Reflectance of AVHRR L1B correlated to MODIS L13A reflectance for a Diachronic vegetation study of Gujarat Environment

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ABSTRACT

A common understanding of the movement of groundwater recharge by rainwater harvesting that occurred for the last decades leads to the belief that it had a significant positive impact on the vegetation of Gujarat, to the least in areas having crops irrigated by groundwater.

Using the historical remote sensing data publicly available from the Internet, assessment of vegetated area variation between twelve years interval was performed. The total area covered by vegetation was processed by districts at 15 days interval for limited significant periods of years 1989 and 2001. The use of a statistical model in the process of calibration of the band-wise reflectance values for the preparation of the NDVI at surface from AVHRR has proven to be very useful. It has also given more practical knowledge on the concept of surface reflectance invariant objects.

Results show that if such movement had an impact on the total vegetation in some districts, it must have been counter-balanced by the 1999 drought. More study may be required to give some more information about the accuracy of such assessment. So far, analysis leads to believe that there is a slight reduction of vegetation cover in the well vegetated districts over the years of observation.

1. INTRODUCTION

The particularly arid climate encountered in Gujarat may be easily translated to the conditions faced in the Sahelian countries of Africa where rain events occur at a number below 20 per year. The only wealth of this rain compared to African conditions, is its amount. The monsoon is a heavy rain coming from the Bengal bay across South Asia up to the Hindu-Khush Mountains of Baluchistan and Afghanistan, eventually reversing its path back to the Eastern part of the South Asian continent. Its rich nature in amount of water is also armful for the soils, while saturating the top layer very rapidly. Run-off is then a basic process that will migrate the rainwater horizontally leaving the soil superficially moist, but without recharging the groundwater lenses.

Since the 1970s, a large amount of efforts have been put in the recollection of the old methods of rainwater harvesting by different religious organizations, and various non-governmental agencies in Gujarat (Shah, 2000). The process of recharging the groundwater by directing the run-off into a recharge well has been traditionally used for centuries in the Upper Gujarat and Rajasthan areas. Lost as a common practice in the last century, it has been re-implemented in the last decades (Khandelwal et al., 2000). A common understanding of the movement that occurred leads to the belief that it had a significant impact on the vegetation of Gujarat, to the least in areas having crops irrigated by groundwater.

The use of remote sensing to evaluate environmental changes is common. Land and water parameters are often well described by the observation of space, like hydrological state variables (Schultz and Engman, 2000), crop growth monitoring and regional statistics (Nieuwenhuis et al., 1996), but also land use disturbance (Narongrit and Tokunaga, 2000) and drought risk assessment (Mongkolsavat et al., 2001)

The striking observation of NDVI histograms between AVHRR and MODIS is the difference of range. In other words, when speaking about NDVI, the contrast of AVHRR is less than the contrast of MODIS, while the contrasts of MODIS and Landsat are comparable at equivalent pixel size (Alexandridis and Chemin, 2002). Deng and Di (2001) found a systematic error of AVHRR NDVI from NOAA 7, 9 and 11, that is proportional to the zenith angle of the sensor IFOV. They relate that the drift of the equator crossing time from 1.30PM to 4.30PM along four years of acquisition as being similar between NOAA 9 and 11. As NDVI is not matching for the same date; there is a need of homogenization of the sensors response in the NIR and Red. Some earlier work on this line can be found in Gao (2000) that concentrated on propagation of NOAA AVHRR information through new sensors. The purpose of this study is to evaluate the opposite using the comparative advancement of the newly launch platform MODIS, having higher spatial/spectral resolution, and especially narrower bands than NOAA AVHRR, in order to assess the effect of a propagation of information from Modis to AVHRR. The advantage would be that all the implicit higher accuracy in terms of technical advancement of new sensors, would somehow improve the low performance of the earlier Polar Orbiter platforms.

2. Objectives

The objectives of this study are first to test harmonization of the NDVI between NOAA AVHRR and MODIS in 2001; second to propagate this knowledge for NOAA AVHRR in 1989 in order to study vegetation change over a gap of 12 years.

3. METHODS

3.1. Satellite images

MODIS (Moderate Resolution Imaging Spectro-radiometer) is a key instrument aboard the Terra (EOS AM-1) satellite, which also started functioning in March 2000. Terra MODIS is viewing the entire Earth's surface every to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths (Table 1). Modis sensor on TERRA platform has a spectral resolution featuring 36 bands ranging from 250 to 1000 meters spatial resolution. Acquisition of L3 NDVI Red and Near InfraRed (NIR) imagery can be done through the Redhook Eros Data Center Internet web site using ftppull protocol. Extraction of the binary file can be performed for the necessary bands through the Modis Reprojection Tool (MRT) available in the World Wide Web at http://edc.usgs.gov/programs/sddm/modisdist/.

The Advanced Very High Resolution Radiometer (AVHRR) is a broad-band, four or five channel (depending on the model) scanner, sensing in the visible, near-infrared, and thermal infrared portions of the electromagnetic spectrum. This sensor is carried on NOAA's Polar Orbiting Environmental Satellites, beginning with TIROS-N in 1978. The AVHRR sensor provides for global (pole to pole) on board collection of data from all spectral channels (Table 1). Each pass of the satellite provides a 2399 km wide swath. The satellite orbits the Earth 14 times each day from 833 km above its surface. NOAA AVHRR online data base is available at http://www.saa.noaa.gov/. Importing the data is automatically done by most of the remote sensing software available to date.

Satellite	Sensor	Spatial resolution	Temporal resolution	Acquisition dates	Purpose
TERRA	MODIS	1 Km	1-2 days	2001-03-21 to 2001-04-06 2001-03-21 to 2001-09-21	Calibration / Assessment Assessment
NOAA	AVHRR	1.1 km at nadir	1-2 days	2001-03-29 & 2001-03-30 1989-01-02 to 1989-06-02	Calibration Assessment

Table 1: Details of satellites and images used in this study

The time-extent of the calibration/comparison is situated in March especially, expanding up to June for the comparison, being the pre-monsoon months, where the influence of groundwater available in the plant water intake is likely to be the most critical. In other terms, if groundwater is not available, then the vegetation will have the strongest effect at the longest time after the last set of rains, that is, just before the next monsoon rain from April to June.

3.2. Band-wise fitting between NOAA AVHRR and MODIS

The method of fitting the band-wise reflectance components of NDVI is mentioned in Ahern et al. (1977) and Koepke et al. (1985), and refers to ground control points of known and stable values to generate NDVI information at surface (thus including simple, area-averaged atmospheric correction). In this study, the ground control points were assumed from a time integrated assessment of Modis band-wise reflectance. AVHRR bands' histograms were subsequently fitted to Modis bands' histograms. These Modis band-wise reflectance timely invariant "ground control points" were selected by a simple statistical GIS/remote sensing model developed for this very purpose. The large availability of high Reflectance points in Gujarat, especially because of the Rann of Khachchh, required the creation of a simple statistical model for the determination of invariant locations over the several Modis images available for the study (Figure 1). In the case of high Albedo invariant search, each band is returning the maximum time-integrated mean pixel-wise, that is then confronted to timely coefficient of variation pixel-wise. A rule of selection at tail-end percentages (i.e. > 95% of maximum mean and ± 5% Coefficient of Variation) is setup for both bands information. Only if it is met at both bands similarly for the same pixel location, then it will be selected in the "common results" pool (Figure 1). A final step is nullifying the values of all non-selected pixels.

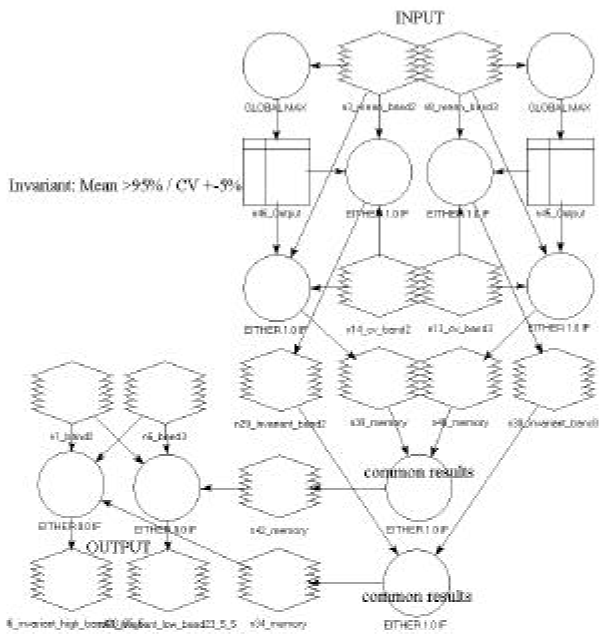


Figure 1. Overview of the statistical model for selection of invariant Albedo pixels

The method is a straight-forward fitting of the surface Albedo values of desert and water points that successfully remained statistically unchanged over several images of MODIS. The values of these selected points were timely averaged for each location in the desert and in the water areas within the vicinity of very few pixels that could be aggregated to the NOAA pixel size, including a probable shift of 2 NOAA pixels on all azimuth directions. The reference areas finally became a 4 x 4 Km square in the Rann of Khachchh and a 3 x 4 Km in a water retention lake of the Eastern side of Gujarat border. The critical 4 x 4 Km area assumed safe could therefore not be reached on land for obvious reasons limiting the extent of water bodies. The statistical model did not show very good stability of inner land open water body values generally. However, off-shore ocean values would have been a fairly easy way to get very stable values in the Red and NIR over time.

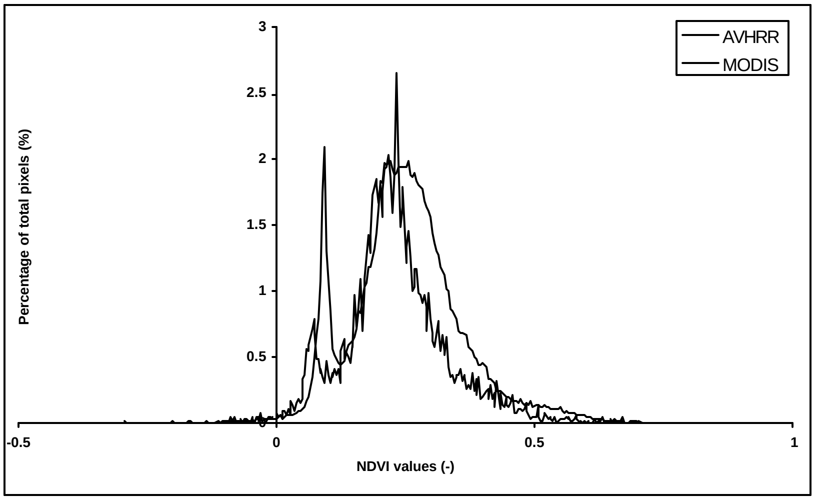


Figure 2. NDVI result of NOAA AVHRR (29-30 March 2001) with Modis for March 21 - April 06, 2001

In figure 2, the first peak (respectively at 0.094 and 0.074) are varying with the number of pixels because the MODIS pixels are more spread in values upper and lower. This type of pixel is under a thin to medium layer of water, as the values are indicating, and corresponds to the most particular geo-morphological formation of Gujarat, The Rann of Khachchh. In addition to this, some areas in The Rann of Khachchh of the MODIS image have been arbitrarily put to null by the processing software of the MODIS receiving station, it can be inferred that the area removed is regularly under water, or subject to regular radiometric artifacts.

3.3. District coverage of Gujarat

The International Water Management Institute sub-office of Anand has kindly gathered the latest information on the boundaries of Gujarat Districts, following some recent mapping updates.

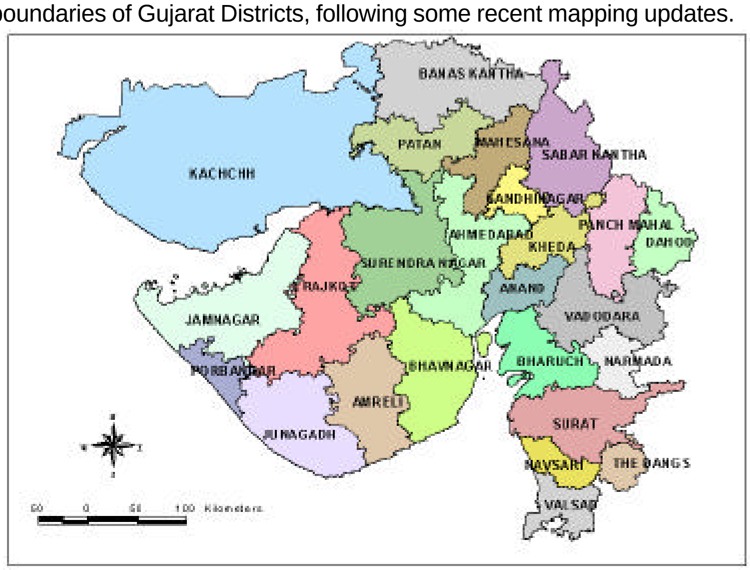


Figure 3. The districts of Gujarat

3. RESULTS

One first thinking (Fig. 4) could be that some variations of AVHRR NDVI data from one consecutive satellite overpass to the other could be due to the sun angle influence on the band-wise reflectance. It was not corrected specifically by the author like it could have been after the inversed modeling work of Privette et al. (1997) for those specific sensors for example. Even if this was not done, the images were checked as to know where the subset of Gujarat was extracted out of the whole NOAA AVHRR images.

Invariably, Gujarat was located in the middle of the path and in the centre of the axis. Finally, most of Gujarat, has a low-level slope considering the pixel size used here, and time of acquisition was regularly constant over the images, thus concluding the argument on the least effect of sun angle variations for the set of AVHRR images used in 1989.

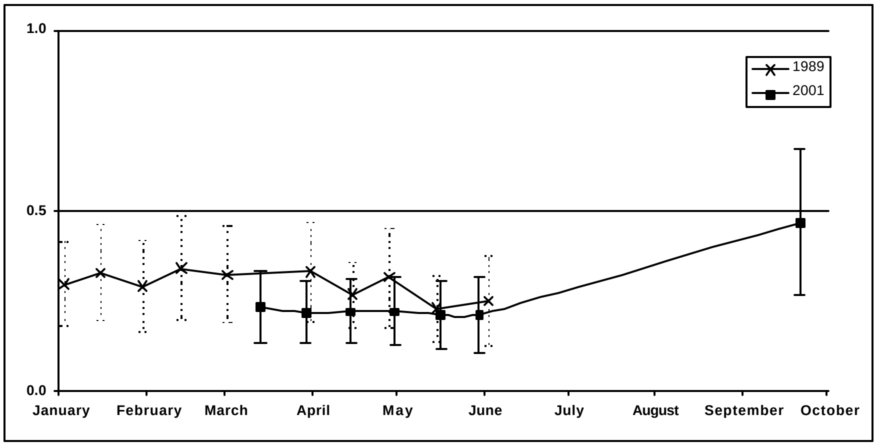


Figure 4. Gujarat mean and SD NDVI from both sources.

Two different types of districts are found by analyzing the diachronic data, the "no-variations" and the "variation" category.

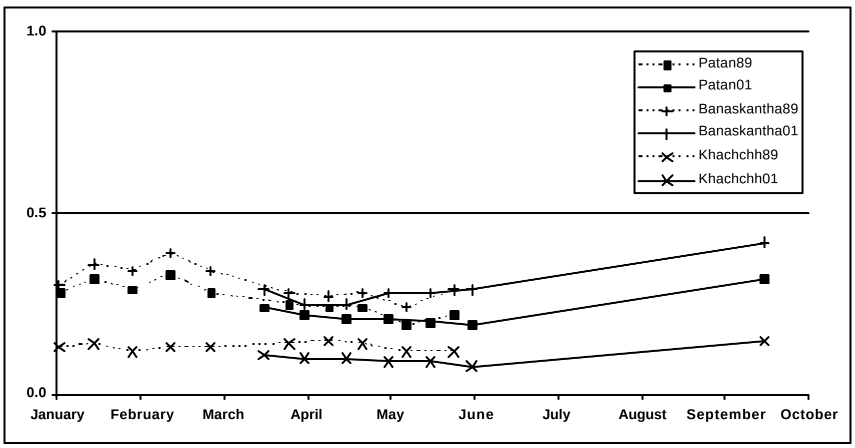
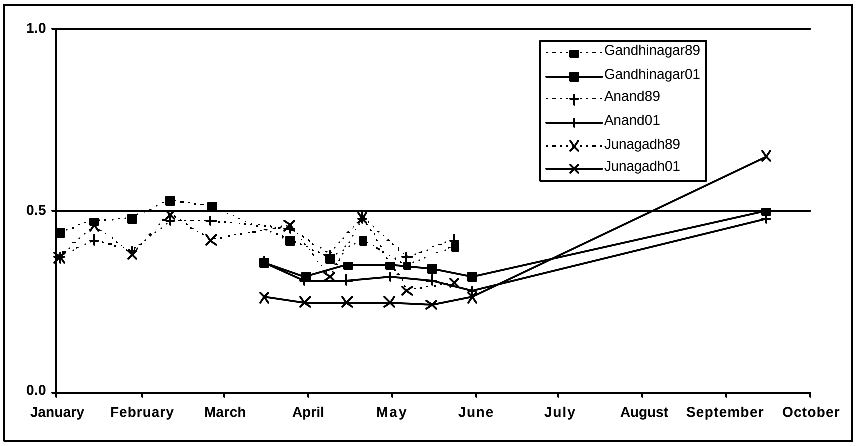


Figure 5. Districts with no variation between 1989 and 2001 (mean NDVI)

Figure 5 is bringing up the districts under low vegetation cover generally, no real variation is observed there, as most of the data curves intertwine themselves not showing differences through the 12 years' gap.



Firgure 6. Sample Districts with variations from 1989 to 2001 (mean NDVI)

On the opposite, figure 6 reveals a high level of variation in between the observed years generally, but also from one date to th e other. The later being more flagrant with the 1989 data coming from AVHRR.

4. CONCLUSIONS

This simple yet very logical peer-to-peer calibration of sensor reflectance has the potential to permit the processing of a high number of NDVI from NOAA AVHRR and compare them with the MODIS NDVI 16 days dataset. Both datasets being available on the Internet, it is giving a wide range of possibilities for environmental assessments at low cost. As it has been noticed, Modis NDVI seems more stable, but with lower va lues. It may mean that the environment is less vegetated than 12 years earlier. However, the date-to-date variations of the NOAA AVHRR images still raise concern on the atmospheric and/or systematic corrections to be applied, even if the NOAA AVHRR L1B products must have processed all the radiometric corrections necessary.

No major comments can be ascertained on the vegetation variation in Gujarat as yet. Further work would involve more image pair sets for calibration of the satellite images in order to refine the relationships quality. Questions are still to be raised on the basic assumption of this study about the equivalent result of band-wise reflectance L1B calibration between different AVHRR sensors numbers. Some future experiments within NOAA AVHRR L1B sensors numbers should bring light to the standardization quality of the resulting reflectance across Polar orbiter missions.

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