ColoradoView Summary Report

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Introduction:

Task one of ColoradoView's project *High-resolution LST and ET maps retrieval and water stress impacts on plant production in CO* is to analyze the long-term pattern of Land Surface Temperature in Colorado using Landsat 5, 7, and 8 Landsat Analysis Ready Dataset (ARD) data between 2000 and 2018. Since multiple Landsat sources were involved, the divergence of their distributions were evaluated in the entire Colorado region before they were merged into a coherent LST dataset. To reduce the computation complexity, the analysis focused on the six representative landcover types of Colorado based on the National Land Cover Database (NLCD). Temporal trends were assessed for each landcover class during the 2000-2018 period.

Methods and Results:

Landsat ARD LST ST data were downloaded for Landsat 5, 7, and 8 for the period from 2000-2018 from USGS Earth Explorer. Data were then uploaded to Google Drive and processed to produce three 16-bit bands for each tile—the surface temperature band, and two quality assurance bands. These data were then uploaded into Google Earth Engine (GEE) to be processed on the GEE distributed computing system.

Before assessing trends of surface temperature in Colorado, distributions of each of the sensors were assessed to ensure that the sensors were directly comparable for the purposes of time-series analysis. The pixel quality assurance band was used to mask pixels that were marked as shadow, snow, water, cloud, or occlusion and the reduce region function was applied to produce histograms of the values of all of the pixels in each tile. Histograms were summarized by year and month for each sensor to assess annual and monthly differences between distributions. The resultant yearly and monthly histograms were then compared based on common periods for each sensor by calculating the Jensen-Shannon divergence for each combination. Overall divergence between the sensors was below .05 for each overall distribution, with values closer to 0 indicating similarity in the distributions and suggesting that the sensors are comparable and can be combined for analysis. Notably, Jensen-Shannon values were lowest (indicating lower divergence) in summer months and higher in winter months (indicating higher divergence). Probability distributions for comparable periods of Landsat 5 and 7 (2000-2011) and Landsat 7 and 8 (2014-2018) are shown in figure 1. *These steps are detailed in the landsat578_compare_histograms python script.*

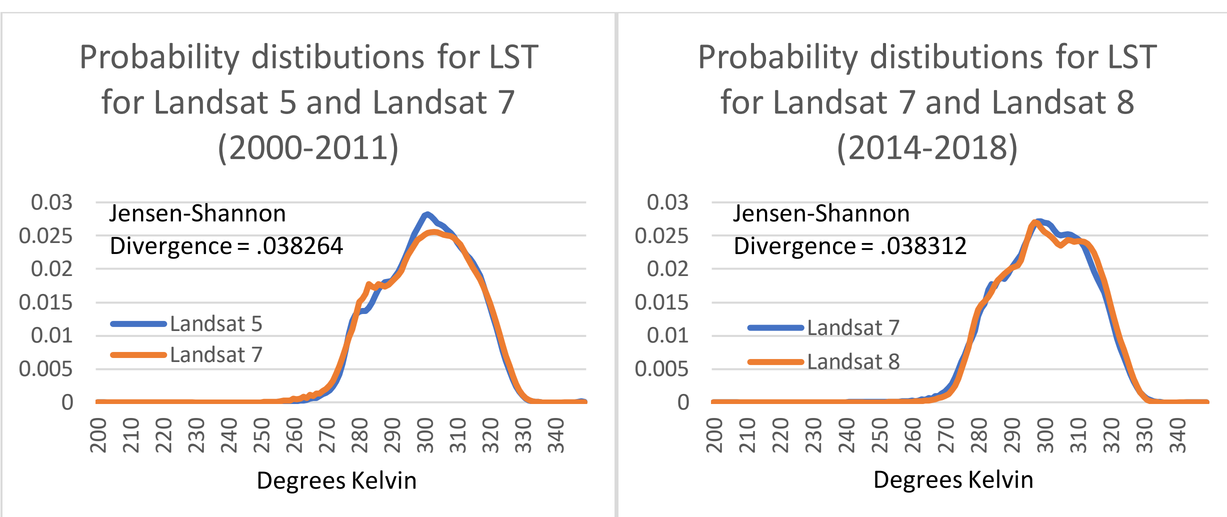

Figure 1: Probability distributions for the comparable periods of the two sensor combinations that were assessed. Data from Landsat were binned to 1 degree increments due to reduce the effect of noise in the original dataset

Once it was determined that ARD ST data could be combined for each sensor, trends in ST were evaluated based on landcover type. Landcover classes were derived from the NLCD using the 2001, 2006, 2011, and 2016 iterations. Developed (classes 21-24), barren (class 31), forest (classes 41-43) shrubland (class 52), grassland and pasture (classes 71 and 81), and cultivated crops (class 82) were each assessed. In calculating trends for each class, only pixels that were stable as a single landcover class over each NLCD (2001, 2006, 2011, and 2016) iteration were used. Additionally, any pixels of a given class that were within three pixels of a different class were eliminated to reduce possibility of edge effects. *These steps are detailed in the landcover_statistics_Jensen Earth Engine script.*

Because Landsat sensors were demonstrated to be directly comparable, image collections were combined for the three sensors to evaluate the time-series trends in ST. Trends were calculated over a six-county area—Denver, Elbert, Gilpin, Moffat, Phillips, and San Juan—with each county comprised of a significant proportion of each landcover class of interest. The same mask as used in the Jensen-Shannon divergence calculation was applied here to the combined image collection. Once masked, daily statistics (mean, median, mode, minimum, maximum, and standard deviation) were calculated for each of the six landcover classes of interest within the six-county analysis area—resulting in 18-year daily summaries for each statistic for each landcover type. *These steps are detailed in the LSTtrends_LandCover python script.*

Temperature data follow a sinusoidal curve when plotted over several years, with high temperatures occurring in summer and low temperatures occurring in winter. The Solver tool in Excel was applied to solve for variables in the non-linear regression function $y = ACos(Bx+C)+D+Ex$ to produce fitted trends for each statistic. Using these fitted trends, a non-linear annual slope was derived from variable E. Annual slope was also calculated from linear regression. Table 1 shows the annual slope in degrees Kelvin for the mean temperatures for each landcover class along with the R^2 of the non-linear regression.

	Landcover type					
	Barren	Cropland	Developed	Forest	Pasture	Shrubland
Non-linear fitted slope (mean)	0.09570	0.04315	0.07710	0.07945	0.04378	0.01865
Linear regression slope (mean)	0.05779	0.06896	0.06781	0.09543	0.04603	0.05517
Non-linear R^2	0.65173	0.76396	0.82538	0.77366	0.76780	0.77322

Table 1: Comparison of linear and non-linear regression annual slopes for the daily means of each landcover type and the R^2 value for the non-linear regression.

The most variation in annual trends was evident in the calculations of maximum values for each landcover type, shown in table 2 below. Maximum values had slopes that were similar to the mean for the barren and forest classes, but maximum values had a much steeper slope in developed sites and a much more gradual or even negative slope, in shrubland, cropland, and pasture sites. R^2 values were similar to those for the means for each class for the non-linear fitting. These trends indicate that shrubland, cropland, and pasture sites may be less susceptible to increases in maximum temperatures, however there may be finer seasonal variations that influenced slope which were not assessed.

	Landcover type					
	Barren	Cropland	Developed	Forest	Pasture	Shrubland
Non-linear fitted slope (maxima)	0.07629	-0.01614	0.13962	0.05899	0.00196	-0.01787
Linear regression slope (maxima)	0.03900	0.01377	0.12519	0.07883	0.00703	0.02373
Non-linear R^2	0.73910	0.75803	0.68814	0.75756	0.78932	0.74552

Table 2: Comparison of linear and non-linear regression annual slopes for the daily maxima of each landcover type and the R^2 value for the non-linear regression.