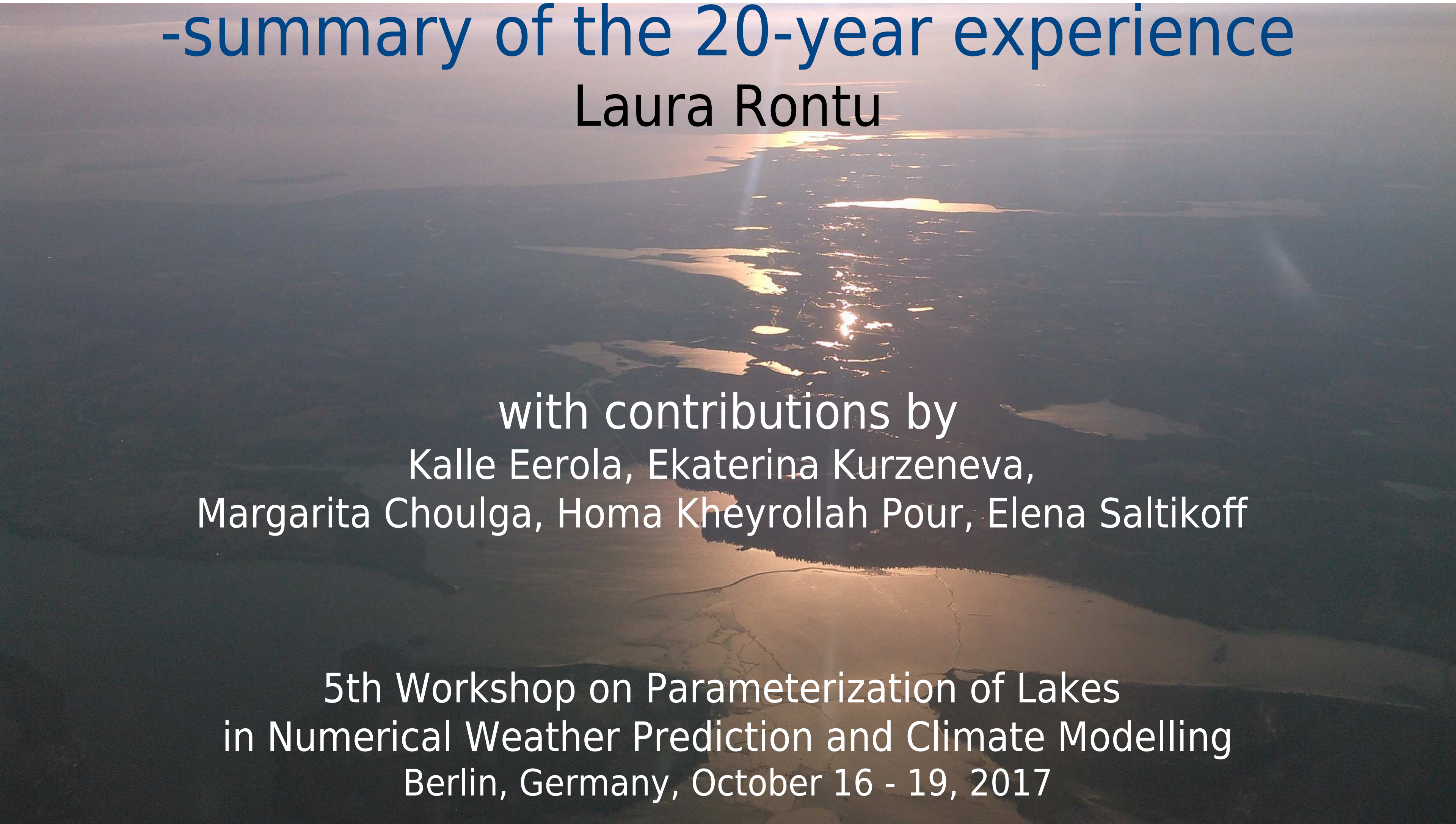
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Lake surface state in the HIRLAM NWP model -summary of the 20-year experience



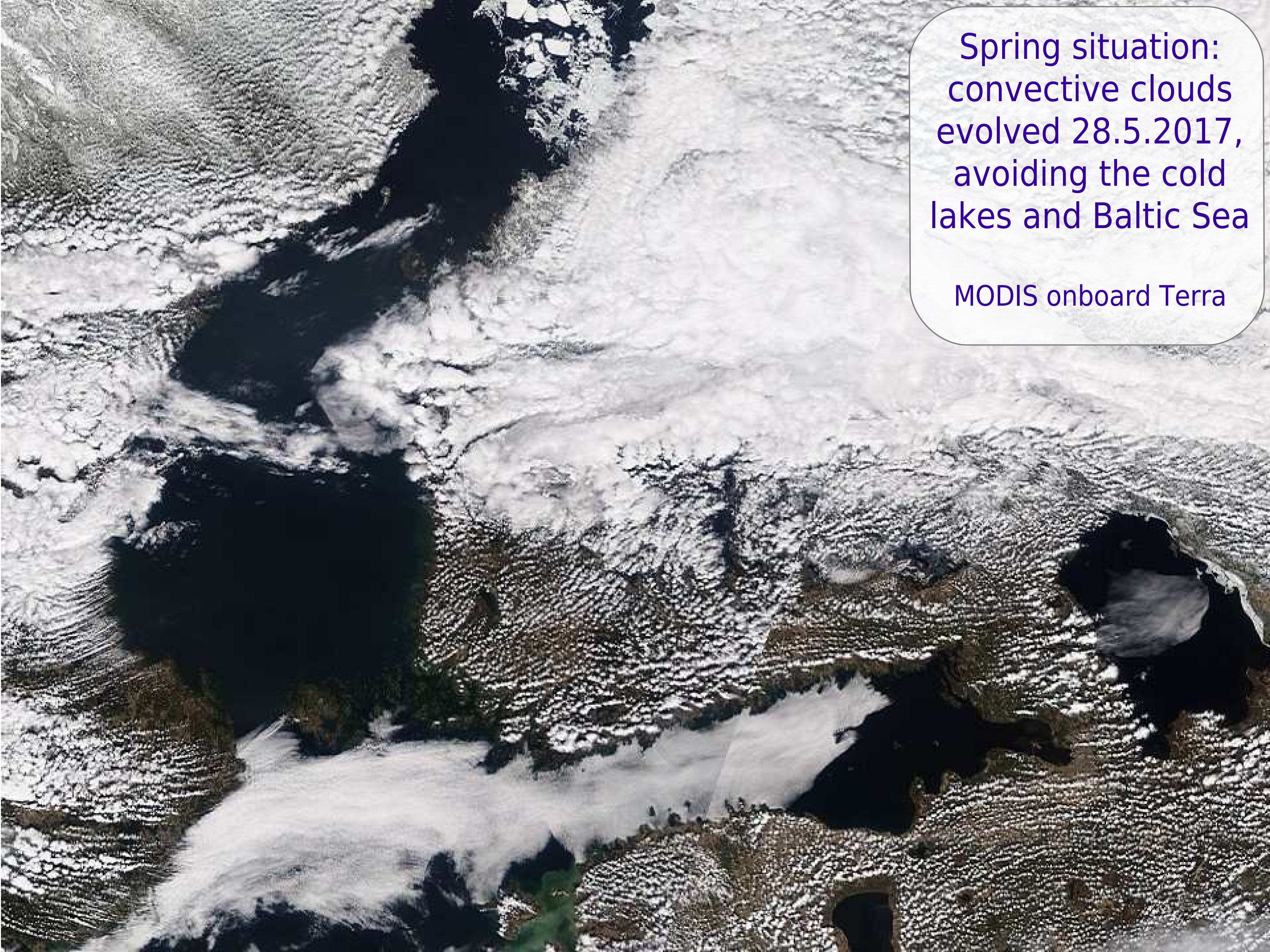
Laura Rontu

with contributions by

Kalle Eerola, Ekaterina Kurzeneva,
Margarita Choulga, Homa Kheyrollah Pour, Elena Saltikoff

5th Workshop on Parameterization of Lakes
in Numerical Weather Prediction and Climate Modelling
Berlin, Germany, October 16 - 19, 2017

CONTENTS

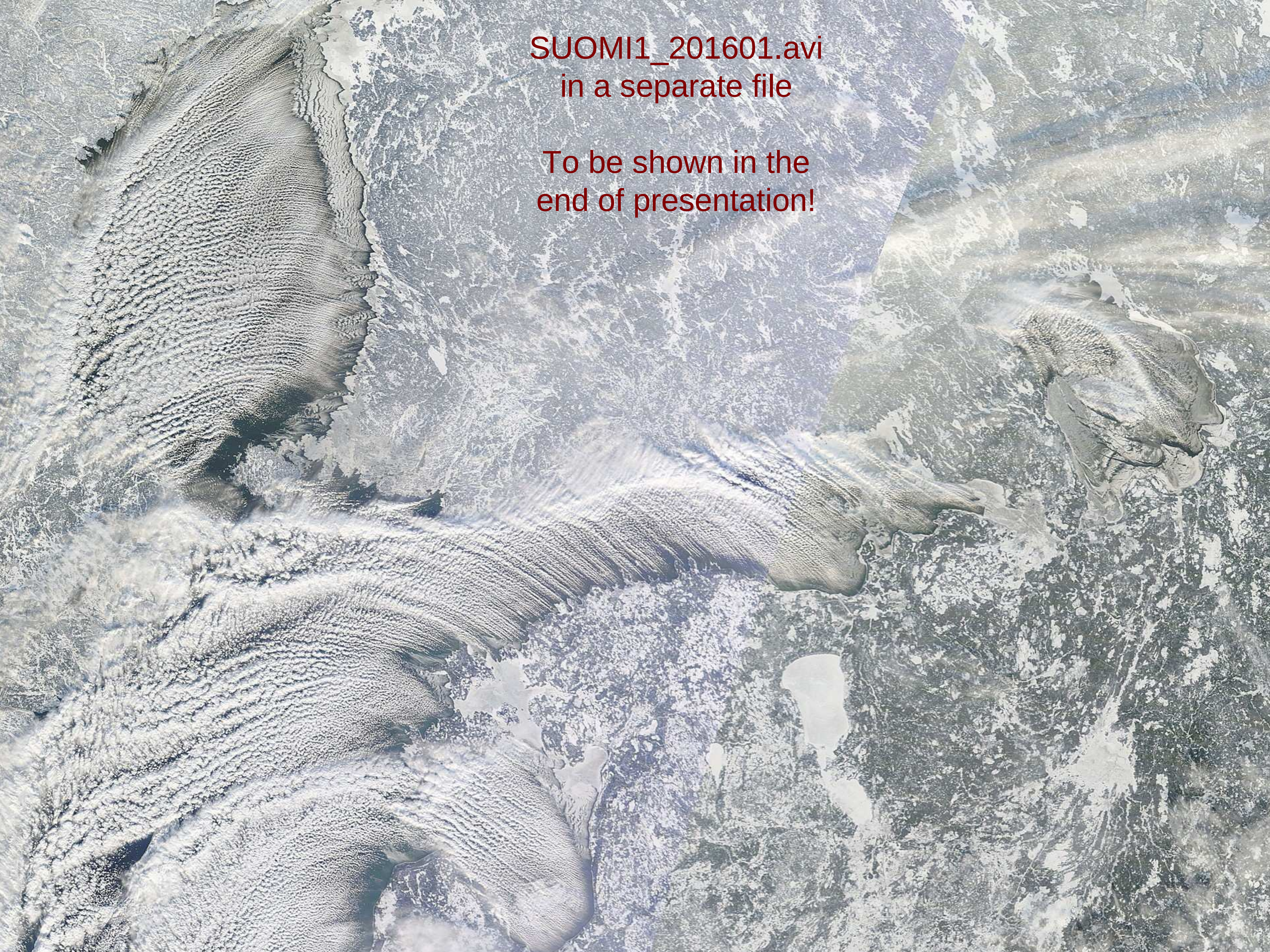

Spring situation:
convective clouds
evolved 28.5.2017,
avoiding the cold
lakes and Baltic Sea
MODIS onboard Terra

Spring sitation: convective clouds evolved 28.5.2017, avoiding the cold lakes and Baltic Sea

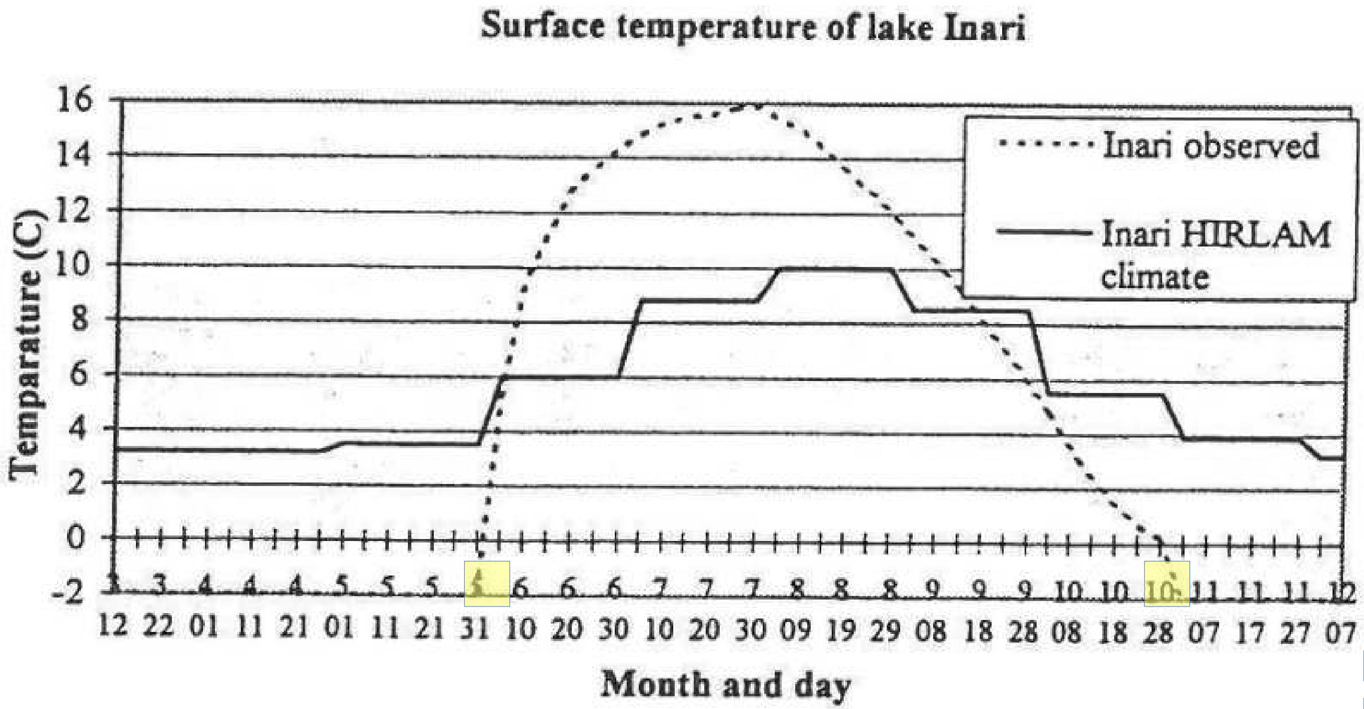
VIIRS onboard Suomi-NPP

Early winter situation - influence of the warm lakeas and Baltic sea. Watch a radar animation in January 2016 over Finland

composed by Elena Saltikoff from the Finnish Meteorological Institute


SUOMI1_201601.avi
in a separate file
To be shown in the
end of presentation!

HIRLAM LAKE MILESTONES



Eerola, 1995
HIRLAM workshop

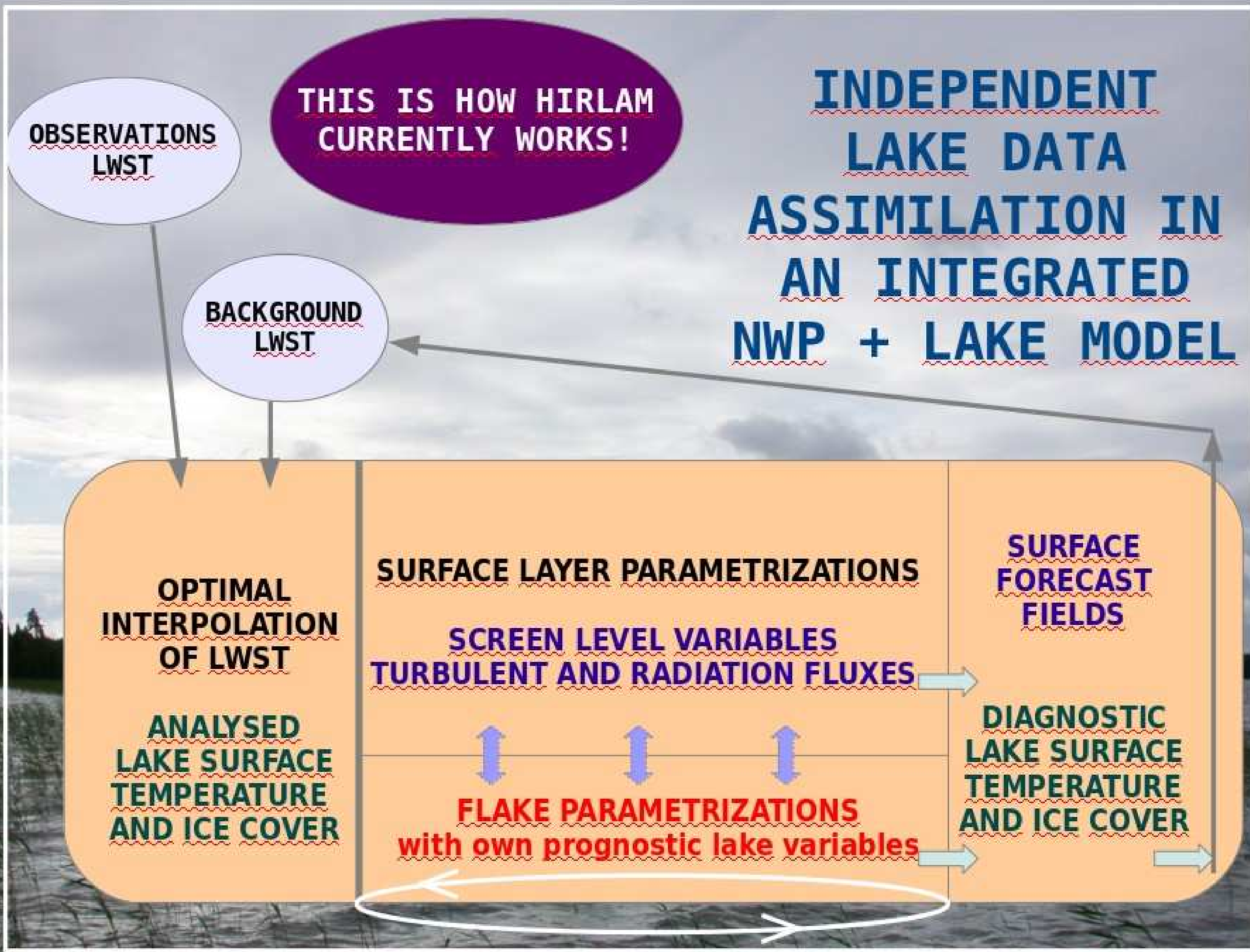
FIGURE 2. The surface temperature of lake Inari in northern Finland from the HIRLAM climate system and corresponding observed long-term averages as a function of the calendar date.

Twenty years ago the northern Finland Lake Inari
was never frozen in HIRLAM
because of the usage of the climatology
extrapolated from the ocean

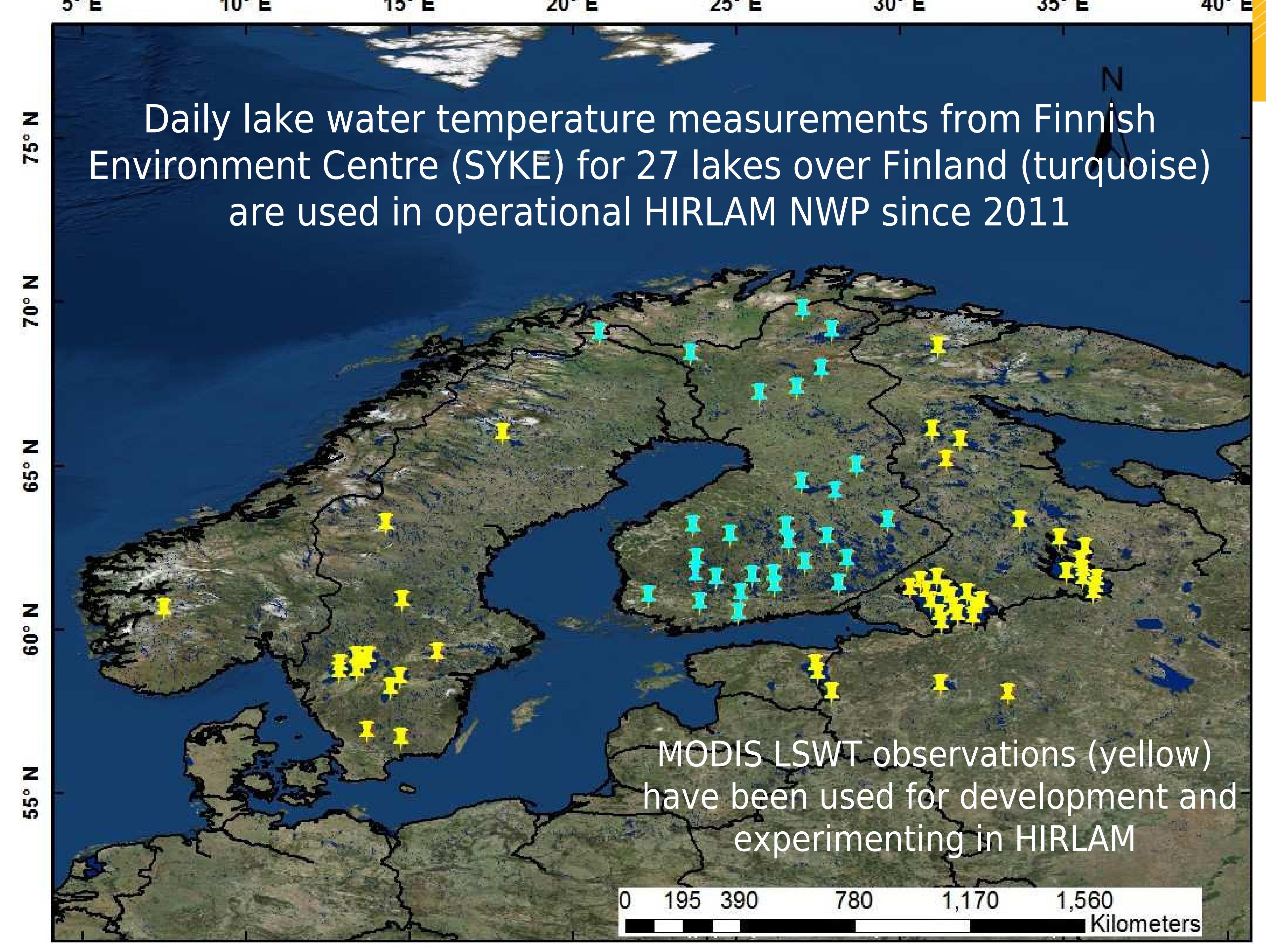
HIRLAM LAKE MILESTONES

	ANALYSED LSWT	FORECAST	DIAGNOSED	
1990	Extrapolated monthly SST climatology, no analysis	-	Ice fraction diagnosed from this SST	
1995	FINLAKE climatology as pseudo LSWT observations. Previous analysis as background. Relaxation of to climatology.	-	Ice fraction diagnosed from LWST analysis	SC[1]
ca. 2000	+ ECMWF time-lagged T_{2m} over big lakes as pseudo LSWT obs	-		
ca. 2003	+ Baltic ice map → pseudo LSWT over Vänern, Vättern	LIT forecast treated as land by the ISBA surface scheme		
2011	SYKE lake water observations replace all pseudos	LIT forecast continued by renewed ISBA		OI[2]
2012	Analysis background from FLake. Relaxation to climatology stopped. LSWT analysis does not influence the atmospheric forecast anymore!	LSWT and LIT forecast by FLake independently of LSWT analysis	Ice fraction diagnosed from analysed LSWT/forecast ice depth	

Acronyms:
1) SC=successive corrections
2) OI=optimal interpolation
3) LIT=lake ice temperature


INDEPENDENT LAKE DATA ASSIMILATION IN AN INTEGRATED NWP + LAKE MODEL
THIS IS HOW HIRLAM CURRENTLY WORKS!
OBSERVATIONS LWST
BACKGROUND LWST
OPTIMAL INTERPOLATION OF LWST
ANALYSED LAKE SURFACE TEMPERATURE AND ICE COVER
SURFACE LAYER PARAMETRIZATIONS
SCREEN LEVEL VARIABLES TURBULENT AND RADIATION FLUXES
FLAKE PARAMETRIZATIONS with own prognostic lake variables
SURFACE FORECAST FIELDS
DIAGNOSTIC LAKE SURFACE TEMPERATURE AND ICE COVER

CONTENTS



5° E
10° E
15° E
20° E
25° E
30° E
35° E
40° E
75° N
70° N
65° N
60° N
55° N
N
Daily lake water temperature measurements from Finnish Environment Centre (SYKE) for 27 lakes over Finland (turquoise) are used in operational HIRLAM NWP since 2011
MODIS LSWT observations (yellow) have been used for development and experimenting in HIRLAM
0 195 390 780 1,170 1,560
Kilometers

HOW TO INTERPOLATE THE POINT OBSERVATIONS TO THE NWP MODEL GRID?

Method of optimal interpolation (Gandin, 1965)

<u>Provides the NWP model with:</u>

An analysed LSWT value in every gridpoint
that contains a fraction of lake

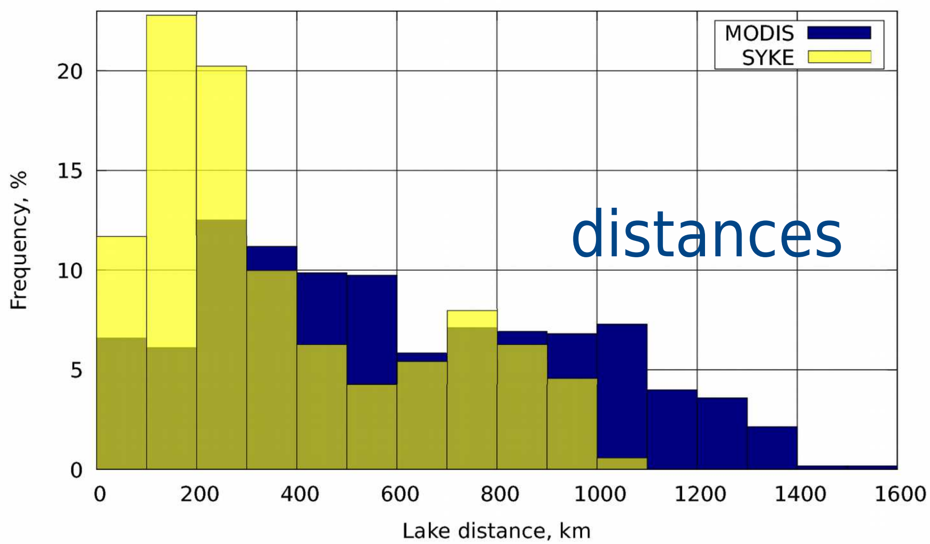
<u>Requires</u>

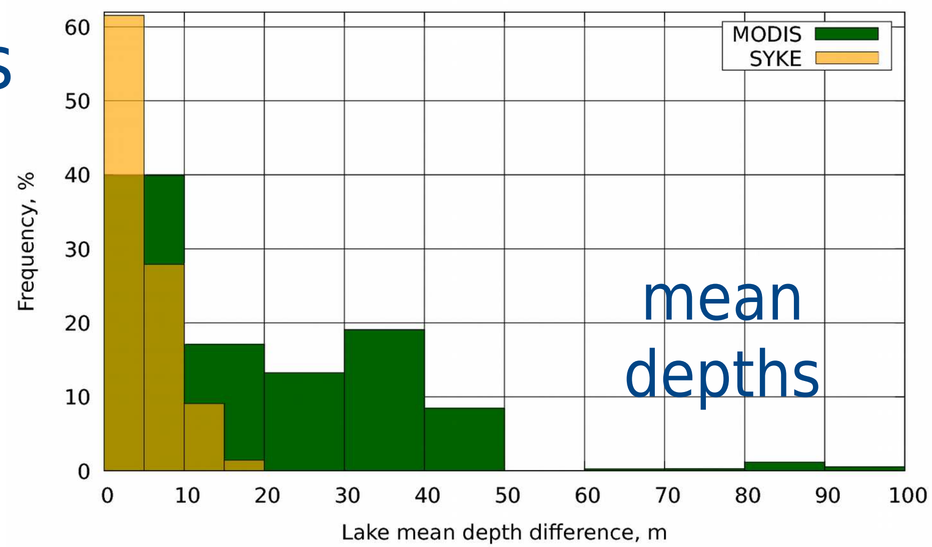
Observations and estimated observation errors
Autocorrelation function for model-observation departures
Background field – short forecast / previous analysis

Kheyorollah Pour et al., 2017. Towards improved objective analysis of lake surface water temperature in a NWP model: preliminary assessment of statistical properties

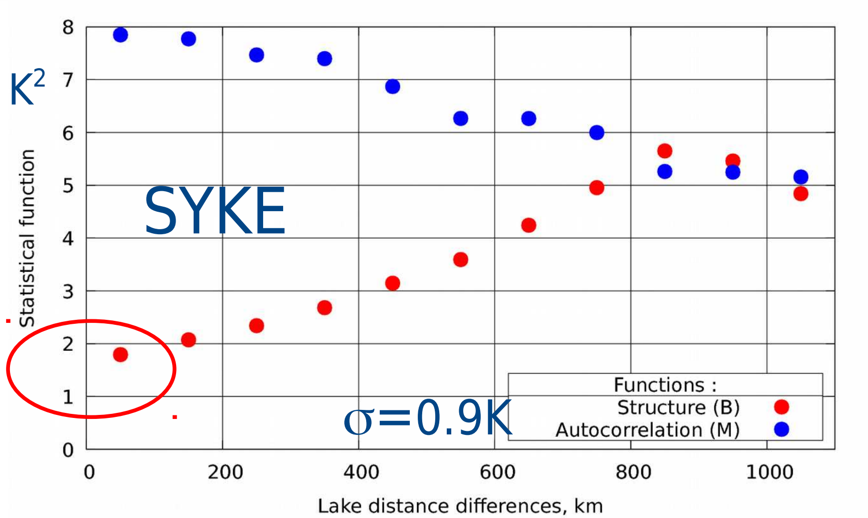
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

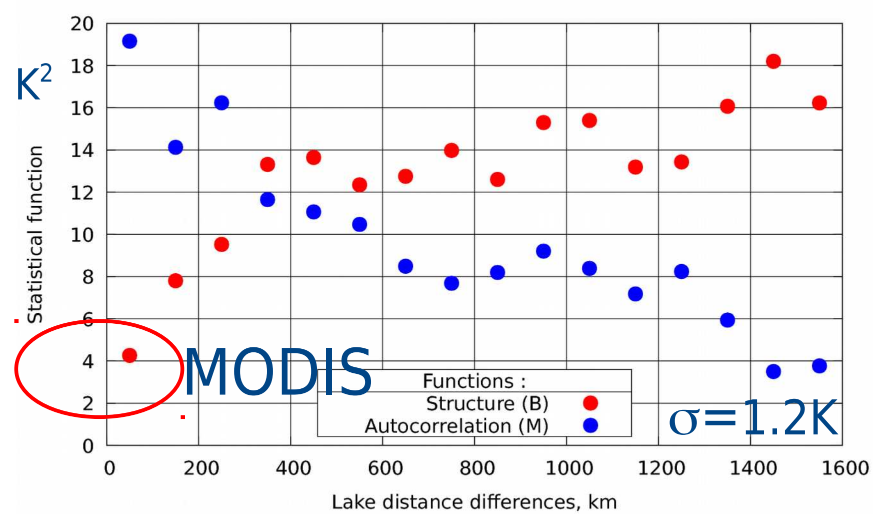
LSWT observation statistics summers 2010 - 2014





Structure and autocorrelation functions depending on distance





ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

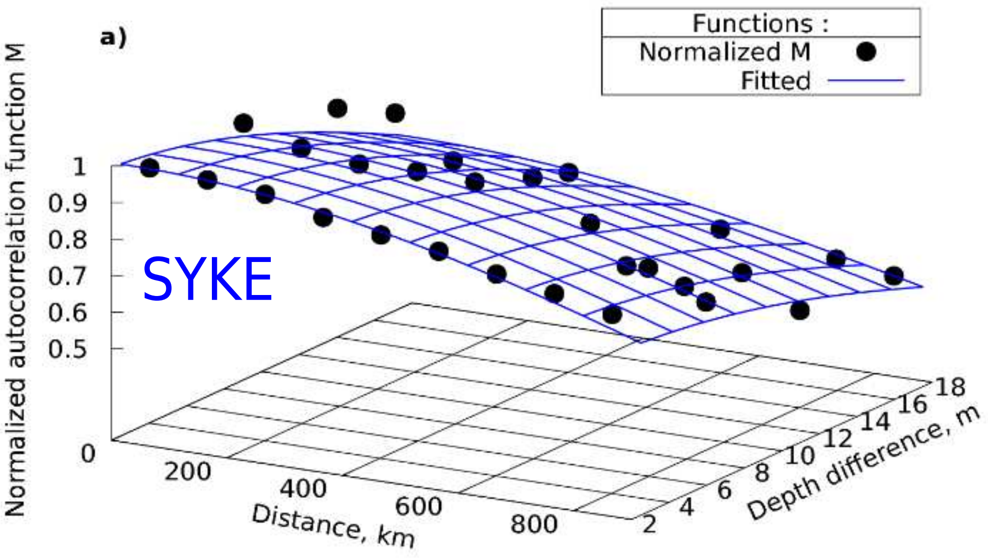
Autocorrelation functions depending on distance and lake depth difference

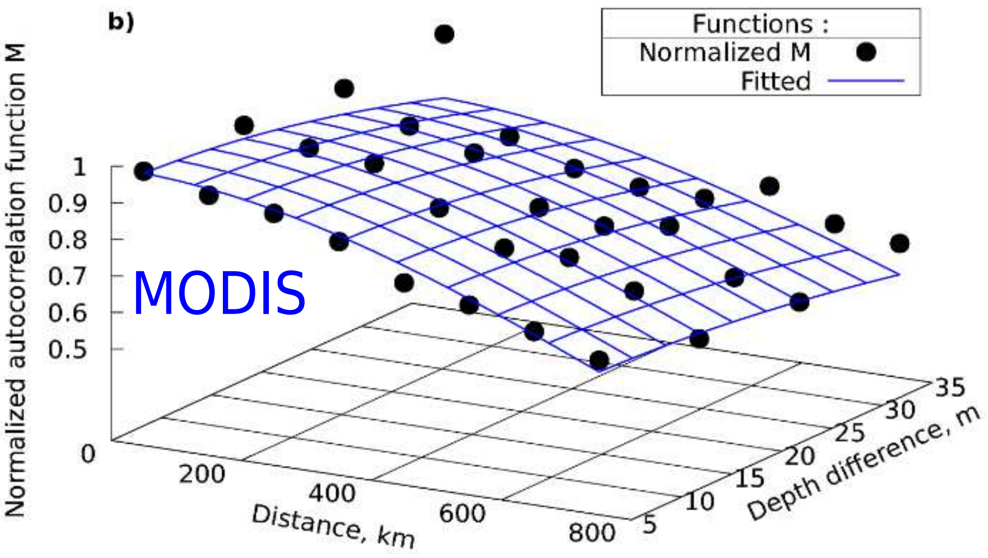
An exponential function has a natural physical interpretation as the scales which can be related to distances and differences. For the two-dimensional autocorrelation function, a two-dimensional exponential approximation may be suggested, for example:

$$\mu(\rho, \delta) = e^{-[\frac{\rho^2}{2{L_H}^2} + \frac{\delta^2}{2{L_V}^2}]} \qquad \text{(A11)}$$

where δ is the vertical distance (or difference in depth) and L_V is the vertical length scale.

Scales L_H = 800 km and L_V = 20 m were tried in HIRLAM





WHERE TO TAKE THE LSWT BACKGROUND FIELD FOR THE OPTIMAL INTERPOLATION?

Climatology

(Possible stand-alone analysis)

Previous analysis

- HIRLAM before 2012
- Contemporary OSTIA

- requires relaxation to climate to prevent drifting in time

Short forecast by the model

HIRLAM since FLake, 2012

- ”peaceful coexistence”

Freshwater lake model FLake is being used in the FMI operational HIRLAM since 2012

Flake has 11 prognostic variables:

(From presentation by Dmitri Mironov in Lake15)

- the mean temperature of the water column,
- the surface temperature, (=mixed layer water temperature T_{ml})
- the bottom temperature,
- the mixed-layer depth,
- the shape factor with respect to the temperature profile in the thermocline,
- the depth within bottom sediments penetrated by the thermal wave, and
- the temperature at that depth.

In case of ice-covered lake, additional prognostic variables are

- the ice depth,
- the temperature at the ice upper surface,
- the snow depth, and the temperature at the snow upper surface.

Flake official site: http://www.flake.igb-berlin.de

CONTENTS

VALIDATION OF FLAKE AND THE ANALYSED LSWT IN OPERATIONAL HIRLAM

(past, ongoing, planned)

Case studies – Ladoga, January 2012

Comparison of background forecast and analysis to LSWT observations 2012-2016

Comparison of forecast and observed freezing and melting dates 2012-2017

Planned within HARMONIE:

Statistical validation of weather forecast by using SYNOP observations close to / far from lakes

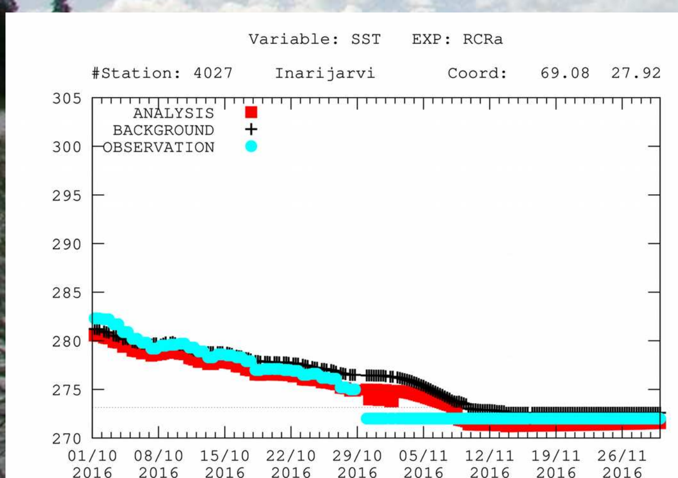
More case studies using satellite information and synoptic data

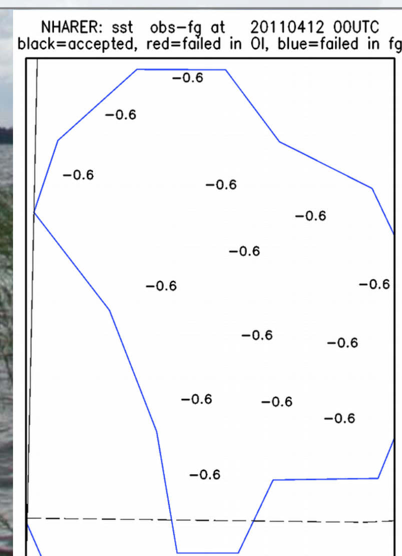
Obsa statistics of HIRLAM

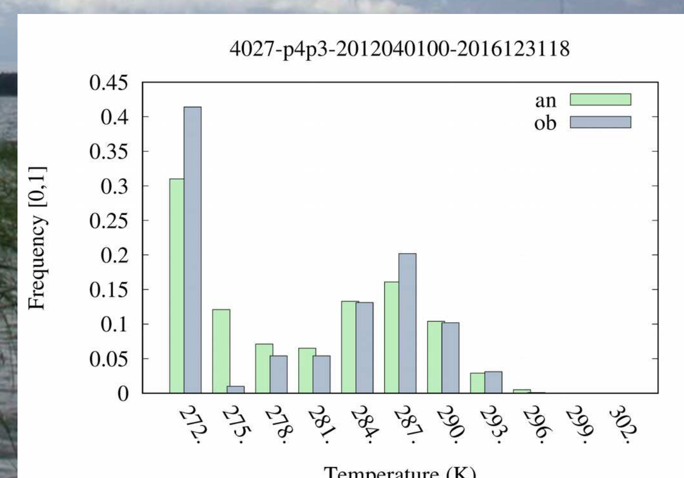
During the surface analysis, information for statistics are collected at each active observation location

Observed value ob = the truth
Analysed value an = result of OI
Interpolated background value
fg = FLake +6h forecast

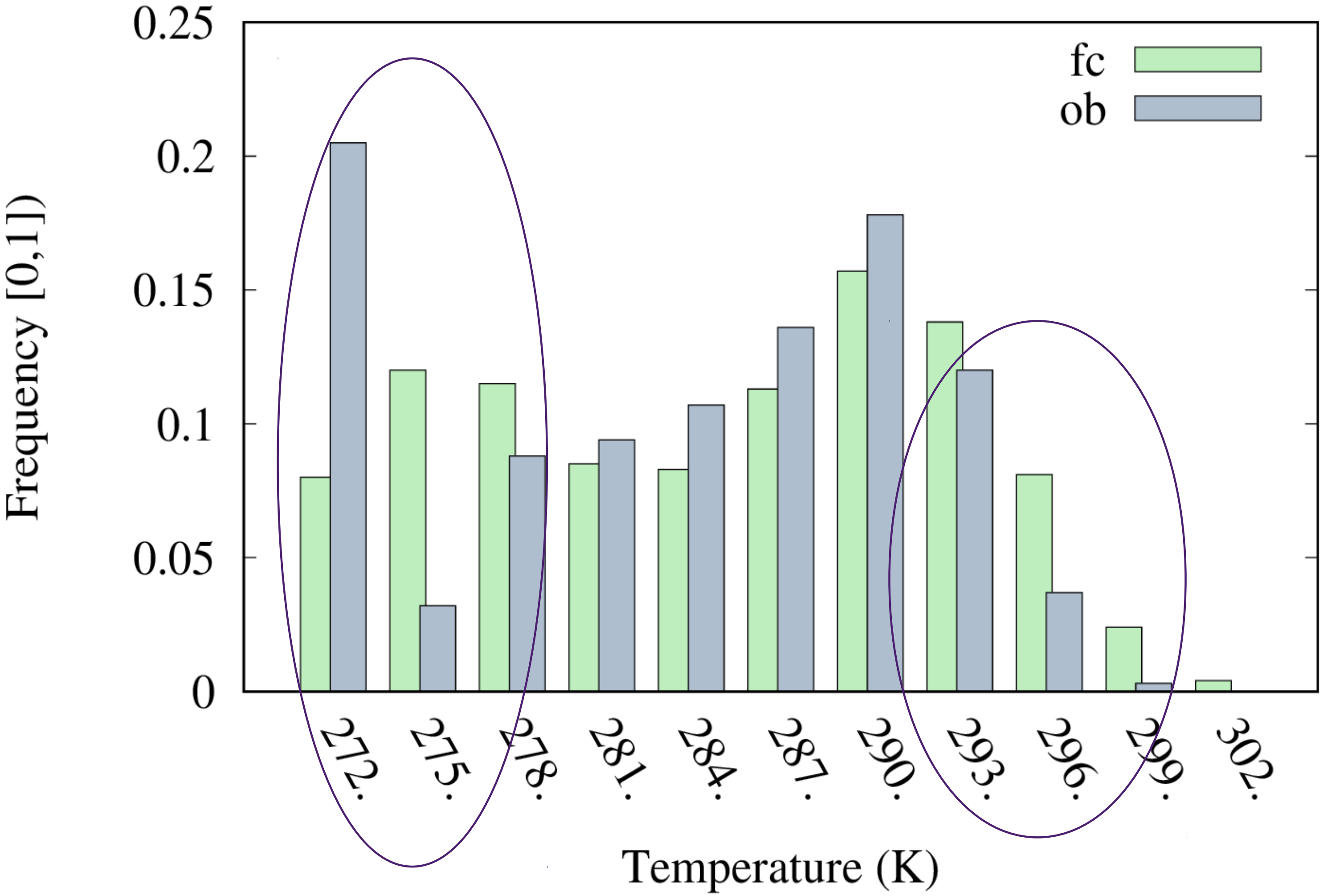
Time-series, maps, statistics are derived from these







HIRLAM/FLAKE LSWT forecasts* v.s. SYKE observations* 2012-2016 (open water periods) over all 27 lakes



N = 88977

Mean T_{obs} = 283.2

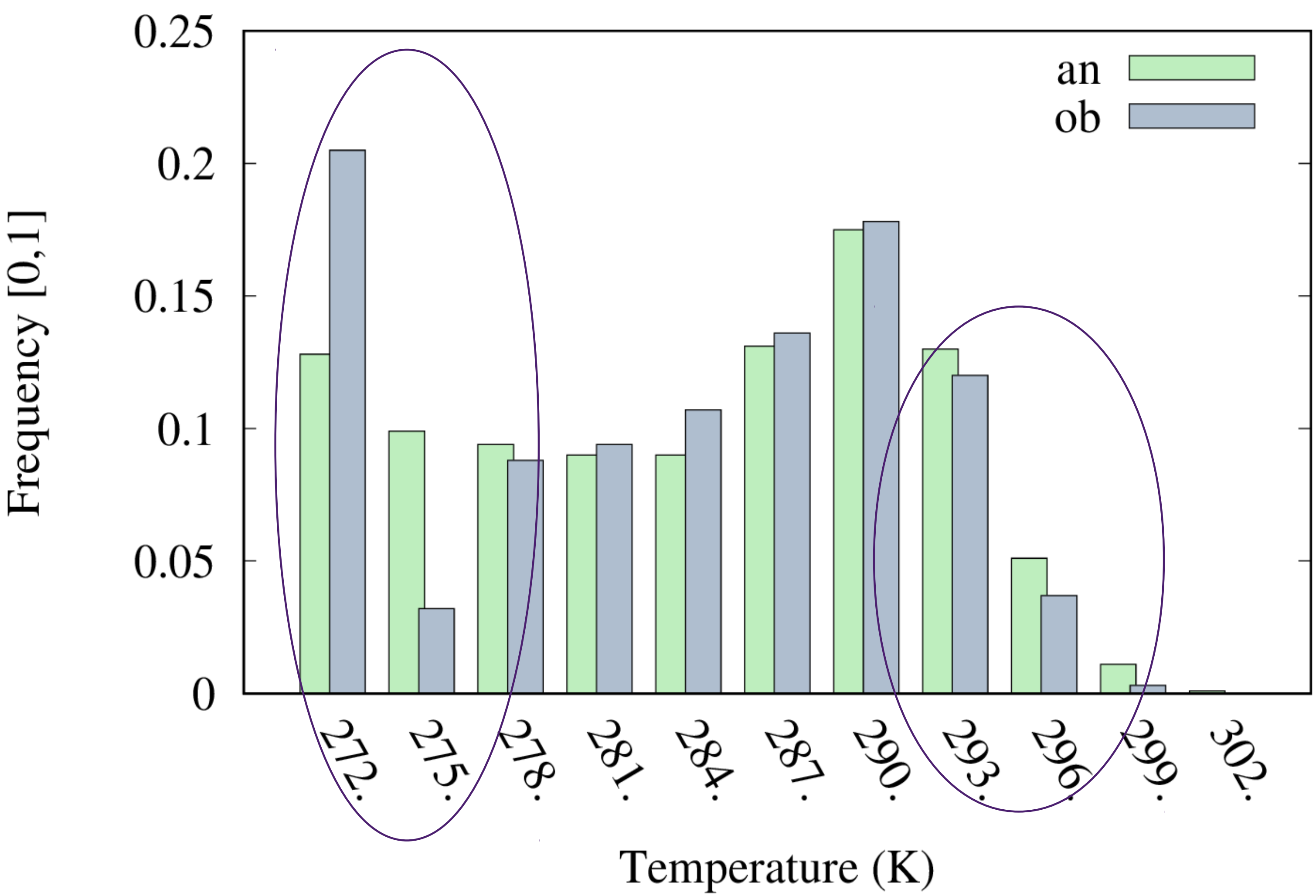
Bias = 1.4 K

Stde = 2.4 K

MAE = 2.2 K

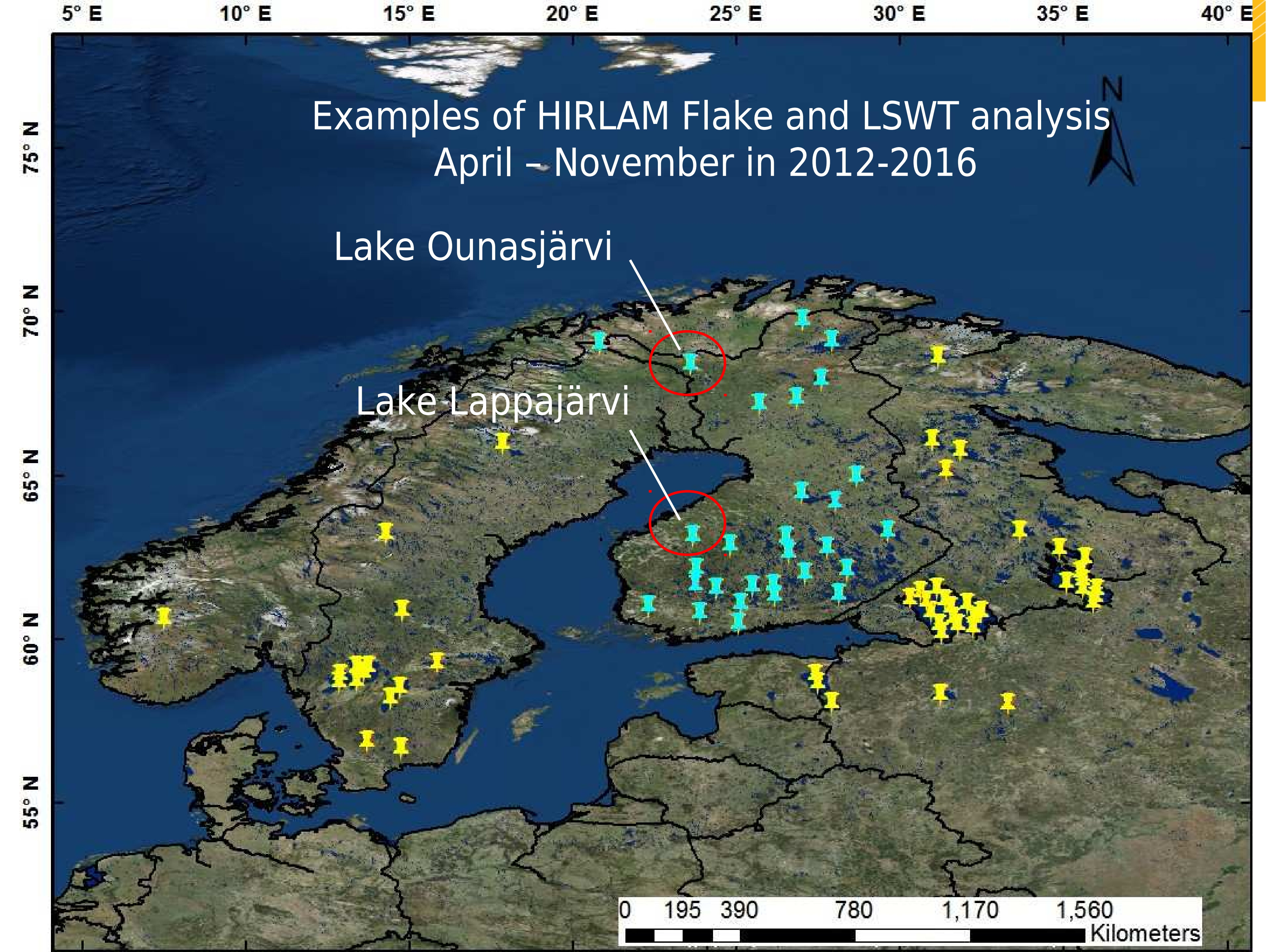
*FC+6h at 00,06,12,18 UTC
SYKE at 6 UTC

HIRLAM/FLAKE LSWT analyses* v.s. SYKE observations* 2012-2016 (open water periods) over all 27 lakes



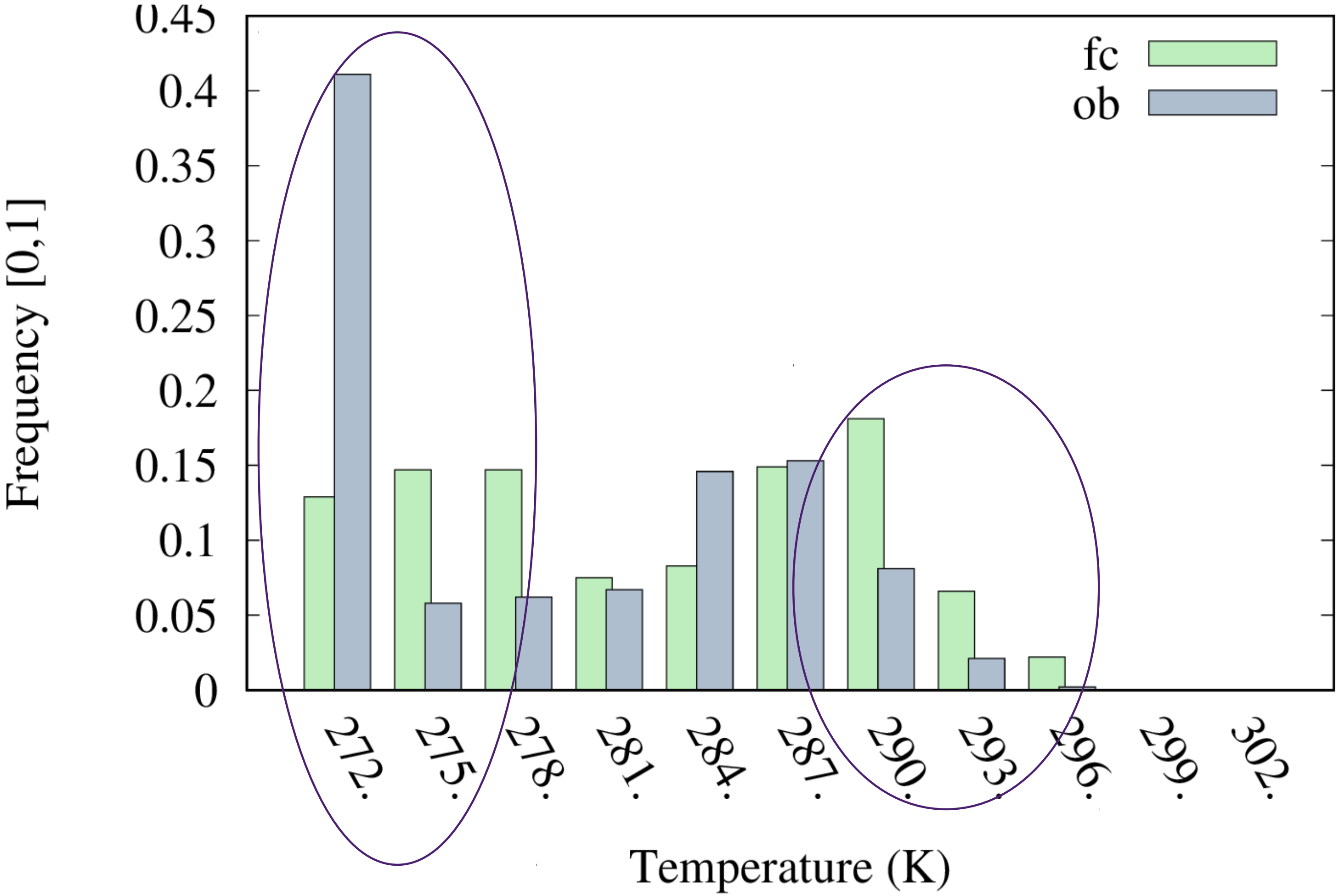
N = 88977
Mean T_{obs} = 283.2K
Bias = 0.6 K
Stde = 1.7 K
MAE = 1.4 K

*AN+00h at 00,06,12,18 UTC
*SYKE at 6 UTC



Examples of HIRLAM Flake and LSWT analysis
April – November in 2012-2016
Lake Ounasjärvi
Lake Lappajärvi
5° E
10° E
15° E
20° E
25° E
30° E
35° E
40° E
75° N
70° N
65° N
60° N
55° N
N
0 195 390 780 1,170 1,560
Kilometers

HIRLAM/FLAKE LSWT forecasts* v.s. SYKE observations* 2012-2016 (open water periods) Ounasjärvi



N = 3850

Mean T_{obs} = 279.0

Bias = 3.3 K

Stde = 1.8 K

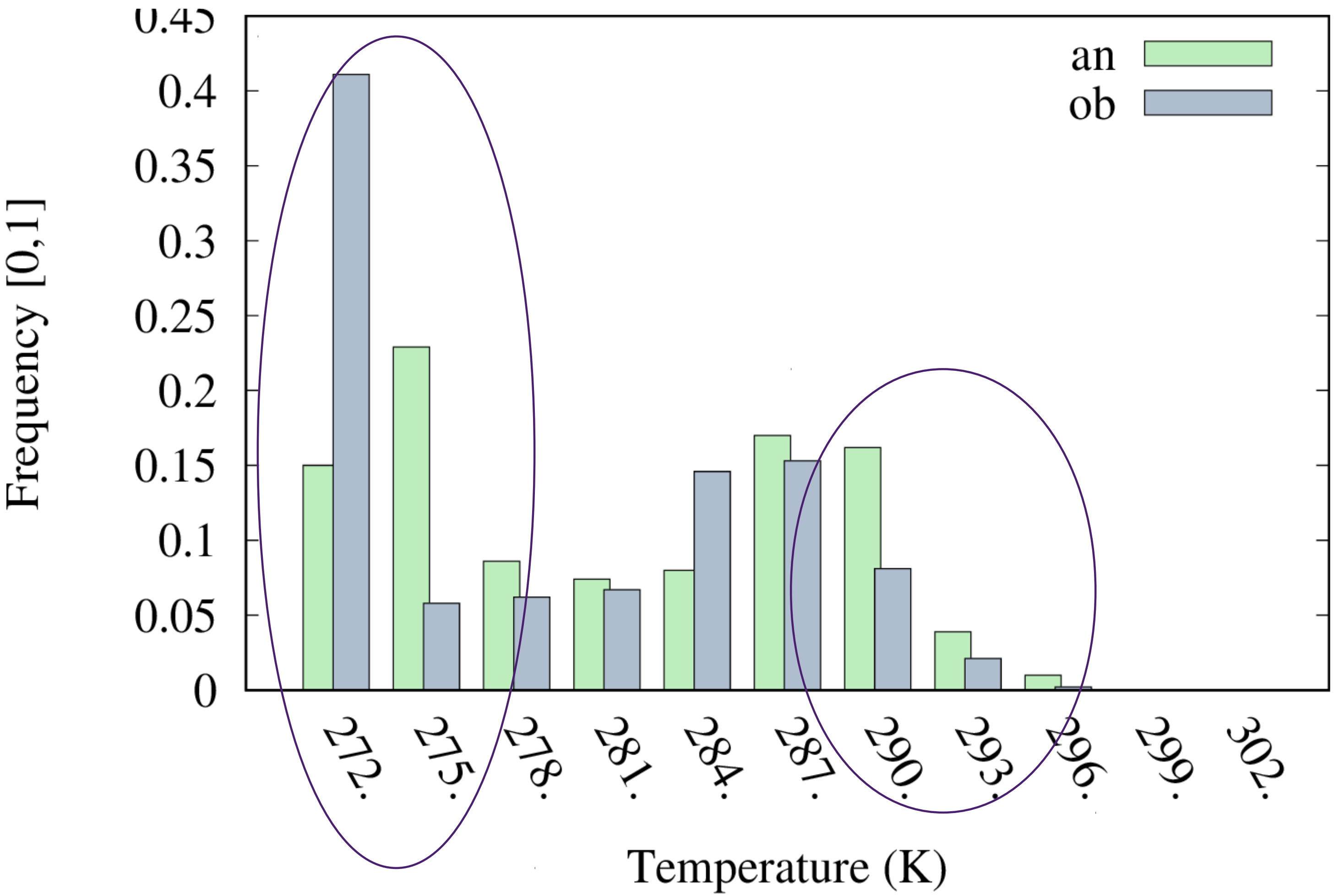
MAE = 3.3 K

Corr = 0.93

*FC+6h at 00,06,12,18 UTC

*SYKE at 6 UTC

HIRLAM/FLAKE LSWT analyses* v.s. SYKE observations* 2012-2016 (open water periods) Ounasjärvi



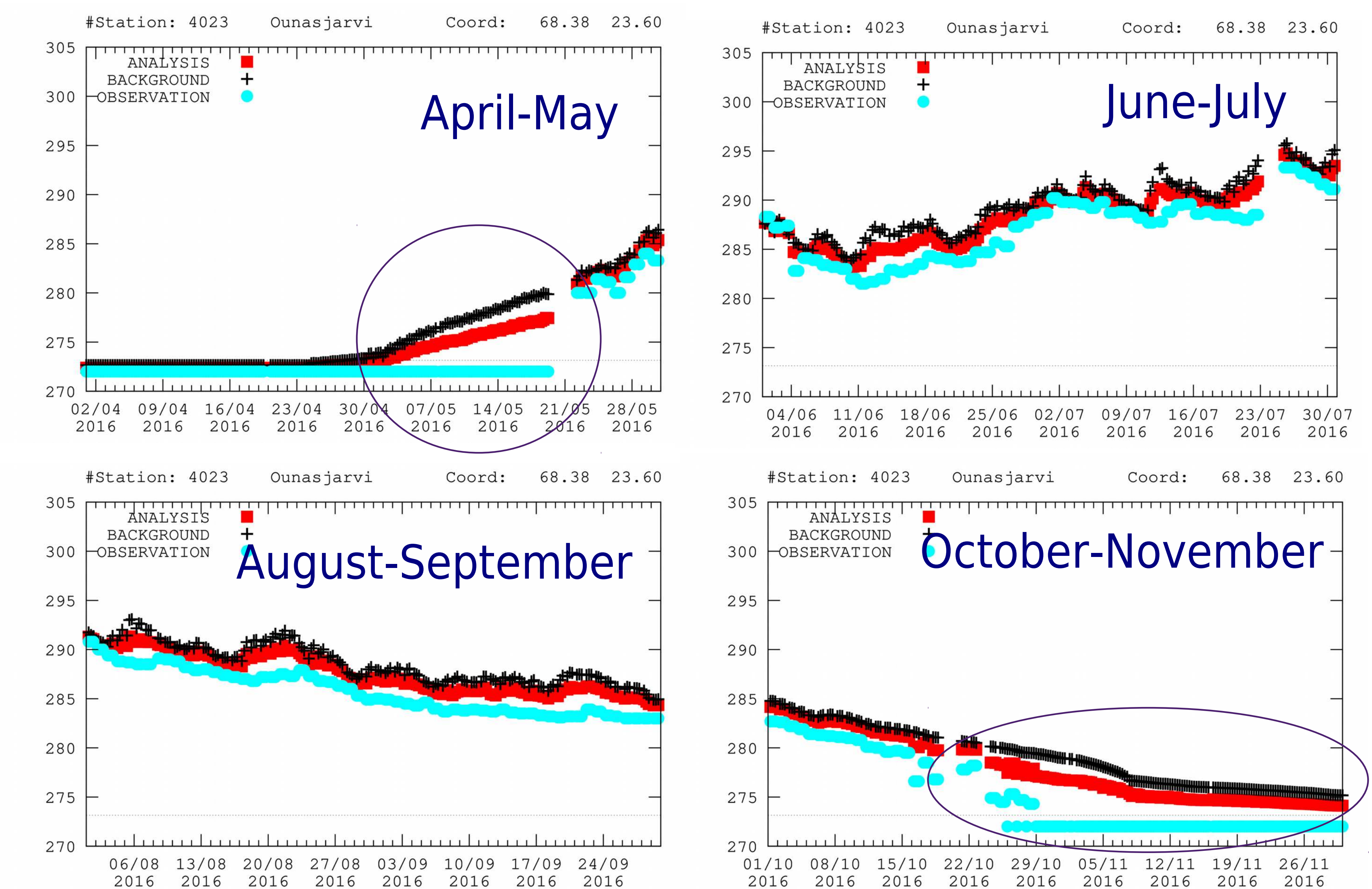
N = 3850
Mean T_{obs} = 278.9
Bias = 2.1 K
Stde = 1.2 K
MAE = 2.2 K
Corr = 0.98

*FC+6h at 00,06,12,18 UTC

*SYKE at 6 UTC

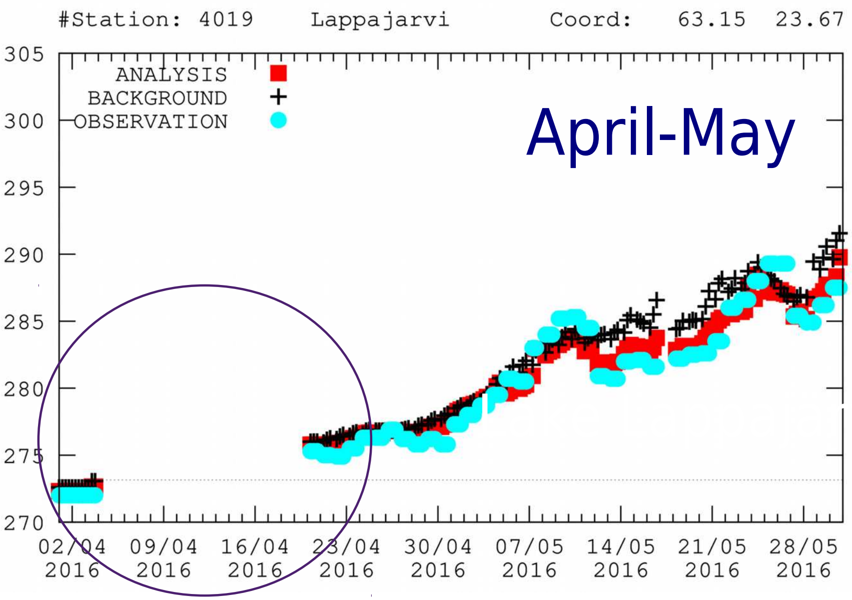
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

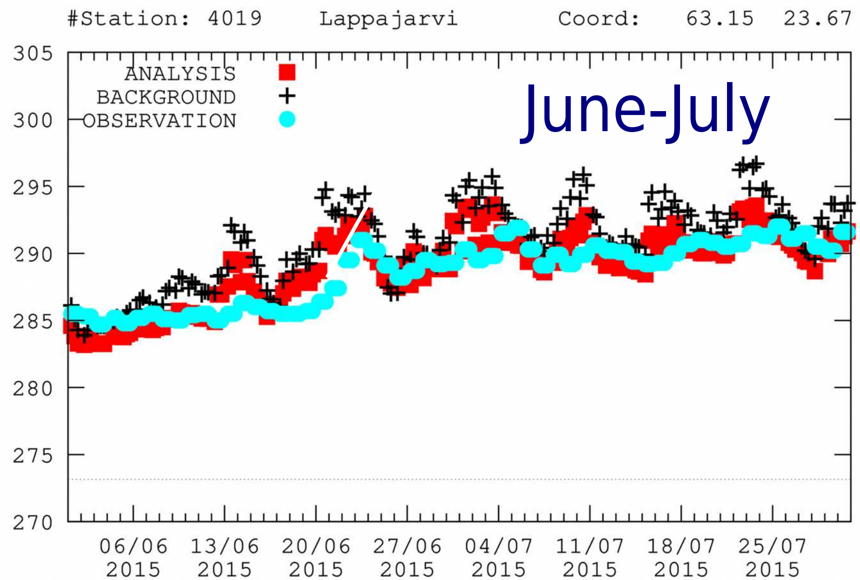
AN, FG, OB on Ounasjärvi 2016

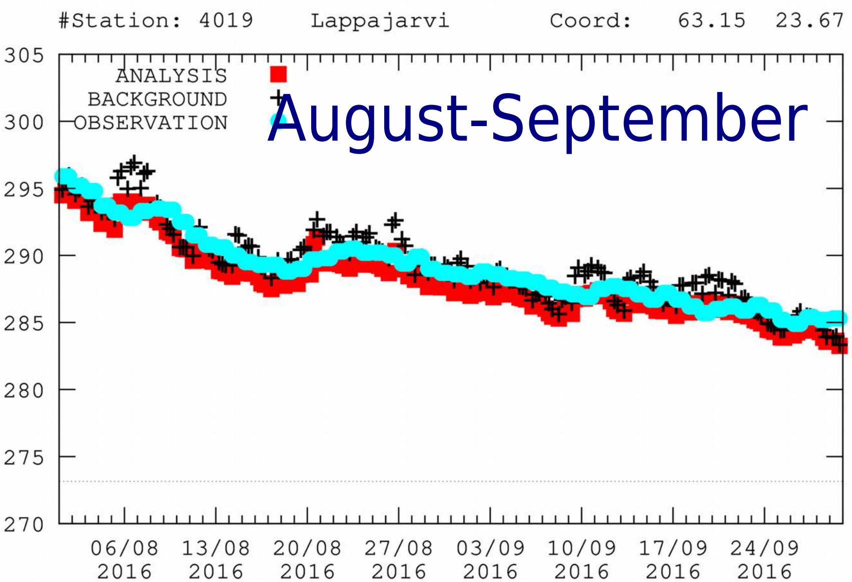


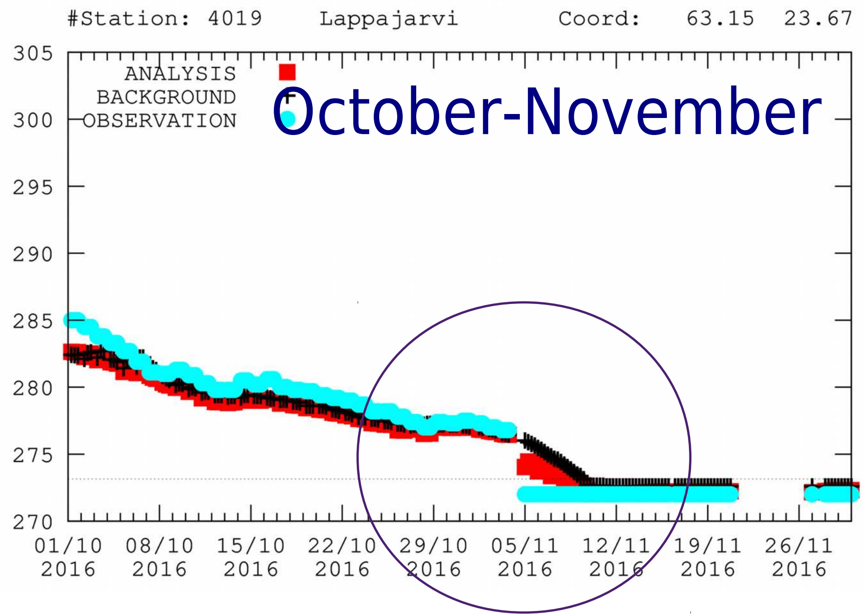
AN, FG, OB on Lappajärvi 2016

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE









CONTENTS

WHAT CAN WE LEARN FROM THE HIRLAM OPERATIONAL LSWT ANALYSIS AND FORECAST EXPERIENCE?

(Case studies have demonstrated the importance of correct description of lake surface state for weather forecast)

Compared to observations over Finnish lakes, the independent analysis of in-situ LSWT observations improves the first guess by +6h Flake forecast

FLake seems to melt ice on all lakes too early, have a tendency to overshoot maximum LSWTs in late summer and keep most of the lakes too warm in the autum

SYKE LSWT observations are regular and reliable but do not really cover the melting period

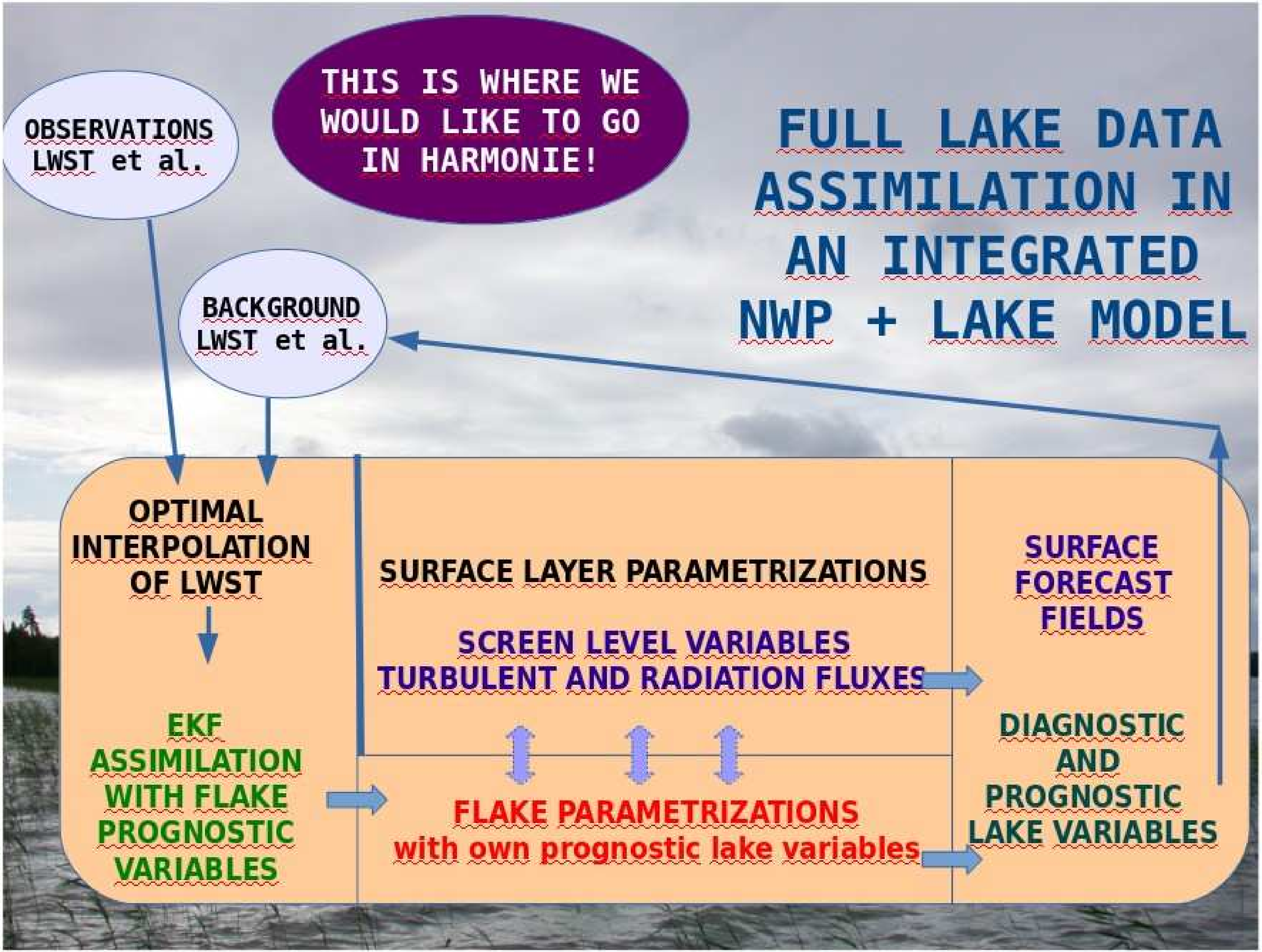
WHAT CAN WE LEARN FROM THE HIRLAM OPERATIONAL LSWT ANALYSIS AND FORECAST EXPERIENCE?

It seems preferable to use FLake
as background for the analysis instead of
the previous analysis + relaxation of climatology,
in spite of the FLake shortcomings

The key tasks to improve lake surface description
in NWP are:

To develop a full data assimilation system in order
to integrate the observed and forecast LSWT and ice

To obtain more real-time observations on
lake surface state (ice, temperature)
for the assimilation


THIS IS WHERE WE WOULD LIKE TO GO IN HARMONIE!
FULL LAKE DATA ASSIMILATION IN AN INTEGRATED NWP + LAKE MODEL
OBSERVATIONS LWST et al.
BACKGROUND LWST et al.
OPTIMAL INTERPOLATION OF LWST
EKF ASSIMILATION WITH FLAKE PROGNOSTIC VARIABLES
SURFACE LAYER PARAMETRIZATIONS
SCREEN LEVEL VARIABLES
TURBULENT AND RADIATION FLUXES
FLAKE PARAMETRIZATIONS
with own prognostic lake variables
SURFACE FORECAST FIELDS
DIAGNOSTIC AND PROGNOSTIC LAKE VARIABLES

Choulga, M., Kourzeneva, E., Zakharova, E. and Doganovsky, A. 2014. Estimation of the mean depth of boreal lakes for use in numerical weather prediction and climate modelling. Tellus A 66, 21295. DOI:10.3402/tellusa.v66.21295.

Eerola, K., Rontu, L., Kourzeneva, E., Kheyrollah Pour, H. and Duguay, C. 2014. Impact of partly ice-free Lake Ladoga on temperature and cloudiness in an anticyclonic winter situation-a case study using a limited area model. Tellus A 66, 23929. DOI:10.3402/tellusa.v66.23929.

Kheyrollah Pour, H., Rontu, L., Duguay, C. R., Eerola, K. And Kourzeneva, E. 2014. Impact of satellite-based lake surface observations on the initial state of HIRLAM. Part II: Analysis of lake surface temperature and ice cover. Tellus A. 66, 21395. DOI:10.3402/937 tellusa.v66.21395.

Kheyrollah Pour, H., Choulga, M., Eerola K., Kourzeneva, E., Rontu, L., Pan F., Duguay C.R., 2017: Towards improved objective analysis of lake surface water temperature in a NWP model: preliminary assessment of statistical properties. Tellus A 69. DOI:10.1080/16000870.2017.1313025

Kourzeneva, E. 2014. Assimilation of lake water surface temperature observations with Extended Kalman filter. Tellus A. 66, 21510. DOI: 10.3402/tellusa.v66.21510.

Kourzeneva, E., Martin, E., Batrak, Y. and Moigne, P. L. 2012. Climate data for parameterisation of lakes in numerical weather prediction models. Tellus A. 64, 17226. DOI:10.3402/tellusa.v64i0.17226.

Rontu, L., Eerola, K., Kourzeneva, E. and Vehviläinen, B. 2012. Data assimilation and parametrisation of lakes in HIRLAM. Tellus A. 64, 17611. DOI:10.3402/tellusa.v64i0.17611.

Semmler, T., Cheng, B., Yang, Y. and Rontu, L., 2012. Snow and ice on Bear Lake (Alaska) – sensitivity experiments with two lake ice models. Tellus A. 64, 17339. DOI:10.3402/tellusa.v64i0.17339

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

THANK YOU FOR YOUR ATTENTION!

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

THANK YOU FOR YOUR ATTENTION!