Remote Sensing of Roads and Highways in Colorado (RSRHC = research)

Initial objectives:

1. Create an advisory board and have meetings.
2. Create a web site for the project.
3. Assess the ability to identify and classify roads.
4. Perform surface condition assessments
   a. collect existing in situ data
   b. determine correlation of in situ data to satellite data
   c. explore the analysis of unpaved roads.

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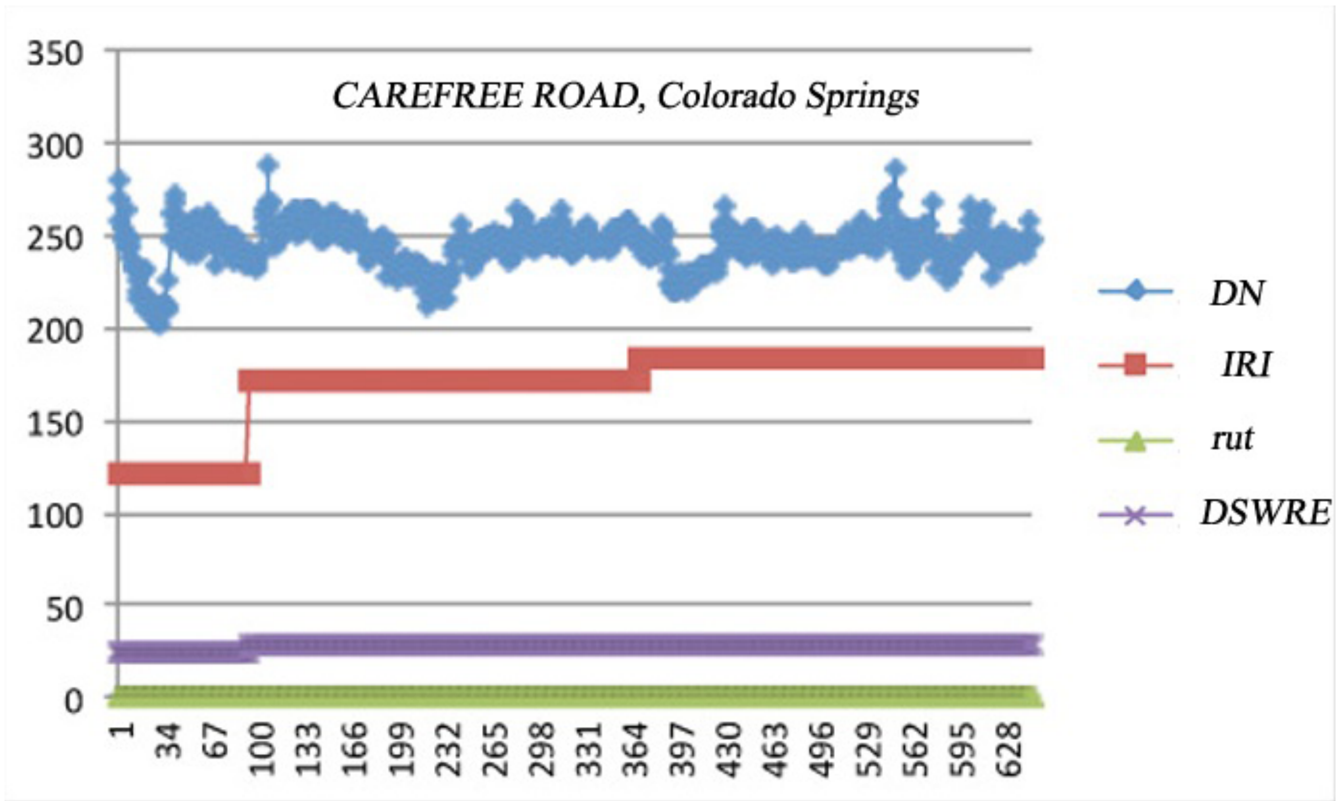
Progress to date:

1. Advisory board has been established and this is the second meeting.
2. A web page is being designed for the project. Results of this meeting will be posted (Tomoko Koyama).
3. In situ data bases have been acquired for: 2007 Colorado Spring Survey (El Paso and Teller Counties); 2012 Larimer County, CDOT from 2007 – 2012; Greely will be coming soon.
4. Acquired QuikBird image for Colorado Springs, 2007; WorldView 2 and aerial images for Larimer County.
5. Scheduled WorldView2 data collection for the week of Nov. 26 when Pikes Peak MPO will be taking a new survey.

We are learning about the differences in scale between the satellite and in situ data sets. This is a 2007 QB image for a small portion of Colorado Springs.

Carefree Road

These are satellite and in situ data along Carefree Road.



Distance along the road from north to south.
DN = digital satellite value
IRI = int. roughness index
Rut = rutting
You can see that there is a lot of variability in the satellite data for only 3 changes in the in situ data. There are changes in DN that coincide with changes in IRI.

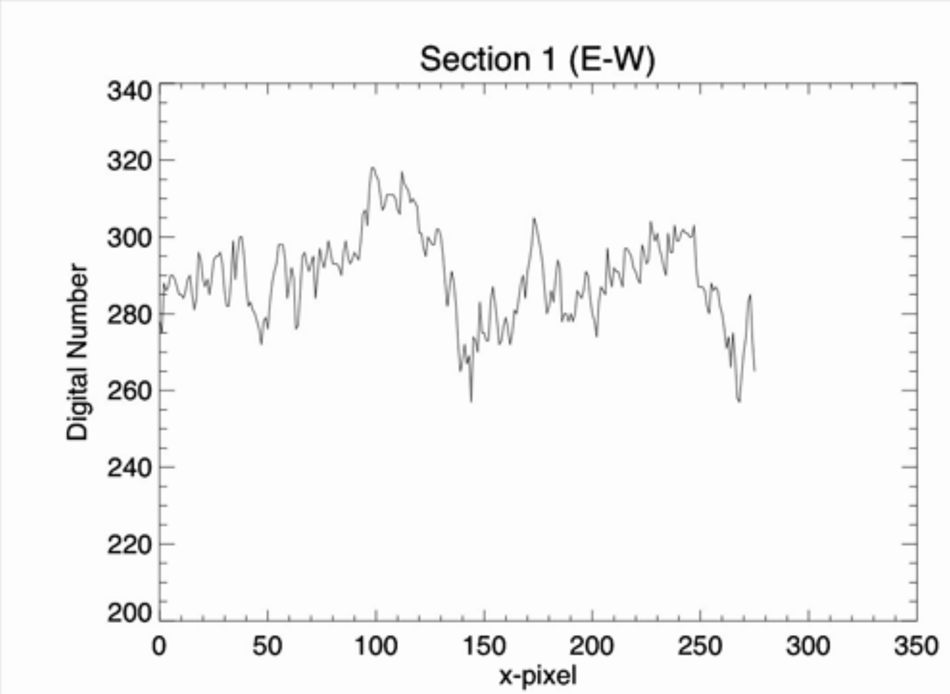
We will have to aggregate the satellite pixels in order to match the in situ data resolution to develop our correlations.

To do so we need to better understand the nature of the variability of the spatial series. We can learn that from some simple wavenumber spectra of the roads done at the full QB spatial resolution.

Section 1

Section 2

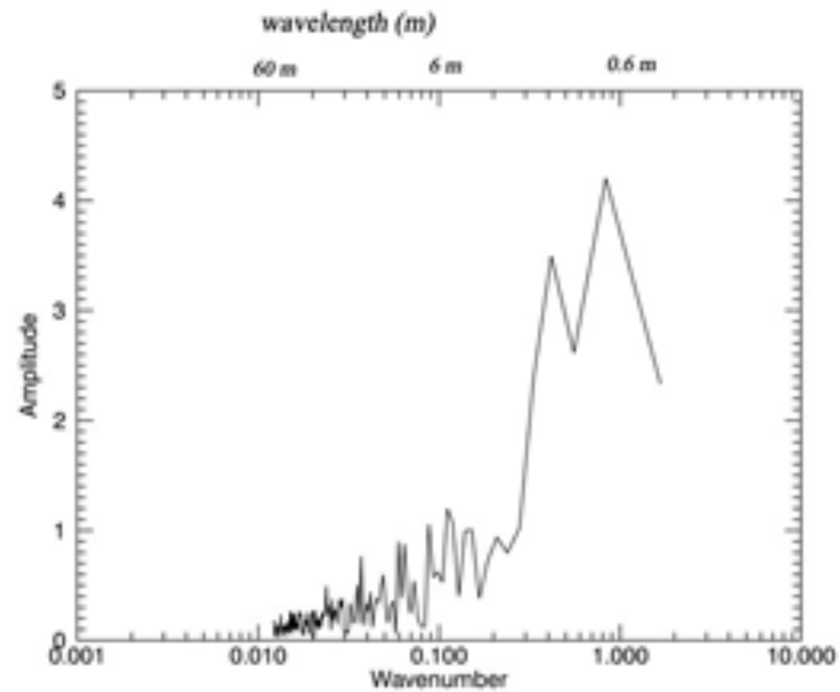
Section 3

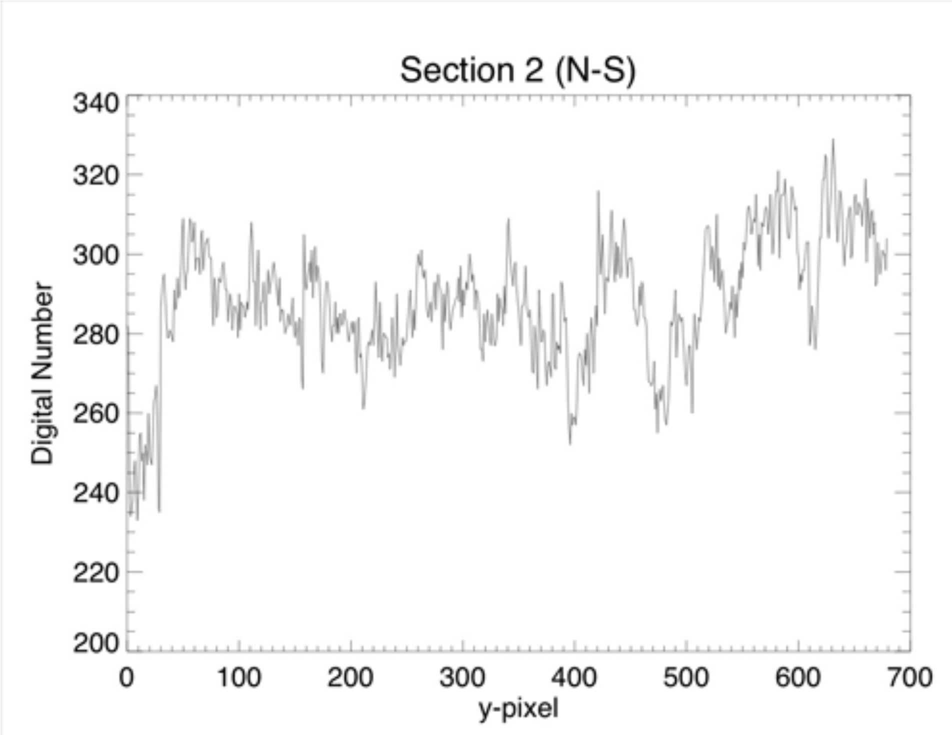


DN values along the road in section 1

Note all of the spectral energy is at the highest wavenumbers which are the shortest wavelengths. This tells us that there is a lot of variability in these DN numbers that we can use for mapping road conditions.

Wavenumber spectrum for section 1

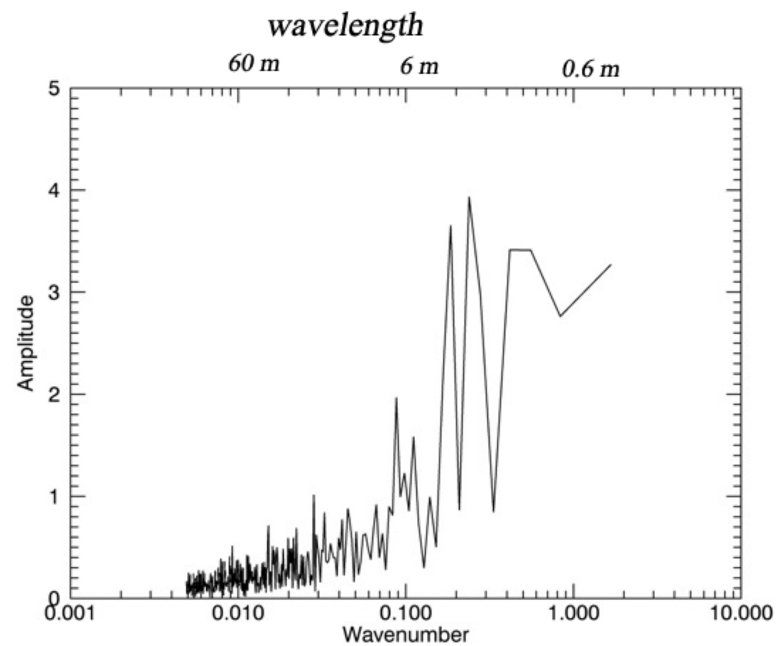


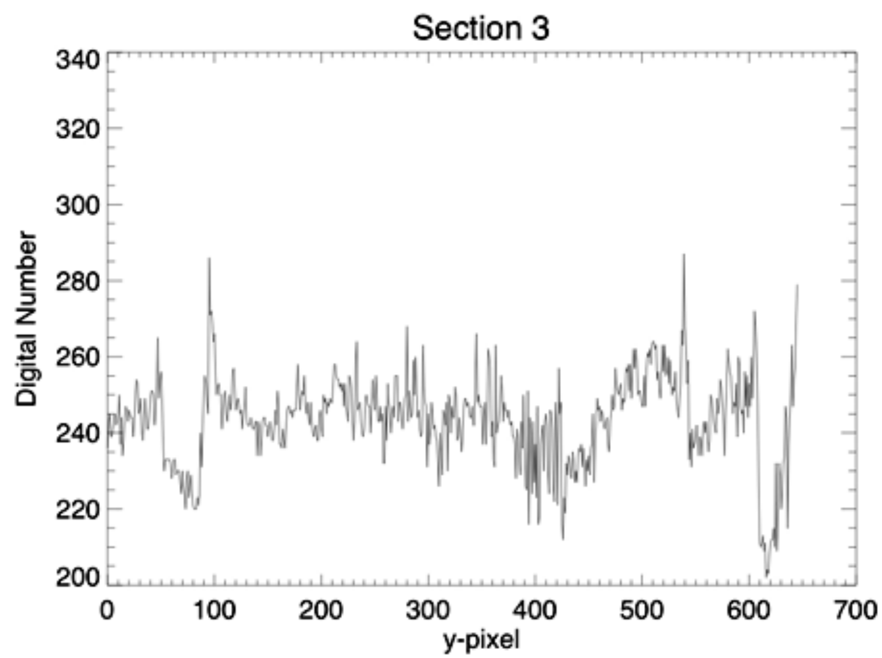


DN values along the road in section 2

Again the spectral energy is greatest at the short wavelengths but the peaks are quite different from section 1 which is a road in the same image.

Wavenumber spectrum for section 2

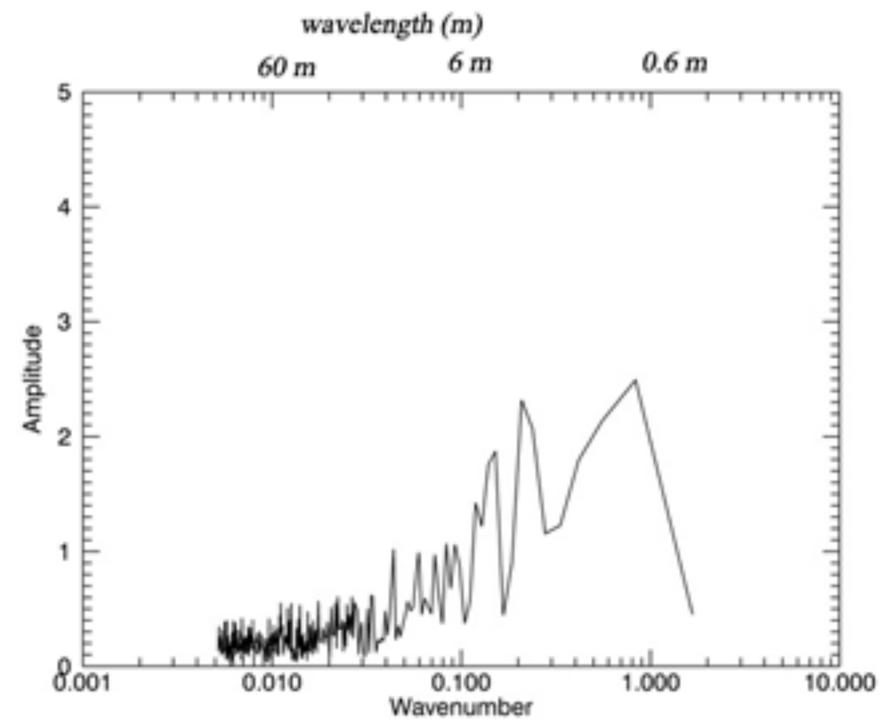




Finally we look at a road on the right of the image. We find the maximum spectral energy again at the 0.6 m peak that we saw in section 1 a much shorter road on the western side of the same image.

DN values along the road in section 3

Wavenumber spectrum for section 3



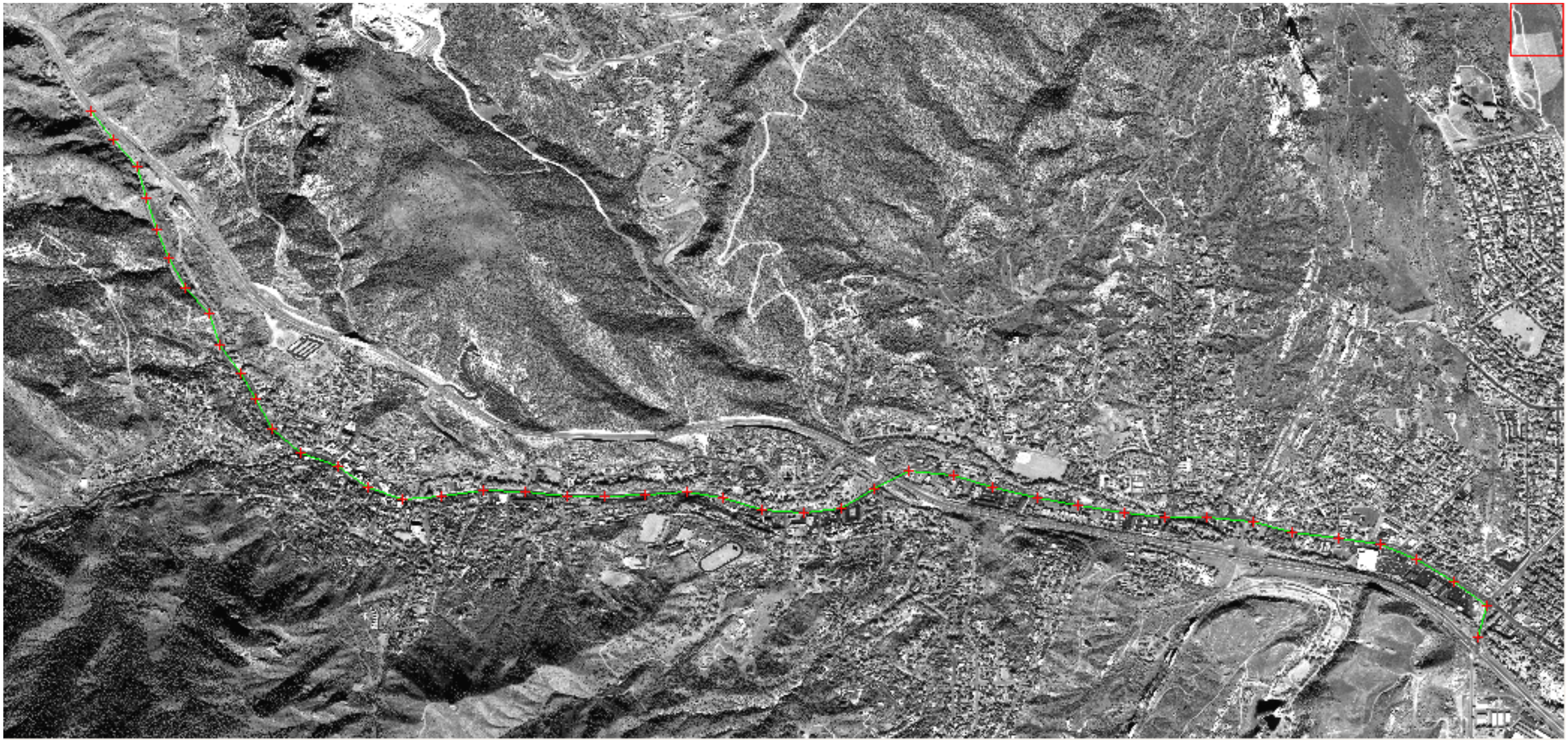
In the follow analyses the in situ data has been taken at the red crosses which have been confirmed to be on the road.

No particular effort has been made to be sure that we have not sampled white lines or vehicles.

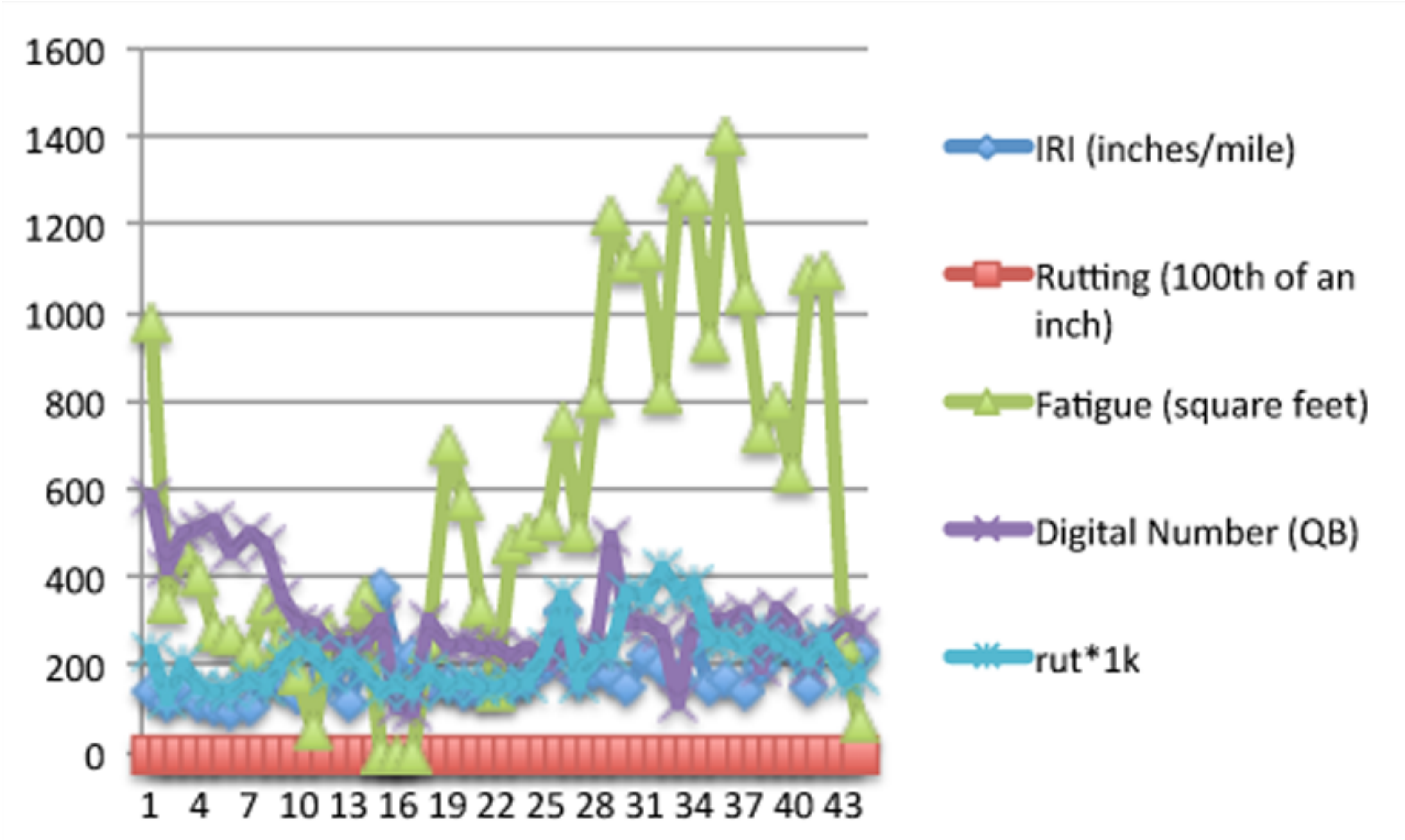
A single satellite pixel has been retrieved for each spot so that the DN value is based on only a single pixel which is much smaller than the in situ areas.

One motivation for this type of analysis was the fact that by connecting these points the road segments actually went off the roads as shown in the next image.

Note that the road segments between the red crosses generally deviate from the road surface.



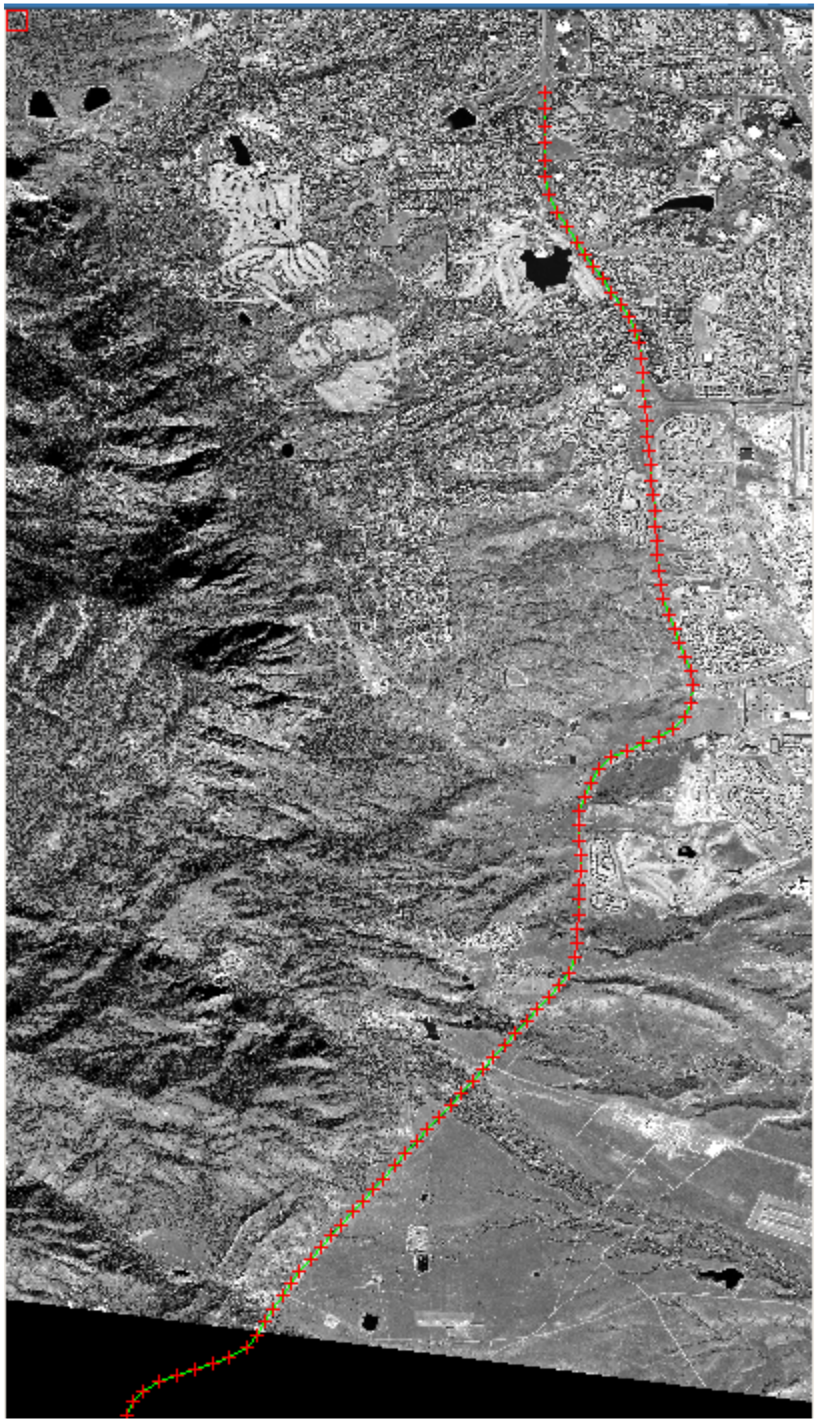
A road in Teller County; sampled from west to east. We will use only data at the red crosses which we know to be on the road.

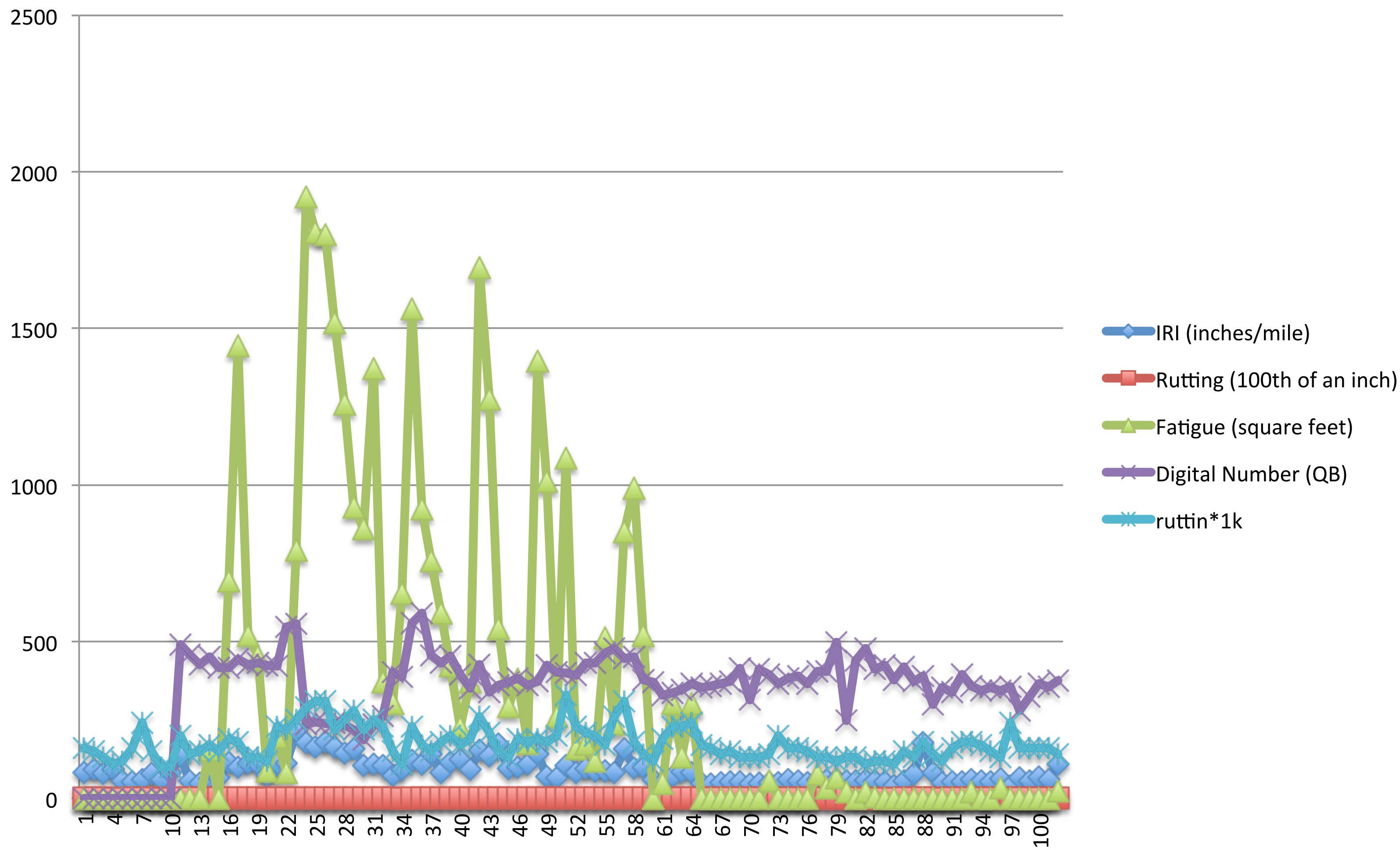


Distance along the road from west to east.

Things are on very different scales. Note the initial decrease in both fatigue and the DN. There is an increase in both after point 23 but the DN is far below the fatigue values.

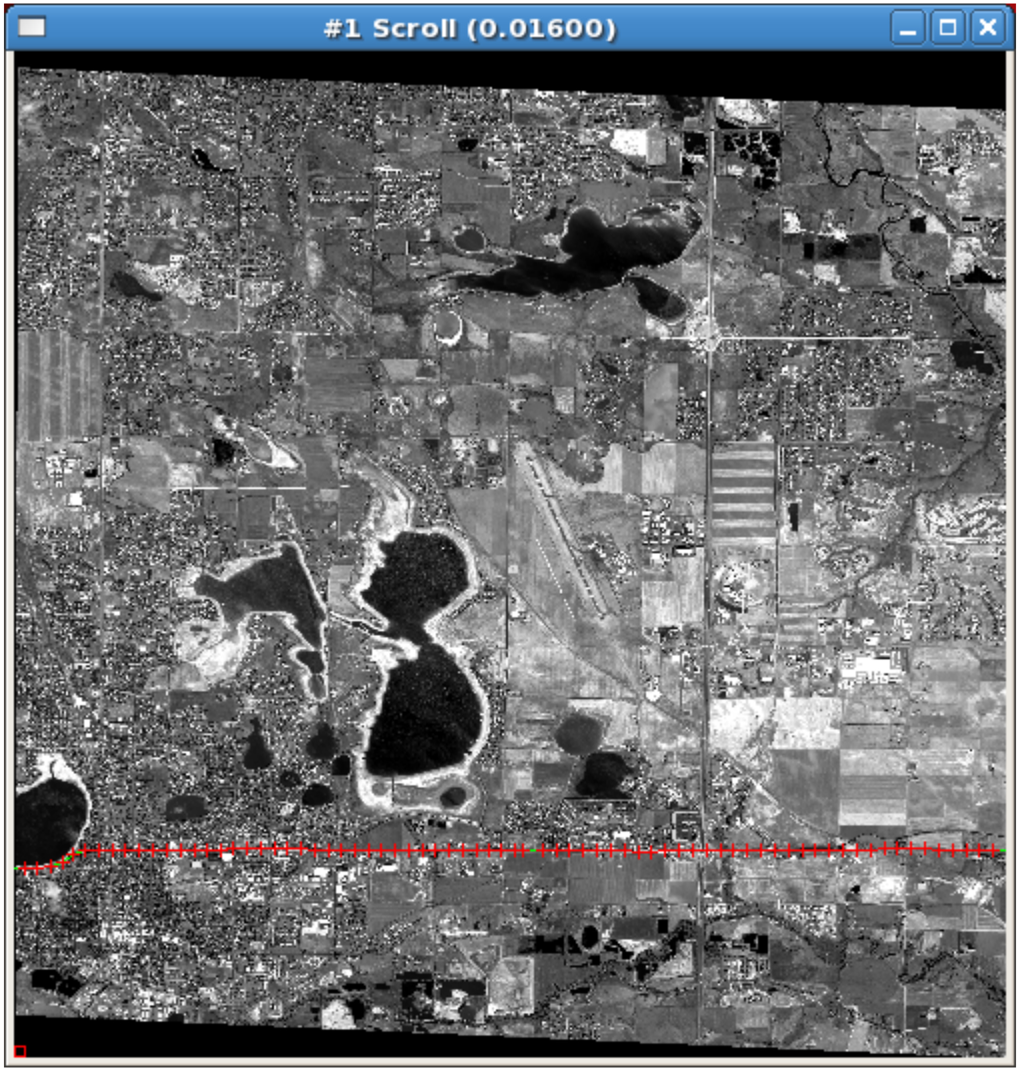
Another road in El Paso County, sampled from south to north.



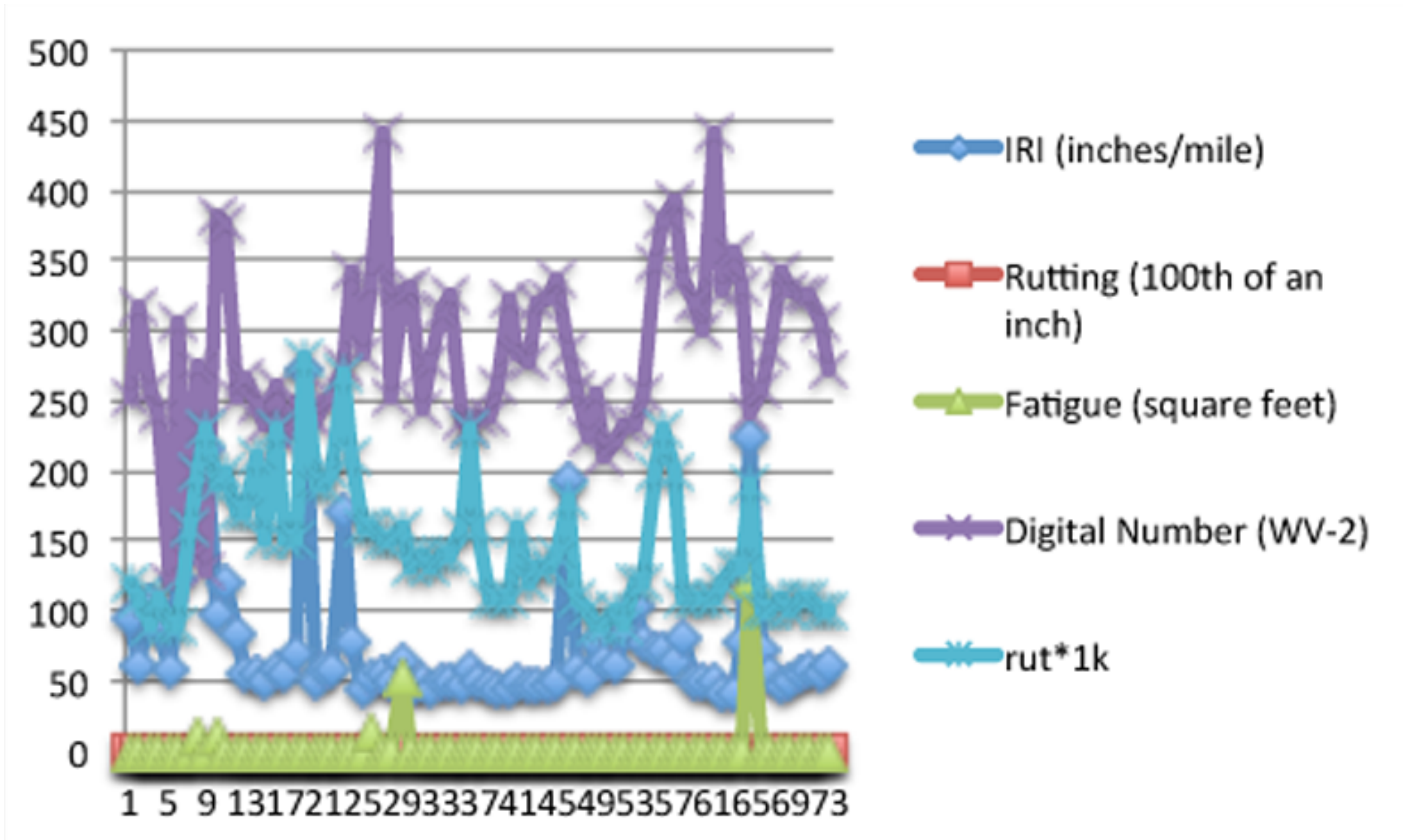


Distance along the road from south to north.

Note fatigue and DN both increase but DN has a drop where fatigue is at a maximum; there is then a general drop off of both for the end of the series



A road in Larimer County Sampled from west to east.



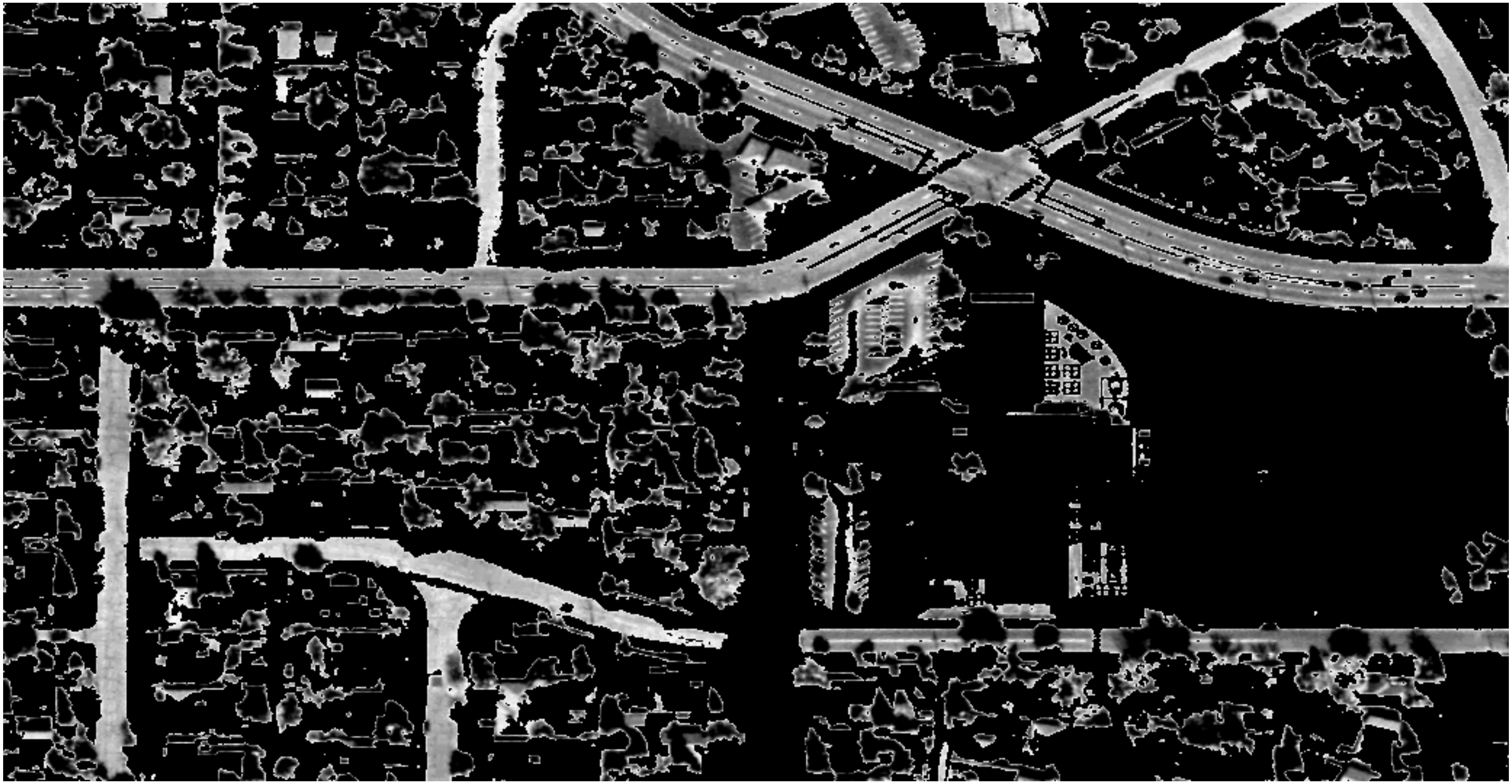
Distance along the road from west to east

Here the DN appears to be almost negatively correlated with the IRI and fatigue. There is more variability in the DN.

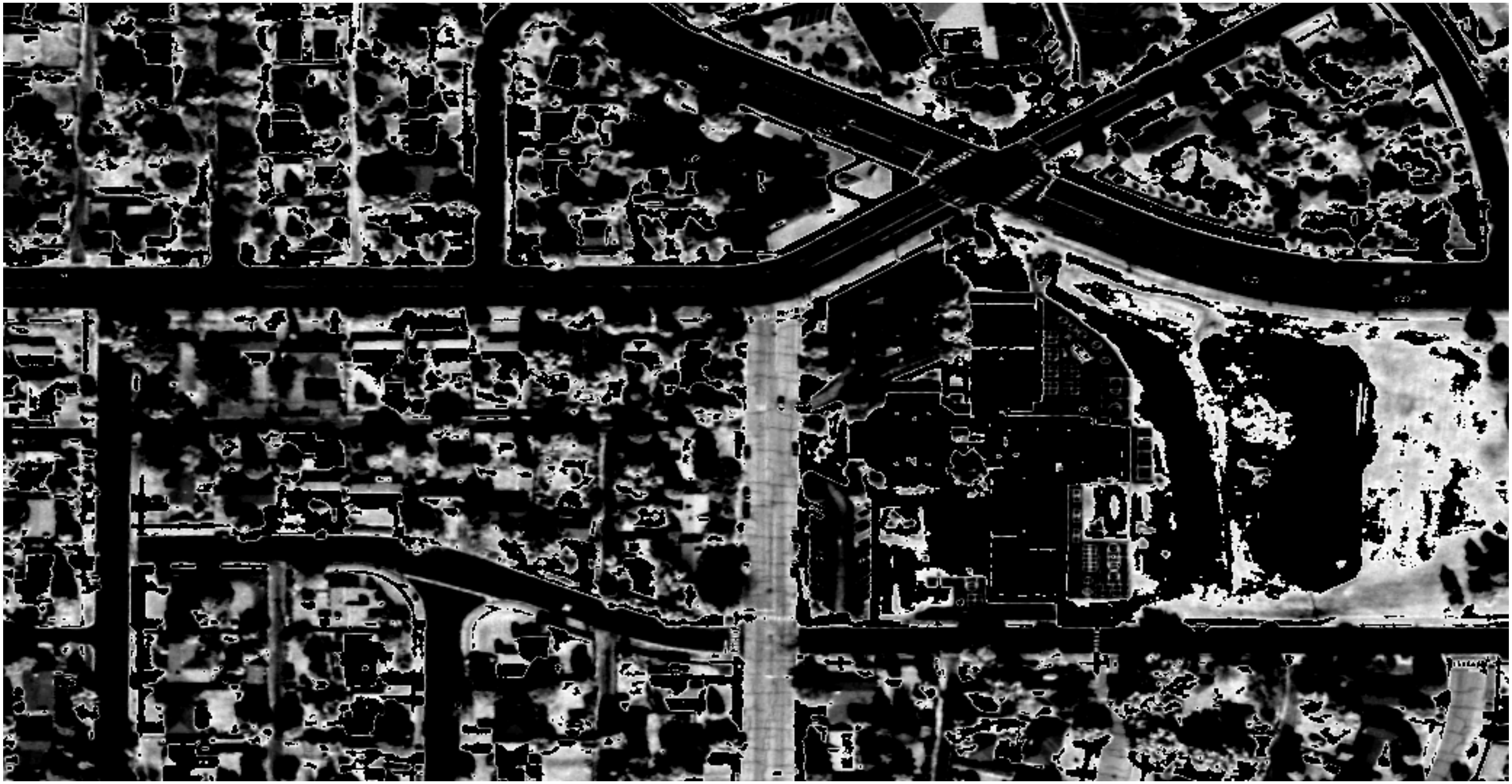
In order to explore the nature of the Colorado Springs QB image we performed a number of “density slices” where we maximized pixel values.

First is the simple gray shade of the full image.

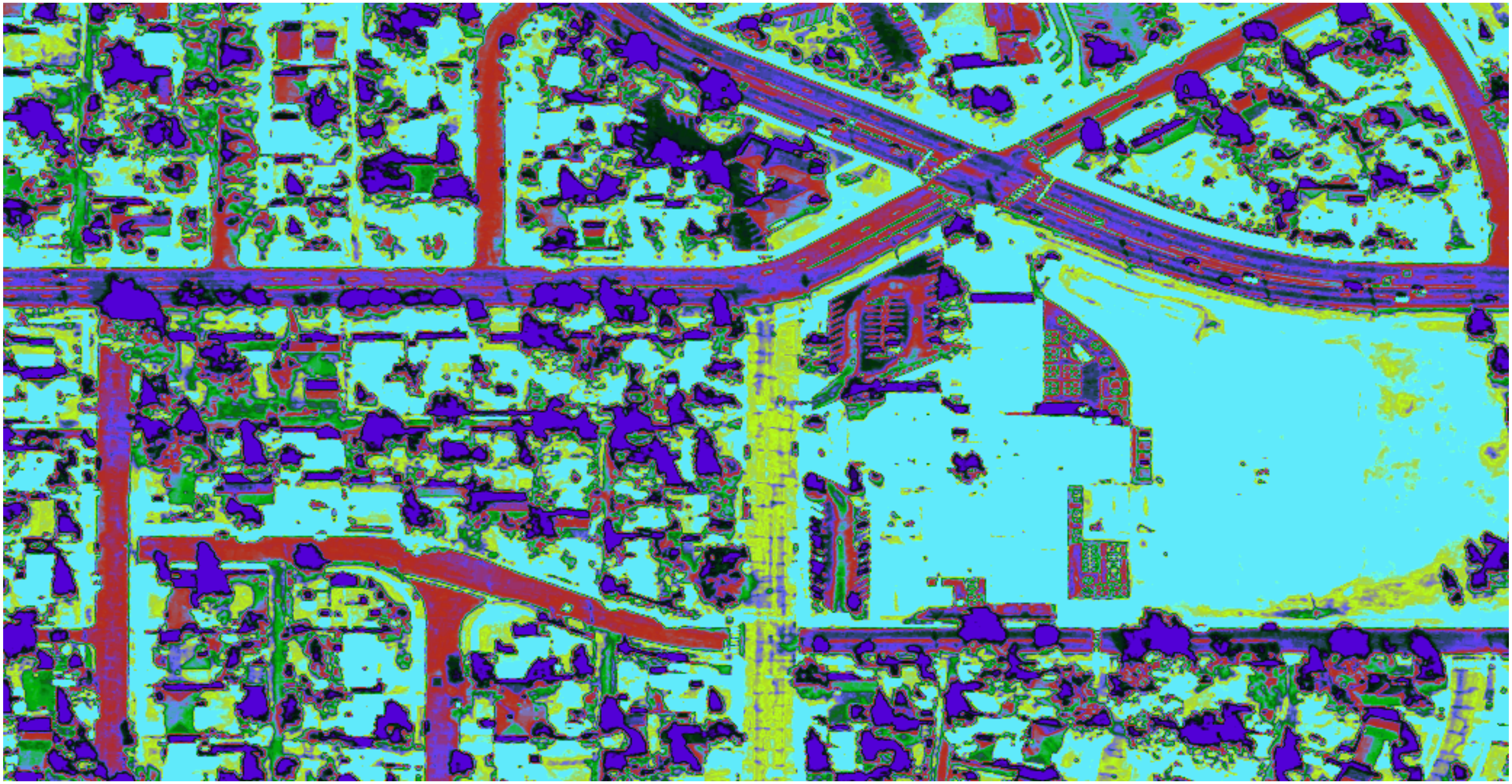
Note the lighter color of this road compared with all others. It is a light as ground color in the far central right of the image. Note also the cars and intermediate white lines.



Removed the bright pixels; bright road, cars, white lines, concrete, etc. to isolate the variability of the dark pavement only.



Removed all the dark pixels from the roads leaving the light road (white lines also mostly removed).



Color scale changes quickly highlighting any changes in DN. This shows the variability on the road surfaces themselves. It is encouraging to note that this image shows considerable variability on the road surfaces that we need to learn to take advantage of.

We need to develop image analysis procedures that will optimize the relationship between the satellite data and the in situ data.

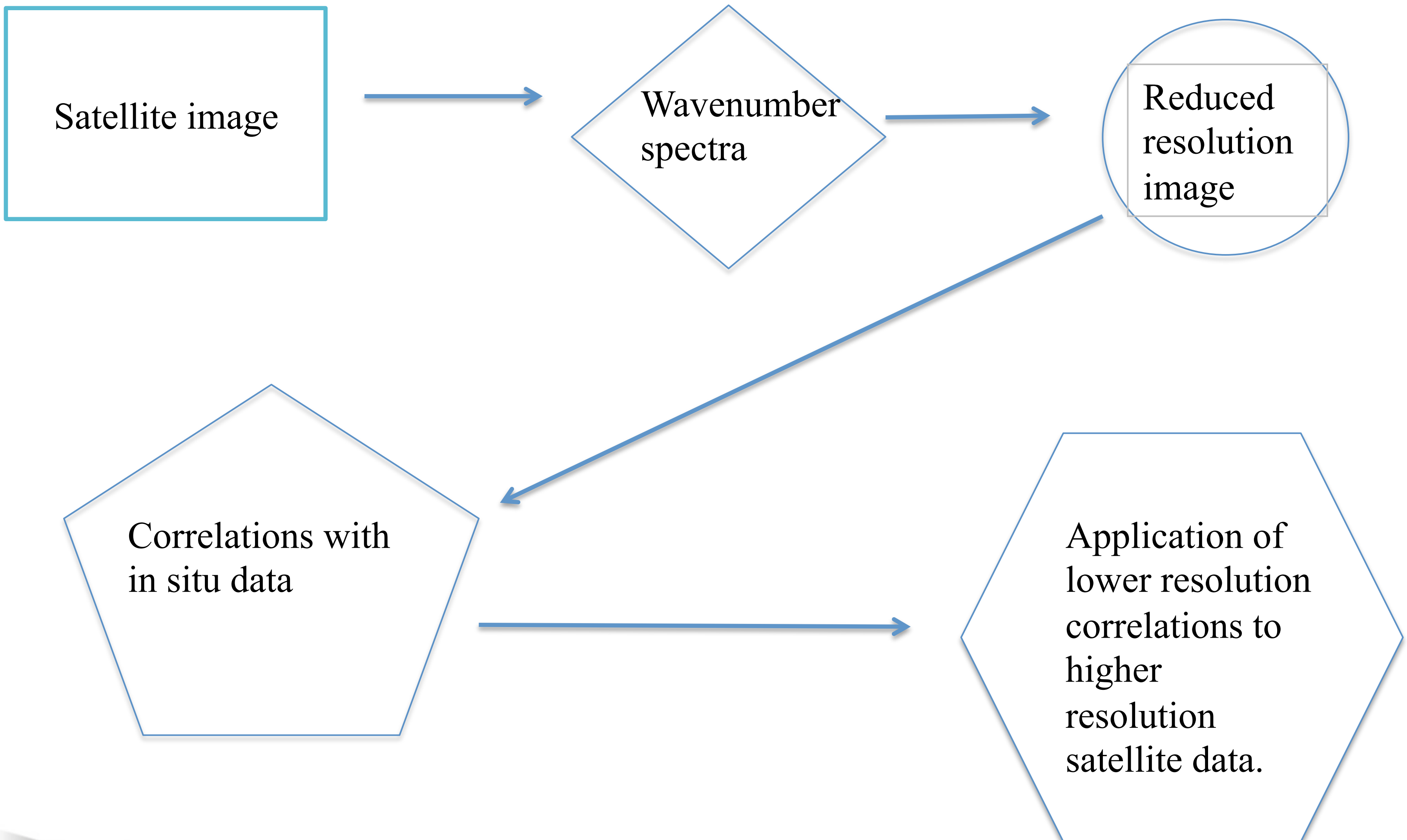
First step will be to characterize the satellite data in terms of spatial variability via wavenumber spectra.

From this we will learn what scale we can use to average over to reduce the resolution of the satellite data in order to match the in situ data. We will then be matching similar scale.

We will examine the wavenumber spectra within a 0.1 mile in situ data interval to determine just how homogeneous the variability is within these spatial intervals.

We can then compute correlations and cross spectral analyses to determine just how well this reduced spatial resolution satellite data can be used to characterize the variability of the road surfaces sampled by the satellite image.

First Approach



In situ data needs:

1. What parameters are really the most important for your assessment and operations?
2. Is the scale of your in situ collections adequate for your assessments and paving decisions? Is the 0.1 mile data interval mainly dictated by the cost of the in situ data collection? Would you find a higher resolution assessment of value in maintaining your roads?

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Needs cont.

When in the year do you need information on road surface conditions?

Does this vary with date and location?

What level of effort do you presently tolerate in your road assessments and what level is reasonable for the future?

How much do you pay out annually for road surface condition assessment?

A New Approach to this Analysis

• First we much acknowledge that the satellite/aerial data have much higher resolutions than do the in situ road data. This new approach will be a method to address this dichotomy of scales.

• We will use a “texture” calculation procedure to take best advantage of the high resolution panchromatic images.

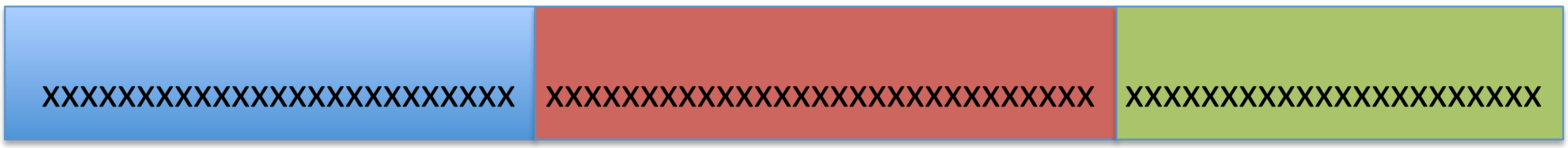
• The approach is to first select out a small portion of the image with a number of roads. The roads much be long enough that we will have a number of in situ segments (0.1 mile for Colorado Springs).

• We will compute the texture in a 3 X 3 matrix so as to be sure that the texture parameters can be kept within a road. The texture parameters will be computed for the entire image portion selected. The texture parameters of interest are: variance, entropy, homogeneity, contrast, dissimilarity and correlation. The results will be new images of these parameters for the image portion selected.

• We will then select those texture pixels that we are certain are on the road and are not contaminated by cars, white lines or concrete structures.

• This will produce series of the texture parameters along the roads.

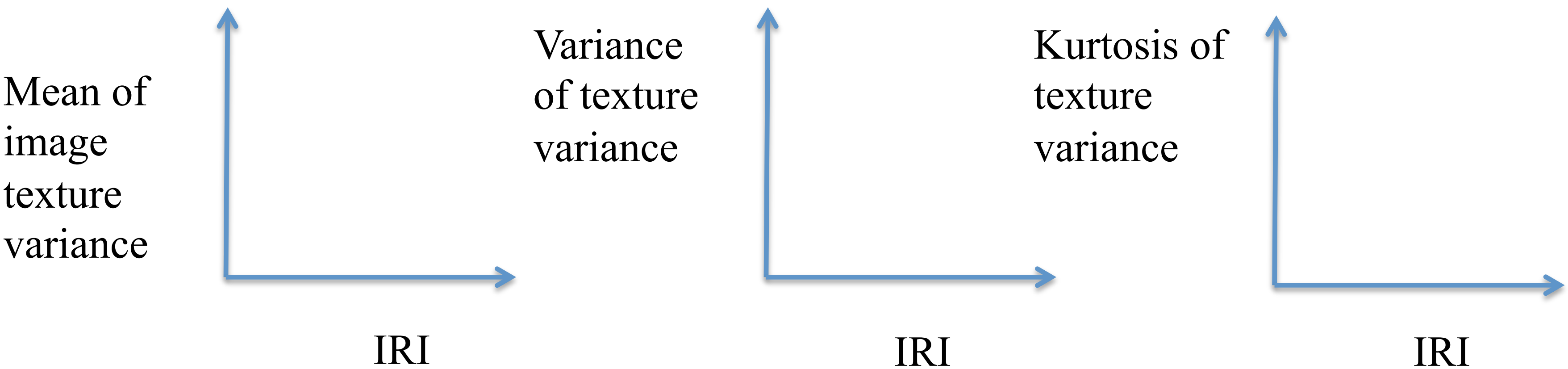
• We will now find those texture pixels that fit into an in situ data segment along this road. This is depicted below.



Where the color rectangles represent road segments with a single in situ values and the x's correspond to the satellite data derived texture parameters selected along these roads.

• For these rectangles we compute the following: mean, standard deviation, kurtosis and skewness. This gives us single values at each rectangle that can be compared with the in situ parameters.

For example we will have plots of IRI (or any other in situ parameter) versus statistics of texture variance



- In this way we will have taken best advantage of the high resolution of the satellite images and at the same time have data products that are consistent in scale with that of the in situ data collected.

- While we will initially examine these results to fully understand them we will eventually need to design a machine based method for selecting these relationships due to the large number of variables we will be dealing with.

• We must acknowledge that different in situ data sets have different spatial resolutions which will result in different numbers of satellite/aerial data being assigned to a road segment of in situ data. It is important to have at least 30 texture values per road segment to insure that we will have Gaussian statistics.

• We also must acknowledge that if a parameter such as the IRI is reduced to quanta such as poor-fair-good we will have a much better chance of suppressing the noise in this process and coming up with a good estimate of these values of the IRI.

• We have learned that almost all of the in situ data sets are different and there are few similarities. One of these seems to be the IRI and it will therefore be our primary variables.

• There is a lot of interest, however, in cracking = stress = fatigue so we will plan on including that in our analysis.

• Rutting is a much smaller number but may have substantial variability and we plan to consider it as well.

• We are very much looking forward to the new in situ data collection that will take place in the Colorado Springs area the week of Nov. 26.

• We have scheduled a WorldView-2 data collect in the surrounding region for the period between Nov. 15 and Dec. 5 which we hope will provide the opportunity and the low cloud (<15 %) condition needed for this continued study.

• This new data set will collect data at a higher resolution and provide high-resolution video as well. We hope to be able to use the technique outline above to analyze the satellite data for this small area and then extend the analysis to imagery from a much larger area.

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