# Evaluation of the Multi-scale Ultra-high Resolution (MUR) Analysis of Lake Temperature

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## Motivation

•Obtaining lake surface water temperature (LSWT) analyses from satellite difficult

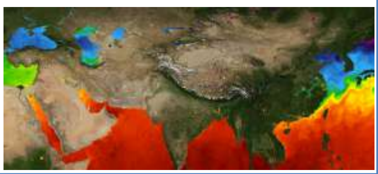
•Data gaps, cloud contamination, variations in atmospheric profiles of temperature and moisture, and a lack of *in situ* observations

•Need for near real-time LSWT analyses for numerical modeling applications

•Only a few global real-time analyses for lakes available worldwide (OSTIA, RTG; Theibaux at al. 2003; Fiedler et al. 2014). These are at 6-8 km resolution which do not cover many smaller lakes

•The NASA Multi-scale Ultra-high Resolution (MUR) analysis at ~1 km resolution covers global oceans and also thousands of lakes worldwide

•This study is the first evaluation of the NASA MUR LSWT



https://podaac-tools.jpl.nasa.gov/soto/

## Lakes Analyzed

- 11 global lakes time series 2003-2016 analyzed
- Validation of MUR versus near-surface (<0.6 m) *in situ* buoy data for 3 lakes: Lake Michigan, Lake Oneida, and Lake Okeechobee

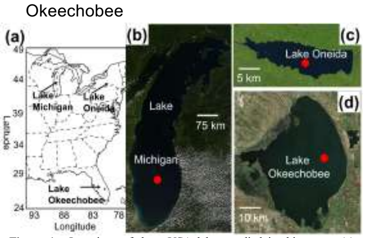
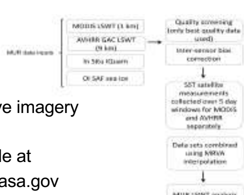



**Figure 1.** Locations of three USA lakes studied in this paper. (a) overview map, (b)-(c) Visible satellite images of the lakes. (b) Lake Michigan. (c) Lake Oneida. (d) Lake Okeechobee. *In situ* buoy location indicated by red dots

## MUR Lake Surface Water Temperature (LSWT) Analysis

- Global grid 0.01˚ x 0.01˚ (equivalent to 1.1132 km at equator)
- MUR LSWT analysis incorporates Moderate Resolution Thermal Imaging Spectroradiometer (MODIS) and Advanced Very High Resolution Radiometer (AVHRR) sensors over 5 day analysis window (Chin et al. 2017). Uses Multi-Resolution Variational Analysis (MRVA)
- No in situ data except over Laurentian Great Lakes



- No microwave imagery passes QC
- Data available at https://mur.jpl.nasa.gov

## MUR vs. *In Situ* Validation

- MUR LSWT analyses generally have biases ~0.25 ºC and RMSE ~0.60-1.00 ºC for Lake Michigan
- MUR LSWT biases of 0.59 ºC compared to *in situ* data for two summer seasons at Lake Okeechobee
- For Lake Oneida, large errors in MUR LSWT for spring and fall, much improved MUR LSWT In summer
- Only MODIS Data for Lake Oneida, increases data gap problem

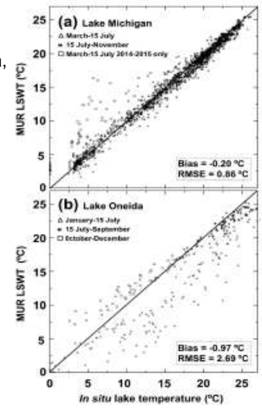



TABLE I
COMPARISON OF MUR AND *IN SITU* LSWT DATA

| Lake (Year/Season) | Bias (MUR LSWT – *in situ*, °C) | Root Mean Squared Error (RMSE, °C) |
|---|---|---|
| Michigan | | |
| 2007/all seasons | -0.24 | 0.84 |
| 2008/all seasons | -0.02 | 0.69 |
| 2009/all seasons | -0.29 | 1.08 |
| 2010/all seasons | -0.41 | 0.73 |
| 2011/all seasons | -0.28 | 0.80 |
| 2012/all seasons | -0.32 | 0.64 |
| 2013/all seasons | -0.16 | 0.61 |
| 2014/all seasons | +0.47 | 1.62 |
| 2015/all seasons | -0.32 | 0.70 |
| 2007-2015 overall | -0.20 | 0.86 |
| Oneida | | |
| Spring 2007-2014 | -3.88 | 4.71 |
| Summer 2007-2014 | -0.70 | 1.13 |
| Fall 2007-2014 | 1.67 | 2.23 |
| 2007-2014 overall | -0.97 | 2.69 |
| Okeechobee | | |
| 2008/Summer | In situ mean: 29.23; | MUR mean: 28.66 |
| 2009/Summer | In situ mean: 28.77; | MUR mean: 29.39 |

- Primary causes of errors in MUR are inaccurate ice analyses and gaps in available imagery resulting in MRVA interpolation of distant unrepresentative values during cloudy periods (e.g., Lake Ontario impacts Lake Oneida)

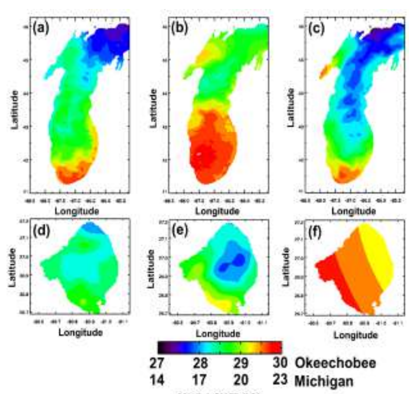
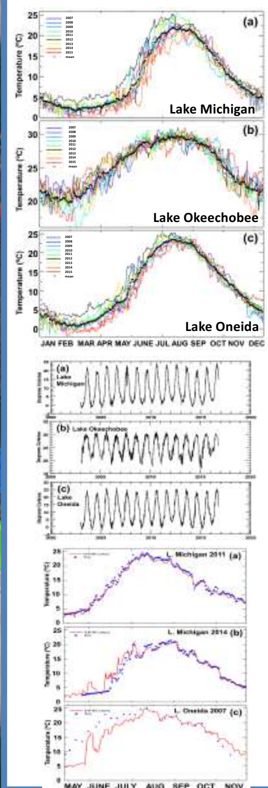



**Figure 2.** MUR LSWT analyses on 1 July of selected years over (a-c) Lake Michigan and (d-f) Lake Okeechobee. (a) 2010, (b) 2012, (c) 2016, (d) 2007, (e) 2012, (f) 2016

- Realistic spatial structure retained by MUR LSWT analysis. Forcing mechanisms include variations in both atmospheric and lake state

## MUR LSWT Seasonal and Interannual Variability




- The mean annual cycle in MUR LSWT varies substantially between Lake Michigan, Lake Oneida, and Lake Okeechobee
- The large thermal inertia of Lake Michigan results in increased year-to-year temperature variability
- The synthesis of multiple years of MUR LSWT to produce a 'climatological' LSWT is promising for future studies utilizing the MUR LSWT dataset
- No large or consistent trends in LSWT noted for these three lakes 2003-2016.
- Lake Michigan wintertime LSWT exhibits a slight warming trend
- Seasonal differences In *in situ* versus satellite measurements at Lake Oneida

## Summary and Future Work

•Advantages of MUR LSWT include daily consistency, near-real time production (latency ~1 day), multi-platform data synthesis

•Future recommended improvements include incorporating first-guess climatological LSWT, decreasing the range of characteristic length scales in MRVA, improved QC procedures, improved cloud masks, and including microwave and additional thermal infrared sensors platforms such as the GOES-16 Advanced Baseline Imager (ABI)

•Plans already underway to include Visible Infrared Imaging Radiometer Suite (VIIRS) in MUR

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