Use of USGS Land Cover Data as an Alternative to the Auer Land Use Analysis for Air Dispersion Modeling

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BACKGROUND

In 40 CFR Part 51, Appendix W (Guideline on Air Quality Models) the U.S. Environmental Protection Agency (EPA) recommends procedures for determining whether urban or rural dispersion coefficients should be used in air dispersion modeling. The primary method for this analysis is the Land Use Procedure which involves:

1) Classifying the land use within the total area (A_0) circumscribed by a 3 kilometer (km) radius circle about the emission source using the meteorological land use typing scheme proposed by Auer (Auer 1978); and

2) If land use types I1, I2, C1, R2, and R3 account for 50 percent or more of A_0, urban dispersion coefficients should be used; otherwise, appropriate rural dispersion coefficients should be used. The specified urban land use types include industrial, commercial, and residential land uses.

A second method, the Population Density Procedure, is also recommended, but of the two methods, the land use method is considered more definitive.

This paper presents a proposed alternative to the Auer land use analysis (Auer 1978) for determining whether rural or urban dispersion coefficients should be used in an air modeling analysis. The proposed alternative simplifies the analysis, and should provide more consistent and accurate determinations of urban and rural land use densities and associated meteorological effects.

There are no current standard references, such as land use or land cover maps, for mapping Auer land use categories. Although the criteria of the Auer system are objective, applying these criteria to an analysis may be quite subjective depending on the level of effort and judgments that are employed to identify specific land uses. This paper recommends using a standard reference, such as U.S. Geological Survey (USGS) land cover maps to eliminate some of the subjectivity that may occur during this analysis.

The methods described in this paper may not be currently approved by any regulatory agency, and it is recommended to include a description of this method within a modeling protocol prior to submitting results that have incorporated a land use analysis based on USGS data.

ANALYSIS

Land Use/Cover Criteria Comparison

The Auer land use categories were defined in the original St. Louis study (Auer 1978). These categories are defined by the amount of vegetative cover within each category. The Auer study included 12 categories of which five (I1, I2, C1, R2, and R3) were defined as urban categories.

The USGS National Land Cover Database 2011 (NLCD2011) data (USGS 2014b) were selected to be compared to the Auer land use data. These USGS data include 14 categories of land cover for the St. Louis area. Of these categories, two (23 and 24) were determined to be comparable to the Auer urban categories

Table 1 presents the Auer urban land use categories and the USGS land use categories that are assumed to be similar to the Auer categories. This table also includes the USGS category 31 that is not accounted for in the Auer categories. All the other Auer categories include a minimum of 70 percent vegetation cover.

These correlations are based on vegetation percentages for the Auer categories and percent of impervious surfaces for the USGS categories that would lack vegetative cover. In other words, the balance of land cover not included in impervious surfaces was assumed to represent vegetative cover.

Table 1

Auer and USGS Urban Land Use/Cover Category Comparison

Auer Land Use Categories	USGS Land Cover Categories
I1: Heavy Industrial - Major chemical, steel, and fabrication industries; general 3-5 story buildings, flat roofs. Grass and tree growth extremely rare; vegetation less than 5 percent	24: Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.
I2: Light-Moderate Industrial - Rail yard, truck depots, warehouses, industrial parks, minor fabrications; generally 1-3 story buildings, flat roofs. Very limited grass, trees almost absent; vegetation less than 5 percent	
C1: Commercial - Office and apartment buildings, hotels; greater than 10 story heights, flat roofs. Limited grass and trees; vegetation less than 15 percent	

Table 1
Auer and USGS Urban Land Use/Cover Category Comparison

Auer Land Use Categories	USGS Land Cover Categories
R2: Compact Residential - Single, some multiple, family dwelling with close spacing; generally less than 2 story, pitched roof structures; garages via alley, no driveways. Limited lawn sizes and shade trees; vegetation less than 30 percent R3: Compact Residential - Old multi-family dwellings with close (less than 2 m) lateral separation; generally 2 story, flat roof structures; garages (via alley) and ashpits, no driveways. Limited lawn sizes, old established shade trees; vegetation less than 35 percent	23: Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover. These areas most commonly include single-family housing units.
No Category	31: Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.

Original Auer Land Use Analysis

In 1978 Auer published his proposed land use classification system based on a study of the St. Louis area. This system was to be used to identify "meteorologically significant" land uses that would help define thermodynamic, kinematic, and radiative anomalies associated with urban areas.

Figure 1 presents a 40 by 40 km area from the original Auer analysis. The areas highlighted in yellow represent the Auer urban classifications I1, I2, C1, R2, and R3.

For the area shown on this map, the areas defined by Auer as urban are 12.9 percent of this area.

USGS Land Cover Analysis

Figure 2 shows the same area as Figure 1 with the USGS urban land cover categories. The concentrations of red show the highly developed urban areas. The area covered by USGS NLCD2011 categories 23 and 24 represent 21.1 percent of the map area.

Figure 3 shows this same map overlaid with the Auer urban land use areas. This figure shows a high correlation between the Auer and USGS urban areas. This map also shows some significant differences from the original Auer analysis:

- Urban corridors between highly developed areas within this area were not included in the Auer analysis, and

- Additional urban development has occurred since the original Auer analysis.

As shown on Table 1, the maximum vegetative cover in the Auer system is 35 percent. The USGS system includes non-impervious cover up to 50 percent within category 23 (the light red areas on figures 2 and 3). This may represent a slightly higher urban density than would be represented the Auer categories, but a review of infrared imagery for this area, suggests that USGS categories 23 and 24 may both be correlated to thermal anomalies.

Infrared Imagery Analysis

Figure 4 demonstrates the correlation between potential meteorological anomalies and the USGS urban categories 23 and 24. This figure shows a thermal infrared map for the St. Louis study area that was developed from USGS Global Land Survey (GLS2010) data (USGS 2014a). These data represent the period from 2008 through 2011. The white areas represent areas of higher surface temperatures, and the areas of higher temperature correlate well with the selected USGS urban areas in Figures 2 and 3. The original Auer urban land use areas have also been added to this map for additional reference.

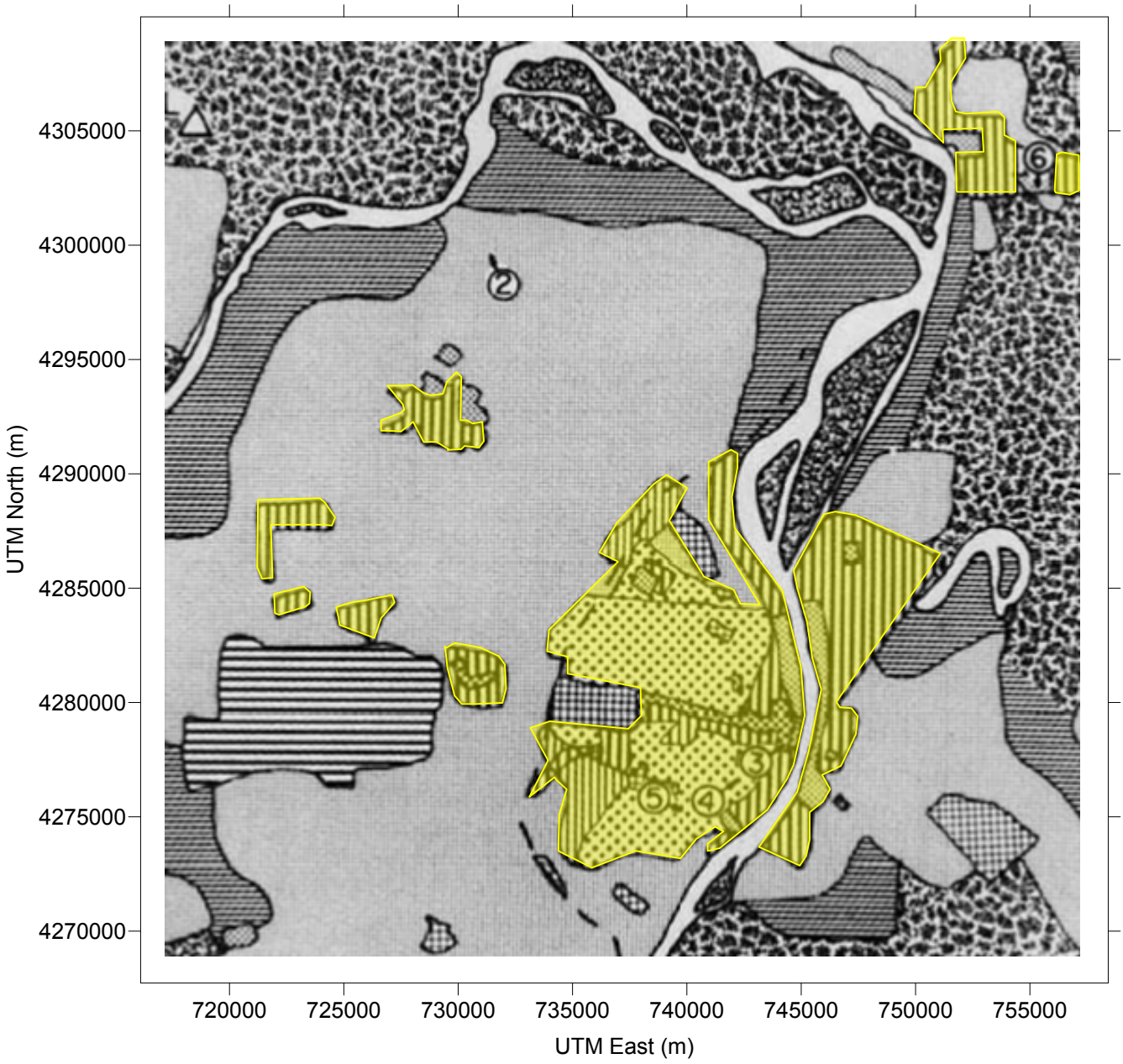


Figure 1
Auer 1978 Land Use Map
of St. Louis Area

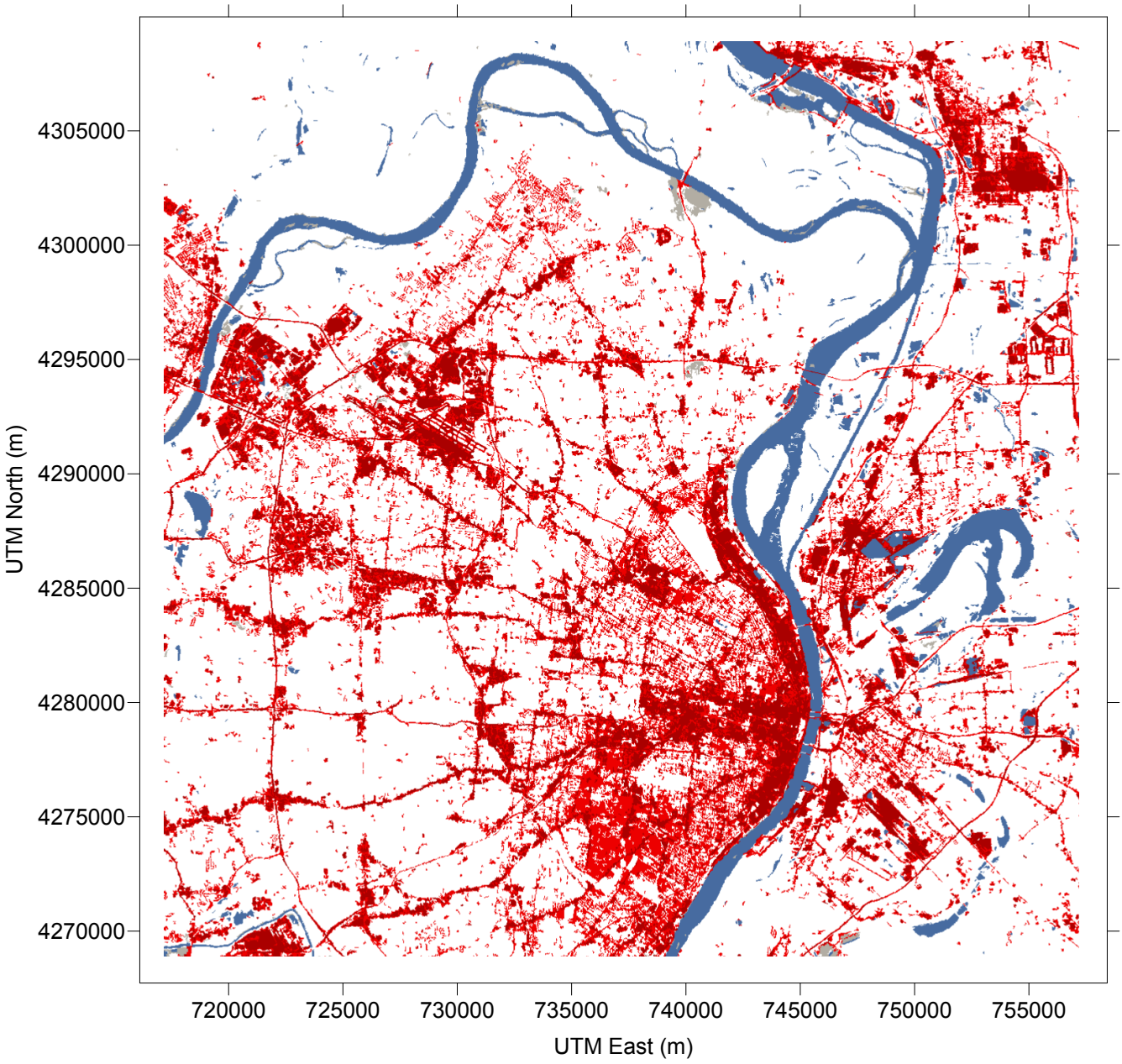
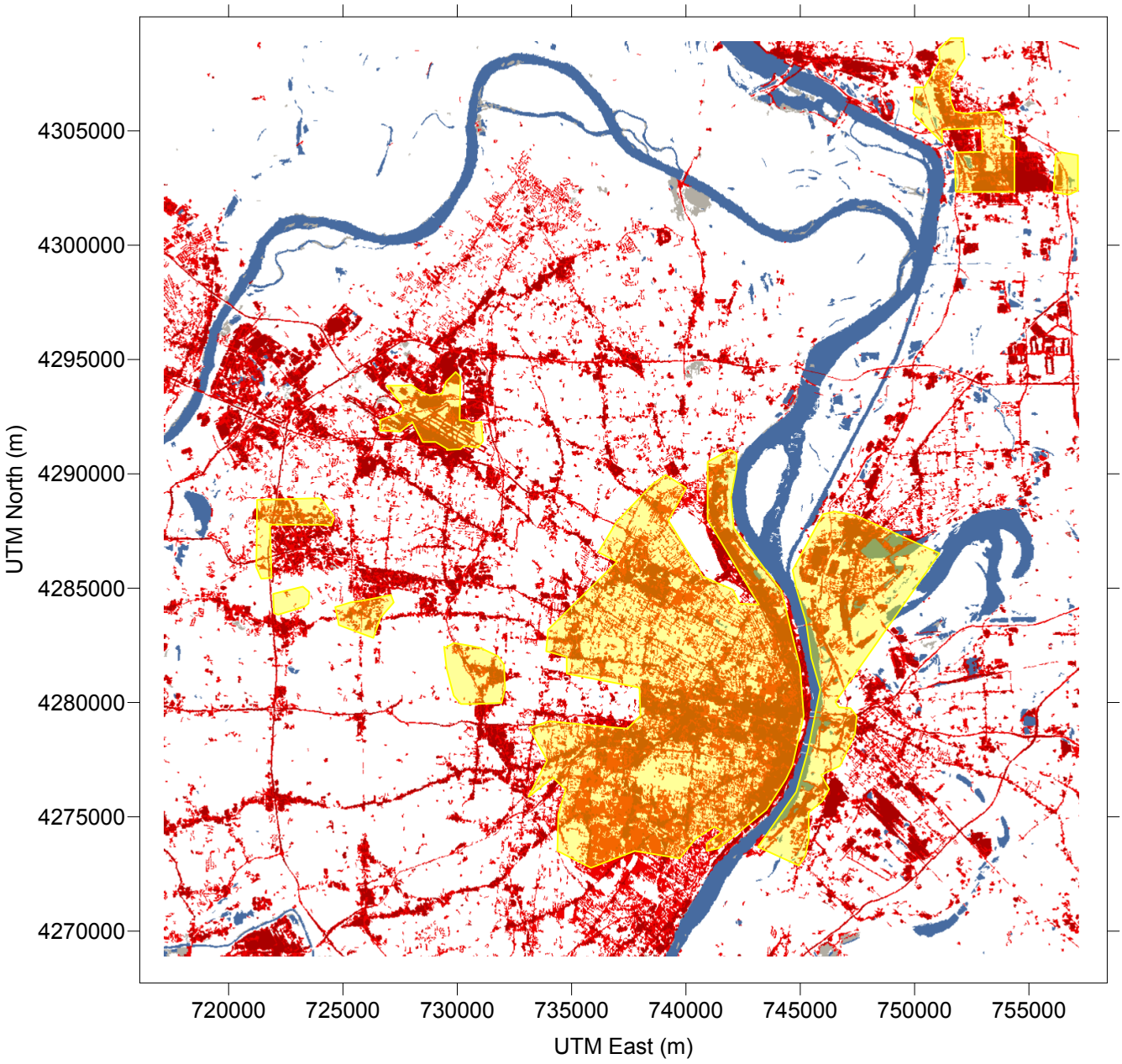


Figure 2
USGS 2011 Land Cover
Map of St. Louis Area



USGS Category 23 Areas - 2012

USGS Category 24 Areas - 2012

Auer Urban (I1, I2, C1, R2, and R3) Areas - 1978

Figure 3
USGS Land Cover Map
with Auer Land Use Overlay

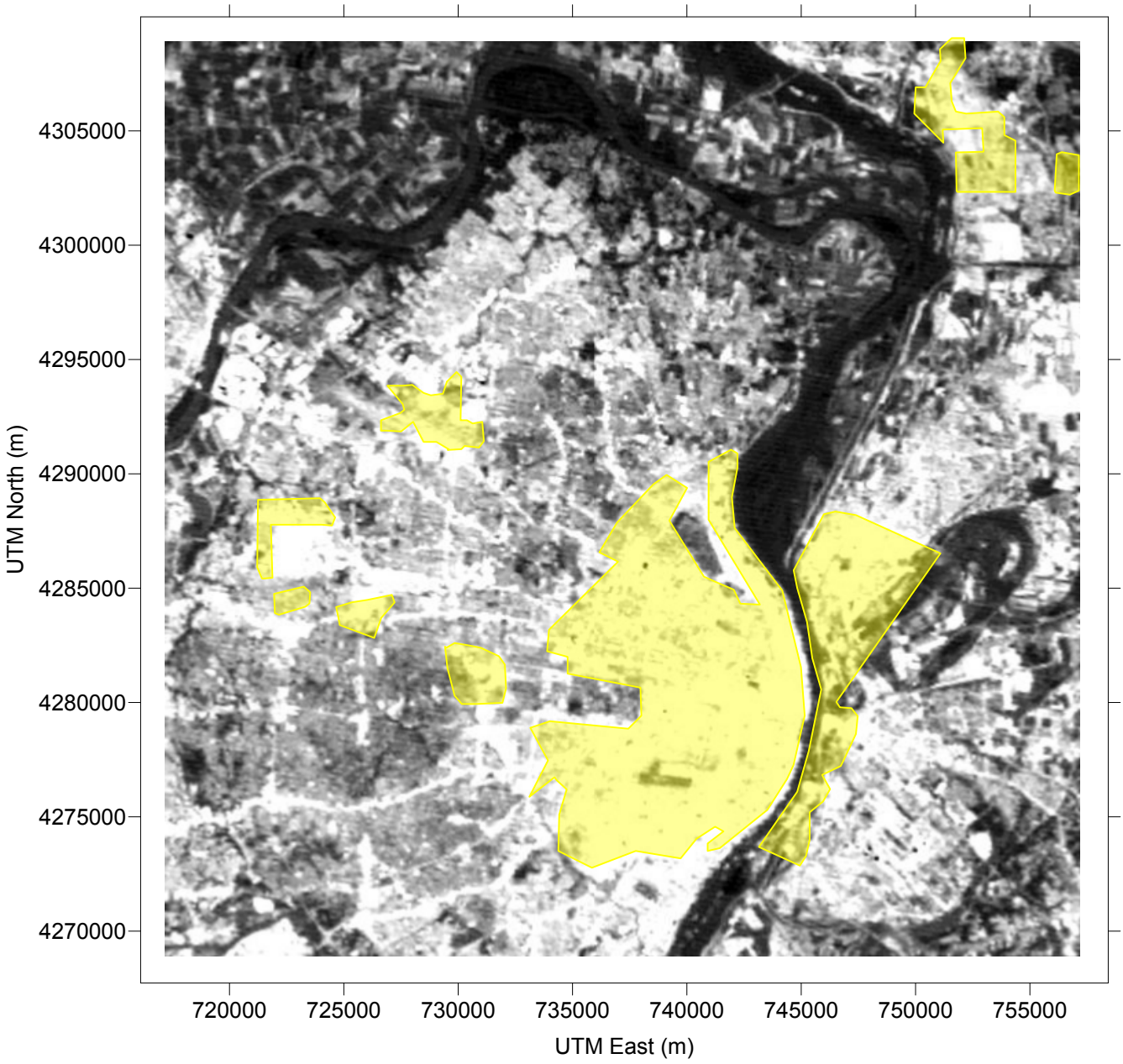


Figure 4
USGS Global Land Survey (GLS)
Thermal Infrared Map
with Auer Land Use Overlay

CONCLUSION

As there is no current standard source of data to perform an Auer land use analysis, this presents two problems:

- A high level of effort is required to accurately define the Auer land categories within a circular area with a 3 km radius, and
- The results of this effort may be highly subjective and may be variable within a given area.

Refinements to this method using standard USGS references are recommended in order to reduce the level of effort, subjectivism, and variability.

This paper has attempted to reproduce the original Auer study of the St. Louis area using standard USGS references. The results of this current study show a higher level of urban development in the St. Louis area than was assessed back in 1978.

Based on U.S. census data (USBC 1982 and USCB 2014), the population of the St. Louis area has only increased 3.5 percent since 1978. Therefore the differences between 2011 USGS and 1978 Auer urban data cannot be correlated with a population increase in this area.

The graphical comparison of the 2011 USGS and the 1978 Auer urban data, does suggest that a significant amount of urban development has occurred in this area over this period. This would correlate to a significant increase in urban land use categories.

In addition, the USGS data provide a greater resolution that can define corridors of urban development between areas of dense urban development. Thermal infrared imagery demonstrates that these corridors area also sources of thermodynamic anomalies. As these were not included in the 1978 study, this would also account for a significant amount of urban area that was not included in the original study.

Therefore, we recommend the following procedure in selecting urban/rural dispersion coefficients in a modeling exercise:

1.If the USGS land cover categories 23 and 24 (as defined in the NLCD2011) account for 50 percent or more of a 3 km radius circle centered on an emission source, then urban dispersion coefficients should be used for modeling that source. If less than 50 percent, rural dispersion coefficients are appropriate.

2. “Barren land” (USGS category 31) was not included in the Auer system. It can be argued that within a predominantly rural area (especially desert areas), this would not create an anomaly. But if this occurs within an urban area, where the ground would normally be covered with vegetation, this category should be included in the calculation of urban land cover.

REFERENCES

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