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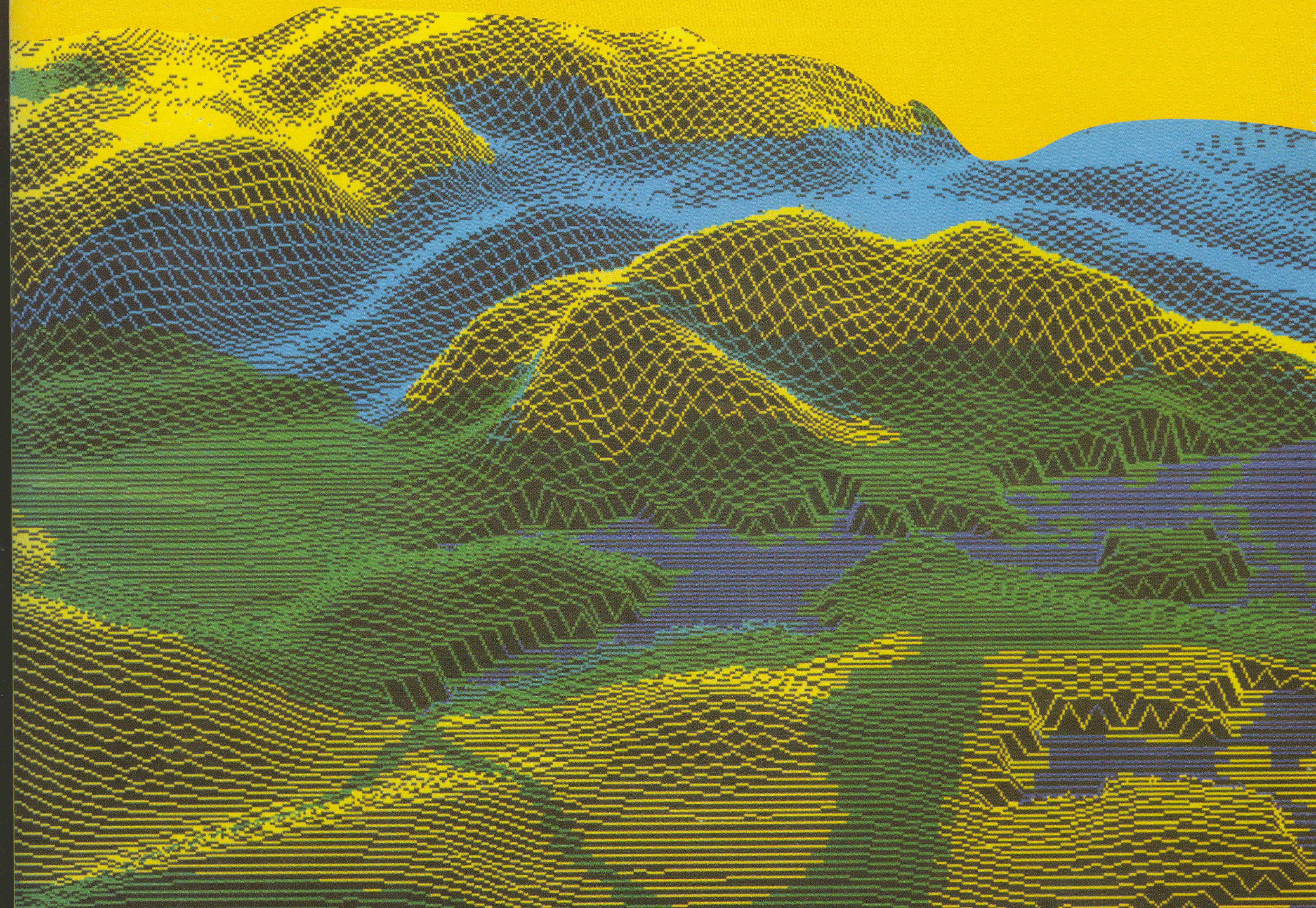

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SOME REMARKS ON DIGITAL MAP PREPARATION

Helmut Beissmann

1. Introduction

At the Institute of Information Processing of the Austrian Academy of Sciences, Department of Spatial Information Processing (former Institute of Cartography) the attempt was made to prepare digital information from Geographical Information Systems for printing with offset lithography. One of the main obstacles within the used low cost computing environment were severe differences in colors seen on a monitor and on color-proofs or prints. This problem concerns especially the reproduction of satellite image maps where the combination of three spectral bands displayed in 256 intensity levels of red, green, and blue produces theoretically 16.7 mill. different colors. In the past, these kind of images have been exposed to color positive film and then prepared like any other photograph for printing (BUCHROITHNER, 1987). The first aim was therefore the production of process color separation halftone screens from the digital GIS data within a PC environment using more or less standard software packages (BEISSMANN, 1994). This project was funded by the municipal authorities of Vienna.

Two examples from our very beginning of digital map preparation are enclosed to this article. We named the resulting products GISMAP because the printed maps are also available in digital form within a Geographical Information System. From this starting point up to now some new ideas had to be realized to meet the needs of some other projects, e.g.:

- the combination of raster and vector graphics, images, and manual fair drafts;
- the placement of names and symbols;
- the organization in layers - that means all themes are treated like hierarchical transparencies in a certain order of succession which determines the visibility or non-visibility of their graphical representation;
- the use of a color calibration tool for the "high fidelity" simulation of the printed colors on a monitor.

Now a GISMAP typically consists of one or more raster images combined with linear features and text in vector format and can therefore be called an "image-line map".

2. Description of enclosed GISMAP Examples

The **Multisensor Image Map of Vienna** (Appendix No.1) using Landsat-TM and SPOT-HRV data was the first attempt to solve the color problem. The data sources were bands 1, 2, and 3 of the Landsat/Thematic Mapper image from 2nd June 1984 with a ground resolution of 30 x 30 m and the SPOT/HRV image from 20th April 1988 with a ground resolution of 10 x 10 m. Both images had been rectified and resampled to a uniform ground resolution of 10 x 10 m which corresponds to a resolution of 0,1 mm in the map scale of 1:100.000. The digitally enhanced color composite from the 3 TM bands (band 3 in red, band 2 in green, and band 1 in blue - RGB color model) was transformed into the IHS (intensity-hue-saturation) color model. The intensity information was replaced with the slightly modified panchromatic band from SPOT and then transformed back into the RGB model. Frame, grid, legend, and text annotations have been added with commercial standard software (Corel Draw). At that time it was necessary for the typesetting process to rasterize all these elements for the a priori selected map resolution of 0,1 mm. This resulted in a rather poor quality of the printed text and was changed in the next GISMAP versions.

For the production of the **Map of Surface-Temperatures of Vienna**, (Appendix No.2) which belongs also to the first GISMAP-generation, the data source was band 6 (Thermal Infrared) of the Landsat/Thematic Mapper image from 2nd June 1984. The radiometric measurements of temperature recorded by the satellite depend on the heat radiation and emission capacity of a surface as well as the absorption and emission capacities of solid, fluid, and gaseous particles in the air between the surface and the measuring devices of the satellite. This leads to variations in the measured values; there is until now no fully satisfactory method for correcting these variations. It should also be noted that surface temperatures have to differ substantially from the ambient air temperature (as measured in a standardized cabin at 2 m above ground). The recording of surface temperatures of large areas by satellite permits the formulation of new research questions.

For the correction of Vienna's surface temperatures the calibration method of R.G. LATHROP and T.M. LILLESAND, 1987 was used. This method is particularly useful when the focus of interest is not the precise surface temperatures of an object but rather the relative differences of their spatial distribution. The temperatures computed in degrees Celsius were filtered digitally according to their spatial frequencies (which produces a smoothing effect), then pseudo-color, frame, grid, legend and text were added.

Of the manifold possibilities of interpretation we would like to mention only the influence of different land uses on the local climate on a typical day at the height of summer. Twelve different classes of land use have been derived by classification of the Thematic Mapper image, interpretation of airborne imagery and field mapping. Some classes are relatively homogeneous and easily discernible, while others are rather inhomogenous and strongly interrelated (i.e. a loosely built-up area intermixed with parks). Thus the new housing areas on Vienna's periphery were classified as "loosely built-up" because their relatively high population density is offset by the intermixing of parks and garden areas. The surface temperatures indicate that these green areas have indeed an adequate beneficial effect on the local climate. Densely built-up areas, large objects such as industrial plants or roads and squares, as well as construction sites can be localized as hot spots. Harvested agricultural areas are characterized by a negative thermal effect; beneficial thermal effects are provided by areas covered with vegetation, forests, and bodies of water.

The thermal image permits even the evaluation of the effect on the local climate of inner-city parks. Their size and make-up has a significant impact on the difference of temperature in comparison to the surrounding built-up areas. Differences of 5° C and more cause the development of a local wind system which results in the local exchange of warm and dry with cool and humid air; thus the higher humidity of the park is carried into surrounding built-up area.

3. Preparation for color printing

The next step within the preparation process for printing for both maps was the conversion from the digital working environment of map preparation - including the visualization on a computer monitor with the underlying additive RGB color model - into the working environment of offset lithography using the subtractive color model. Some more details are given in this paragraph.

The visible spectrum contains about 10 mill. discernible colors. Only about 1.2 mill. colors are surface colors; 48 % of these can be printed using 4 process colors. If 7 process colors are allowed the quota rises to 57 % (SCHLÄPFER, 1993). Every device for producing a color illustration reproduces a different range of color which is called the "gamut" of the device. It should be noted that it is impossible to get the same colors in print exactly as seen on the monitor. When "true" color prints of an image are required it is necessary to consider a lot of influences and to perform extensive calibrations so that acceptable fidelity is obtained. In 1931, an effort was made by the Commission Internationale de l'Eclairage (CIE) to build a model defining the range of visible colors. The so-called chromaticity diagram is a two-dimensional plot with a third axis, the luminance, which corresponds to the panchromatic brightness. The other two primaries, called x and y, are always positive and combine to define any color - omitting individual and subjective variations - a so-called standard observer can see. One of the drawbacks of the CIE diagram is that it does not indicate the variation in color that can be discerned by the eye. Sometimes this is shown by plotting a series of ellipses (instead of circles) on the diagram.

The original model and the underlying colorimetric relationships expressed in mathematical terms have been modified several times. In 1967 the CIE L*a*b model was developed which serves as an internationally used device independent reference model. "L" describes a luminance or brightness component whereas "a" (reaching from green to red) and "b" (reaching from blue to yellow) describe chromatic components. The conversion between different color spaces usually is done by means of lookup tables which are also provided in several commercial software packages such as Adobe Photoshop.

Video technology uses three color phosphors (RGB) to generate a very large fraction of the total range of colors that the human eye can see. The colors are simulated by the combination of varying intensities of the three wavelengths. The "missing colors" that cannot be generated using these particular phosphors include the most saturated colors, also pure cyan or yellow cannot be displayed correctly on a monitor. Variations between devices may be caused by influences of mask or phosphors; thus, even within one individual device, color representation can vary. The natural aging process of the phosphor coating of the monitor and external factors, such as changes in temperature, affects the colors displayed on the screen over time.

As the CIE standard allows reference to the wavelength of colors, a spectrophotometric calibration of computer displays is possible. A calibration tool allows color-calibrating the graphics system by means of an electronic sensor which is attached with a suction cup to the monitor screen. The calibration software evaluates the data measured by the sensor and accordingly calibrates the hardware (color temperature, system gamma, ambient lighting conditions). Considering a lot of some other parameters like type of inks used for printing, paper quality and finish, half tone dot gain of the used printing press and many more, it is possible to simulate the printed colors on the monitor.

Printing uses the subtractive color mixture by deposing several color inks on paper. These inks absorb and reflect light - we perceive the reflected light as different colors. To guarantee the printing of a considerable high amount of colors with a tolerable amount of economic expense, usually three or four standardized printing inks (cyan - C, magenta - M, yellow - Y, black - K) are used and called process-colors. Except for dye-sublimation technology continuous-tone images have to be broken up (separated) for printing into varying sized dots for each process color and any spot color ink. The pattern of dots is called a halftone screen; by printing overlapping dots the possible range of colors is simulated. In terms of the subtractive color space the blank paper starts off as non-ideal white and the addition of inks removes the complementary colors from the reflected light. To create blue for example, cyan (which absorbs red and reflects blue and green) and magenta (which absorbs green and reflects blue and red) dots are combined. The human eye merges the dots to perceive the color blue, which has very little in common with the blue displayed on a monitor. Using standardized cyan, magenta and yellow ink a large portion of the color space is omitted, causing a small gamut of mostly rather unsaturated colors. Especially blue and purple hues are represented rather unsatisfactorily. In fact, this is one of the major problems with color printing, which has difficulty producing strong, vibrant colors. Non-printable colors have to be transformed (usually by reduction of saturation) for printing.

In addition, the colors depend critically on a lot of parameters:

- *Viewing conditions*: Changing the room light will slightly alter the visual appearance of colors on a RGB monitor, but because the monitor is generating its own illumination this is a secondary effect. Since a print is viewed by reflected light only, changing the amount or color temperature of room light can completely alter the appearance of the image. The color temperatures of incandescent bulbs, fluorescent bulbs, direct sunlight, or open sky are all quite different. It is necessary to select for the display on monitor the color temperature and the brightness of the light source which normally illuminates the printout.

- *Black generation:* The mixture of all three colors (CMY) cannot produce a very good black, but instead gives a muddy grayish brown. The most common solution is to add a separate, black ink (K) to the printing process. This reduces the need for large amounts of colored inks, the thickness of ink buildup on the page and it allows dark colors to be printed without appearing muddy. Rules to calculate how much black to put into various color representations depend mainly on visual response to colors, the kind of paper to be printed, the illumination the print will be viewed with, and even the contents of the image. Algorithms for converting from CMY to CMYK specify levels of undercolor removal (UCR) and gray component replacement (GCR) which are essentially arbitrary, little documented and vary considerably from one software program to another. The general approach is to use the darkest value of the three components to determine the amount of black to be added. It is difficult to design algorithms for these substitutions that do not cause color shifts. Also, the substitutions do not work equally well for printing with different combinations of ink, paper finish, etc.
- *Total ink limit:* The addition of black ink to CMY may cause the problem that there can be too much ink on the page. Depending on the paper quality, the printing press, and many other influencing factors, the recommendations for the maximum ink coverage differ between 180 % to 320 % so that the paper does not become oversaturated and stretch or tear. Otherwise multicolor jobs tend to print out of register. This would cause three problems: slight gaps between overlapping colors, moiré patterns and color shifts. To minimize the effects of misregistration adjacent colors are slightly overprinted (trapping).
- *Halftone dot gain:* The overall quality of the print is also influenced by the halftone dot gain. One problem could be a miscalibrated image setter, but many other processes affect the size of printed halftone dots. Typically, dots increase in size during printing. If to much dot gain occurs, images plug up and colors print darker than specified. As the dot gain differs between the process colors gray balance can be lost. It is important to know the behavior of paper and printing press to correct this effect within the digital data in advance.

It is not only color which needs to be considered as a challenge within the production process of a GISMAP. In fact, one has to consider some more influencing factors:

- *Screen ruling:* The decision for a certain screen ruling (also called halftone or screen frequency, halftone cell) defines the size of the halftone cells that make up the printed image. Screen ruling is measured in lines per inch or the number of halftone dots in a row one inch long. A high screen ruling prints the dots close together creating sharp distinct colors and images. A low screen ruling prints the dots farther apart, creating a coarser effect. Because different types of paper absorb ink differently, the characteristics of paper and printing press determine the screen ruling to be used; for the GISMAP example it was 60 lines per cm (152 lpi).
- *Screen angle:* The halftone screen for each process color ink is printed at a specific angle so that the ink dots do not print on top of each other. They form a symmetrical pattern, called a rosette pattern, which the human eye merges into smooth color gradations. If the rosette pattern is not printed correctly, a so-called moiré pattern appears which disrupts the perception of smooth color gradations. But even ideal screen angles cause some of the dots to be superimposed on each other. Since some inks are partially transparent, this can produce various color biases depending on the order of printing. Several screening technology solutions address this problem. New developments in this area, especially the frequency-modulated screening solutions, promise better results.
- *Resolution of image setter:* The resolution of the image setter is the number of tiny black dots that can be deposited on film to form halftone dots, characters and lines. Within this halftone cell, some or all of the dots may actually be printed. Where no dot is printed, the paper shows through. If the cell is reasonably small, the observer will

not see the individual dots but will instead visually average the amount of dark ink and light paper to form a grayscale or process color. To print a visually convincing halftone image it is necessary to print more than 140 shades of gray (color) so that the halftone cell is composed by an array of 12 x 12 image setter dots in the minimum. Generally, the rule for the maximum number of grayscales available is (printer resolution/screen ruling)2 + 1. The resolution of a professional image setter is required to be 2540 dpi or more. This resolution causes a screen ruling of only 158 dpi when halftone dots with 256 gradations (16 x 16 array) are exposed.

- *Scan resolution:* The last factor mentioned here influencing the preparation for printing is the required resolution for scanning the image to be printed. The rule for the desired scanning resolution is screen ruling x 2 to 2.5 if the image will not be resized. As mentioned above, the resolution of the GISMAPs is 100 dots per cm. Following the rule it should have been 120 to 150 dots per cm to receive the best possible quality.

4. Concluding remarks

As described, the enclosed GISMAPs of the first generation have been our starting point of digital map preparation, which is not a kind of desktop mapping system but suitable for the preparation of image-line maps. Many of the mentioned problems have been solved in expensive commercial systems some time ago. The low cost computing environment we used was occasionally a limiting factor because it was often necessary to find a compromise between available disk space, memory and achieved quality in printing. At present, most of the necessary software tools are offered by commercial packages. The described way of map production should be applicable for anyone who is interested in; nevertheless, we think that satisfactory results cannot be achieved without a certain level of personal experience.

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GISMAP* WIEN

Multisensorbildkarte

Landsat-TM / SPOT-HRV

- Dicht verbaut
- Locker verbaut
- Landwirtschaftliche Nutzfläche
- Wiese
- Wald
- Gewässer

Herstellung der Multisensorbildkarte Wien:
Als Datenquellen dienten digitale Satellitenbilder von Landsat/Thematic Mapper (Spektralkanäle: 1 in Blau, 2 in Grün und 3 in Rot dargestellt, Grundauflösung 30 x 30 m, Aufnahmedatum 2. 6. 1984) und von SPOT/HRV (panchromatischer Spektralkanal, Grundauflösung 10 x 10 m, Aufnahmedatum 20. 4. 1988). Die Farbinformation der 3 Spektralkanäle von Thematic Mapper wurde lasierend über den panchromatischen Kanal von SPOT gelegt, um die Vorteile der Farbinformation mit denen der höheren Grundauflösung zu kombinieren. Dazu erfolgte während der geometrischen Rektifikation auf das Gauß-Krüger-Netz eine Angleichung auf die einheitliche Grundauflösung von 10 x 10 m.

Danach wurden die 3 Spektralkanäle von Thematic Mapper von der Darstellung im Rot-Grün-Blau (RGB)-Farbsystem in das Intensity-Hue-Saturation (IHS)-Farbsystem transformiert. In diesem System wird jede Farbe durch ihre Helligkeit (Intensity), ihren Farbton (Hue) und ihre Sättigung (Saturation) festgelegt. Nach dem Ersetzen oder der Modifikation der Intensität durch den panchromatischen Kanal von SPOT erfolgte die Rücktransformation in das RGB-Farbsystem.

Diese so entstandene Multisensorbildkarte wurde mit Methoden der digitalen Bildverarbeitung optimiert und digital mit Rahmen, Gitternetz, Legende und Beschriftung versehen.

Die zur Visualisierung auf einem Farbbildschirm abgestimmte Bildkarte wurde mit Methoden der digitalen Reproduktionstechnik für die Farbseparation und den anschließenden Offsetdruck mit Normdruckfarben aufbereitet. Dabei muß besonders beachtet werden, daß nur ein Teil der am Farbbildschirm darstellbaren Farben druckbar ist, da die Druckfarben mangelnde Hauptabsorption und relativ hohe Nebenabsorptionen aufweisen.
Zur Lösung dieser Probleme wurde die Farbinformation der Bildkarte in das CIE-Farbsystem (Commission Internationale de l'Eclairage) transformiert und auf den Bereich der druckbaren Farben eingeschränkt. So war es möglich, die Druckfarben am Farbbildschirm zu simulieren und zu modifizieren.

* GISMAP ist das kartographische Endprodukt von verschiedenen am Institut für Kartographie der Österreichischen Akademie der Wissenschaften eingesetzten Methoden zur Verwaltung, Auswertung und Darstellung digitaler, raumbezogener Informationen. Die als GISMAP in analoger Form gedruckten Kartenthemen sind auch in digitaler Form als geographisches Informationssystem verfügbar.

Herstellung am Institut für Kartographie der Österreichischen Akademie der Wissenschaften von H. Beissmann (digitale Bildverarbeitung und Reproduktionstechnik), R. Hengsberger (digitale Bearbeitung) und Ch. Hsu (kartographische Bearbeitung).

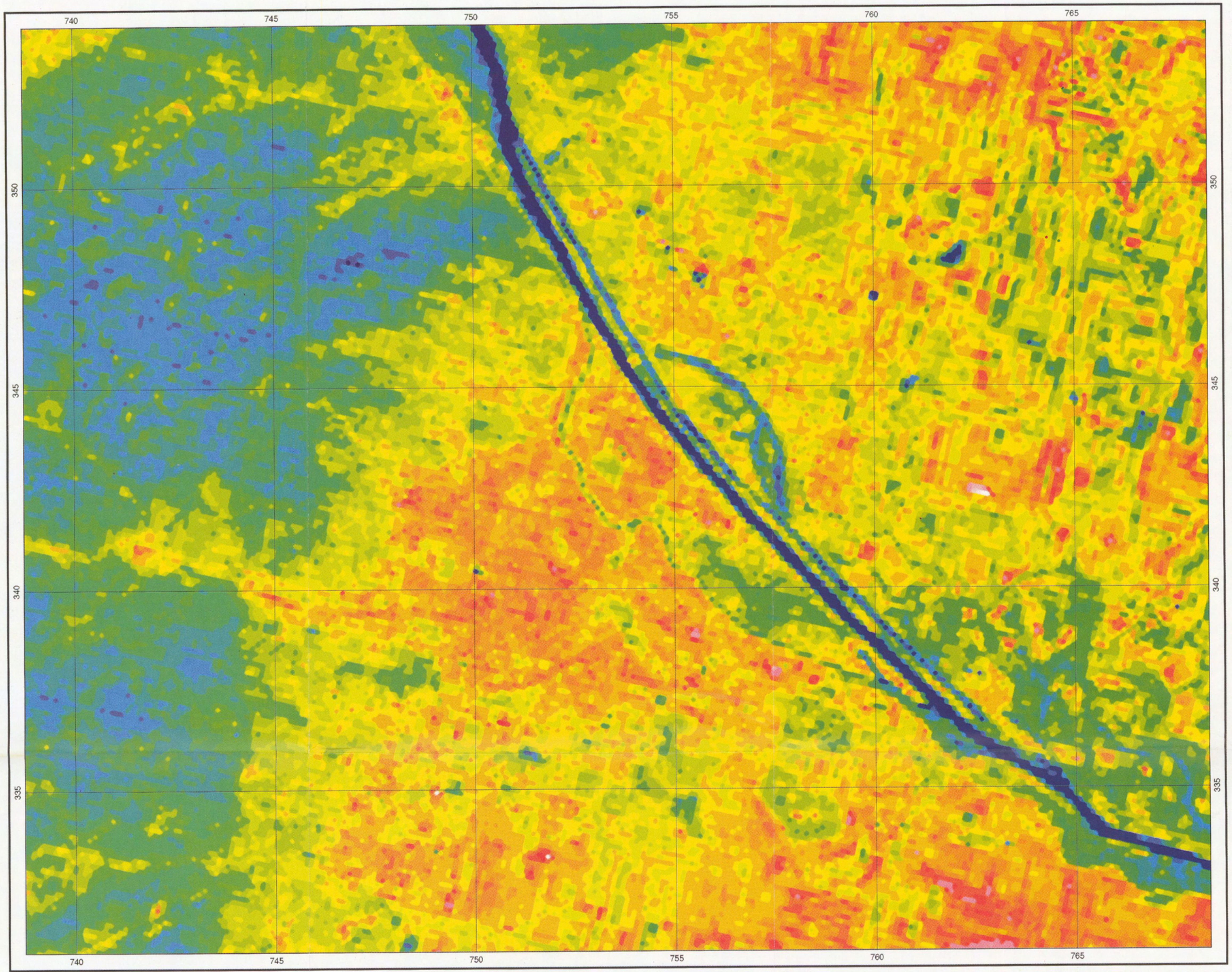
Maßstab 1:100 000

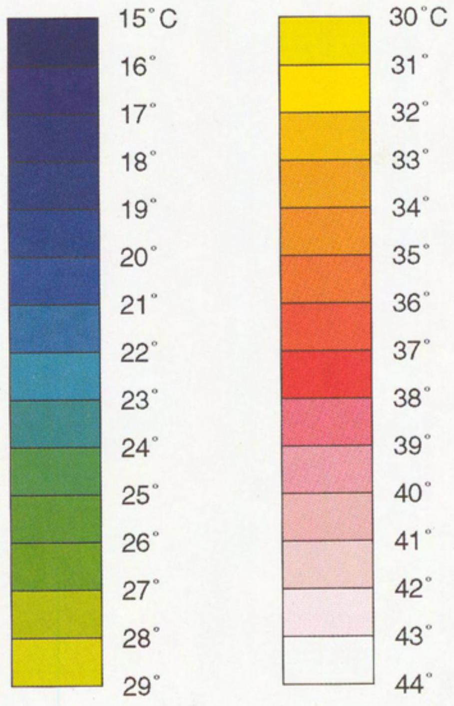
0 1 2 3 4 5 km

Wien, 1993

GISMAP* WIEN

Karte der Oberflächen-temperaturen





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Maßstab 1:100 000

0 1 2 3 4 5 km

Herstellung der Oberflächentemperaturenkarte von Wien:
Als Datenquelle diente der Kanal 6 (thermisches Infrarot) des digitalen Satellitenbildes von Landsat/Thematic Mapper (Grundauflösung 120 x 120 m, Aufnahmedatum 2. 6. 1984). Die am Satelliten aufgezeichneten radiometrischen Temperaturmeßwerte hängen von der Wärmestrahlung und dem Emissionsvermögen einer Oberfläche, aber unter anderem auch vom Absorptions- und Emissionsvermögen von festen, flüssigen und gasförmigen Teilchen der Luftschicht zwischen der zu messenden Oberfläche und der Meßvorrichtung am Satelliten ab. Diese Effekte bedingen Meßwertverschiebungen, deren Korrektur bis jetzt erst teilweise gelungen ist. Es ist noch darauf hinzuweisen, daß die Temperaturen von Oberflächen erheblich von der Lufttemperatur (gemessen in 2 m Höhe in einer Wetterhütte) abweichen müssen. Die flächenhafte Erfassung von Oberflächentemperaturen durch den Satelliten ermöglicht die Bearbeitung neuer Fragestellungen.
Für die Korrektur der Oberflächentemperaturen von Wien wurde die Kalibrierungsmethode von R.G. Lathrop und T. M. Lillesand (In: Remote Sensing of Environment 22, 1987. S. 297-305) angewendet. Diese ist vor allem dann zweckdienlich, wenn nicht die genauen Oberflächentemperaturen eines Objektes, sondern die relativen Unterschiede in ihrer räumlichen Verteilung von Interesse sind. Die in Grad Celsius berechneten Temperaturen wurden digital hinsichtlich ihrer Ortsfrequenz gefiltert (dies entspricht einem Weichzeicheneffekt), gefärbt, mit Rahmen, Gitternetz, Legende und Beschriftung versehen, und schließlich mit Methoden der digitalen Reproduktionstechnik für den Offsetdruck mit Normdruckfarben aufbereitet.
Von den vielfältigen Interpretationsmöglichkeiten soll hier nur die Untersuchung lokalklimatischer Wirkungen der verschiedenen Klassen der Landnutzung erwähnt werden. So verbessert z.B. eine Grünfläche erst dann auch das Lokalklima ihrer verbauten Umgebung, wenn durch eine genügend hohe Temperaturdifferenz zwischen diesen Gebieten ein lokaler Austausch von warmer/trockener und kühler/feuchter Luft verursacht wird.

Wien, 1993