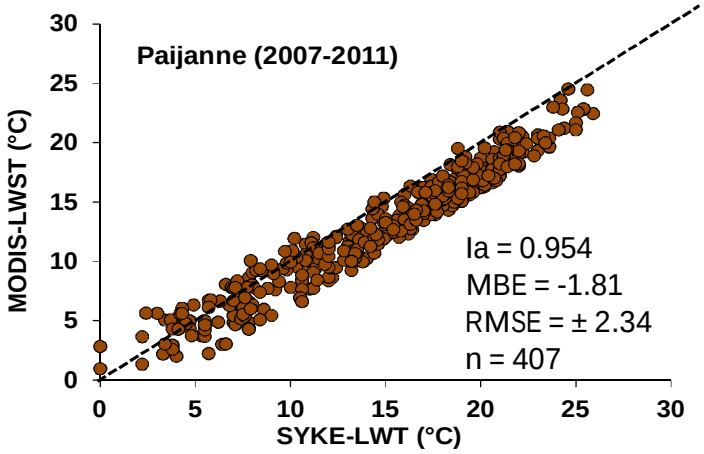
- Basic idea of data assimilation is to **combine measurements and models** to obtain an initial condition for NWP.
- The more accurate the estimate of the initial conditions, the better the quality of the forecast.



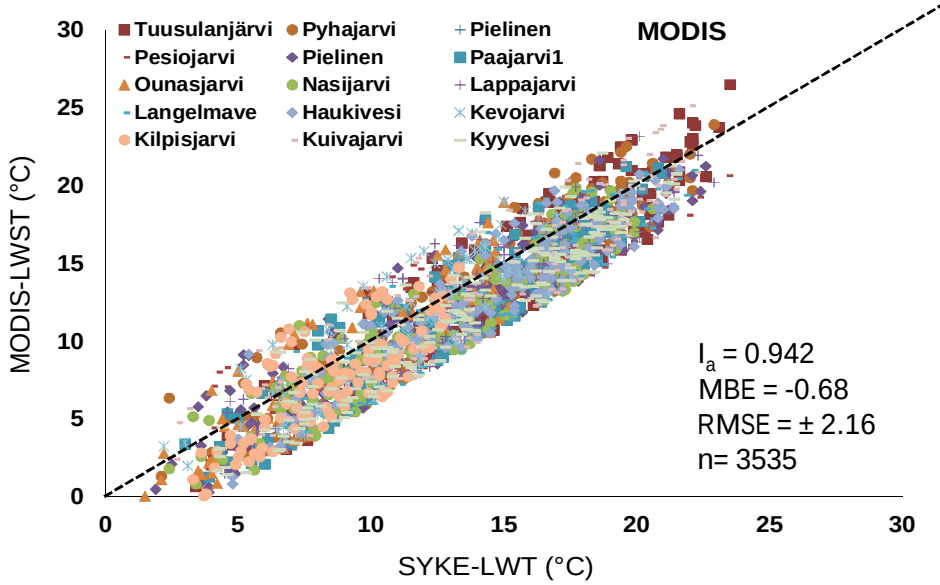
Evaluation of MODIS LWST for Lake Paijanne

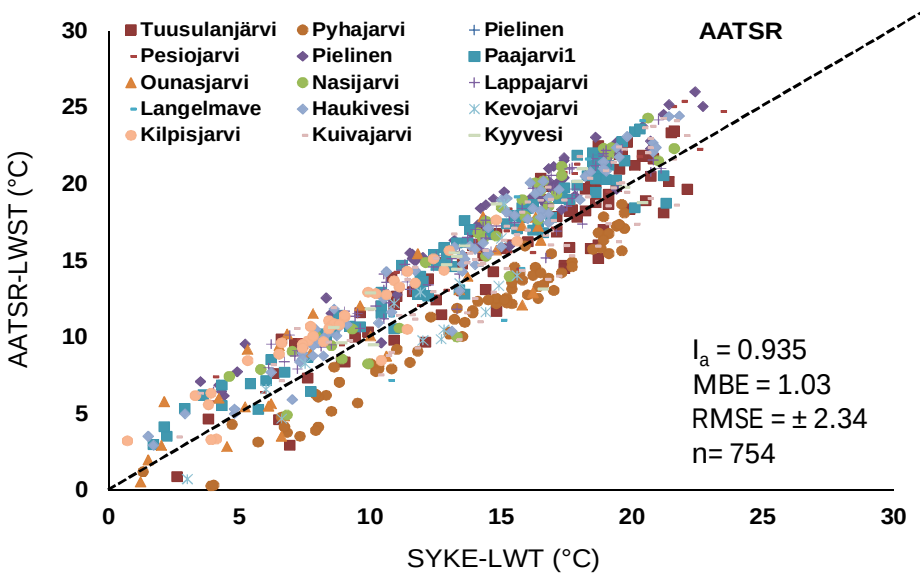




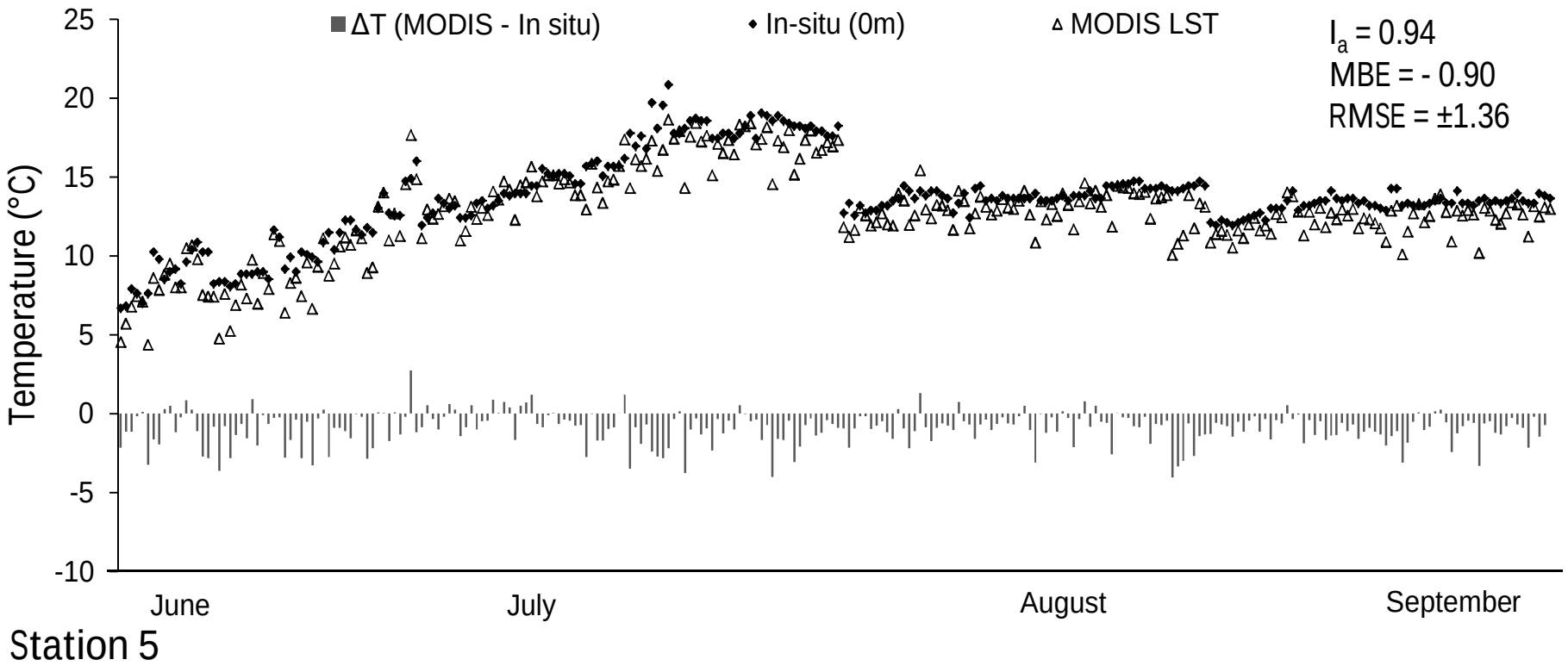


MODIS versus AATSR for 15 Finnish lakes (2007-2009)





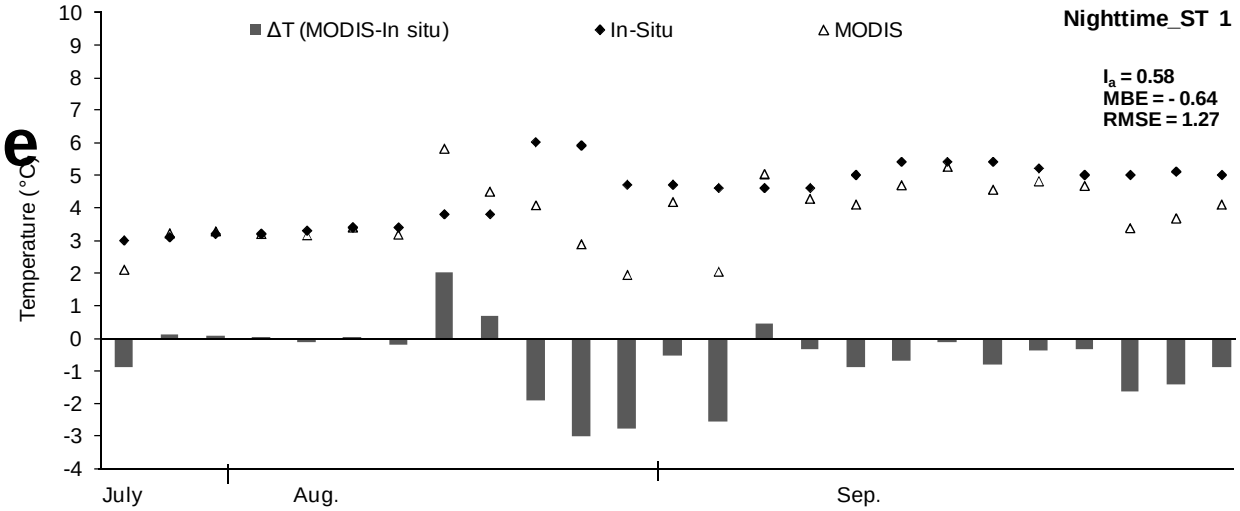
Evaluation of MODIS with *in situ*



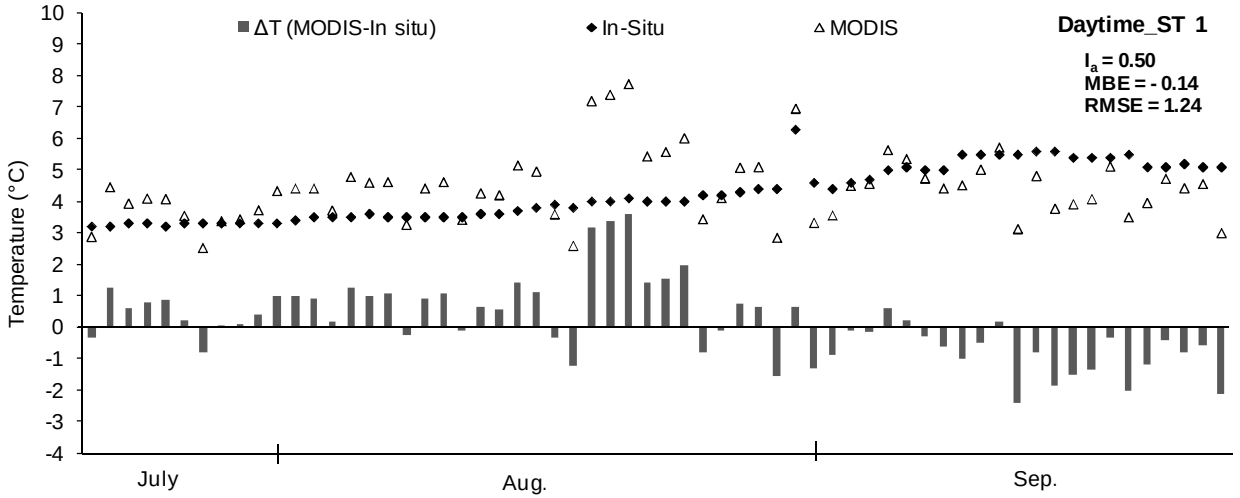
Kheyrollah Pour, H., Duguay, C. R., and Yerubandi, R. R., Analysis of lake and land surface temperature patterns during the open water and ice growth seasons in the Great Bear and Great Slave Lake region, Canada, from MODIS (2002-2010), in preparation.

Evaluation of MODIS LWST data

Nighttime

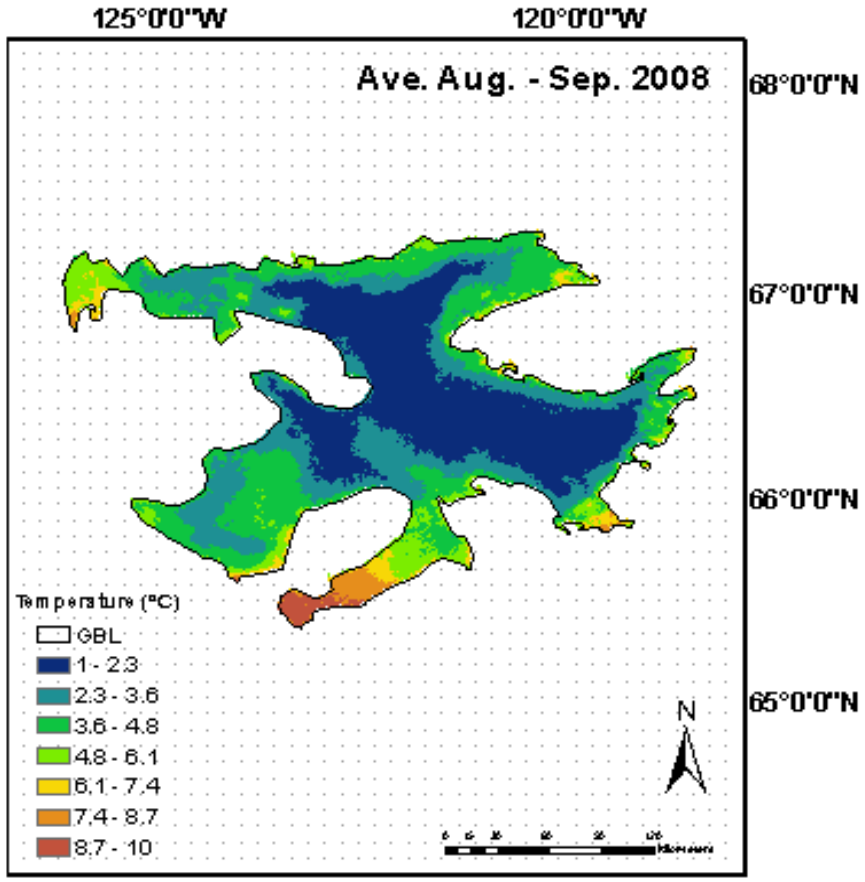


Daytime

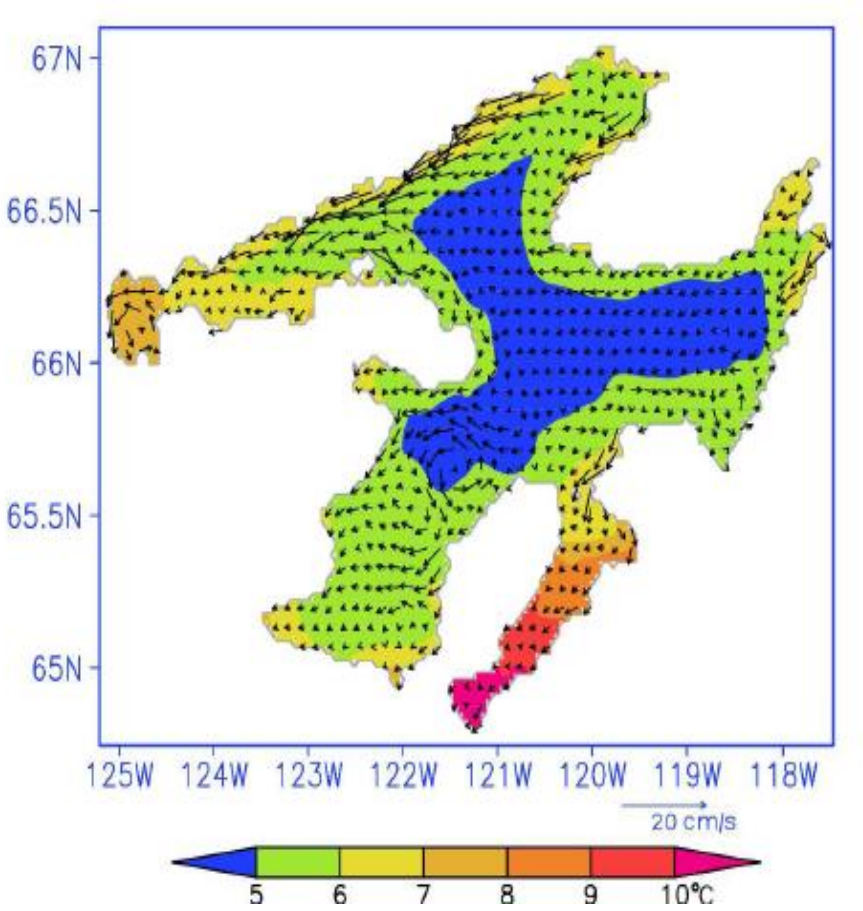


Kheyrollah Pour, H., Duguay, C. R., and Yerubandi, R. R., Analysis of lake and land surface temperature patterns during the open water and ice growth seasons in the Great Bear and Great Slave Lake region, Canada, from MODIS (2002-2010), in preparation.

MODIS versus 3-D Princeton Ocean Model (POM)



MODIS LWST (Aug.-Sep., 2008)

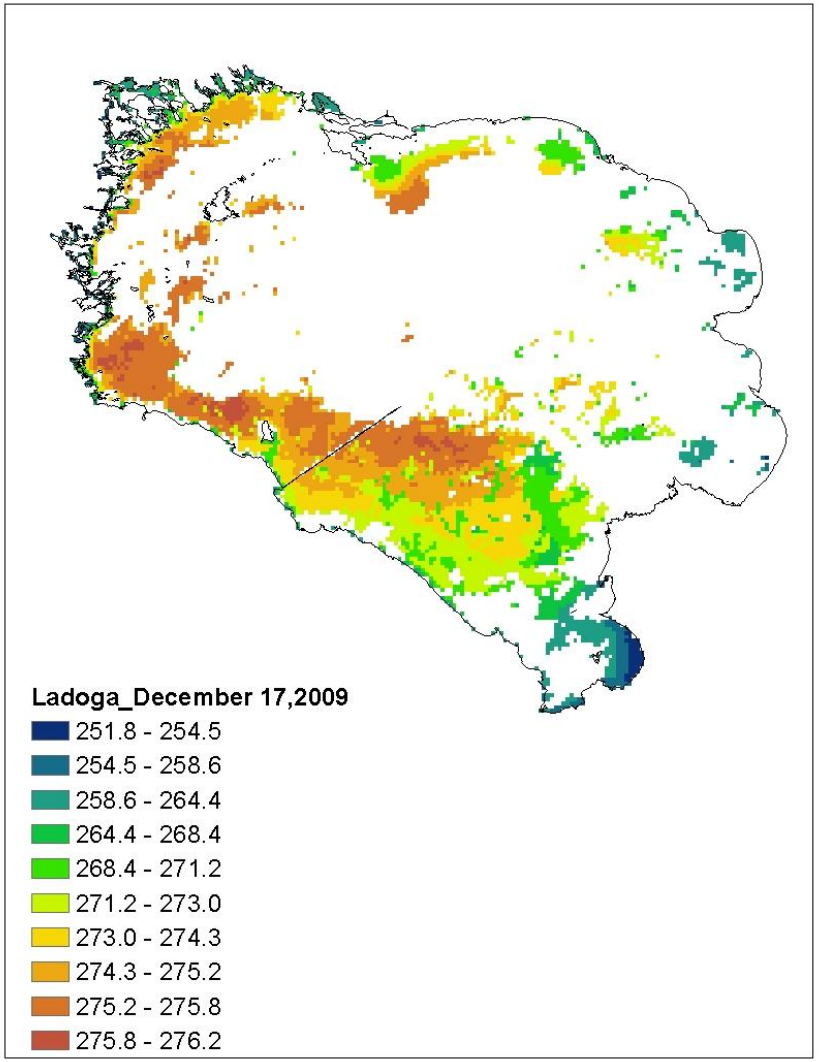


Modelled LWST (Aug.-Sep., 2008)

Limitation of cloud cover

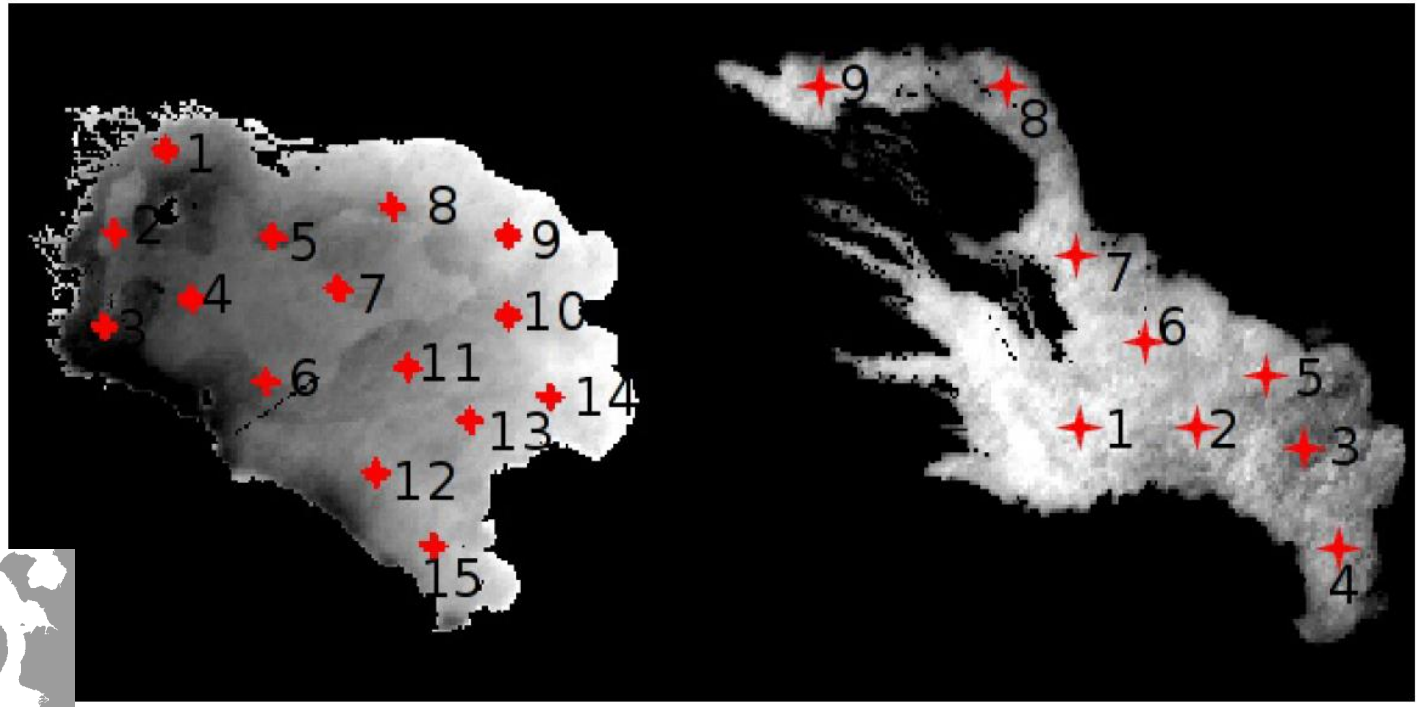
Ladoga
December 17, 2009

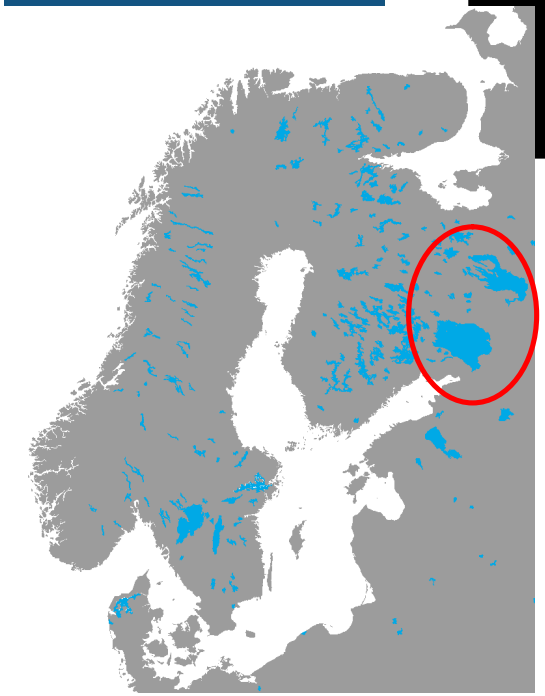
Visible Image



Thermal Image

MODIS TEMPERATURE PIXELS

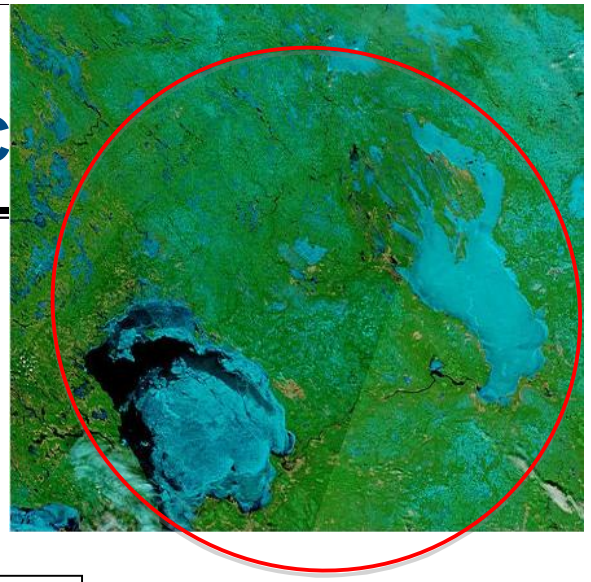


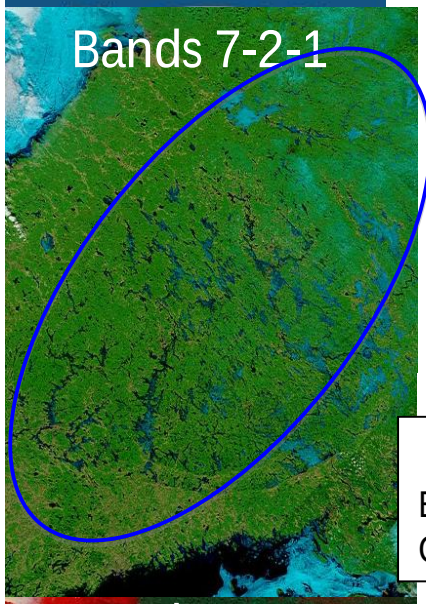


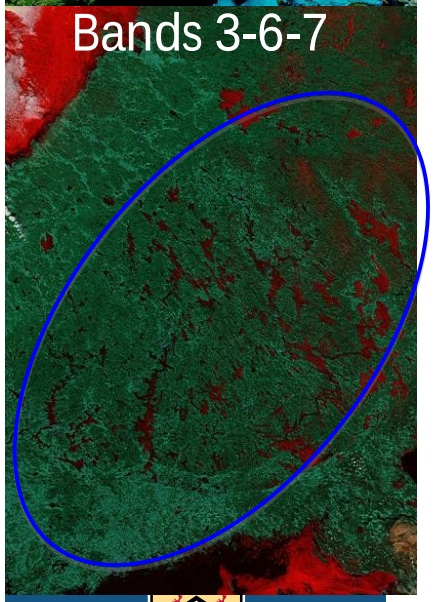
CHOSEN OVER LAKES
LADOGA AND ONEGA

FOR OPTIMAL
INTERPOLATION
IN HIRLAM

Lake Ice Fraction
25 April 2011 Analysis 6 UTC



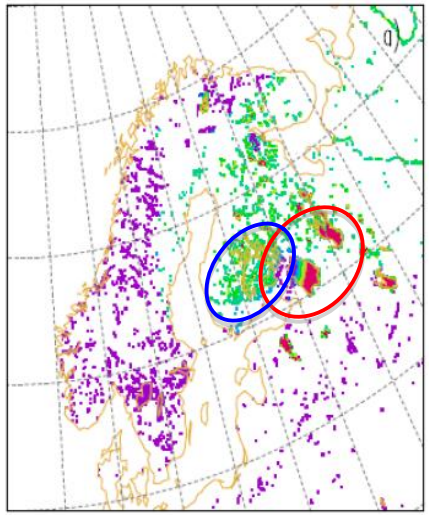


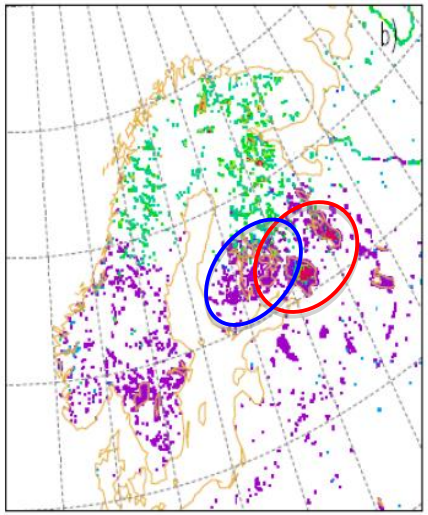


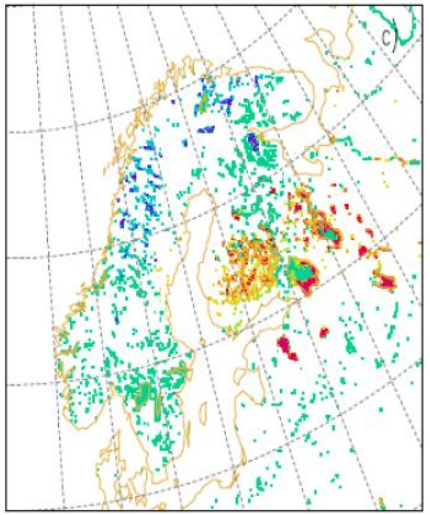
NOFLAK
Background: Previous analysis
Observation: MODIS + SYKE

KARLAK
Background: FLake model
Observation: MODIS + SYKE

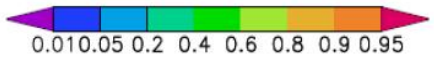
Differences







min=0 max=1 mean=0.314665



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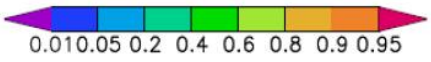

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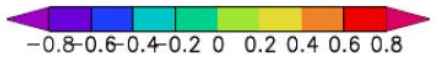
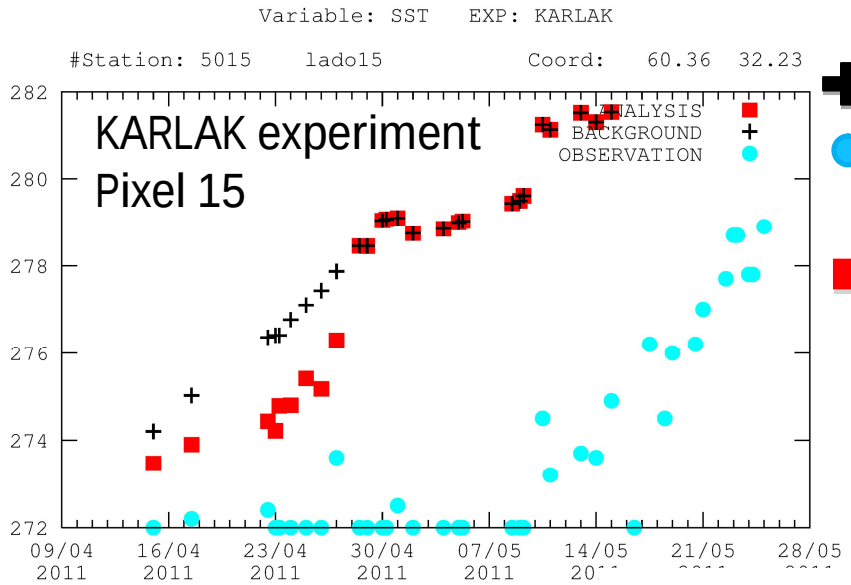


Experiment set-up – KARLAK and NOFLAK

Waterloo

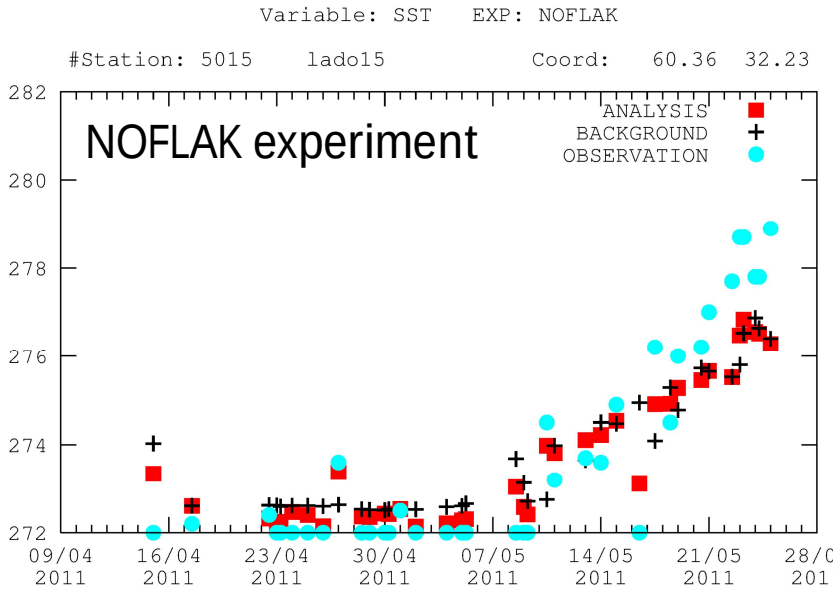


Background: FLake

Observation: MODIS + *in situ* (SYKE)

Analysis result

KARLAK



NOFLAK

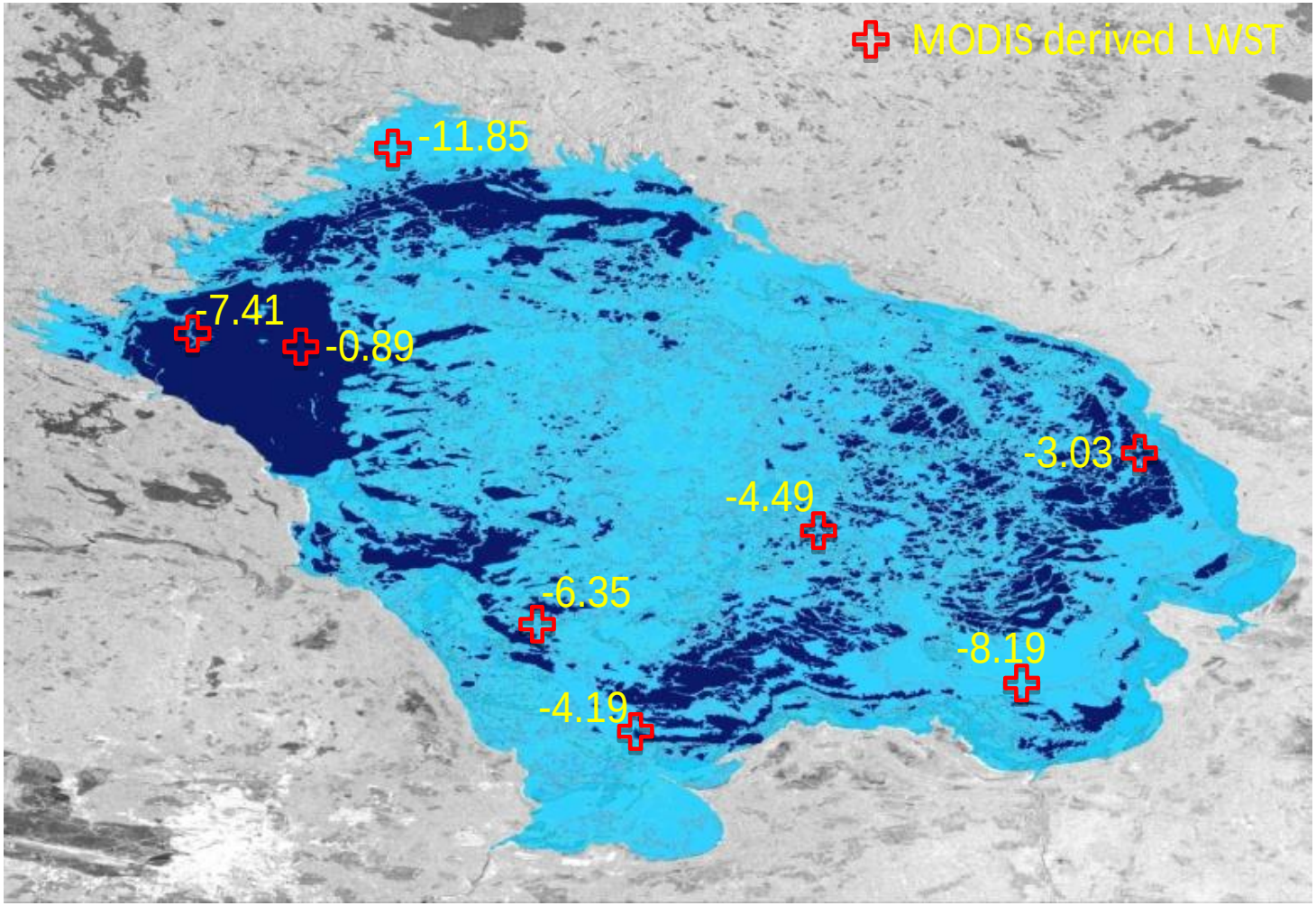
Background: Previous analysis

Observation: MODIS + *in situ* (SYKE)

Analysis result

Ice fraction for Lake Ladoga derived from MAGIC classification of SAR scenes

22 February 2009



Discussion

- MODIS LST data used in HIRLAM experiments resulted in a more realistic lake analysis outcome, which can be considered as a significant step towards improving future weather forecasts in cold regions.

- Improved analysis does not lead to an improved weather forecast as long as there is no real connection between the analyzed (observed) and predicted state of lakes.

- Climate models use observations only for calibration and validation, not as data assimilation. But it is possible to benefit from the use of satellite lake observations to improve parameterization and therefore climate models.

Future Plan

- Update MODIS observations, continuing HIRLAM experiments, analyzing the results systematically.
- Run a new HIRLAM experiment using MODIS observations for all major Scandinavian lakes within the HIRLAM domain.
- Work on structure functions in optimal interpolation to consider lake depth and elevation in the analysis.
- Validate forecasting results with weather station observations using 2-m air temperature, cloud cover, precipitation, and surface energy budget to test the sensitivity of the forecasts by changing initial conditions.

Thanks

Lake Louise, Banff National Park, April