CHANGES IN THE NIGHTTIME LANDSCAPES DERIVED BY SATELLITE IMAGERY

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Abstract

In the inter-disciplinary project “Fiat Lux”, combining the work of sociologists, historians, architects and remote sensing experts, the nighttime landscape in Switzerland is analyzed. We used Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) data for analyzing cities boundaries and the their surrounding to derive the landscape. Doing this with the old analog DMSP data was a challenge. In this work we present the first results of “Changes in the nighttime landscape of Bern 1977 – 2001”.

Keywords: nighttime lights, population density, settlement boundaries, urban sprawl

INTRODUCTION

This work is part of an interdisciplinary project combining historical and sociological research with remote sensing and interpreted by architects. The National Research Programme NRP 48 “Landscapes and Habitats of the Alps” which is a programme of the Swiss National Science Foundation finances this project called “Fiat Lux”.
In the remote sensing subproject, we reconstruct the nighttime landscape for the past six decades in Switzerland.
Nighttime landscape consists mainly of light emitted from man-made illumination. Due to that fact the nighttime landscape is limited to settlements and their surroundings. In contrast to the daytime landscape the nighttime is not only spatial but also temporal, from dusk till dawn, defined. We recognize landscape as a relatively homogeneous area that differs from surroundings. The landform can include vegetation, water bodies, human-built structural elements, life forms, particularly in terms of members of fauna and wildlife communities and the perception depends on the beholders point of view. Changes in the landscape, also nighttime, effect the habitat, fauna and flora inhere. Our further goal is monitoring the changes in nighttime landscape since World War II.

At night, only the Operational Linescan System (OLS), part of the Defense Meteorological Satellite Program (DMSP), records useful data in the visible channel. Its instrument consists of two telescopes and a photo multiplier tube (PMT). The OLS records visible and infrared imagery, which are used to monitor the global distribution of clouds and cloud top temperatures during day and nighttime. The visible nighttime data was applied to map city lights and model population density. The DMSProgram started in the early 70ies. The data between 1973 and 1992 is archived on filmstrips. These data has been scanned and the geolocation is in process.
The pre-processing of the DMSP data carried out according to Elvidge et al. (1997a, 1997b, 1998, 1999). As pointed out by Elvidge et al. (1997a, 1997b, 1999), Henderson et al. (2003), Imhoff et al. (1997a, 1997b) Sutton (1997), Sutton et al. (1997, 1999a, 1999b) the illuminated area detected by DMSP nighttime imagery is useable for mapping urban areas and boundaries. Based on their findings we analyzed the time series to derive the size of settlements.

STUDY AREA

Switzerland located in the European Alps (45°50’-47°40’N, 5°50’-10°30’E), is very inhomogeneous in its altitude. The highest peaks are over 4500m a.s.l. (i.e. Dufourspitze, 4634m) and the lowest valleys (i.e. Locarno, 198m) are below 200m a.s.l. Nearly 50% of Switzerland has an elevation between 200m and 1000m a.s.l. Most cities in the Alps like Bern, Zurich or the Austrian capital Vienna are located between 200m and 500m a.s.l. Nevertheless, in higher regions are although some towns, like the well-known winter sport resort Davos (Switzerland), which is located in a valley beneath peaks elevated between 2500m and 3100m a.s.l. Most of the intramontaneous towns are, compared to the other European cities, small with a population figure under 10.000. As Switzerland is quite small and dense populated, small villages are spreading the whole cuntry. Even the alpine meadows are full with huts for pastoral use. This study is focused on Bern and its surrounding.

Bern

Bern, Swiss capital and capital of Canton Bern, is one of the bigger Swiss cities. It is located in the

Northwestern part of Switzerland (46.95°N, 7.44°E) in the hilly so-called Mittelland at an elevation around 500m. Bern is an old city founded on a peninsula in the River Aare in 1191. This old part exists nearly complete since the middle ages – a lively UNESCO world heritage. In the course of the next centuries the city expands step by step till the present-days. These steps are traceable in the townscape. Depending on the structure of the districts of Bern the illumination during night differs significantly. The old center with illuminated churches and old houses with a lot of shops and restaurants is much brighter than the outer districts. The industrial areas are in the west and the south of the city center.

METHODS

This is the first time using digitalized "old" analog and "new" digital DMSP data in one study. The data recording remained the same since the DMSP started; archiving has changed in 1992 from film to digital data. The data is described in the manual by the United States Air Force and by Elvidge et al. (1997a). Due to the automated geolocation being in progress we geolocated selected data in advance. This was done by finding ground points with known Latitude and Longitude and resample the data in ENVI. The old data processing was done according to the new data processing. The city centres are the points of origin for deriving the nighttime landscape by isoradiances. The digital data processing is described in detail by Maus and Wunderle (2004). The old data differs after scanning from the new data being stretched to 8bit data. Thus the maximum digital number (DN) is 255 and the structure changed.

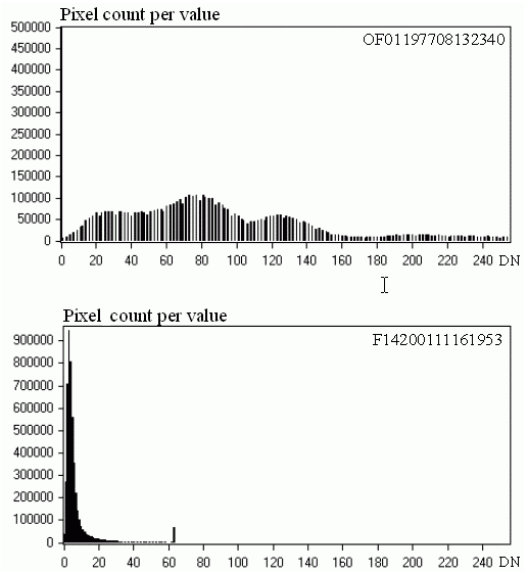

Figure 1. Pixel count per value, differing old and new DMSP data, top: 1977, DN0 – DN255, reduced to 500000 counts, bottom: 2001, DN0 – DN63, peak at DN63

Figure 1 shows two histograms with pixel values and DN. The typical peak at DN63 is missing in the old data. The landscape deriving process using thresholds depending on the mean adapts to that automatically. The fixed bottom threshold was set to DN60.

RESULTS AND ANALYSIS

The following figures show Bern's nighttime landscape in 1977 and 20 years later in 1997. The later data was analyzed first. Processing the old data is in progress.

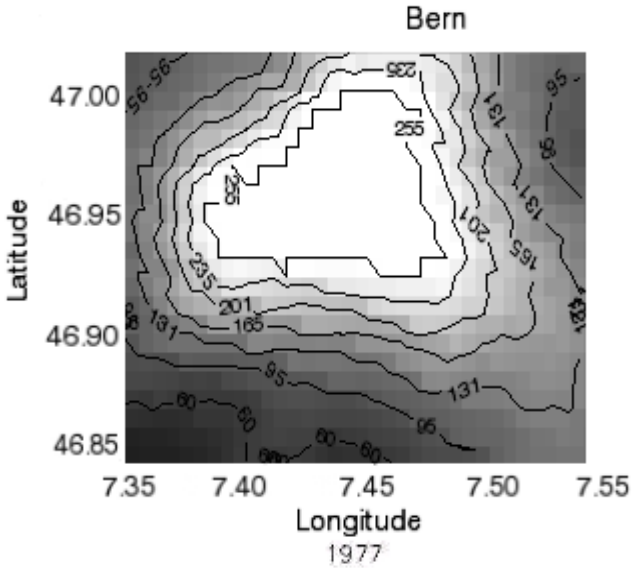

Figure 2. Bern, Isoradiances, 1977

Figure 2 shows an early DMSP image subset with isoradiances around Bern. This is the first attempt using a process - landscape designation - developed for standard data in old DMSP data.
The calculated threshold varies between DN60 and DN255.

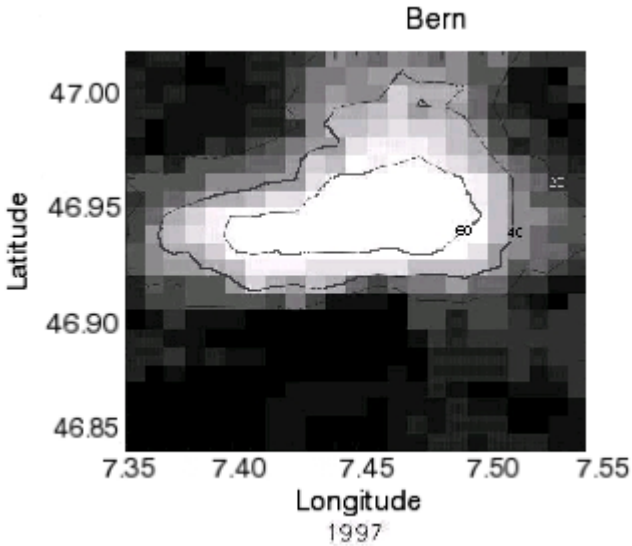

Figure 3. Bern, Isoradiances, 1997

The settlement structures found in and around Bern in 1997 are shown in Figure 3. The city center is lit most. Here the calculated threshold varied between DN61 und DN63. This characterizes Bern as a quite big and constant lit city (compare Maus and Wunderle, 2004).

DISCUSSION AND CONCLUSIONS

Working with former analog satellite data means a challenge. Many difficulties have to be solved. Bern occurs in 1977 more lit as in 1997. This ought to be wrong. We are going to calculate year means to solve this later this year. The bottom threshold at DN60 needs further adjustment.
Due to be in the beginning of this process we can't give many conclusions by know. The authors are open for questions and suggestions (see address at top).

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