Estimation of Ocean Heat Content of 700m Layer on Operational Basis

National Remote Sensing Centre

20 Aug 2013

NATIONAL REMOTE SENSING CENTRE
REPORT / DOCUMENT CONTROL SHEET

1.	Security Classification	Unclassified			
2.	Distribution	Through soft and hard copies			
3.	Report / Document version	(a) Issue no.: 01	(b) Revision & Date	R01/ August 2013	
4.	Report / Document Type	Technical Report			
5.	Document Control Number	NRSC-RC-AUG-13-TR-553			
6.	Title	Estimation of Ocean Heat Content of 700m Layer on Operational Basis			
7.	Particulars of collation	Pages: 07	Figures: 05	Tables: 01	References:
8.	Author(s)	Neethu Chako[1], Anju Bajpai[1], Sonal Agarwal[2], Arulraj[2] , D . Dutta[1] , A. Jeyram`[1] and MM Ali[3]			
9.	Affiliation of authors	1-Regional Remote Sensing Centre, Kolkata 2-Bhuvan Cell, NRSC; 3-Director's office , NRSC			
10.	Scrutiny mechanism	Compiled by RRSC	Reviewed by GM, RRSC-East	Approved /Controlled by Director, NRSC	
11.	Originating unit	RRSC, Kolkata			
12.	Sponsor(s)/Name and Address	NRSC, Balanagar, Hyderabad			
13.	Date of Initiation	January, 2013			
14.	Date of Publication	August, 2013			
15.	**Abstract:** Ocean Heat Content up to 700m depth (OHC_{700}) is an important climatic parameter required for atmospheric and ocenic studies like cyclone and monsoon prediction and ocean heat transport estimations. This parameter is estimated on a daily basis from 2002 to present with a one week time delay. The data used to estimate this parameter are (a) sea surface height anomaly (SSHA) from the available altimeters, (b) sea surface temperature (SST) from Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and the climatological values of OHC_{700}. The artificial neural network techniques, similar to the one used by Ali et al. (2012: IEEE GRSL) for the estimation of Tropical Cyclone Heat Potential, is followed in the estimation of OHC_{700}. Since some studies need Climatological values of this parameter, we also provide this value. **Key Words:** OHC_{700}, Sea surface height anomaly, sea surface temperature, Cyclones, Monsoons, Ocean heat transport				

Estimation of Ocean Heat Content of 700m Layer on Operational Basis

Neethu Chacko[1], Anju Bajpai[1], Sonal Agarwal[2], M Arulraj,[2] D. Chakraborrty[1] D . Dutta[1],
A. Jeyaram[1] and M M Ali[3]
1-RRSC, Kolkatta
2-Bhuvan Cell, RSC
3-Director's office, NRSC

Abstract:

Ocean Heat Content up to 700m depth (OHC_{700}) is an important climatic parameter required for atmospheric and ocenogaphic studies like cyclone and monsoon prediction and ocean heat transport estimations. This parameter is estimated on a daily basis from 2002 to present with a one week time delay. The data used to estimate this parameter are (a) sea surface height anomaly (SSHA) from the available altimeters, (b) sea surface temperature (SST) from Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and the climatological values of OHC_{700}. The artificial neural network techniques, similar to the one used by Ali et al. (2012: IEEE GRSL) for the estimation of Tropical Cyclone Heat Potential, is followed in the estimation of OHC_{700}. Since a few studies use the OHC of a layer with respect to the climatological mean, we also provided the climatological value of OHC_{700} along with these data.

Introduction

Ocean Heat Content up to 700m depth (OHC_{700}), an important ocean climatic parameter required for atmospheric and oceanographic studies, is obtained by summing the heat content of the ocean column from the sea surface to a depth of 700m. OHC_{700} can be computed from *in situ* measurements from the equation (1)

$$OHC_{700} = \rho\, C_p \int_0^{700} T\, dz \quad \text{………………………………………………(1)}$$

where ρ is the average density of the sea water, C_p the specific heat capacity of the sea water at constant pressure, p, and the temperature, T (^{o}C).

The best approach for computing OHC_{700} is to use in situ measurements, but due to the spatial and temporal limitations with the availability of in situ data, especially over regions of tropical (TC) activity, there is a need for satellite based estimations.

Since the Sea Surface Height Anomaly (SSHA) is strongly correlated with the thermal structure of the upper ocean, OHC_{700} can be estimated from this parameter over finer spatial and temporal scales on an operational basis. Ali et al. (2012) suggested a better method of estimating tropical cyclone heat potential from SSHA and sea surface temperature (SST) using a neural network approach. Here, we use a similar approach. The only difference is (i) in estimating the heat content upto 700m depth instead of up to the depth of 26^{o}C isotherm depth and (ii) in using the climatological values of OHC_{700} in place of D_{26}. However, a brief description of the methodology to compute this parameter on daily basis

using the available altimeter observations of SSHA, sea surface temperature from Tropical Rainfall Measuring Mission Mocrowave Imager (TMI) and climatological values of OHC_{700} is given below:

The data are available for a researcher to download from the NRSC Bhuvan website from 2002 onward over the north Indian Ocean spanning 30^{O}S - 30^{O} N and 30^{O}E - 120^{O}E.

Data and Methodology:

Following data have been used in this ANN approach for estimating OHC_{700} :

- SSHA: Aviso (Archiving, Validation and Interpretation of Satellite Oceanographic data) distributes satellite altimetry data from Topex/Poseidon, Jason-1, ERS-1 and ERS-2, and EnviSat, and Doris** precise orbit determination and positioning products. Ssalto/Duacs Gridded Sea level anomalies (1/3°x1/3° on a Mercator grid) is a gridded SSHA computed with respect to a seven-year mean and are provided in near-real-time and in delayed time bases.

- SST: The SST from TMI is used in this analysis. This radiometer is well-calibrated, and contains lower frequency channels (10.7 GHz channel) required for SST retrievals. The TMI data are provided as daily maps (separated into ascending and descending orbit segments). The data are available from December 1997 to the present, and cover a global region extending from 40^{o}S to 40^{o}N at a resolution of 0.25 deg (~25 km). The important feature of microwave retrievals is that SST can be measured through clouds, which are nearly transparent at 10.7 GHz. Ocean areas with persistent cloud coverage can now be viewed on a daily basis. Furthermore, microwave retrievals are insensitive to atmospheric water vapor.

- OHC_{700} Clim: The climatological values of OHC_{700} are estimated from the temperature profiles of World Ocean Atlas 2009 [Locamini et al. 2009]

- OHC_{700}: OHC_{700} is estimated using the Argo in situ temperature profiles from 2002 to 2012.

SSHA data is of 0.33^{o} x 0.33^{o} resolution while SST is of 0.25^{o} x 0.25^{o} resolution. Hence, we brought these two data sets to the same grid size of 0.25^{o} x 0.25^{o}. These two satellite observations are collocated with the in situ OHC_{700} estimations and a climatological value of OHC_{700} clim is assigned to these data set depending upon the grid and month of the observation. Following Ali et al. [2012], an artificial neural network (ANN) model is developed between OHC700 (in situ) and SSHA, SST and OHC700clim. This relation is used to further compute the OHC700 from satellite observations on a day-to-day basis. In the present approach we used 5821 in situ observations during 2002-2009 to developed the model, and 2631 independent observations during 2009-2012 to validate the model.

Validation results:

Absolute error mean (AEM: average of absolute differences between estimated and *in situ* values), absolute mean percentage error (AMPE: the percentage of the AEM to data mean), standard

deviation errors in estimations (ESD), SD ratio (SDR: ratio of ESD to data SD), root mean square error (RMSE), scatter index (SI: ratio of RMSE to mean of *in situ* observations), for the training, verification and validation data sets are shown in table 1.

Table 1. Statistics of the training, verification and validation data sets

Case	No. of Obs.	*In situ* OHC_{700} (kJ/cm^2)				Estimated OHC_{700} (kJ/cm^2)					
		Min	Max	Mean	SD	AEM	AMPE	ESD	SDR	RMSE	SI
Training	2535	1518	6167	4184	289	75.7	1.8	121.1	0.41	121.1	0.03
Verification	3286	2215	531.6	4231	329	88.2	2.1	148.1	0.45	149.1	0.04
Validation	2631	3285	5222	4137	297	78.9	1.9	102.7	0.35	102.7	0.02

In our ANN analysis, the AEM for the validation set is 78.9 kJ/cm^2 for a range of 3285 to 5222 kJ/cm^2 with a mean value of 4137 kJ/cm^2. The RMSE for this data set is 102.7 kJ/cm^2 with SDR value of 0.35 and SI of 0.02 indicating an accurate estimation.

Visualization of OHC_{700} on Bhuvan:

The Process of obtaining OHC_{700} output (a data file with a PNG file) on a daily basis is consolidated and a combined script is generated to automate the entire process. This script is then deployed in a Computer with Linux Operating System. A scheduler is made in the Crontab which runs every day and process the data of 8 days back.

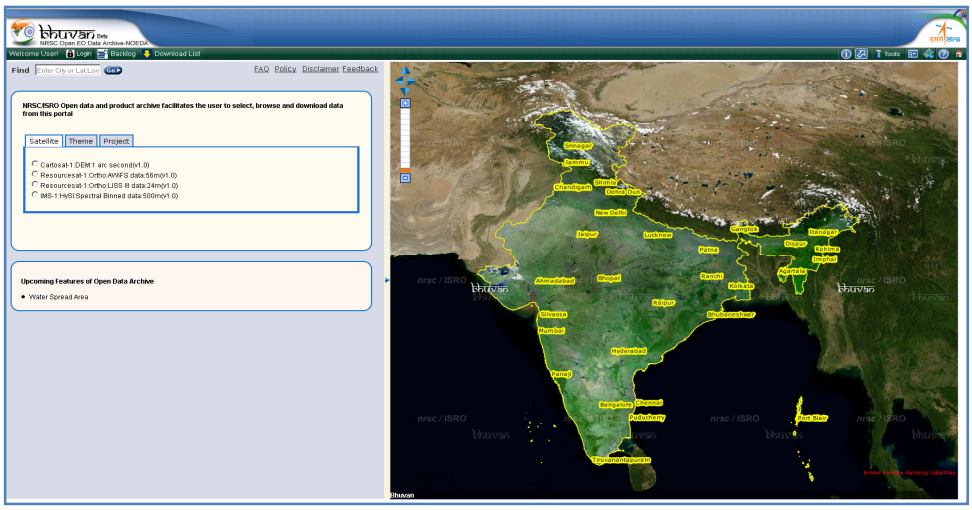
The automated process includes the downloading of SSHA file in the form of netCDF file from Aviso website, running the ferret script to get the data in desired format, Downloading the SST file from discover earth website, Regridding and Collocation of the input files, and final generation of the output using NCarGraphics in the form of postscript file. T he postscript file is then converted to PNG format and this file along with the output Data file is zipped.

After the process runs on the linux system, the files are transferred to Bhuvan servers to showcase via Bhuvan NOEDA using another scheduler task.

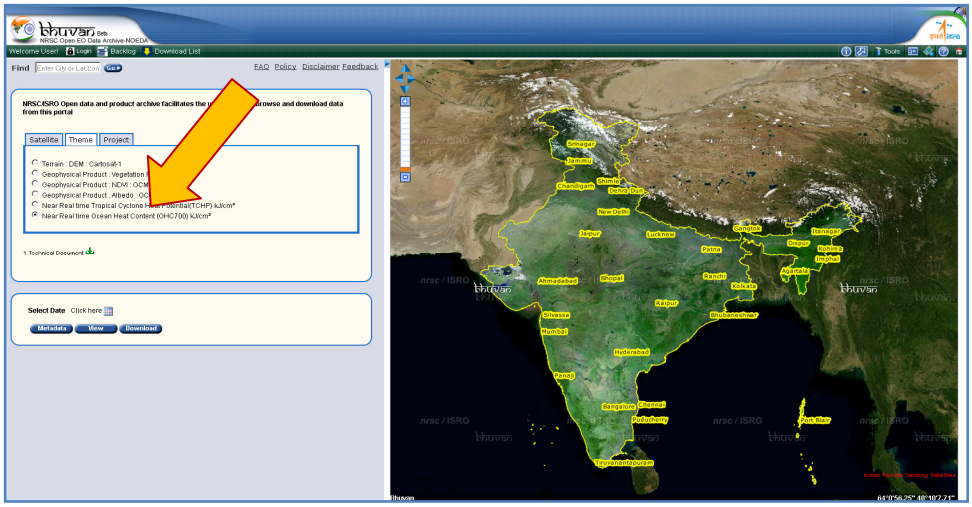
Simple steps to visualize and download OHC data from Bhuvan

1. Go to www.bhuvan.nrsc.gov.in

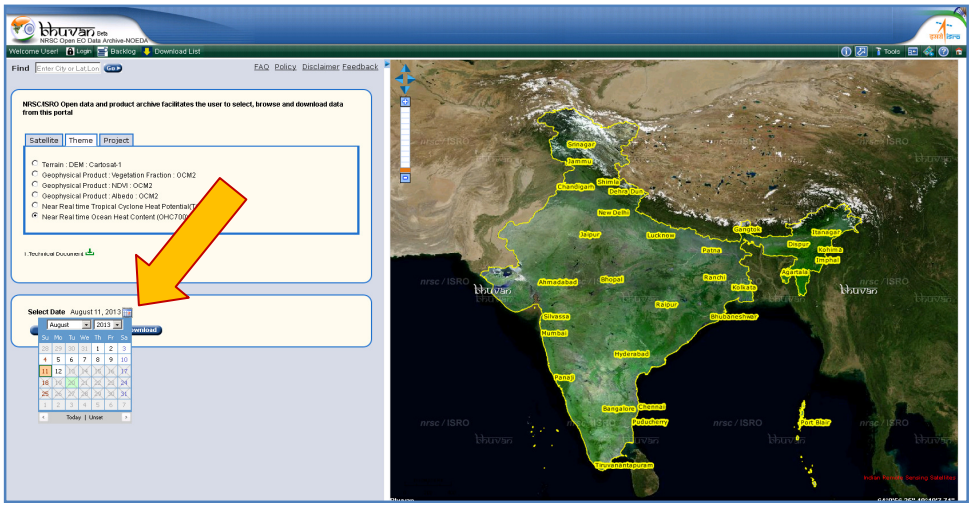
2. Click on NRSC open EO data Archive or directly visit http://bhuvan- noeda.nrsc.gov.in



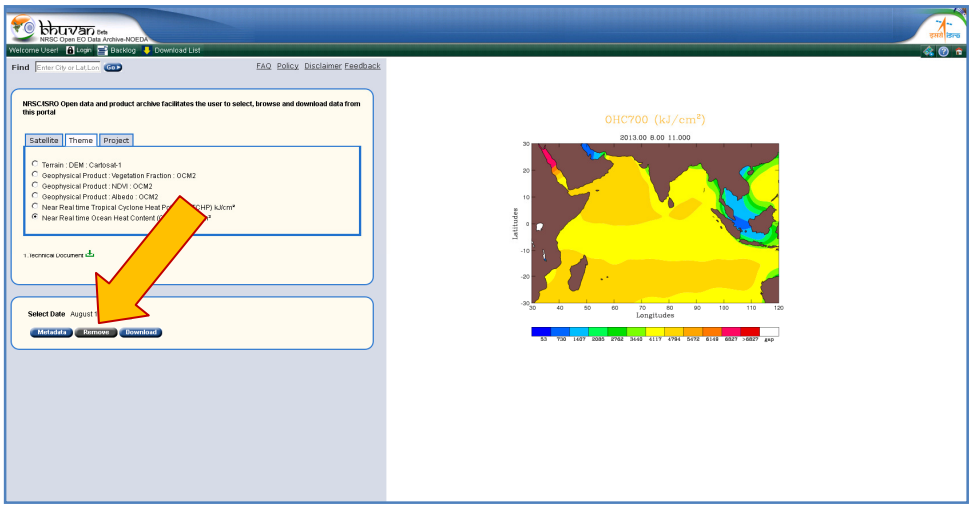
3. Under themes, select "Near Real Time Ocean Heat Content (OHC)" option.



4. Select the date



5. Click View button to visualize the output and Click Download for downloading the corresponding files.



Please note that to download the OHC data one need to Login. Registration on Bhuvan is a simple process, which requires a valid email-id, and few other details form the user.

Summary and conclusions:

OHC_{700} is one of the critical parameter for climate studies. The accurate estimation and regional validation of this parameter is essential in the regions like Indian Ocean where monsoon and cyclone activities are of concern. We estimated OHC_{700} by ANN technique and validated the results using in situ observations. The results suggest the utility of ANN technique in estimating OHC_{700} with a reasonable accuracy. Hence, we adopted this technique to estimate this parameter on operational basis.

Acknowledgements:

We thank the CNES/AVISO team for providing the altimeter product via http://www.aviso.oceanobs.com/duacs/. Thanks also to the Remote Sensing System for providing the SST data and to the US NOAA (National Oceanographic and Atmospheric Administration) for providing the ocean depth-temperature profiles. The authors acknowledge the support and the encouragement provided at NRSC.

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