Normalized Difference Vegetation Index Climate Data Record

1. Intent of This Document and POC

1a) This document is intended for users who wish to compare satellite derived observations with climate model output in the context of the CMIP/IPCC historical experiments. Users are not expected to be experts in satellite derived Earth system observational data. This document summarizes essential information needed for comparing this dataset to climate model output. References are provided at the end of this document to additional information.

Dataset File Name (as it appears on the ESGF):

--to be added once file is accepted-----

1b) Technical point of contact for this dataset:

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2. Data Field Description

CF variable name, units:	--to be added--
Spatial resolution:	*0.05-deg in latitude and longitude*
Temporal resolution and extent:	*Monthly average, 06/1981 – 07/2016??*
Coverage:	*Global*

3. Data Origin

This dataset uses the Advanced Very High Resolution Radiometer (AVHRR) Land Bundle Surface Reflectance climate data record (CDR) as the primary input. Primary sensor data for the surface reflectance data are calibrated and geolocated AVHRR Global Area Coverage (GAC) 'Level 1B' reflectance at 2 channels and brightness temperature at 3 channels from AVHRR sensor, geolocation information, and sensor data quality flags. Surface Reflectance products are generated for each cloud-free pixel (0.05°x0.05°) observed by the AVHRR imager channel 1-3. Channels 3-5 are used to retrieve atmospheric conditions, (e.g., water vapor) cloud and snow masks.

Multiple ancillary data sources are used in combination with the GAC input to produce the surface reflectance data. Among the inputs are digital elevation models from USGS, land/water masks from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS), ozone data from NASA's Total Ozone Mapping Spectrometer (TOMS), water vapor information from National Centers for Environmental Prediction (NCEP), the bidirectional reflectance distribution function (BRDF) database from MODIS, BRDF-corrected reflectance climatologies from MODIS, as well as internally derived stratospheric and tropospheric aerosol climatologies.

Various corrections are made to the GAC inputs in the derivation of surface reflectance. This includes performing BRDF-correction and atmospheric correction accounting for Rayleigh scattering, stratospheric and tropospheric aerosols, and gaseous absorption of O_3, O_2, CO_2, and water vapor.

Furthermore, pixels with cloud or cloud shadow present are not included in the dataset. This is assessed with comparisons of the spectrally-adjusted AVHRR to the MODIS Channel 1 BRDF-corrected climatology. If the difference between the AVHRR reflectance and the climatology is larger than 0.03, the pixel is considered to be cloud. Cloud height range (minimum and maximum) is estimated based on temperature derived from AVHRR Channel 4 and 5. Shadow pixels correspond to the projection of the cloudy pixels on the surface following the pixel location (lat, lon) – sun angle.

NDVI is computed from the surface reflectance CDR using the following equation:

$$NDVI = \frac{\rho_{830} - \rho_{640}}{\rho_{830} + \rho_{640}} \quad (1)$$

where ρ_{830} = *Ch. 2 reflectance (830 nm)* and ρ_{640} = *Ch. 1 reflectance (640 nm).*

4. Validation and Uncertainty Estimate

Cross-comparisons were made with MODIS NDVI over AERONET sites for 2003-2004. In Figure 1, AVHRR nadir-corrected surface reflectance is compared to MODIS nadir-corrected surface reflectance acquired the same day. The RMSD is 0.074 for NDVI. One source of deviation that is not taken into account is the spectral differences which can be identified using synthetic data. Figure 2 shows the corrected NDVI after using a simple band-pass.

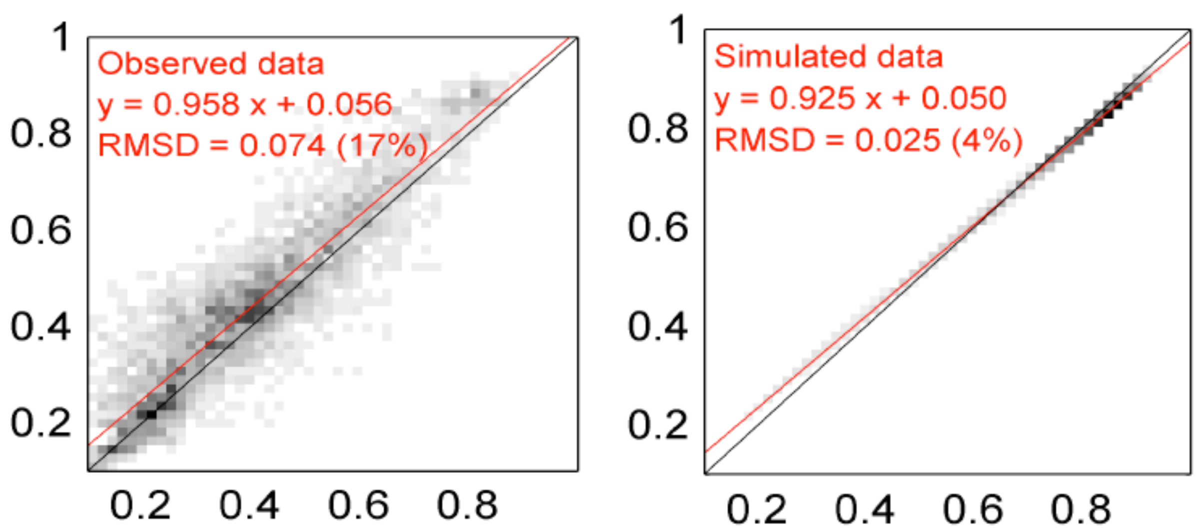

Figure 1: *Comparison of MODIS Aqua and NOAA16 AVHRR data. Left panel contains NDVI observed over AERONET sites for 2003-2004. Right panel is simulated using a vegetation model that accounts for spectral differences between MODIS and AVHRR bands. In both panels, x-axis is AVHRR and y-axis is MODIS.*

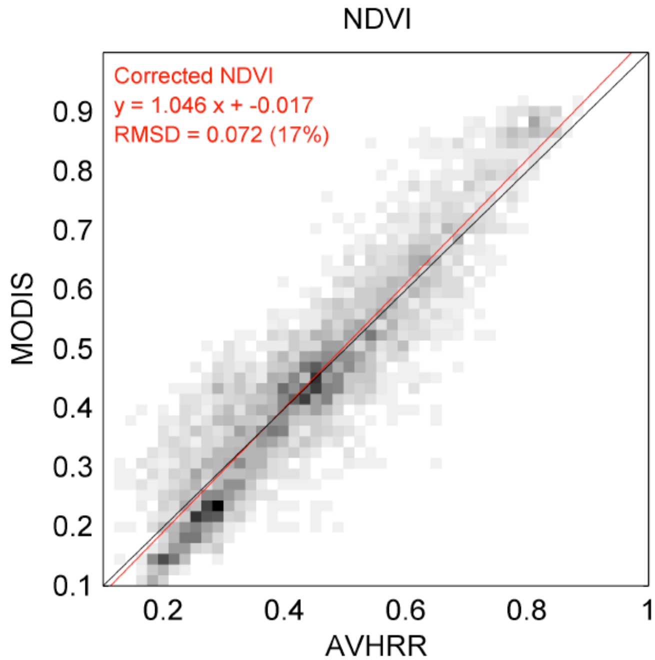

Figure 2: *MODIS NDVI versus corrected AVHRR NDVI computed from spectrally adjusted AVHRR surface reflectance.*

Comparison of NDVI data from TOA, Pathfinder AVHRR Land (PAL) and this CDR to reference data at the AERONET stations are presented in

Table **1**. A, P and U metrics stand for Accuracy, Precision and Uncertainty, respectively. They are described in Eq. 2-4 where ε and N correspond to the deviation between estimates and A reference and the number of points, respectively. The table showed that CDR has better accuracy and precision when compared to PAL and TOA data. For the forest and savanna sites most of the data points (> 70%) had average atmospheric conditions (AOT = 0.05 to 0.25) and about 20% were hazy (AOT > 0.25). However, for semi-arid site more than half data points had clear atmospheric conditions (AOT < 0.05) and only 0.5% points were hazy. The direct validation shows that in hazy conditions all three datasets become very unreliable with precision as much as 0.22 in the forest site. These results show precision for TOA NDVI data between 0.023 for clear atmospheric conditions at the semi-arid site to 0.085 for average atmospheric conditions at the forest site (not considering data points with hazy atmospheric conditions). For the NDVI CDR, precision varied between 0.0061 for clear atmospheric conditions at semi-arid site to 0.0611 for average atmospheric conditions at forest site. A similar improvement in precision was observed at the savanna site.

$$A = \frac{1}{N} \times \sum_{i=1}^{N} \varepsilon_i \quad (2)$$

$$P = \sqrt{\frac{1}{N-1} \times \sum_{i=1}^{N} (\varepsilon_i - A)^2} \tag{3}$$

$$U = \sqrt{\frac{1}{N} \times \sum_{i=1}^{N} \varepsilon_i^{\,2}} \tag{4}$$

Simulated Data	Land cover	Clear (AOT < 0.05)			Average (AOT = 0.05 to 0.25)			Hazy (AOT > 0.25)		
		A	P	U	A	P	U	A	P	U
TOA	Semiarid	-0.062	0.023	0.066	-0.067	0.023	0.071	-0.140	0.063	0.151
TOA	Savanna	-0.170	0.044	0.176	-0.177	0.051	0.184	-0.305	0.182	0.355
TOA	Forest	-0.247	0.082	0.260	-0.280	0.085	0.293	-0.586	0.188	0.615
PAL	Semiarid	-0.039	0.011	0.041	-0.051	0.016	0.054	-0.132	0.078	0.150
PAL	Savanna	-0.079	0.015	0.081	-0.107	0.043	0.115	-0.252	0.171	0.305
PAL	Forest	-0.056	0.026	0.061	-0.124	0.072	0.143	-0.508	0.219	0.553
CDR	Semiarid	-0.007	0.006	0.009	-0.011	0.011	0.015	-0.085	0.085	0.114
CDR	Savanna	-0.014	0.011	0.017	-0.038	0.036	0.052	-0.166	0.164	0.233
CDR	Forest	-0.025	0.021	0.032	-0.085	0.061	0.104	-0.429	0.199	0.473

Table 1: *Accuracy (Eq. 2), precision (Eq. 3), and uncertainty (Eq. 4) for NDVI from simulated TOA and CDR datasets. For the forest site; 20 (4%), 376 (75%), and 105 (21%) of 501 data points had clear, average, and hazy atmospheres respectively. For the savanna site; 40 (9%), 317 (71%), and 89 (20%) of 446 data points had clear, average, and hazy atmosphere respectively. For the semi-arid site; 384 (52%), 348 (47%), and 8 (1%) of 740 data points had clear, average, and hazy atmosphere respectively. A, P and U are statistical metrics (refers to Vermote and Kotchenova, 2008) standing for Accuracy, Precision and Uncertainty, respectively.*

5. Considerations for Model-Observation Comparisons

The original NDVI CDR contains a wealth of associated quality assurance information (see Table 2). For ease of use in the obs4MIPS context, we chose to only include CDR data under certain conditions for the monthly averages. In particular, we did not include data with any of the quality flags set EXCEPT bits 5 (pixel is over dense dark vegetation) and 7 (Ch. 1-5 are valid). That is, if any of bits 1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 14, or 15 are set, the data is not included.

Further, the original NDVI CDR has a daily temporal resolution. However, the obs4MIPS version has monthly temporal resolution derived by taking the average of all pixels that passed quality filtering for the month.

Bit #	Description	Value=1	Value=0
15	polar flag (latitude over 60 degrees (land) or 50 degrees (ocean));	yes	No
14	BRDF-correction issues;	yes	No
13	RHO3 value is invalid;	yes	No
12	Channel 5 value is invalid;	yes	No
11	Channel 4 value is invalid;	yes	No
10	Channel 3 value is invalid;	yes	No
9	Channel 2 value is invalid;	yes	No
8	Channel 1 value is invalid;	yes	No
7	Channels 1 - 5 are valid;	yes	No
6	Pixel is at night (high solar zenith);	yes	No
5	Pixel is over dense dark vegetation;	yes	No
4	Pixel is over sunglint;	yes	No
3	Pixel is over water;	yes	No
2	Pixel contains cloud shadow;	yes	No
1	Pixel is cloudy;	yes	No
0	(unused);	-	-

Table 2: *Quality assurance description. Bits are listed from the most significant bit (bit 15) to the least significant bit (bit 0).*

6. Instrument Overview

Surface reflectance products are generated for each cloud-free pixel (0.05°x0.05°) observed by the AVHRR imager channel 1-3. Channels 3-5 are used to retrieve atmospheric conditions, (e.g., water vapor) cloud and snow masks. The AVHRR imager system is on board the NOAA polar-orbiting satellite series. The timeline of the NOAA platform numbers used to generate this dataset is presented in Figure 3.

Channel number	**Wavelength (μm)**
1	0.63
2	0.83
3a	1.61
3b	3.75
4	11.0
5	12.0

Table 3: *AVHRR channels and the associated central wavelengths. Channel 3a is only available for the AVHRR instrument on NOAA-16, -17, -18.*

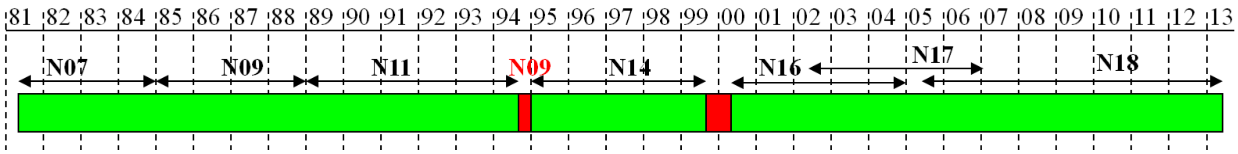

Figure 3: *Timeline of the NOAA platform numbers.*

7. References

Primary CDR references:

Vermote, E., and M. Claverie, (2013). CDR Climate Algorithm Theoretical Basis Document: AVHRR Land Bundle – Surface Reflectance and Normalized Difference Vegetation Index.

Vermote, E., C. Justice, I. Csiszar, J. Eidenshink, R. Myneni, F. Baret, E. Masuoka, R. Wolfe, M. Claverie (2014): NOAA Climate Data Record (CDR) of Normalized Difference Vegetation Index (NDVI), Version 4. NOAA National Climatic Data Center. doi: 10.7289/V5PZ56R6

Background and related references:

Holben, B. N. *et al*. (1998). AERONET - A federated instrument network and data archive for aerosol characterization. *Remote Sensing of Environment*, 66(1), 1-16.

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Saleous El, NZ, Vermote, EF, Justice, CO, Townshend, JRG, Tucker, CJ, Goward, SN (2000). Improvements in the global biospheric record from the Advanced Very High Resolution Radiometer (AVHRR). *International Journal of Remote Sensing*, 21(7-Jun), 1251-1277.

Tanr, D., Holben, B. N. and Kaufman, Y. J. (1992). Atmospheric Correction algorithm for NOAA-AVHRR Products: Theory and Application. *IEEE Transaction on Geoscience and Remote Sensing*, 30, 231-248.

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Vermote, E.F., & Kotchenova, S. (2008). Atmospheric correction for the monitoring of land surfaces. *Journal of Geophysical Research-Atmospheres,* 113, D23S90.

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8. Dataset and Document Revision History

Rev 0 – 29 July 2016 - This is a new document/dataset, referring to Version 4 of the Normalized Difference Vegetation Index CDR data set.