NOAA / AVHRR RSGB
Normalized Difference Vegetation Index (NDVI) Data Set

Summary:

This document gives an overview on operational pre-processing of NOAA-AVHRR data and the calculation of NDVI for a subset covering the European Alps and surroundings. NDVI is calculated with the data of channel 1 (0.58-0.68) and channel 2 (0.725-1.10) of the AVHRR sensor. It is a measure of the greenness of the vegetation in the range of –1.0 and +1.0. High vegetation coverage has values greater than 0.5. All used NOAA-AVHRR data are ingested at the Remote Sensing Research Groups receiving station.

Table of Contents:

1. Dataset Overview:

Dataset Identification:

Remote Sensing Research Group Normalized Difference Vegetation Index Data Version 1.0 Algorithm

Dataset Introduction:

NDVI is a simple measure of the greenness of the surface and is calculated by using the channel 1 (0.58-0.68) and channel 2 (0.725-1.10) of the AVHRR sensor.

$$NDVI = (ch2 - ch1) / (ch2 + ch1). \qquad (1)$$

NDVI values range from -1.0 to +1.0 and are unitless. Values greater than 0.1 generally denote increasing degrees in the greenness and intensity of vegetation. Values between 0 and 0.1 are commonly characteristic of rocks and bare soil, and values less than 0 sometimes indicate ice-clouds, water-clouds, and snow. Vegetated surfaces typically have NDVI values ranging from 0.1 in deserts up to 0.8 in dense tropical rain forest. 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.

Objective/Purpose:

The mandate of the NDVI task is to produce operational AVHRR-derived normalized difference vegetation index data for use in local climate investigations and modeling, such as input for a NWP model.

Summary of Parameters:

Normalized Difference Vegetation Index

Discussion:

In order to understand the processes involved in global climate change many different scientific measurements are needed. One relevant parameter is the vegetation cover in its annual cycle. Denser vegetation coverage results in an increase of leaf area, which is one relevant parameter in soil-vegetation-atmosphere-transfer (SVAT) models. The exchange of water vapor between vegetation and the atmosphere is mainly controlled by leaf area, whereas the sensible heat flux is more dominated by barren ground because the transpiration is regulated by the stomata of green leafs. Changes in the ratio of sensible and latent heat flux (bowen ratio), has direct impact on the boundary layer climate. The normalized difference vegetation cover index is a measure to describe the greenness as well as the starting point to calculate the fraction of vegetation cover and leaf area index.

2. Investigator(s):

Stefan Wunderle & David Oesch
Remote Sensing Research Group
Department of Geography
University of Bern
has implemented the NDVI scheme for the alpine region.

3. Theory of Measurements:

"The first AVHRR channel is in a part of the spectrum where chlorophyll causes considerable absorption of incoming radiation, and the second channel is in a spectral region where spongy mesophyll leaf structure leads to considerable reflectance. This contrast between responses of the two bands can be shown by a ratio transform; i.e., dividing one band by the other. Several ratio transforms have been proposed for studying different land surfaces (Tucker, 1979). The Normalized Difference Vegetation Index (NDVI) is one such ratio, which has been shown to be highly correlated with vegetation parameters such as green-leaf biomass and green-leaf area and, hence, is of considerable value for vegetation discrimination (Justice et al. 1985).

A ratio between bands is of considerable use in reducing variations caused by surface topography (Holben and Justice 1981). It compensates for variations in radiance as a function of Sun elevation for different parts of an image. The ratios do not eliminate additive effects caused by atmospheric attenuation, but the basis for the NDVI and vegetation relationship holds generally. The soil background contributes a reflected signal apart from the vegetation, and interacts with the overlying vegetation through multiple scattering of radiant energy. Huete (1988) found the NDVI to be as sensitive to soil darkening (moisture and soil type) as to plant density over partially vegetated areas."(http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/FTP_SITE/INT_DIS/readmes/pal.html#400; 2003)

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 has 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. Calibration is done according to [Goodrum *et al.*1999] and [EPO1992].

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:

Computing the apparent radiance:

Source: http://www.vtt.fi/tte/research/tte1/tte14/docs/avhrrguide/avhrr_guide.pdf
The apparent radiance is computed from the calibration coefficients using the following formula:

Up to NOAA-14:

$rad_i(l,c) = \alpha_i * (CN_i(l,c) – CN_{oi})$

where:

i	= channel, I or 2
l,c	= line, column
α_i	= gain for band i ($W\ m^{-2}\ sr^{-1}\ \mu m^{-1}\ count^{-1}$)
$CN_i(l,c)$	= digital count for band i at pixel (l,c)
CN_{oi}	= deep space digital count for band i (offset)

NOAA publishes updated calibration coefficients monthly. This has lead to a possibility of doing absolute and time depending calibration for AVHRR visible channels.

From NOAA-15 (NOAA-K) on the calibration coefficients (published by NOAA) are expressed as “reflectance factors”. Using these factors, the TOA reflectance will be computed instead the apparent radiance. The pre-launch calibration coefficients can be found from NOAA KLM User’s Guide, section 7.1.

For NOAA-KLM (15-17) instruments, operational calibration coefficients are extracted from the Level1B-format image.

Computing the TOA reflectance

Up to NOAA-14.

The apparent radiance is converted to equivalent TOA (Top Of Atmosphere) reflectance using the following formula (SHARP LEVEL-2 user guide, 1992):

$ref_i(l,c) = 100 * \pi * ds^2 * rad_i(l,c) / E_{si}$

$d_s = 1 - 0.01672 * \cos(0.9856 * (Dy - 4))$

where:

i = channel, I, 2 or 3(A)

l,c = line, column

$rad_i(l,c)$ = radiance for band i at pixel (l,c) ($W\ m^{-2}\ sr^{-1} \mu m^{-1}$)

d_s = rate between the actual Sun-Earth distance and the Sun-Earth mean distance

Dy = day of the year

E_{si} = equivalent solar irradiance ($W\ m^{-2} \mu m^{-1}$)

$\upsilon_{l,c}$ = solar zenith angle for pixel of co-ordinate l, c

From NOAA-15 on.

Raw digital counts, not the radiance, are converted to TOA reflectance using the formula below:

$ref_i(l,c) = (\alpha_i * CN_i(l,c) + \beta_i) / \cos \upsilon_{l,c}$

where:

i = channel, I, 2 or 3(A)

l,c = line, column

α_i = gain for band i

$CN_i(l,c)$ = digital count for band i at pixel (l,c)

β_i = intercept for band i

$\upsilon_{l,c}$ = solar zenith angle for pixel of co-ordinate l, c

Calibration coefficients are expressed as ‘reflectance factors’, see NOAA KLM User’s Guide, section 7.1.

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:

The solar reflectance channels on the NOAA AVHRR instrument have no on-board calibration source and are known to drift in sensitivity following launch. Various methods have been developed for the post-launch calibration of these channels. The basis of the calibration of the visible channels is the compilation by the Commonwealth Scientific & Industrial Research Organisation (CSIRO) of Australia. This document brings together the results of the state-of-the-art of the operational calibration of AVHRR data sets from both historical and currently operational sensors. (source: http://www.dar.csiro.au/rs/CalWatch/calwatch.htm); Our module VIS_CAL in the processing chain is based on this documentation.

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 NDVI 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, BRDF corrected and orthorectified.

6. Data Description:

Spatial Characteristics:

The NDVI data are distributed in full resolution. Each data product is produced as ascending (daytime) image.
The re-sampled dataset for input in the alpine Local Model (aLMo) is produced using the mean value of all NDVI 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 ground station, typical is around 4 datasets within daytime. Archive data goes back to the mid eighties.

Temporal Coverage Map:

Temporal Resolution:

Up to 4 passes during daylight

Data Characteristics:

Parameter/Variable:

Normalized Difference Vegetation Index

Variable Description/Definition:

NDVI - Normalized Difference Vegetation Index.

Unit of Measurement:

Full resolution dataset: unitless with two digits 0.XX
aLMo dataset: unitless with two digits 0.XX

Data Source:

AVHRR

Data Range:

The data range is greater than -1 and less than +1

Sample Data Record:

Not Available

Related Datasets:

RSGB AVHRR calibrated, orthorectified BRDF corrected 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:

Data Processing Sequence:

Processing Steps:

Pre-processing
After navigation of the raw AVHRR imagery using orbital parameters and reading the calibration information in the HRPT data stream the imagery is transformed to level 1b format. The calibration of the visible channels 1 and 2 is done using the standard calibration and the satellite inter-calibration module VIS_CAL. In a further step the navigated imagery is geo-coded. The rectification method implemented here, is based on the use of a tie point grid. This grid is extracted from the suffix data on raw image records (SHARP and NOAA Level1B) or it can be computed using the orbital prediction (TBUS) and the time code on the HRPT data stream. On the grid, latitude and longitude locations, sun angles and satellite angles are given at constant steps. This step is every 32 pixels within each 16 scan lines on a SHARP-1 image. HRPT unpacking routines produce a grid with a step of 30 pixels in both directions. On Level1B images, the step is 40 pixels between the grid points.

The rectification process is carried out by using piecewise linear mapping functions throughout the whole image. Input and output images are partitioned into patches defined by closest grid points. An affine transformation function is evaluated at every pixel on the output image (i.e. on the rectified image) by using three closest geo-referenced points on the grid and their respective image co-ordinates.

In the first version of NDVI processing we have no atmospheric correction included because the aerosol product has to be validated. In the near future we will add the atmospheric correction using Simplified Method of Atmospheric Correction (SMAC) based on 5S (Rahman and Dedieu 1994). The input for SMAC is ozone, air pressure as a measure for the atmospheric depth, water vapor and aerosol.

Based on the orbit and the calculated view angle as well on the altitude of the mountains, derived from GTOPO30, the ortho-shift is calculated for every pixel and afterwards corrected. The result is a NOAA-AVHRR image in parallel projection similar to topographic maps.

The calculated reflectance of the normalized imagery is based on the assumption of a lambertian surface. Therefore a module is added to correct the bi-directional reflectance distribution (BRD). The BRD correction is done for the surface classes forest, barren, cropland and grass using the function published by (Wu *et al.*1995). The BRD corrected reflectance is normalized to a nadir view with solar zenith of 45°.

Processing Changes:

None

Calculations:

Special Corrections/Adjustments:

No NDVI calculated if less than 25 ground control points (GCP's) found during the georeferencing procedure. This might be the case, if the satellite data is mostly cloudy.

Calculated Variables:

NDVI

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.

Quality Assessment:

None

10. Notes:

Limitations of the Data:

None

Known Problems with the Data:

Cloud cover. Periods of high aerosols in valleys.

Usage Guidance:

For more detailed information, contact Stefan Wunderle at swun@giub.unibe.ch

Any Other Relevant Information about the Study:

none

11. Application of the Dataset:

Local climate studies, studies of vegetation changes in the European Alps, derivation of leaf area index and vegetation cover fraction.

12. Dataset Plans:

Description of Future Plans:

Reprocessing efforts are ongoing. Validation of aerosol product to add atmospheric correction

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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17. Glossary of Terms:

Normalized Difference Vegetation Index

Measure of the greenness of vegetation.

18. List of Acronyms:

AVHRR....Advanced Very High-Resolution Radiometer
FTP....File Transfer Protocol
NOAA....National Oceanic and Atmospheric Administration
SMAC....Simplified Method of Atmospheric Correction

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