NOAA / AVHRR RSGB
Sea & Lake Surface Temperature Data Set

Summary:

Multichannel sea surface temperature (SST) products have been constructed operationally from the five-channel AVHRR by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) since late 1981. The AVHRR Oceans Pathfinder (http://podaac.jpl.nasa.gov:2031/DATASET_DOCS/avhrr_pathfinder_sst.html) seeks to expand on this work by developing a satellite SST database for global climate studies, yielding a consistent time series (more than 10 years) that incorporates extensive calibration and validation information. NOAA / AVHRR RSGB Sea & Lake Surface Temperature Data Set is based on this procedure. This document is based on the description found on the web location quoted above.

Table of Contents:

1. Dataset Overview:

Dataset Identification:

Remote Sensing Research Group Sea and Lake Surface Temperature Data Version 1.1 Algorithm

Dataset Introduction:

Non-linear sea-surface temperatures (NLSST) have been computed from AVHRR radiances operational since 1981. This dataset uses observations from the 5-channel Advanced Very High Resolution Radiometer (AVHRR-2 and AVHRR-3 instruments) on the operational polar satellites. These satellites are in sun-synchronous orbits, with nominal ascending equatorial crossings at 7:30 AM and 2:00 PM. The instruments measure emitted and reflected radiances

in the following bands: 0.58-0.68, 0.725-1.10, 3.55-3.93, 10.3-11.3, and 11.5-12.5 micrometers. The nominal instrument spatial resolution is approximately 1.1 km. The 1.1 km 'HRPT' data are broadcast to any ground receiver in the field of view of the transmitting antenna. The algorithm used to convert the observed radiances to sea surface temperatures is called Remote Sensing Research Group Lake and Sea Surface Temperature Data Version 1.0 Algorithm, and was derived by D. Oesch and collaborators at the University of Bern, Switzerland. The algorithm is based mainly on [McClain *et al.*1984] as modified in [Schwab *et al.*1999] and [2002]. A validation for lake waterbodies was done by [Li *et al.*2001]. In essence a set of coefficients (http://manati.wwb.noaa.gov/sst/coefficient.html, http://www.sat.dundee.ac.uk/_cal/noaa.sst and according to personal communication from Xiaopheng Li (NOAA) is used.

Objective/Purpose:

The mandate of the SST task is to produce operational AVHRR-derived SST for use in local climate investigations and modeling, such as input for a NWP model and climatological studies.

Summary of Parameters:

Sea and Lake Surface Temperature

Discussion:

In order to understand the processes involved in global climate change many different scientific measurements are needed. One of the parameters critical to understanding how the ocean affects climate on a global scale and lakes affect on regional scale is sea / lake surface temperature (SST). An example of the importance of this measurement for climate studies is their use in the study of the western boundary currents of the world's ocean. The western boundary currents play an important role in the Earth's heat balance. They carry a tremendous amount of heat poleward from low-latitude regions. Because the currents exhibit strong SST gradients, the SST measurements can be used to determine their displacements. Knowledge of the displacements, in turn, allows us to improve our understanding of ocean circulation and heat transport. Also an important factor for local scale is the Lake surface temperature, especially useful as an input for NWP and regional climate monitoring.

2. Investigator(s):

David Oesch
Remote Sensing Research Group
Department of Geography
University of Bern
Has implemented the Lake surface processing scheme for the alpine region.

3. Theory of Measurements:

The history of SST computation from AVHRR radiances is discussed at length by [McClain *et al.*1984]. Briefly, radiative transfer theory is used to correct for the effects of the atmosphere on the observations by utilizing "windows" of the electromagnetic spectrum where little or no atmospheric absorption occurs. Channel radiances are transformed (through the use of the Planck function) to units of temperature, then compared to a-priori temperatures measured at the surface. This comparison yields coefficients which, when applied to the global AVHRR

data, give estimates of surface temperature which have been nominally accurate to 0.3 C, or better depending on the satellite platform [Li *et al.*2001].

4. Equipment:

Sensor/Instrument Description:

Collection Environment:

NOAA-Series Satellites

Source/Platform:

all active NOAA AVHRR polar-orbiting satellites

Source/Platform Mission Objectives:

Each of the NOAA polar-orbiting satellites have carried an AVHRR as one of three sensors aboard the spacecraft. AVHRR was designed for multispectral investigations of meteorological, oceanographic, and hydrologic parameters, measuring emitted and reflected radiance in four or five spectral bands, spanning the visible portion of the spectrum to the thermal infrared.

Key Variables:

The sensor measures emitted and reflected radiation from Earth in two visible channels and three infrared channels.

Principles of Operation:

Each AVHRR scan views Earth for 51.282 milliseconds, during which time each channel of the analog data output is digitized. Scans occur at the rate of 6 per second, and the sampling rate of the AVHRR sensors is 39,936 samples per second per channel. During a scan, the detectors view an internal target, cold space, and the external scene. The temperature of the internal target is monitored, and space is assumed to have a black- body temperature of 3K. Calibration is done According to [Goodrum *et al.*1999] and [EPO1992]. The nonlinear modification to this calibration is achieved at the time of postprocessing, and takes into account sensor nonlinearities, measurement of internal target temperature, calculation of target radiance, internal reflections and emissions, etc.. as discussed at [Rao *et al.*1993]

Sensor/Instrument Measurement Geometry:

The AVHRR has a cross-track scanning system which use an elliptical beryllium mirror rotating at 360 RPM about an axis parallel to the Earth. The 110.8° cross-track scan equates to a swath width of about 2700 km. This swath width is greater than the 25.3° separation between successive orbital tracks, and provides overlapping coverage. Coverage is global, twice daily, at an instantaneous field of view (IFOV) of ~1.4 milliradians, giving a ground field of view of ~1.1 km at nadir for a nominal altitude of 833 km.

Manufacturer of Sensor/Instrument:

ITT Aerospace

Calibration:

Specifications:

Channels 1 and 2 are calibrated to produce at-satellite radiances using a time dependent correction which accounts for sensor degradation and intercalibrates among the satellites. Channels 4 and 5 are calibrated using a non-linear function based on the internal calibration targets, baseplate temperatures, instrument dependent response curves, and NOAA-provided gains and offsets. The thermal channels are then converted to equivalent brightness temperatures based on the inverse Planck function convolved with the instrument response according to [Goodrum *et al.*1999], [EPO1992] and [Rao *et al.*1993].

Tolerance:

The instrument is designed to maintain a constant operating temperature for the IR detectors and provide a signal-to-noise ratio (SNR) of 3:1 at 0.5% albedo.

Frequency of Calibration:

The thermal infrared channels are calibrated in flight using a view of a stable blackbody and space as a reference. Channels 1 and 2 have no onboard calibration capabilities, however, they are calibrated before launch.

Other Calibration Information:

In an effort to develop a consistent set of in-flight calibration algorithms for channels 4 and 5, a radiance-based correction procedure was developed to account for the non-linear response characteristics of the detectors [Rao *et al.*1993]. This procedure resulted in a single correction algorithm applicable over the entire range of AVHRR operating temperatures, representing a significant improvement over the use of myriad tables to look up temperature corrections.

5. Data Acquisition Methods:

Full resolution AVHRR data are read out in High Resolution Picture Transmission (HRPT) format at University of Bern, Bern Switzerland. These data are the starting point for the AVHRR RSGB SST processing. The Level-1B data are defined as radiometrically-corrected and calibrated data in physical units at full instrument resolution as acquired. Data is calibrated, atmospherically (SMAC) and BRDF corrected, terrainormalized and orthorectified.

6. Data Description:

Spatial Characteristics:

The SST data are distributed in full resolution. Each data product is produced as either an ascending (daytime) or descending (nighttime) image. These products are produced as dataset of each satellite pass.
The resampled dataset for input in the alpine Local Model (aLMo) is produced using the mean value of all SST pixels within the radius (e.g 0.03125°) of the corresponding aLMo gridpoint.

Spatial Coverage:

Full resolution subset: 0°E-17°E,40.5°N-50°N
aLMo dataset: -19.43-23.41°E, 35.11-57.75°N

Spatial Resolution:

Full resolution subset: 1.1km
aLMo dataset: 0.0625° (ca.7km)

Projection:

Full resolution subset: Geographic, WGS84
aLMo dataset: Spheroid

Grid Description:

Full resolution subset: The AVHRR RSGB SST data are processed in a geographic grid. The pixel size in X Dimension is pixx=0.007 degrees in the Y- Dimension pixy=0.01 degress. The Data Sets has the dimension of 1700x1357 pixels.
aLMo dataset: For each aLMo gridpoint (385x325), the corresponding SST values are written to an ASCII file with the layout of 385colums and 325lines.

Temporal Characteristics:

Temporal Coverage:

Varies on the reception schedule of the RSGB groundstation, typical is around 8 datasets within 24h. Archive data geos back to the mid eighties.

Temporal Coverage Map:

Temporal Resolution:

Up to 8 passes a day

Data Characteristics:

Parameter/Variable:

Sea and Lake Surface Temperature

Variable Description/Definition:

SST - temperature of the sea / lake surface.

Unit of Measurement:

Full resolution dataset: Pixel value devided by 10 to convert to °C
aLMo dataset: Degree Kelvin

Data Source:

AVHRR

Data Range:

The data range is greater than 0°C (273.15 K) and less than 35°C (308.5 K)

Sample Data Record:

Not Available

Related Datasets:

RSGB AVHRR calibrated, orthorectified, BRDF – and SMAC corrected, terrainormalized product

RSGB AVHRR cloud cover according to CASPR

7. Data Organization:

Data Granularity:

Full resolution dataset: The basic granule is every l1b pass data set, which is subset to 0-17°E and 40.5-50°N . The data volume is ca.10MB.
aLMo dataset: same as Full resolution dataset, data outside of Full resolution dataset have been assigned as nodata.

Data Format:

Full resolution dataset: The data are stored in the ER Mapper data format, 16bit signed,1700pixels, 1357lines
aLMo dataset: Data is stored into an ASCII file. First line represents dataset name. The following block of 385columsx325lines represent for each aLMo gridpoint the Temperature in Kelvin

Sample Data Record:

Information not available.

8. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

The AVHRR Level-1B sensor counts in the visible channels (1 and 2) are first converted to Rayleigh-corrected radiances and then to optical depth for use in removing the effects of the atmosphere and viewing and illumination geometry. Channels 3-5 are transformed to units of "brightness temperature", using the Planck black body function and a newly- determined [Rao *et al.*1993] correction for sensor calibration non-linearity in the longer-wavelength channels. The algorithm used is essentially the nonlinear SST (NLSST: [Walton *et al.*1998]).
The form of the algorithm is:

NLSST=A1 (T11) + A2(T11-T12)(MCSST) + A3(T11-T12)(Secq -1)-A4

MCSST= B1 (T11) + B2(T11-T12) + B3(T11-T12)(Secq -1) - B4

Where, T11 and T12 are the AVHRR 11 and 12 µm channel temperatures in Kelvin; Secq is the secant of the satellite zenith angle q; NLSST and MCSST are the non-linear and linear multi-channel SST, respectively, in Centigrade; A1-A4 and B1-B4 are constant coefficients (http://manati.wwb.noaa.gov/sst/coefficient.html, http://www.sat.dundee.ac.uk/cal/noaa.sst and personal communication from Xiaopheng Li, NOAA).

The RSGB equations differ from the global SST equations in the following aspects:

(1) The RSGB SST equations use the MCSST value in the non-linear term rather than an priori SST estimate obtained from an analysis of past satellite SST data. This means that there is somewhat more noise in the RSGB SST observations. The value of the a priori SST or the MCSST is constrained to the range 0°C to 35°C.

(2) The NLSST split-window equation is used for RSGB SST rather than the triple-window equation (employing all three infrared channels) which is used in the global operation.

Data Processing Sequence:

Processing Steps:

Level-1B data are first ingested from HRPT data, then converted from to a standard image format. Data is calibrated georeferenced, orthorectified,etc. Data is processed in latitude/ longitude coordinates and subset. Next the non-linear correction algorithm adjusts for the calibrations of the AVHRR channels, and SST is computed.
The next phase is masking cloud contaminated pixels. A cloud mask produced according to CASPR [Key2002] is used. An additional threshold schemes is used according to http://www.bom.gov.au/sat/SST/sst.shtml:

DAYTIME algorithm:
- Daytime MCSST is used where sunzenith is lower or equal than 75°
- gross IR test - if the channel 4 temperature is less than 0° C then do not compute a SST

- visible cloud threshold test - if the corrected albedo (albedo value divided by the cosine of the solar zenith angle) is greater than 10 percent then do not compute a SST

NIGHTIME algorithm:
- Nightime MCSST is used where sunzenith is greater than 75°
- gross IR test - if the channel 4 temperature is less than 0° C then do not compute a SST
- nighttime IR cloud test - if a calculated channel 4 temperature based on the channel 5 value (channel 5 temp * 1.0439 - 11.49) differs from the actual channel 4 temperature by more than 1.0° C then do not compute a SST
- night time low stratus cloud test - the difference obtained when subtracting the channel 3; temperature from the channel 5 temperature must be less than or equal to -0.6° C.

A Sea/Lake/Landmask according to GSHHS - A Global Self-consistent, Hierarchical, High-resolution Shoreline Database (http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html) si applied.

Valid SST pixels are only those, where satellite zenith angle is less than 53 °.

Valid pixels are only those which, surrounding pixels have a standard deviation lower 3°C according to [Schwab *et al.*1999].

Valid pixels are only those, which are not completely surrounded by nonvaliddata according to [Schwab *et al.*1999].

Valid pixels are only those, which are not warmer than 35°C.

The result is filtered with a 9*9 average filter to smooth any high frequency noise in the image, according to [Schwab *et al.*1999].

Processing Changes:

None

Calculations:

Special Corrections/Adjustments:

No SST calculated if the RMSE of the model to fit the dataset to a reference mapl is bigger than 0.018.This might be the case, if the satellite data is mostly cloudy.

Calculated Variables:

Sea Surface Temperature is calculated from a non-linear correction algorithm
(see above).

Graphs and Plots:

Information not available.

9. Errors:

Sources of Error:

One of the greatest limitations is the obstruction by clouds in the field of view. Other sources of error include atmospheric gases and emissions as well as water surface characteristics.

Quality Assessment:

For every pixel an information is available on which test mentioned above the pixel did not pass:

Flag Type	
GROSS IR (day)	1
VIS cloud (day)	2
GROSS IR (night)	4
IR cloud (night)	8
Low Stratus (night)	16
land/sea mask	32
cloud mask	64
scan angle LT 53°	128
Homogenity Test (3*SDEV)	256
Exclude singel pixels	512
Temp not in 0°-35°C range	1024

10. Notes:

Limitations of the Data:

None

Known Problems with the Data:

Cloud cover. Periods of high aerosols after major volcanic eruptions such as Mt. Pinatubo. NOAA KLM Satellite night data: bad performance of CASPR cloud mask.

Usage Guidance:

For more detailed information, contact D. Oesch at oesch@giub.unibe.ch

Any Other Relevant Information about the Study:

none

11. Application of the Dataset:

Local climate studies, studies of ocean/lake circulation and its interaction with the atmosphere, calculate heat transport in the ocean /lake.

12. Dataset Plans:

Description of Future Plans:

Reprocessing efforts are ongoing.

13. Related Software:

Software Description:

The RSGB is supplying IDL routines to read and ER Mapper data on request.

14. Data Access:

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15. Output Products and Availability:

FTP

Products will be available by ftp pull.

WWW

Quicklook of products will be available by WWW.

16. References:

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Walton, C.C., W.G. Pichel, J.F. Sapper, and D.A. May, 1998. The development and operational application of nonlinear algorithms for the measurement of sea surface temperatures with the NOAA polar-orbiting environmental satellites. Journal of Geophysical Research. 103 (C12): 27999-28012.

17. Glossary of Terms:

Sea / Lake Surface Temperature

The temperature of the layer of sea water nearest the atmosphere.

18. List of Acronyms:

AVHRR....Advanced Very High-Resolution Radiometer
FTP....File Transfer Protocol
MCSST....Multichannel Sea Surface Temperatures
NOAA....National Oceanic and Atmospheric Administration
SST....Sea Surface Temperature

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