Lake surface temperature as a proxy of climate change
Satellite observations versus multi probe data

S. Pareeth[1,2,4], M. Metz[1], D. Rocchini[1], N.Salmaso[2], R. Adrian[3,4], and M. Neteler[1]

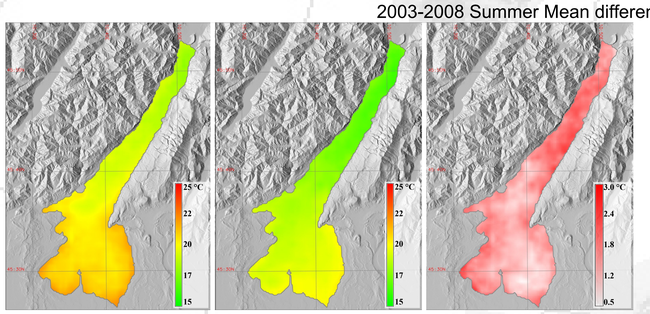
Corresponding email: sajid.pareeth@fmach.it

[1] GIS and Remote Sensing unit, Department of Biodiversity and Molecular Ecology, The Research and Innovation centre (CRI), Fondazione Edmund Mach (FEM), Trento, Italy
[2] *Limnology and River Ecology unit, Department of Sustainable Agro-Ecosystems and Bioresources, The Research and Innovation centre (CRI), Fondazione Edmund Mach (FEM), Trento, Italy*
[3] *Department of Ecosystem Research, Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Muggelseedamm, Berlin, Germany*
[4] *Department of Biology, Chemistry and Pharmacy, Freie Universität, Berlin, Germany*

Introduction - WarmLakes

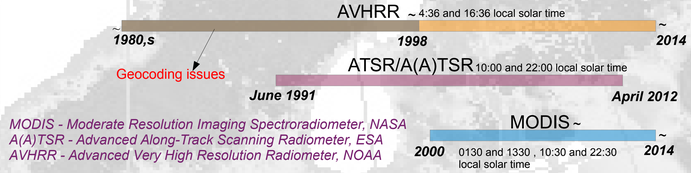
- Study the long term warming trends of **Sub-Alpine lakes** using surface temperature derived from satellite data
- Leveraging the availability of daily thermal imageries for last 2 decades from multiple sensors aboard satellites
- Lake specific validation and model development using field data
- Develop daily homogenized Lake Surface Water Temperature (LSWT) for last 2 decades.
- Time series analysis linking the trend with climatic tele-connection index - Eastern Mediterranean Pattern (EMP)
- EMP explains well, variation in water surface temperature over Mediterranean area than NAO (North Atlantic Oscillation)
- Presenting here the preliminary results for Lake Garda

2003-2008 Summer Mean difference



2003 Summer Mean 2008 Summer Mean

Sensors and Thermal data



Global products for daily Surface Temperature

MODIS Land Surface Temperature (LST) products
- MOD11A1, MYD11A1 @ 1km , daily 2 observations, from 2002
- Covers all the lakes globally
- 1km spatial resolution
- https://lpdaac.usgs.gov/products/modis_products_table

MODIS Sea Surface Temperature (SST) products
- 4 km spatial resolution, daily 2 observations, from 2002
- few lakes
- http://oceancolor.gsfc.nasa.gov/

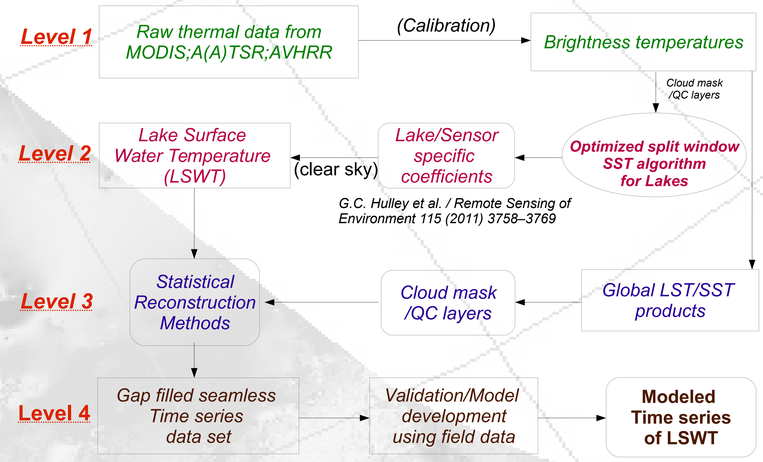
AVHRR pathfinder SST products
- 4 km spatial resolution, daily
- Not suitable for Sub-alpine Lakes
- longest time series (from 1981)

ArcLakes – Lake Surface Water Temperature(LSWT) from ATSR/AATSR
- 0.05 degrees, 1995 – 2012, daily
- by School of Geosciences, University of Edinburg
- daily recostructed data, day and night
- covers1600 lakes globally
- http://www.geos.ed.ac.uk/arclake/

Shortcomings

- LST algorithm not suitable for water surface
- Gaps in time series due to clouds and bad raw data
- Coarse spatial resolution of the available products
- Scope of using lake/sensor specific coefficients to derive Lake Surface Water Temperature (LSWT)

Methods



Gap Reconstruction Algorithms

Mutiple Spatio-temporal regression approach using secondary datasets (Metz et.al, 2014)
- Daily four observations of MODIS LST at 250m for entire Europe
- Using hierarchial temporal and spatial interpolation
- Regression model using climatology parameters, Digital Elevation Model (DEM) etc

Harmonic ANalysis of Time series (HANTS) (Roerink et.al)
- Fourier Analysis
- Temporal interpolation
- Implemented in GRASS – *"r.hants"*

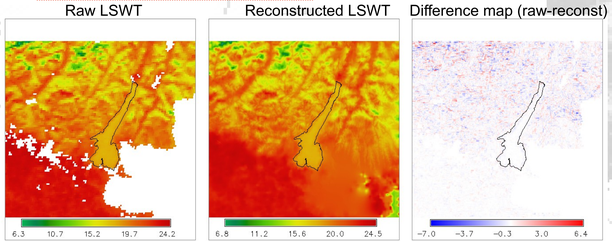
http://grass.osgeo.org/ http://r-project.org/

Open source data processing environment

Results

Reconstruction of time series

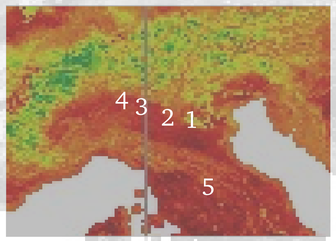
Raw LSWT Reconstructed LSWT Difference map (raw-reconst)



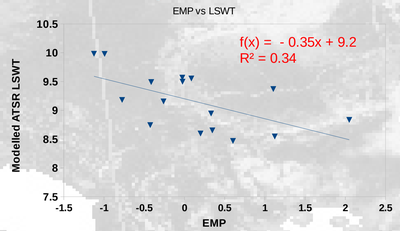
October 27 2006, MODIS-Aqua – 13:30; Metz et.al, 2014

Lakes under study

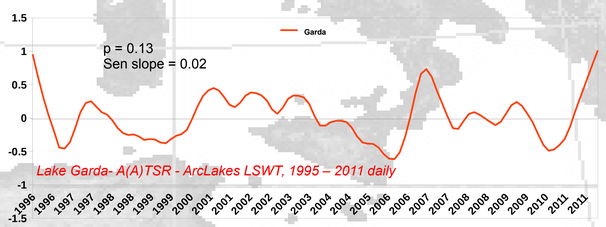
1. *Lake Garda*
2. *Lake Iseo*
3. *Lake Como*
4. *Lake Maggiore*
5. *Lake Trasimeno*



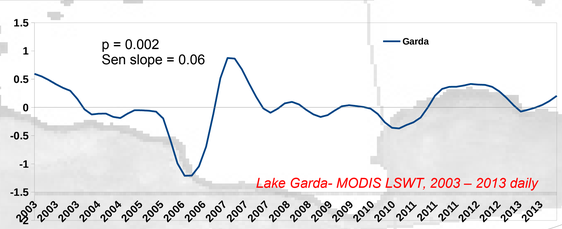
EMP vs Winter Average Temp from LSWT



Trend of daily mean deviation

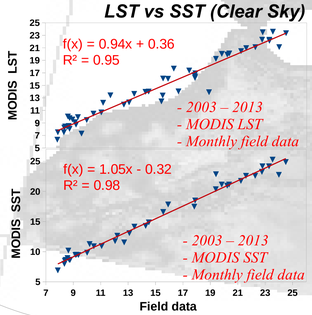


Lake Garda- A(A)TSR - ArcLakes LSWT, 1995 – 2011 daily

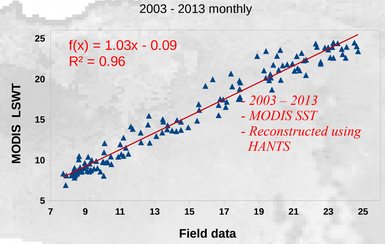


Lake Garda- MODIS LSWT, 2003 – 2013 daily

Validation



2003 - 2013 monthly



Conclusions/Future directions

- Thermal imageries from Satellite sensors can measure LSWT accurately, with an overall R squared above 0.90
- SST algorithms are more accurate for water surfaces than LST based data
- Out of the available products MODIS SST and ArCLakes data (A(A)TSR) performs well.
- Products are of very coarse resolution, not suitable for inter lake studies
- The available products does not have the data for all the sub/alpine lakes
- The negative correlation of satellite derived winter averages with EMP is proven trend explaining the local variation

- Extending back the database to begin from 1980 using NOAA AVHRR data
- Extending the study to other sub/alpine lakes
- Homogenizing the LSWT data based on Split window SST algorithm and optimized lake specific coefficients (Hulley et.al, 2011) to develop daily LSWT from 1980 - 2013

References

Metz, M.; Rocchini, D.; Neteler, M. Surface Temperatures at the Continental Scale: Tracking Changes with Remote Sensing at Unprecedented Detail. Remote Sens. 2014, 6, 3822-3840

Glynn C. Hulley, Simon J. Hook, Philipp Schneider, Optimized split-window coefficients for deriving surface temperatures from inland water bodies, Remote Sensing of Environment, Volume 115, Issue 12, 15 December 2011, Pages 3758-3769, ISSN 0034-4257

Roerink, G. J., Menenti, M. and Verhoef, W., 2000. Reconstructing cloudfree NDVI composites using Fourier analysis of time series. International Journal of Remote Sensing, 21 (9), 1911-1917

Salmaso N (2012) Influence of atmospheric modes of variability on a deep lake south of the Alps. Clim Res 51:125-133