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15.	**Abstract:** Tropical Cyclone Heat Potential (TCHP), an important ocean parameter influencing cyclones and hurricanes, is defined as the energy available for cyclones and is calculated by summing the heat content in a column where sea surface temperature is above 26° C isotherm. This parameter, by definition, is estimated from the in situ temperature profiles. In view of the limitations of temperature profiles, methods have been evolved to estimate this parameter from satellite altimeter derived sea surface height anomalies (SSHA). In this report, we summarise the computation of TCHP on daily basis from the available altimeter observations of SSHA, sea surface temperature using Tropical Rainfall Measuring Mission Mocrowave Imager (TMI) and climatological depth of 26° C isotherm. These daily values of TCHP are available for a researcher to download from the NRSC Bhuvan website from 1998 onward over the north Indian Ocean spanning 30° S - 30° N and 30° E - 120° E. **Key Words:** Cyclones, SST, SSHA, Ocean Heat Content				

Computaion of Tropical Cyclone Heat Potential on Operational Basis

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Abstract:

Tropical Cyclone Heat Potential (TCHP), an important ocean parameter influencing cyclones and hurricanes, is defined as the energy available for cyclones and is calculated by summing the heat content in a column where sea surface temperature is above 26^o C isotherm. This parameter, by definition, is estimated from the in situ temperature profiles. In view of the limitations of temperature profiles, methods have been evolved to estimate this parameter from satellite altimeter derived sea surface height anomalies (SSHA). In this report, we summarise the computation of TCHP on daily basis using the available altimeter observations of SSHA, sea surface temperature from Tropical Rainfall Measuring Mission Mocrowave Imager (TMI) and climatological depth of 26^o C isotherm. These daily values of TCHP are available for a researcher to download from the NRSC Bhuvan website from 1998 onward over the north Indian Ocean spanning 30^o S - 30^o N and 30^o E - 120^o E.

INTRODUCTION :

Tropical Cyclone Heat Potential (TCHP) an important ocean parameter influencing cyclones and hurricanes is defined as the energy available for cyclones and is calculated by summing the heat content in a column where sea surface temperature is above 26^o C isotherm. TCHP can be computed from in situ measurements following Leipper and Volgenau (1972):

$$\mathrm{TCHP} = \rho C_p \int_0^{D_{26}} (T - 26)\mathrm{d}z, \qquad (1)$$

where ρ is the average density of the sea water, C_p the specific heat capacity of the sea water at constant pressure p, T the temperature (^{o}C) of each layer of dz thickness and D26 the depth of the 26^o C isotherm. When the sea surface temperature (SST) is below 26^o C, TCHP for the layer is assumed to be zero.

Given the importance of TCHP in the prediction of cyclone intensity (CI) for Indian Ocean cyclones (Lin et al. [2012], Goni et al. [2009], Ali et al. [2010]), it is necessary to improve the accuracies of the TCHP estimates to assist CI forecast and analysis. The best approach for computing TCHP 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, TCHP can be estimated from this parameter over finer spatial and temporal scales on an operational basis. Here, we present 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 depth of 26^o C isotherm. We adopted the approach of Ali et al. (2012). The data are available for a researcher to download from the NRSC Bhuvan website from 1998 onward over the north Indian Ocean spanning 30^o S - 30^o N and 30^o E - 120^o E.

Data Methodology:

Following data have been used in this ANN approach for estimating TCHP :

- **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 40S to 40N 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.

- **D26**: This parameter is estimated from the temperature profiles of World Ocean Atlas 2009 [Locamini et al. 2009]

SSHA data is of 0.33 x 0.33 resolution while SST is of 0.25 x 0.25 resolution. Hence, we brought these two data sets to the same grid size of 0.25 x 0.25. Then the two data sets have been collocated and a value of D26 is assigned to this data set depending upon the grid and month of the observation. Using D26, SSHA and SST, we used the artificial neural network (ANN) approach following Ali et al. [2012]. In this approach they have used 25000 insitu subsurface temperature profiles during 1998-2007 to developed the model, which derives TCHP in the Indian Ocean using satellite-derived SSHA, SST and D26. The estimations have been validated using more than 8000 independent in situ profiles during 2008-2009.

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 TCHP (kJ/cm^2)				Estimated TCHP (KJ/cm^2)					
		Min	Max	Mean	SD	AEM	AMPE	ESD	SDR	RMSD	SI
Training	11812	6.3	199.1	69.3	25.4	11.9	17	9.5	0.37	15.2	0.22
Verification	14916	4.0	175.7	76.4	25.2	11.9	16	9.1	0.36	15.2	0.20
Validation with in situ observations	8437	4.4	172.2	73.6	26.0	11.6	16	8.9	0.34	14.6	0.20

5.1 Validation with in situ observations:

In our ANN analysis, the AEM for the validation set is 11.6 KJ/cm^2 for a range of 4.4 to 172.2 KJ/cm^2 with a mean value of 73.6 KJ/cm^2. The RMSE for this data set is 14.6 KJ/cm^2 with SDR value of 0.34 and SI of 0.2 indicating an accurate estimation. Comparing the 8329 *in situ* and altimeter-derived TCHP observations during 2002-2005, Mainelli et al. (2008) obtained a mean absolute error of 13.5 KJ/cm^2 in the Atlantic Ocean for a range of 0 to 150 KJ/cm^2 with a mean value of 41 KJ/cm^2. The scatter between the *in-situ* and ANN-estimated TCHP values is in reasonably good agreement with an R value of 0.81 (Figure 2a). The histogram analysis of the data reveals that 80% of the estimations lie within +/- 20 KJ/cm^2.

Visualization of TCHP on Bhuvan

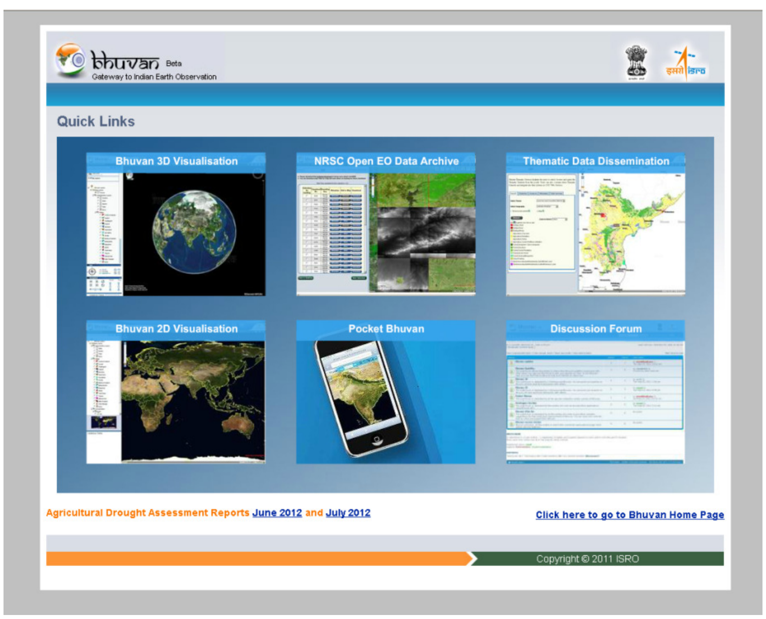
The Process of obtaining TCHP output (a data file with a PNG file) on a daily basis is consolidated and a combined script is generate to automate the entire process. This script is then deployed in a Computer with Linux Operating System. A scheduler is made in the Crontab which runs everyday and process 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. Also the postscript file is then converted to PNG format and this file along with the output Data file is zipped.

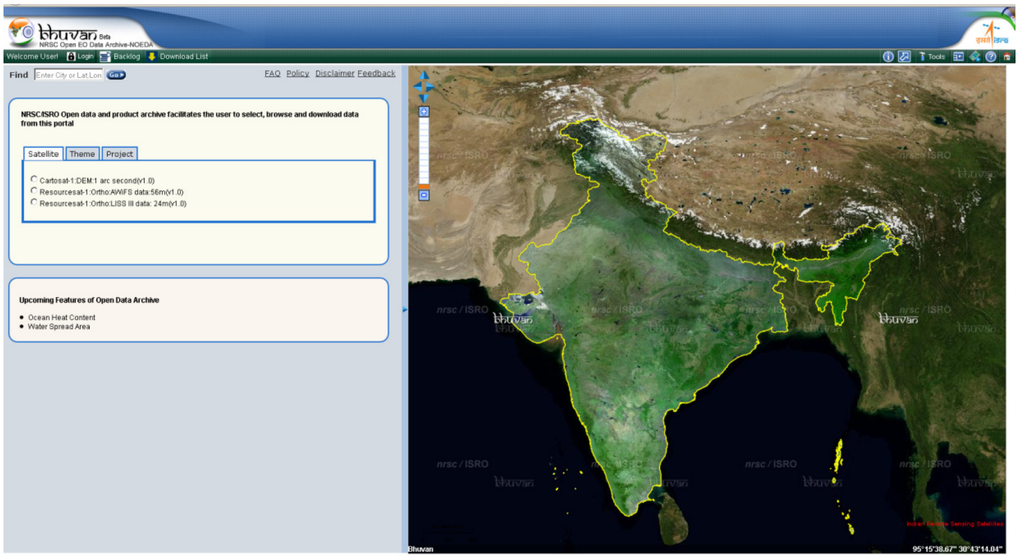
After the process runs on the linux system, the files are transferred to Bhuvan servers to showcase via Bhuvan NOEDA using another scheduler task.

Simple steps to visualize and download TCHP data from Bhuvan

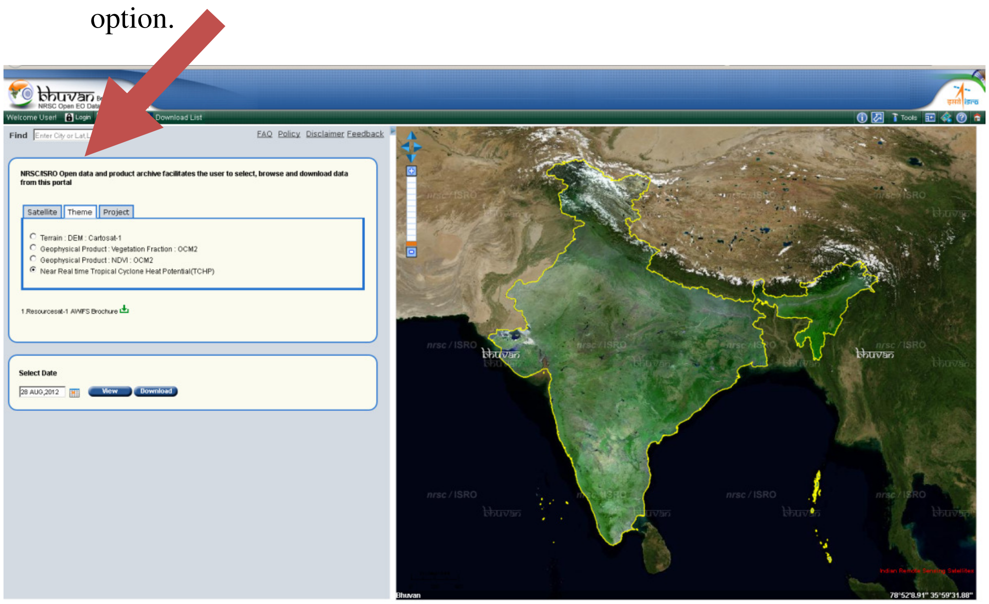
1. Go to www.bhuvan.nrsc.gov.in



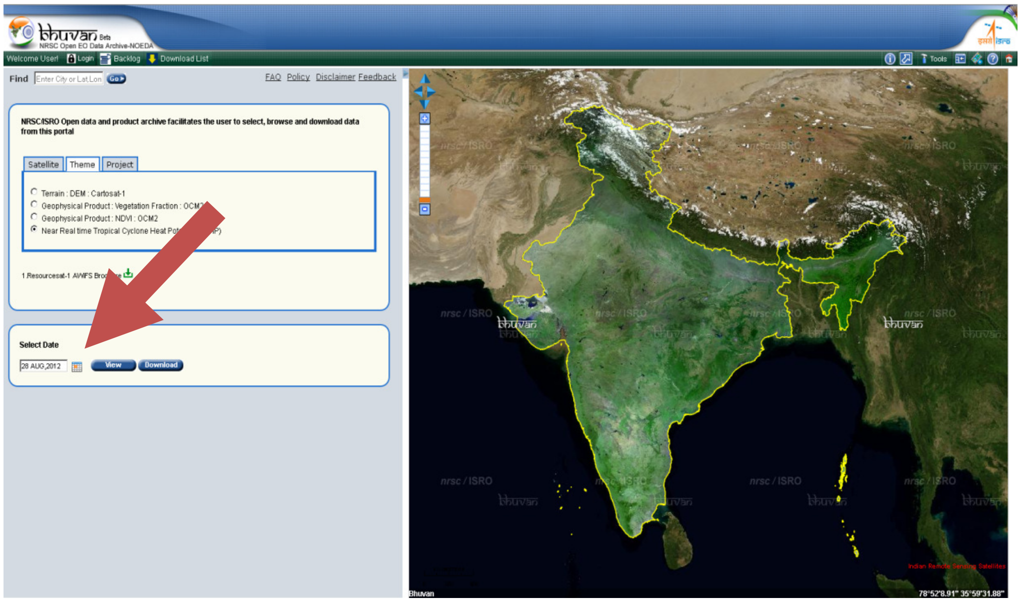
2. Click on NRSC open EO data Archive or directly visit http://bhuvan-noeda.nrsc.gov.in



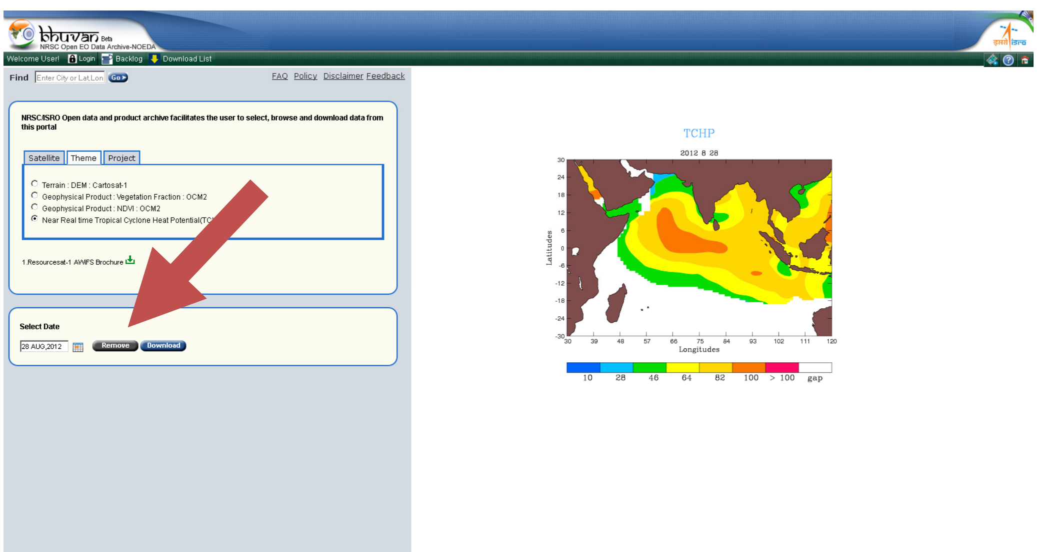
3. Under themes, select "Near Real time Tropical Cyclone Heat Potential (TCHP)" option.



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 TCHP data you 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:

TCHP is one of the critical factors in controlling the intensity of cyclones. The accurate estimation and regional validation of this parameter is essential in the regions like Indian Ocean where devastating cyclones frequently occur. We estimated TCHP by ANN technique and validated the results using in situ observations The results suggest the utility of ANN technique in estimating TCHP with a reasonable accuracy. Hence, we adopted this technique to estimate this parameter on operational basis.

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