# Analyzing Cuba's Economic Insulation from International Markets

# Using Nighttlime Lights as a Proxy for Economic Development

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ABSTRACT:

Cuba is considered one of the most isolated countries in the world.[1] Under the shadow of the United States trade embargo since 1960,[2] its economic growth has been deprived of half a century of growth. Domestic policy plays a role in this scenario, however, and to what extent Cuba's economic despair is due to imposed isolationism is unclear. In this study, satellite imagery of nighttime lights (NTLs) is used to better understand the correlation between economic patterns of Cuba and the rest of the world.

# I. Background:

Currently in its 57th year under the strict censorship of the Castro regime, Cuba has long been deprived of social contact with the outside world, as well as access to the international monetary regime. While wrapped in the Cuban flag, 90-year-old Fidel Castro still contends that Cubans have suffered because of sanctions imposed by the American embargo. But the level of isolation that this legislation mandates may not be as great as 'el comandante' will have you believe. Contrary to popular belief, commerce exchange between the United States and Cuba is not completely blocked by the famous trade restriction. In fact, the United States is currently one of Cuba's biggest trading partners,[3] providing $349 million in goods in 2013,[4] and is its top supplier of food.[5]

The Castro regime became legendary for both Fidel's outlandish antics in speaking out against the evils of capitalism and neo-colonialism, and for its longevity. At the time of writing, the dictatorship has outlasted 10 American presidents;[6] but this longevity may be in the early stages of decline. Younger Cubans want desperately to join this age of globalism and are becoming restless with their situation. Only about 5% of Cubans have access to the Internet[7] and, although international travel bans have recently been relaxed,[8] Cuba's stale bureaucracy and underperforming economy makes international tourism too costly for the average citizen. Fortunately for this wayward generation, or perhaps because of them, the Cuban government has been making notable advancements toward the international economic regime, indicating openness to change. The 180 square mile Mariel Free Trade and Development Zone,[9] along with a wish list of investment opportunities, published in 2015 and aimed to bring $2 billion of foreign investment into Cuba,[10] indicate the Castro regime's desire to compromise some of its socialist values for a stake in the international money pot. Response to these advancements have been disappointing, however, as Cuba's opaque business environment is out of touch with contemporary economies. Cuba's clandestine financial practices, further complicated by its dual currency and multiple exchange rates, prevent external calculations about the state of the communist economy,[11] deterring advancements form potential investors.

1 Committee to Protect Journalists. 10 Most Censored Countries. 2 May 2006. http://wjla.com/news/nation-world/getting-online-in-one-of-the-world-s-most-isolated-countries-92331
2 Fabry, Merrill. The U.S. Trade Embargo on Cuba Just Hit 55 Years. Time Magazine. 19 August 2015. http://time.com/4076438/us-cuba-embargo-1960/
3 The Observatory of Economic Complexity. Cuba. http://atlas.media.mit.edu/en/profile/country/cub/
4 The Observatory of Economic Complexity. Cuba. http://atlas.media.mit.edu/en/visualize/tree_map/hs92/import/cub/usa/show/2013/
5 The Observatory of Economic Complexity. Cuba. http://atlas.media.mit.edu/en/profile/country/cub/#Imports
6 Gjelten, Tom. 10 Presidents, One Dictator: U.S.-Cuba Policy. National Public Radio, 4 August 2006. http://www.npr.org/templates/story/story.php?storyId=5615898
7 National Public Radio. Internet Access Expands In Cuba — For Those Who Can Afford It. 6 October 2015. http://www.npr.org/sections/parallels/2015/10/06/445998527/internet-access-expands-in-cuba-for-those-who-can-afford-it
8 PBS Newshour. Cuba Opens Travel Abroad for Most Citizens, Eliminating Exit Visa Requirement. 14 January 2013. http://www.pbs.org/newshour/bb/world-jan-june13-cuba1_01-14/
9 Mark Frank. Cuba: Port Upgrades and Free-Trade Zones. March 2014. http://www.americasquarterly.org/content/cuba-port-upgrades-and-free-trade-zones
10 Reuters. Cuba seeks $8.2 billion in foreign investment for 326 projects. 3 November 2013. http://www.reuters.com/article/cuba-trade-idUSL1N12Y3HK20151104
11 Desilver, Drew. What we know about Cuba's economy. 28 May 2015.
http://www.pewresearch.org/fact-tank/2015/05/28/what-we-know-about-cubas-economy/

## II. Conceptual Framework:

Over the last 20 years, more than 3,000 studies have been done using nighttime light (NTL) data as a proxy for economic development, urbanization, and population.[12] Launched by the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) in 1992, this technology uses four Defense Meteorological Satellite Program satellites carrying the Operational Linescan System in low-altitude polar orbits to detect low levels of visible-near infrared (VNIR) emission sources at night.[13] Since NTL have been increasingly used as a proxy for economic development, studies have been done analyzing its relationship with economic growth. Findings have been positive. Martin Prosperity Institute's correlation analysis, for example, which used geographically weighted regressions to examine the statistical validity of this proxy, found significant correlations between the two indicators.[14] Results published in the Journal of Economic Geography suggest that NTLs are even more useful in studying developing countries, as a method to circumvent institutional censorship and analyze isolated economies, on which economic analysis would not otherwise be feasible.[15]

Since the debut of NOAA's NTL dataset, the world has undergone significant events that have effected even the most isolationist countries. In an increasingly connected international economy, fluctuations of a single market on one side of the world influences markets on the other. Using NTL as a proxy for economic development of both Cuba and the Dominican Republic (DR), along with data from the World Bank Database, this study will attempt to evaluate Cuba's economic insulation from the database, this study will attempt to evaluate Cuba's economic insulation from the international economy by calculating its rate of economic development during spikes and dips in the international economy.

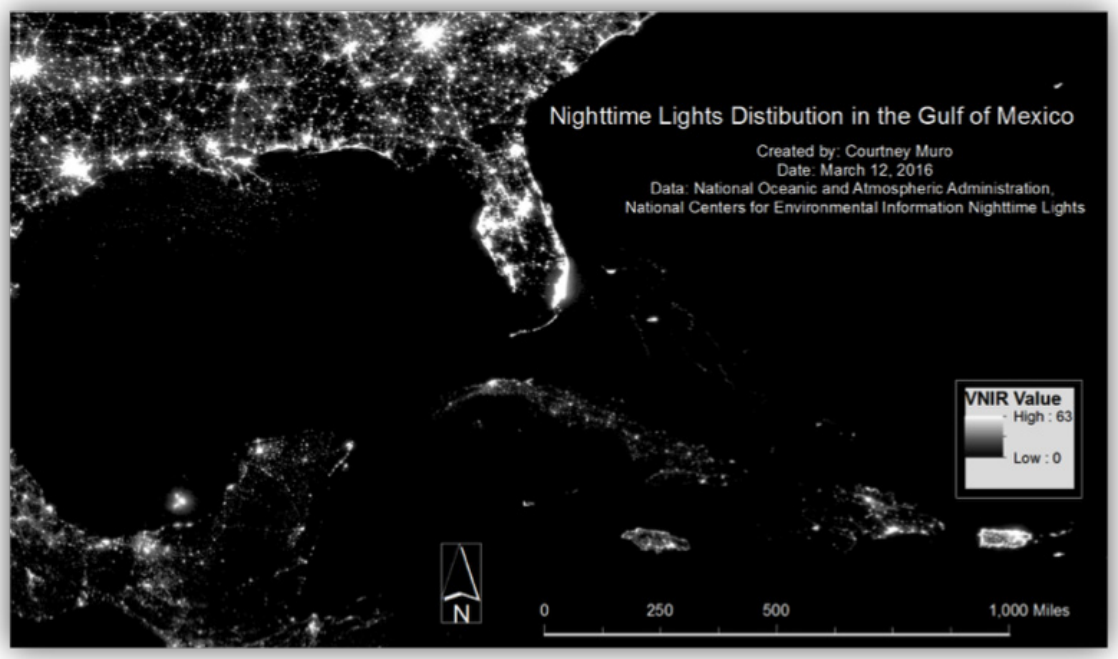



*Figure 1 suggests a dim Cuban economy, giving off little light in comparison with neighbors in Florida, Texas, Puerto Rico, and Mexico.*

12 Florida, Richard. The Economic Data Hidden in Nighttime Views of City Lights. From the Atlantic: City Lab. 29 May 2014. http://www.citylab.com/tech/2014/05/the-economic-data-hidden-in-satellite-views-of-city-lights/371660/

13 NOAA: National Centers for Environmental Information. Nighttime Lights Posters. http://www.ngdc.noaa.gov/eog/night_light_posters.html

14 Florida, Richard. The Economic Data Hidden in Nighttime Views of City Lights. From the Atlantic: City Lab. 29 May 2014. http://www.citylab.com/tech/2014/05/the-economic-data-hidden-in-satellite-views-of-city-lights/371660/

15 Florida, Richard. The Economic Data Hidden in Nighttime Views of City Lights. From the Atlantic: City Lab. 29 May 2014. http://www.citylab.com/tech/2014/05/the-economic-data-hidden-in-satellite-views-of-city-lights/371660/

## III. Methodology and Visual Analysis:

Before calculating Cuba's economic performance against that of the international economy, domestic patterns were visualized and calculated in Google Earth Engine. Nighttime light rasters were created for 1992 and 2012 by filtering NOAA's Nighttime Light (NTL) data to targeted years, and Cuba was extracted using a countries feature collection. A mean reducer was applied in order to extract the mean pixel value of each annually calculated image of the image collection, and images were created, displaying domestic patterns in Cuba's development from 1992 to 2012 in Google Earth Engine.

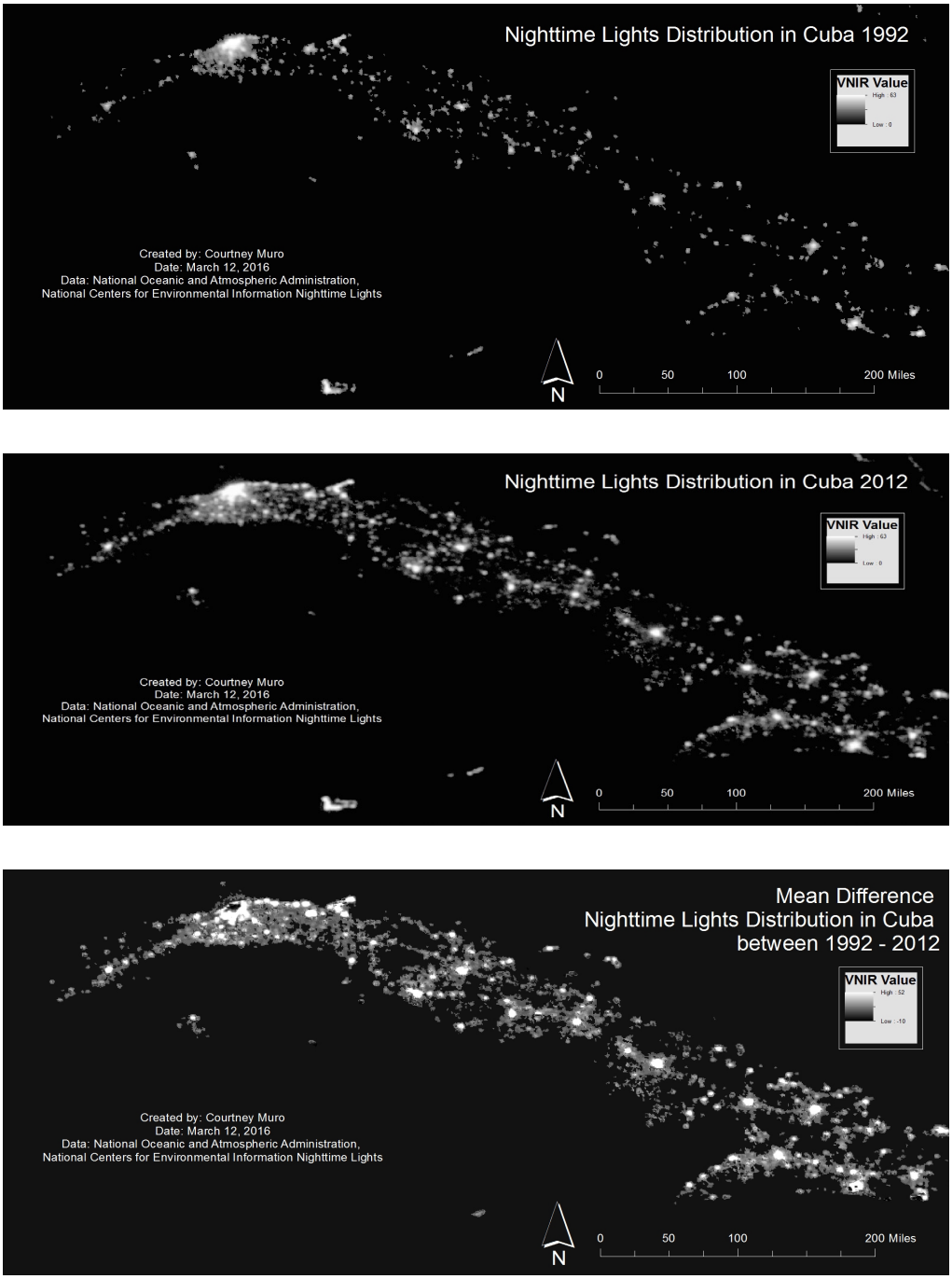



*Figure 2 shows Cuba's visible-near infrared (VNIR) distribution in 1992 and 2012, as well as the distribution of NTLs that were present in 2012, but not in 1992, representing Cuba's economic development during this time period.*

In order to get a more precise calculation of Cuban development, a regional analysis was done using both the Google Earth and Google Earth Engine platforms. Five regions were strategically chosen to be equally representative of the country. Four of Cuba's main cities, Viñales, Havana, Trinidad, Camaguay, as well as the center point of four cities that make up the southern region, Oriente, were marked in Google Earth using the placemark feature. This placemarked raster was then exported as a KMZ file, uploaded to Google Drive as a KML file, converted to a fusion table, and uploaded to Google Earth Engine Coder (GEE) as an image collection. Five evenly distributed Cuban regions were then created by using a GEE function to add 75,000 meter buffers over the existing points (Figure 3). To obtain economic calculations by region, mean NVIR value for 2012 was subtracted by the mean value of 1992, and this difference in value was extracted for each region.

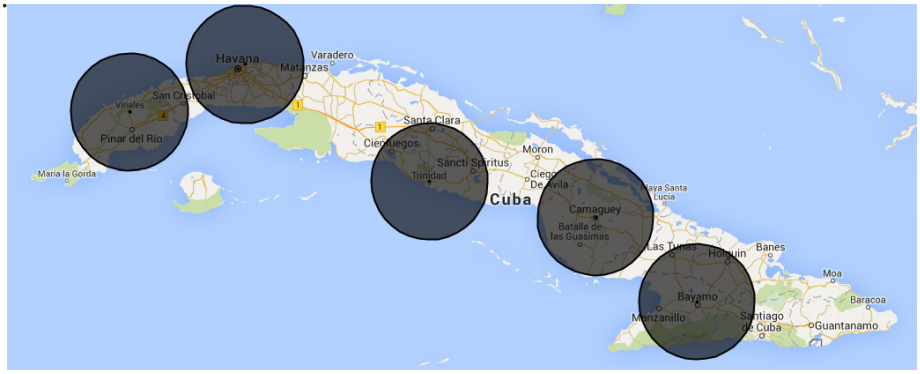



*Figure Shows 3 75,000 meter buffers were added over existing points using a GEE function*

| Change in NTL 1992-2012 | |
|---|---|
| Region | Mean Difference |
| Havana | 2.86 |
| Vinales | 0.55 |
| Camaguay | 1.32 |
| Trinidad | 1.53 |
| Oriente | 2.29 |

A third study of Cuba's domestic economy was done using a MODIS training site database for global landcover, created by University of Maryland's Global Land Cover Facility, in partnership with NASA and GOFC-Gold. The database, containing 16 categories of 500m spatial resolution landcover spanning the entire earth[13] was uploaded to GEE. The NTL raster was uploaded and merged, yielded mean difference calculations by landcover type.

*Figure 4 Cuba's mean difference between economic growth in 1992 and 2012, by region, shows that Havana and Oriente grew much faster than the other regions.*

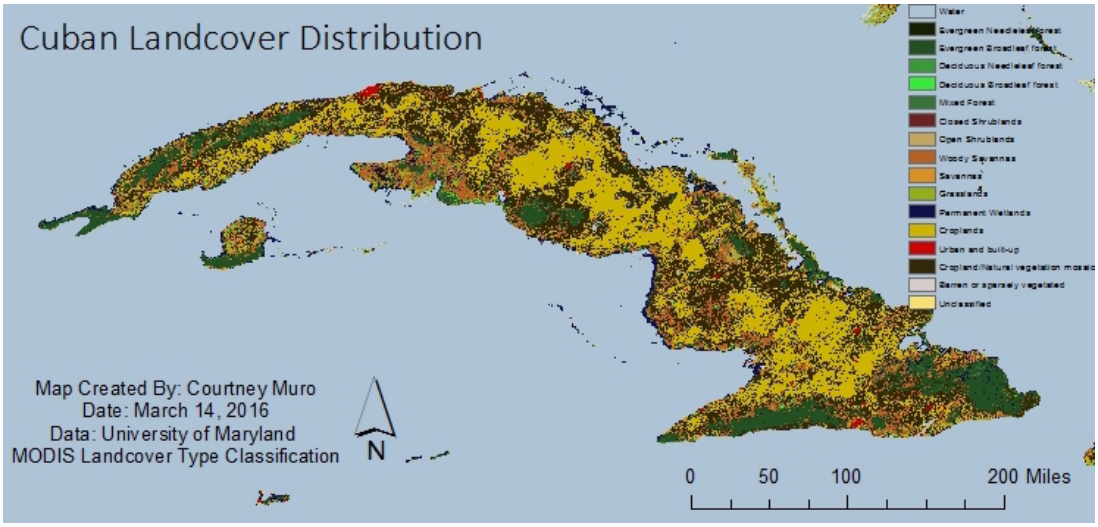
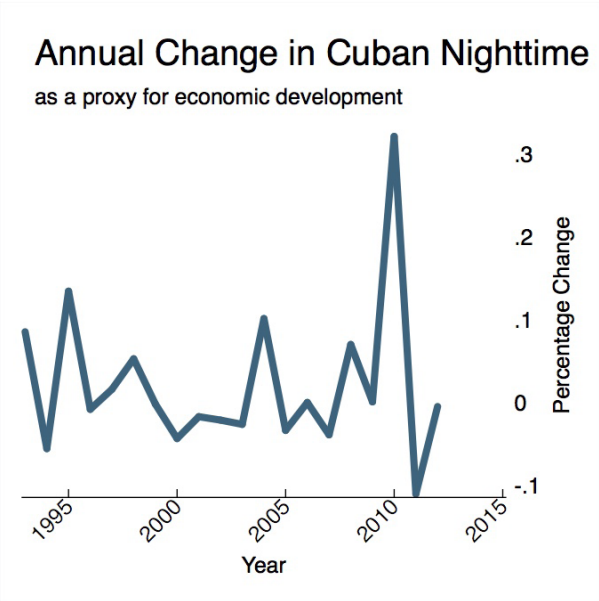



*Figure 5 shows a visual representation of Cuba's landcover distribution*

16 Boston University. User Guide for the MODIS Land Cover Type product (MCD12Q1). 8 August 2012. http://www.bu.edu/lcsc/files/2012/08/MCD12Q1_user_guide.pdf

# IV. Results:

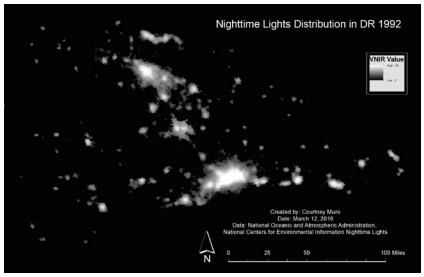
Results of this study indicate that Cuba experienced an overall growth in NTLs, and therefore economic development, of 0.42 during the studied period.

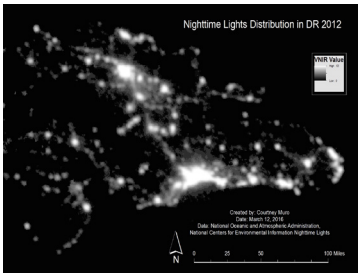


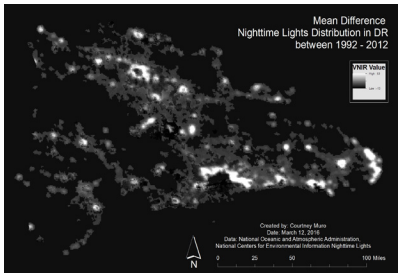

Next, Cuba's NTL statistics were examined in the international level. The Dominican Republic (DR) was chosen, based on GDP per capita, primary industries, geographic size, and geographic location, as a 'comparable' Caribbean economy to analyze against Cuba's, through the NTLs mechanism, to analyze through the NTL proxy to help determine if diverging patterns observed between Cuba's and international economies are a regional phenomenon. Figure 7 shows that both countries experienced disproportionate growth in urban and buildup areas, reflecting international urbanization rates of 200%.[17]

*Figure 6 shows Cuba's annual change in NTL*

*Figure 7 shows mean difference in DR's NTL between 1992 to 2012*

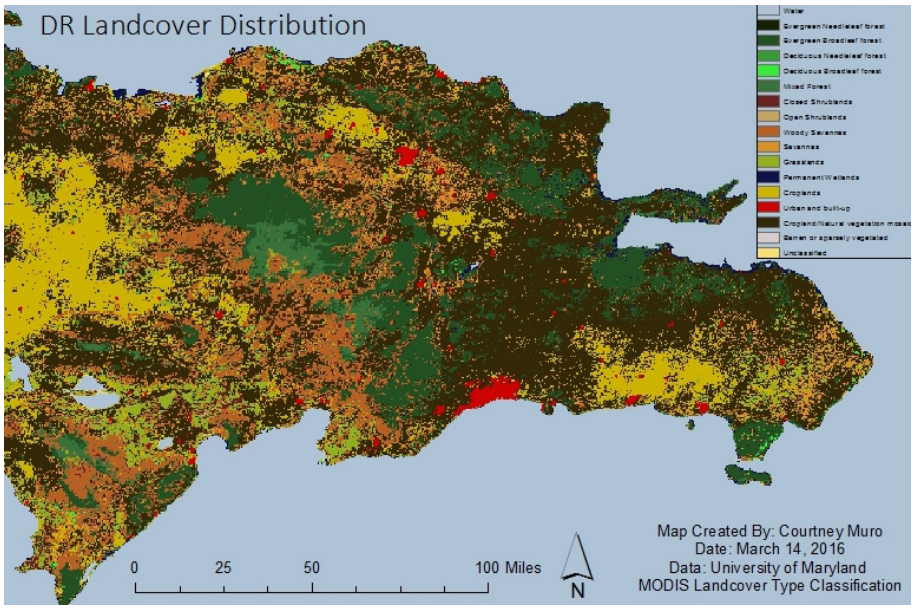



| NTL Growth 1992-2012 | |
|---|---|
| Region | Growth |
| Cuba | 0.42 |
| DR | 1.60 |

*Figure 8 NTL calculations comparing Cuba and DR show that the DR grew at almost 400% the rate of Cuba over the given study period*




*Figures 9 Shows MODIS landcover distribution of DR*

Abdullah Baqui, DrPH, MPH, MBBS. Global Urbanization: Trends, Patterns, Determinants, and Impacts. Johns Hopkins University Boston University. http://ocw.jhsph.edu/courses/urban-health/PDFs/Urban-sec2_Baqui.pdf

| Landcover Class | Mean Difference in NTL from 1992-2012 | |
|---|---|---|
| | Cuba | Dominican Republic |
| Water | 2.43 | 1.94 |
| Evergreen Needleleaf Forest | 2.79 | 0.42 |
| Evergreen Broadleaf Forest | 1.53 | 0.35 |
| Dicidious Needleleaf Forest | 0.00 | 2.07 |
| Dicidious Broadleaf Forest | 2.26 | 1.16 |
| Mixed Forest | 0.69 | 0.73 |
| Closed Shrublands | 2.17 | 1.64 |
| Open Shrublands | 0.25 | 1.58 |
| Woody Savannas | 1.56 | 0.93 |
| Savannas | 3.74 | 1.12 |
| Grasslands | 2.78 | 1.03 |
| Permanent Wetlands | 2.72 | 0.92 |
| Croplands | 4.59 | 3.14 |
| Urban and Builtup | 8.58 | 16.69 |
| Cropland/ Natural Vegetation Mosaic | 3.57 | 2.52 |
| Barren or Sparsely Vegetated | 3.53 | 2.51 |

*Figure 10 shows that both countries appear to have experienced disproportionate growth in urban and buildup areas.*

Next, notable spikes and dips in international economy were identified through a literature review, and examined using NTL data for Cuba and DR, and World Bank data for all other economies. Results are detailed below.

Overall GDP Growth:
To begin with a general parameter of economic health, data on annual GPD growth of the international economy as well as five economies with which Cuba has some financial connection was downloaded from the World Bank Database. These data, along with Cuban NTL data, was uploaded to STATA and a twoway line graph was created for visual analysis. Results of the twoway suggest that the Cuban economy has only a loose correlation with the economies in question, save for Venezuela, to which Cuba may be more closely tied (Figure 11).

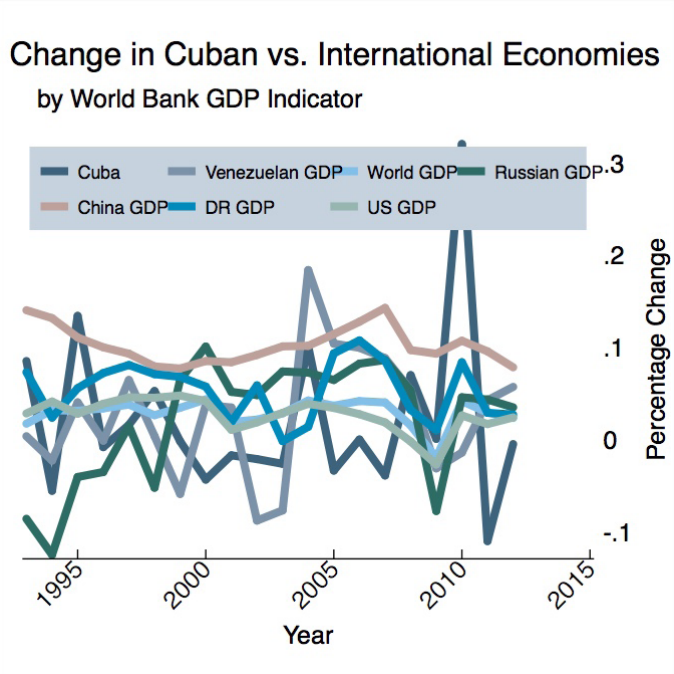



*Figure 11 Twoway graph shows Cuba's correlation with various economies*

A closer look at the two countries highlights the correlation between them, of which causes are clear. Venezuela has essentially been propping up the Castro regime since Hugo Chavez took office in 1999, with heavily subsidized oil and bilateral trade constituting as much as 20.8% of Cuba's GDP.[18] In return, Cuba provides doctors, teachers, sports trainers and military advisors,[19] as well as a moral compass for Hugo Chavez's rebellious Bolivarian movement, of which Chavez considers Fidel Castro the true leader. Graphically, Chavez's 1999 election into office should mark where this economic relationship begins, and it should not untangle until Venezuela's economic crash in 2014.[20] Figure 12, however, shows Cuba notably surpassing Venezuela in 2010, when Cuba's mean difference NTL value increases by 31% from the year before.

18 Piccone, Ted and Harold Trinkuas. The Cuba-Venezuela Alliance: The Beginning of the End? Brookings Institution. June 2014. http://www.brookings.edu/~/media/research/files/papers/2014/06/16-cuba-venezuela-alliance-piccone-trinkunas/cubavenezuela-alliance-piccone-trinkunas.pdf
19 Piccone, Ted and Harold Trinkuas. The Cuba-Venezuela Alliance: The Beginning of the End? Brookings Institution. June 2014. http://www.brookings.edu/~/media/research/files/papers/2014/06/16-cuba-venezuela-alliance-piccone-trinkunas/cubavenezuela-alliance-piccone-trinkunas.pdf
20 Piccone, Ted and Harold Trinkuas. The Cuba-Venezuela Alliance: The Beginning of the End? Brookings Institution. June 2014. http://www.brookings.edu/~/media/research/files/papers/2014/06/16-cuba-venezuela-alliance-piccone-trinkunas/cubavenezuela-alliance-piccone-trinkunas.pdf

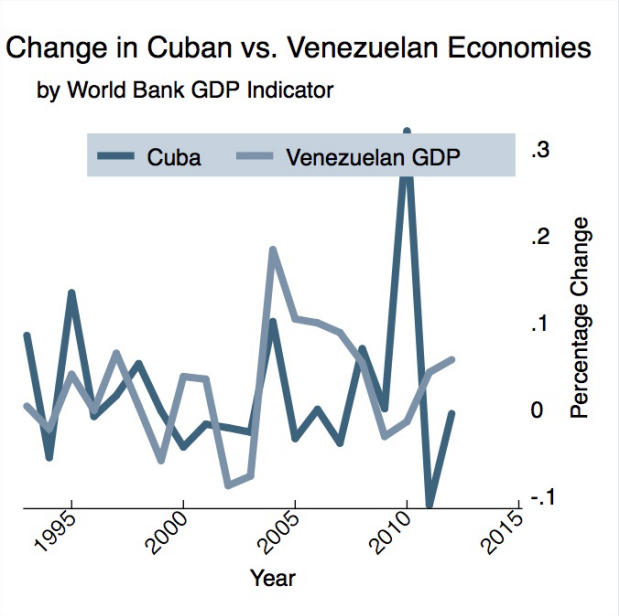



*Figure 12 A closer look highlights the correlation between the Cuban and Venezuelan economies*

The International Financial Crisis:
NTL analysis shows that Cuba's economy suffered less during the US housing market collapse than the global average. Decline in economic performance during the crisis, relative to average overall growth, was calculated using the difference between the growth rate during the crisis (2008 to 2009) and the overall growth rate of the study (1992 to 2012), as a ratio of the overall growth rate. Results, shown in Figure 13, indicate that Cuba may be mildly insulatied from the international economy, or specific economic shocks. It may also indicate a lag time between negative financial growth and corresponding negative growth in NTLs.

| Relative Performance Decline due to Global Financial Crisis | | | |
|---|---|---|---|
| Economy | 1992-2012 | 2008-2009 | Relative Decline |
| Cuba | 0.40 | 0.00 | -1.00 |
| DR | 1.04 | 0.01 | -0.99 |
| China | 2.04 | 0.09 | -0.95 |
| Venezuela | 0.50 | -0.03 | -1.06 |
| Russia | 0.40 | -0.08 | -1.19 |
| US | 0.52 | -0.03 | -1.05 |
| World | 0.56 | -0.02 | -1.04 |

*Figure 13 Calculations using NTL and World Bank data shows that Cuba's economy suffered less than the global average*

Cuba's trade Partners:
To see if Cuba's correlation with the international economy may be more apparent in the commodities market, this study will analyze Cuban trade patterns. In 2013, Cuba exported $2.43 billion and imported $6.72 billion, resulting in a negative trade balance of $4.29 billion.[21] This presents an opportunity to find high correlation between Cuban NTLs and international commodity prices of commodities traded by Cuba.

Imports:
Cuba's top imports, in descending order, are refined petroleum, wheat, cord, poultry, and concentrated milk, and these goods are received from China, Venezuela, Spain, the Netherlands, and the United Kingdom. Data on trade partners' GDP growth and inflation rates were downloaded from the World Bank Database, to be compared against Cuba's NTL patterns.

correlation becomes positive. Iron and rubber prices may be explained by the commodities bubble, but Cuba's economic growth that coincides with it must due to an exogenous factor.

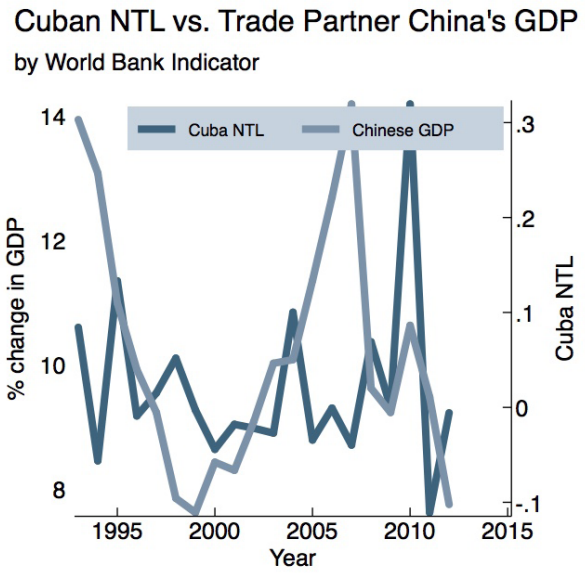



*Figure 14 Cuba's NTL growth against GDP and infltion of countries from which Cuba imports goods suggest that Cuba may have higher correlation with China*

21 The Observatory of Economic Complexity. Cuba. http://atlas.media.mit.edu/en/profile/country/cub/

To see if this relationship could be explained by Chinese-Cuban bilateral trade, graphs were created using World Bank data on commodities traded between them. After cranes, telephones, and legumes, Cuba's two largest imports from China are rubber and iron.[22] Figure 14 shows a strong, inverse correlation between Cuban economic development and prices of rubber and iron. In 2010, however this correlation becomes positive. Iron and rubber prices may be explained by the commodities bubble,[23] but Cuba's economic growth that coincides with it must due to an exogenous factor.

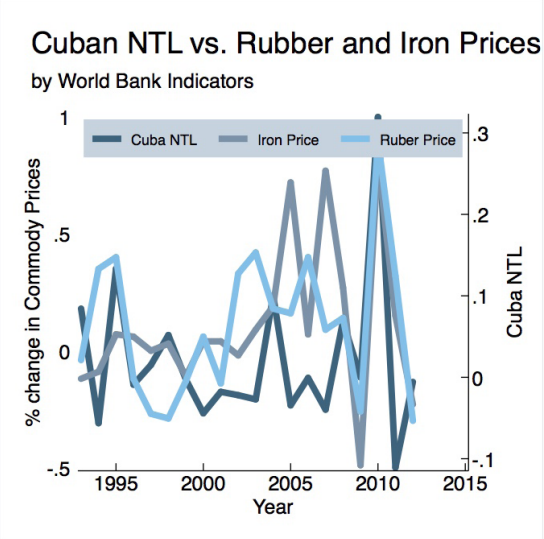



*Figure 15 shows a strong, inverse correlation between Cuban economic development and prices of rubber and iron*

Food:

Food is the largest sector of the Caribbean economy as a whole.[24] However, it constitutes less of the Caribbean GDP each year.[25] Cuba is behind the times in this regard, importing 70% of the food it consumes.[26] Because of this, an increase in food prices should effect its economic development.

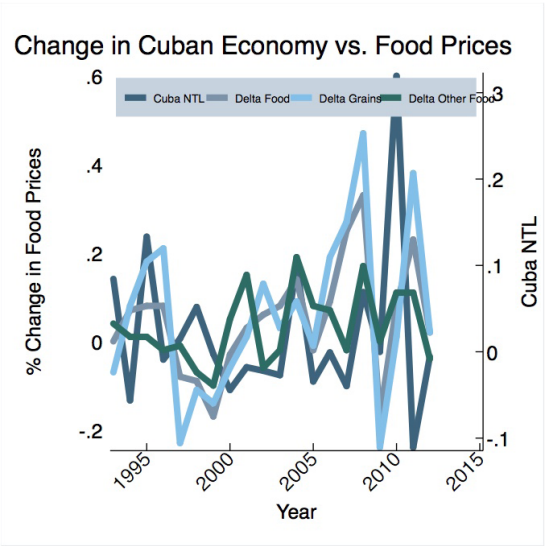



*Figure 16 shows Cuban NTLs and International Food Prices*

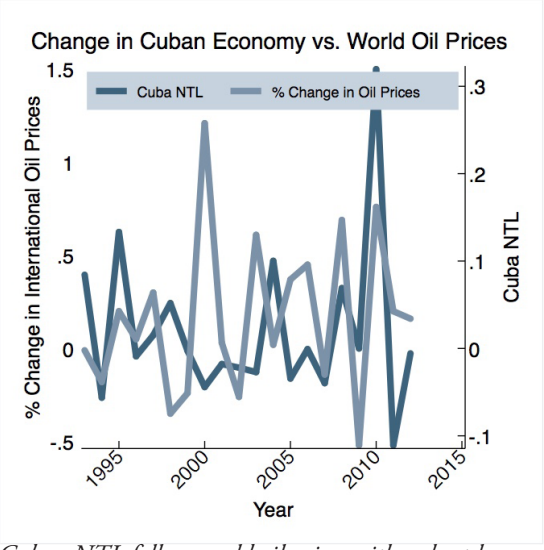



*Figure 17 Cuban NTL follow world oil prices with a short lag*

Oil:

Foreign investment in Cuban oil increased in the early 1990s, and new resource expansion on the island has concentrated on petroleum deposits, including offshore fields.[27] Plummeting oil prices in 2014, however, have had the most devastating effect Cuba's financial supporter, Venezuela - so much that it may have been a significant factor in the Cuban relent of its 50-year hardline policy against capitalism economies of the West.[28] Indeed, skeptics of the uncompromising dictatorship point to the shattered fiscal situation of Cuba's benefactor to explain the regime's recent concessions with the United States. A twoway graph (Figure 17) of Cuban NTLs and world oil prices show this relationship.

22 The Observatory of Economic Complexity. What Does Cuba Import from China? http://atlas.media.mit.edu/en/visualize/tree_map/hs92/import/cub/chn/show/2013/
23 Coombo, Jesse. The Commodities Bubble. http://www.thebubblebubble.com/commodities-bubble/
24 Wikipedia. Caribbean Food Crops Society.
https://en.wikipedia.org/wiki/Caribbean_Food_Crops_Society
25 Wikipedia. Economy of the Caribbean. https://en.wikipedia.org/wiki/Economy_of_the_Caribbean
26 Wikipedia. Agriculture in Cuba. https://en.wikipedia.org/wiki/Agriculture_in_Cuba
27 Wikipedia. Economy of the Caribbean. https://en.wikipedia.org/wiki/Economy_of_the_Caribbean
28 Catañeda, Jorge. Behind Cuba's Opening to the U.S.: Dropping Oil Prices Are Forcing an End to Venezuela's Subsidy of the Cuban Economy. The World Post. 18 December 2014. http://www.huffingtonpost.com/jorge-castaeda-/venezuela-oil-cuba-us-deal_b_6348824.html

Exports:
Cuba's top exports, in descending order, are raw sugar, refined petroleum, rolled tobacco, and nickel. Trading partners for these exports are China, Venezuela, Spain, the Netherlands, and the UK.

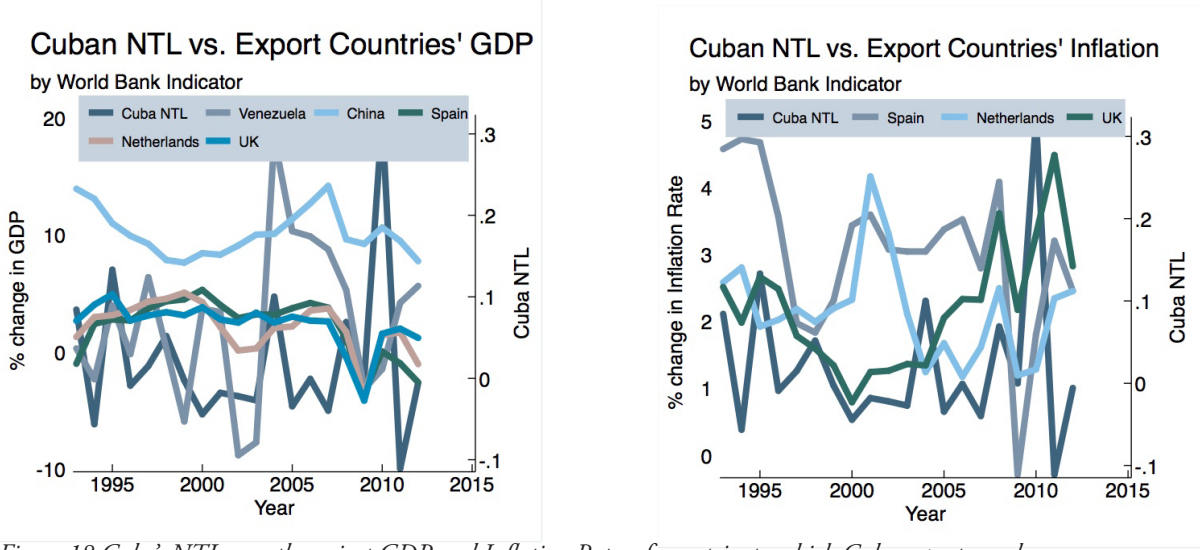



*Figure 18 Cuba's NTL growth against GDP and Inflation Rates of countries to which Cuba exports goods*

Once upon a time, Cuba was once the world's largest sugar exporter. Pre-embargo, the US received over a third of its sugar supply from Cuba, at subsidized prices of up to 400% of the market.[29] After the revolution and resulting expropriations of US holdings in Cuba, this sponsorship was terminated in exchange for more hostile relations. Cuba was not left to fend for itself, however, and sugar subsidies of comparable discount became the mechanism through which the Soviet Union propped up the regime during tough times of the Cold War. When both the USSR and sugar prices collapsed simultaneously in the early '90s, Cuba's economy was hit with the loss of over two-thirds of its sugar mills and 100,000 jobs. Prices temporarily resurged in 2008, but have never fully rebounded. While sugar production in some countries has grown as much as 300% over the last decade, Cuba's production has faltered, hovering around just 23%. Consumption over this period has fallen to 14%; a compiling effect of drastically reduced Russian consumption, a 2-3% decrease of Cuba's non-communist markets Japan and Canada,[30] and recent capacity increase of former communist markets such as East Germany, Hungary, and Poland, who now produce domestically.[31] Of Cuba's current sugar yield, between a third and a half gets exported to China, and a bit less than that gets consumed domestically.[32] Figure 19 presents a strong association between the Cuban economy and sugar prices. The relationship with world prices appears strongest, while the relationship with US prices appears weak.

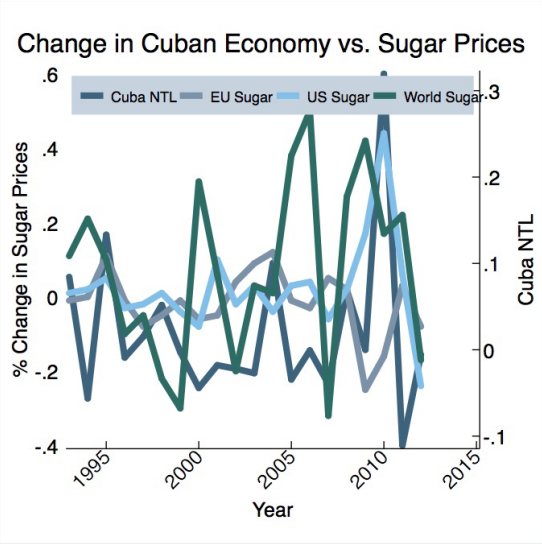



*Figure 19 presents a clear correlation between the Cuban economy and sugar prices*

29 Echevarría, Oscar A. Cuba and the International Sugar Market. http://www.ascecuba.org/c/wp-content/uploads/2014/09/v05-FILE30.pdf
30 Echevarría, Oscar A. Cuba and the International Sugar Market. http://www.ascecuba.org/c/wp-content/uploads/2014/09/v05-FILE30.pdf
31 Echevarría, Oscar A. Cuba and the International Sugar Market. http://www.ascecuba.org/c/wp-content/uploads/2014/09/v05-FILE30.pdf
32 Wikipedia. Agriculture in Cuba. https://en.wikipedia.org/wiki/Agriculture_in_Cuba

Nickel:

Cuba is the world's 4th largest nickel exporter[33] and, prior to the revolution, almost all of Cuba's nickel was owned by the United States.[34] Nickel remains Cuba's leading export after sugar[35] and it is in such high demand that the US embargo has been defied in favor of purchasing this metal from the communist state. The 2010 increase in nickel prices, shown in Figure 20, may provide an explanation for Cuba's minimal NTL setback during the financial crisis. To visually analyze this potential relationship, Cuba's 2008 economic growth was calculated regionally, and inspection focuses on the Oriente region, which contains Cuba's largest nickel mine, Moa Nickel. Figure 21 shows the rate at which Cuba's different regions grew in 2008, compared to their 20-year growth. The chart displays that, whereas Havana grew quicker than the Oriente during the 20-year study period, Oriente grew much faster than Havana during 2008, when nickel prices rose. This demonstrates that Cuba's economic performance may be more dependent on nickel prices than intentional economic crises.

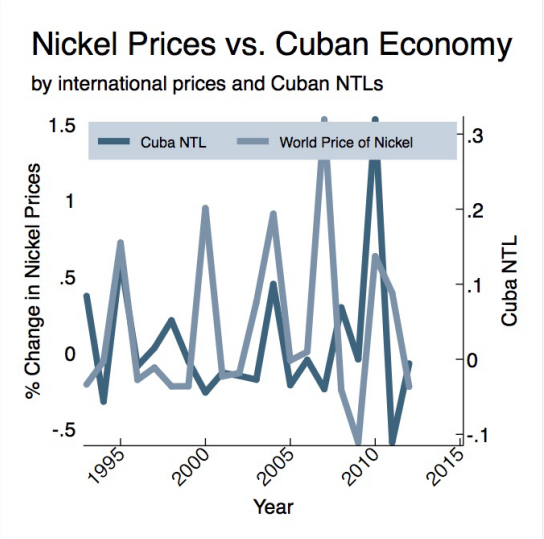



*Figure 20 shows a correlation between Cuban NTLs and nickel prices*

| Mean Difference Change in NTL | | |
|---|---|---|
| Region | 1992-2012 | 2008-2009 |
| Havana | 2.86 | 0.80 |
| Vinales | 0.55 | 0.03 |
| Camaguay | 1.32 | 0.22 |
| Trinidad | 1.53 | 0.25 |
| Oriente | 2.29 | 1.02 |

*Figure 21 shows the rate at which Cuba's different regions grew in 2008, compared to their 20-year growth*

33 Ecclestone, Christopher. Putting the Cuban nickel and cobalt resources back into its orbit. 25 September 2014. http://investorintel.com/gold-precious-metals-intel/cracking-open-cuba-next-vietnam/

34 Country Quest. Cuba: Economy, Mining. http://www.countriesquest.com/caribbean/cuba/economy/mining.htm

35 Nations Encyclopedia. Cuba: Mining. http://www.nationsencyclopedia.com/Americas/Cuba-MINING.html

# V. Discussion and Conclusion

Findings derived from NTL satellite imagery suggest that Cuba is at least relatively insulated from shocks of the international economy, and more prone to fluctuations of its trade partners economies and prices of commodities traded between them. Specifically, rubber, iron, 'other food,' sugar and nickel prices, as well as Venezuela's national economic performance, have a detectable correlation with Cuban economic development, indicated through NTLs.

NTLs is a useful proxy variable for determining economic development growth in countries that have little or unreliable economic data. Cuba is a prime example of this, as its 50-year-old dictatorship operates the country's financial books in complete seclusion from the rest of the world. However, this proxy is not without imitations. For one, economic changes based on NTLs may have a significant lag behind actual changes in the financial market. NTLs is a measure of physical structure, which takes time to both construct and deconstruct. On the other hand, modern financial indicators such as stock market positions and real prices are based on floating credit, and can change drastically in real time. Furthermore, increases in NTLs may be more closely tied to actual economic development than their decrease, as the time it takes for financial hardship to manifest in the demolition of structures, electricity shutoffs, and land abandonment may be slower than the time it takes for growing economies to engage in construction. Take for example, Cuba's deteriorated housing stock, still standing after 50 years of economic stagnation, in contrast to the architecture phenomenon of United Arab Emirates, which was a desert until to the fairly recent oil boom.

While there are current shortcomings of NTL technology as a proxy for economic development, future studies have the potential to scale up, with increased accuracy. If NTLs' lags can be calculated in a consistent formula, to be adjusted situationally, then it could substitute for more expensive means of data collection.

# Appendix - Google Earth Engine Code

```
//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var geometry = /* color: bf04c2 */ee.Geometry.Polygon(
        [[[-97.3828125, 15.029685756555674],
          [-63.10546875, 14.774882506516272],
          [-64.16015625, 32.32427558887655],
          [-96.943359375, 34.23451236236987]]]);

// Load nightlights image inputs.
var nl2001 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152001')
  .select('stable_lights');
Map.addLayer(nl2001, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl2001');
var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
Map.addLayer(nl2012, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl2012');

// Compute the nightlights decadal difference, without regions.
var nlDiff = nl2012.subtract(nl2001).clip(geometry);
print(nlDiff);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nlDiff');

//Print mean reducer, difference in Cuba from 1992 to 2012
var stats = nlDiff.reduceRegion(
{
'reducer': ee.Reducer.mean(),
'geometry': geometry,
'maxPixels': 1e9
});
print(stats);
//but is this just for Cuba?

// Export the image, specifying scale and region.
Export.image(landsat, 'exportImageExample', {
  scale: 30,
  region: geometry
});
  //Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var geometry = /* color: ff9999 */ee.Geometry.Polygon(
        [[[-85.27587890625, 22.492257220085193],
          [-84.375, 21.309846141087206],
          [-82.06787109375, 20.447602397594167],
          [-77.89306640625, 19.041348796589016],
          [-73.916015625, 19.352610894378635],
          [-73.8720703125, 20.776659051878816],
          [-79.34326171875, 23.56398712845123],
          [-84.287109375, 23.382598284178858]]]);

var imageCollection = ee.ImageCollection("NOAA/DMSP-OLS/NIGHTTIME_LIGHTS");
print(imageCollection);

// Load nightlights image inputs.
var nl1992 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101992')
  .select('stable_lights');
Map.addLayer(nl1992, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl1992');
var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
Map.addLayer(nl2012, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl2012');

// Compute the nightlights decadal difference, without regions.
var nlDiff = nl2012.subtract(nl1992).clip(geometry);
print(nlDiff);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nlDiff');
//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var geometry = /* color: ff9999 */ee.Geometry.Polygon(
        [[[-85.27587890625, 22.492257220085193],
          [-84.375, 21.309846141087206],
          [-82.06787109375, 20.447602397594167],
          [-77.89306640625, 19.041348796589016],
          [-73.916015625, 19.352610894378635],
          [-73.8720703125, 20.776659051878816],
          [-79.34326171875, 23.56398712845123],
          [-84.287109375, 23.382598284178858]]]);


//add fusion table with points
var Cuba5Points = ee.FeatureCollection('ft:1Iw9Vrx_F4iASB2FU1wHF4C4Dvdzyn9wYi5lZXIt5');
Map.addLayer(Cuba5Points.draw({'color': '000000', pointRadius:1}));

//Single Buffer
var createBuffer= function(feature)
{
var bufferedCuba = feature.buffer(75000);
return bufferedCuba;
};
```

```
var bufferAroundEachFeature = Cuba5Points.map(createBuffer);
print(bufferAroundEachFeature);
Map.addLayer(bufferAroundEachFeature,{'palette':'0000FF'});
Export.image(bufferAroundEachFeature, 'Figure3', {
  scale: 90,
  region: geometry
});
//Wont export
//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var geometry = /* color: ff0000 */ee.Geometry.Polygon(
        [[[-85.80322265625, 18.979025953255267],
          [-73.5205078125, 18.95824648598139],
          [-73.9599609375, 23.543845136505833],
          [-85.40771484375, 23.765236889758675]]]);

//add fusion table with points
var Cuba5Points = ee.FeatureCollection('ft:1Iw9Vrx_F4iASB2FU1wHF4C4Dvdzyn9wYi5lZXIt5');
Map.addLayer(Cuba5Points.draw({'color': '000000', pointRadius:1}));

//Single Buffer
var createBuffer= function(feature)
{
var bufferedCuba = feature.buffer(75000);
return bufferedCuba;
};

var bufferAroundEachFeature = Cuba5Points.map(createBuffer);
print(bufferAroundEachFeature);
Map.addLayer(bufferAroundEachFeature,{'palette':'0000FF'});
Export.image(bufferAroundEachFeature, 'Figure3', {
  scale: 90,
  region: geometry
});


// Load nightlights image inputs.
var imageCollection = ee.ImageCollection("NOAA/DMSP-OLS/NIGHTTIME_LIGHTS");
print(imageCollection);
var nl1992 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101992')
  .select('stable_lights');
var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');

// Compute the nightlights decadal difference, without regions.
var nlDiff = nl2012.subtract(nl1992);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nlDiff');

//create a function that calculates the mean nlDiff within the buffer
var nlDiffmean = function(feature) {
var stats = nlDiff.reduceRegion(
{
'reducer': ee.Reducer.mean(),
'geometry': feature.geometry(),
'maxPixels': 1e9
});
//and creates a new property "nlDiffbyRegion" with this mean
return feature.set({'nlDiffbyRegion': stats});
};
print(nlDiffmean);
//then, we apply this function on each of the buffered mines
var meannlDiffperBuffer = bufferAroundEachFeature.map(nlDiffmean);
print(meannlDiffperBuffer);
//save the results of getInfo() to a variable: "features". Then, create a loop to print the mean nlDiff within the buffer
var features = meannlDiffperBuffer.getInfo().features;

for (var i = 0; i < features.length; ++i) {
var thisFeature = features[i].properties;
print(thisFeature.name + ': ' + thisFeature.nlDiffbyRegion.stable_lights);
}
```

```
//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var CubaGeo = /* color: 98ff00 */ee.Geometry.Polygon(
        [[[-85.23193359375, 21.6778482933475],
          [-76.53076171875, 19.08288436934017],
          [-74.6630859375, 19.476950206488425],
          [-73.71826171875, 20.550508894195637],
          [-75.87158203125, 21.963424936844223],
          [-80.15625, 23.664650731631614],
          [-85.10009765625, 23.926013033021203]]]);

var region = ee.Feature(
  ee.FeatureCollection('ft:1tdSwUL7MVpOauSgRzqVTOwdfy17KDbw-1d9omPw')
  .filterMetadata('Country', 'equals', 'Cuba')
  .first());

//Use reducer.group() to group the output of a reducer by the value of a specified input.
//For example, to compute the total population and number of housing units in each state,
//group the output of the counties reduction

//The groupField argument is the index of the input in the selectors array that contains the
//codes by which to group, the groupName argument specifies the name of the property to store
//the value of the grouping variable. Since the reducer is not automatically repeated for each
//input, the repeat(2) call is needed.

//Group output of image.reduceRegions() by specifying a grouping band. This type of conputation
//is sometimes called "zonal statistics" where the zones are specified as the grouping band and
//the statistic is determined by the reducer. In the following example, change in nightlights
//in the United States is grouped by land cover category

//Note that in this example, the groupField is the index of the band containing the zones by
//which to group the output. The first band is index 0, the second is index 1, etc.


// Load a region representing Cuba
var region = ee.Feature(
  ee.FeatureCollection('ft:1tdSwUL7MVpOauSgRzqVTOwdfy17KDbw-1d9omPw')
  .filterMetadata('Country', 'equals', 'Cuba')
  .first());
print(region);

// Load MODIS land cover categories in 2001.
var landcover = ee.Image('MODIS/051/MCD12Q1/2001_01_01')
  // Select the IGBP classification band.
  .select('Land_Cover_Type_1');
print(landcover);
Map.addLayer(landcover);

// Load nightlights image inputs.
var nl2001 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152001')
  .select('stable_lights');
print(nl2001);
Map.addLayer(nl2001, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl2001');

var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
print(nl2012);
Map.addLayer(nl2012, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max':43}, 'nl2012');

// Compute the nightlights decadal difference, add land cover codes
var nlDiff = nl2012.subtract(nl2001).addBands(landcover);
print(nlDiff);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 23}, 'nlDiff');

// Compute the nightlights decadal difference, without land cover
var nlDiffnolandcover = nl2012.subtract(nl2001);
print(nlDiffnolandcover);
Map.addLayer(nlDiffnolandcover, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 23}, 'nlDiffnolandcover');
// Export the FeatureCollection.
Export.table(nlDiffnolandcover, 'nlDiffnolandcover', {fileFormat: 'CSV'});


// Grouped a mean reducer: change of nightlights by land cover category.
var means = nlDiff.reduceRegion({
  reducer: ee.Reducer.mean().group({
    groupField: 1,
    groupName: 'code',
  }),
  geometry: region.geometry(),
  scale: 1000,
  maxPixels: 1e8
});

// Print the resultant Dictionary.
print(means);


// Make a feature without geometry and set the properties to the dictionary of means.
var feature = ee.Feature(null, means);
// Wrap the Feature in a FeatureCollection for export.
var featureCollection = ee.FeatureCollection([feature]);
// Export the FeatureCollection.
Export.table(featureCollection, 'exportTableMeans', {fileFormat: 'CSV'});

//Export to GIS and add legend - adjust scale for resolution OR use UMD table Emily sent you
```

```
//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var geometry = /* color: ff9999 */ee.Geometry.Polygon(
        [[[-85.27587890625, 22.492257220085193],
          [-84.375, 21.309846141087206],
          [-82.06787109375, 20.447602397594167],
          [-77.89306640625, 19.041348796589016],
          [-73.916015625, 19.352610894378635],
          [-73.8720703125, 20.776659051878816],
          [-79.34326171875, 23.56398712845123],
          [-84.287109375, 23.382598284178858]]]);

var region = ee.Feature(
  ee.FeatureCollection('ft:1tdSwUL7MVpOauSgRzqVTOwdfy17KDbw-1d9omPw')
  .filterMetadata('Country', 'equals', 'Cuba')
  .first());

//Use reducer.group() to group the output of a reducer by the value of a specified input.
//For example, to compute the total population and number of housing units in each state,
//group the output of the counties reduction

//The groupField argument is the index of the input in the selectors array that contains the
//codes by which to group, the groupName argument specifies the name of the property to store
//the value of the grouping variable. Since the reducer is not automatically repeated for each
//input, the repeat(2) call is needed.

//Group output of image.reduceRegions() by specifying a grouping band. This type of conputation
//is sometimes called "zonal statistics" where the zones are specified as the grouping band and
//the statistic is determined by the reducer. In the following example, change in nightlights
//in the United States is grouped by land cover category

//Note that in this example, the groupField is the index of the band containing the zones by
//which to group the output. The first band is index 0, the second is index 1, etc.


// Load a region representing Cuba
var region = ee.Feature(
  ee.FeatureCollection('ft:1tdSwUL7MVpOauSgRzqVTOwdfy17KDbw-1d9omPw')
  .filterMetadata('Country', 'equals', 'Cuba')
  .first());
print(region);

// Load MODIS land cover categories in 2001.
var landcover = ee.Image('MODIS/051/MCD12Q1/2001_01_01')
  // Select the IGBP classification band.
  .select('Land_Cover_Type_1');
print(landcover);
Map.addLayer(landcover);

// Load nightlights image inputs.
var nl1992 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101992')
  .select('stable_lights');
print(nl1992);
Map.addLayer(nl1992, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl1992');

var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
print(nl2012);
Map.addLayer(nl2012, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max':43}, 'nl2012');

// Compute the nightlights decadal difference, add land cover codes
var nlDiff = nl2012.subtract(nl1992).addBands(landcover);
print(nlDiff);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 23}, 'nlDiff');

// Grouped a mean reducer: change of nightlights by land cover category.
var means = nlDiff.reduceRegion({
  reducer: ee.Reducer.mean().group({
    groupField: 1,
    groupName: 'code',
  }),
  geometry: region.geometry(),
  scale: 1000,
  maxPixels: 1e8
});

// Print the resultant Dictionary.
print(means);

// Make a feature without geometry and set the properties to the dictionary of means.
var feature = ee.Feature(null, means);
// Wrap the Feature in a FeatureCollection for export.
var featureCollection = ee.FeatureCollection([feature]);
// Export the FeatureCollection.
Export.table(featureCollection, 'exportTableMeans', {fileFormat: 'CSV'});

//Export to GIS and add legend - adjust scale for resolution OR use UMD table Emily sent you

// Export the image, specifying scale and region.
Export.image(landcover, 'exportImagelandcover', {
  scale: 80,
  region: geometry,
});
```

```
//Map Extent
Map.setCenter(-70.66, 19,7);

//Geometry
var geometry = /* color: bf04c2 */ee.Geometry.Polygon(
        [[[-71.7791748046875, 17.858518676113984],
          [-71.4166259765625, 17.607375018147255],
          [-70.6585693359375, 17.973508079068797],
          [-68.5107421875, 17.931702385498127],
          [-68.170166015625, 18.687878686034196],
          [-69.093017578125, 19.3940678953966628],
          [-69.80712890625, 19.75636423075239],
          [-70.8233642578125, 20.086888505561017],
          [-71.8341064453125, 19.849393958422805],
          [-71.7626953125, 19.694314241825747],
          [-71.6912841796875, 19.528730138897643],
          [-71.69677734375, 19.362976133341846],
          [-71.8011474609375, 19.33706180106996],
          [-71.630859375, 19.202241064923054],
          [-71.8890380859375, 18.95824648598139],
          [-71.8011474609375, 18.95824648598139],
          [-71.7132568359375, 18.880300444535084],
          [-71.773681640625, 18.646245142670608],
          [-72.0098876953125, 18.63583516062285],
          [-71.91650390625, 18.490028573953296],
          [-71.71875, 18.3336694457713],
          [-71.773681640625, 18.166730410221938],
          [-71.7626953125, 18.04142122189195]]]);

//Use reducer.group() to group the output of a reducer by the value of a specified input.
//For example, to compute the total population and number of housing units in each state,
//group the output of the counties reduction

//The groupField argument is the index of the input in the selectors array that contains the
//codes by which to group, the groupName argument specifies the name of the property to store
//the value of the grouping variable. Since the reducer is not automatically repeated for each
//input, the repeat(2) call is needed.

//Group output of image.reduceRegions() by specifying a grouping band. This type of conputation
//is sometimes called “zonal statistics” where the zones are specified as the grouping band and
//the statistic is determined by the reducer. In the following example, change in nightlights
//in the United States is grouped by land cover category

//Note that in this example, the groupField is the index of the band containing the zones by
//which to group the output. The first band is index 0, the second is index 1, etc.


// Load a region representing DR
var region = ee.Feature(
  ee.FeatureCollection('ft:1tdSwUL7MVpOauSgRzqVTOwdfy17KDbw-1d9omPw')
  .filterMetadata('Country', 'equals', 'Dominican Republic')
  .first());
print(region);

// Load MODIS land cover categories in 2001.
var landcover = ee.Image('MODIS/051/MCD12Q1/2001_01_01')
  // Select the IGBP classification band.
  .select('Land_Cover_Type_1');
print(landcover);
Map.addLayer(landcover);

// Load nightlights image inputs.
var nl1992 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101992')
  .select('stable_lights');
print(nl1992);
Map.addLayer(nl1992, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl1992');

var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
print(nl2012);
Map.addLayer(nl2012, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max':43}, 'nl2012');

// Compute the nightlights decadal difference, add land cover codes
var nlDiff = nl2012.subtract(nl1992).addBands(landcover);
print(nlDiff);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 23}, 'nlDiff');

// Grouped a mean reducer: change of nightlights by land cover category.
var means = nlDiff.reduceRegion({
  reducer: ee.Reducer.mean().group({
    groupField: 1,
    groupName: 'code',
  }),
  geometry: region.geometry(),
  scale: 1000,
  maxPixels: 1e8
});

// Print the resultant Dictionary.
print(means);

// Make a feature without geometry and set the properties to the dictionary of means.
var feature = ee.Feature(null, means);
// Wrap the Feature in a FeatureCollection for export.
var featureCollection = ee.FeatureCollection([feature]);
// Export the FeatureCollection.
```

```
//Map Extent
Map.setCenter(-70.66, 19,7);

//Geometry
var geometry = /* color: bf04c2 */ee.Geometry.Polygon(
        [[[-71.7791748046875, 17.858518676113984],
          [-71.4166259765625, 17.607375018147255],
          [-70.6585693359375, 17.973508079068797],
          [-68.5107421875, 17.931702385498127],
          [-68.170166015625, 18.687878686034196],
          [-69.093017578125, 19.394067895396628],
          [-69.80712890625, 19.75636423075239],
          [-70.8233642578125, 20.086888505561017],
          [-71.8341064453125, 19.849393958422805],
          [-71.7626953125, 19.694314241825747],
          [-71.6912841796875, 19.528730138897643],
          [-71.69677734375, 19.362976133341846],
          [-71.8011474609375, 19.33706180106996],
          [-71.630859375, 19.202241064923054],
          [-71.8890380859375, 18.95824648598139],
          [-71.8011474609375, 18.95824648598139],
          [-71.7132568359375, 18.880300444535084],
          [-71.773681640625, 18.646245142670608],
          [-72.0098876953125, 18.63583516062285],
          [-71.91650390625, 18.490028573953296],
          [-71.71875, 18.3336694457713],
          [-71.773681640625, 18.166730410221938],
          [-71.7626953125, 18.04142122189195]]]);

var imageCollection = ee.ImageCollection("NOAA/DMSP-OLS/NIGHTTIME_LIGHTS");
print(imageCollection);

// Load nightlights image inputs.
var nl1992 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101992')
  .select('stable_lights');
Map.addLayer(nl1992, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl1992');
var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
Map.addLayer(nl2012, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl2012');

// Compute the nightlights decadal difference, without regions.
var nlDiff = nl2012.subtract(nl1992).clip(geometry);
print(nlDiff);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nlDiff');


//Print mean reducer, difference in DR from 1992 to 2012
var stats = nlDiff.reduceRegion(
{
'reducer': ee.Reducer.mean(),
'geometry': geometry,
'maxPixels': 1e9
});
print(stats);

// Export the image, specifying scale and region.
Export.image(nl1992, 'nl1992', {
  scale: 80,
  region: geometry,
});

Export.image(nl2012, 'nl2012', {
  scale: 80,
  region: geometry,
});

Export.image(nlDiff, 'nlDiff', {
  scale: 80,
  region: geometry,
});

//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var geometry = /* color: ff9999 */ee.Geometry.Polygon(
        [[[-85.27587890625, 22.492257220085193],
          [-84.375, 21.309846141087206],
          [-82.06787109375, 20.447602397594167],
          [-77.89306640625, 19.041348796589016],
          [-73.916015625, 19.352610894378635],
          [-73.8720703125, 20.776659051878816],
          [-79.34326171875, 23.56398712845123],
          [-84.287109375, 23.382598284178858]]]);

var imageCollection = ee.ImageCollection("NOAA/DMSP-OLS/NIGHTTIME_LIGHTS");
print(imageCollection);

// Load nightlights image inputs.
var nl1992 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101992')
  .select('stable_lights');
Map.addLayer(nl1992, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl1992');
var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
Map.addLayer(nl2012, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl2012');

// Compute the nightlights decadal difference, without regions.
```

```
Map.setCenter(-70.66, 19,7);

//Geometry
var DRGeo = /* color: 00ff00 */ee.Geometry.Polygon(
        [[[-71.74072265625, 17.20376982191752],
          [-69.14794921875, 17.54977183258917],
          [-67.7197265625, 18.812717856407772],
          [-70.29052734375, 20.14878463216417],
          [-71.806640625, 19.98367396609249]]]);


var imageCollection = ee.ImageCollection("NOAA/DMSP-OLS/NIGHTTIME_LIGHTS");
print(imageCollection);

// Load nightlights image inputs.
var nl1992 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101992')
  .select('stable_lights');
Map.addLayer(nl1992, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl1992');
var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
Map.addLayer(nl2012, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl2012');

// Compute the nightlights decadal difference, without regions.
var nlDiff = nl2012.subtract(nl1992).clip(DRGeo);
print(nlDiff);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nlDiff');

//Print mean reducer, difference in DR from 1992 to 2012
var stats = nlDiff.reduceRegion(
{
'reducer': ee.Reducer.mean(),
'geometry': DRGeo,
'maxPixels': 1e9
});
print(stats);
//but is this just for DR?
//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var geometry = ee.Geometry.Polygon(
        [[[-85.23193359375, 21.6778482933475],
          [-76.53076171875, 19.08288436934017],
          [-74.6630859375, 19.476950206488425],
          [-73.71826171875, 20.550508894195637],
          [-75.87158203125, 21.963424936844223],
          [-80.15625, 23.664650731631614],
          [-85.10009765625, 23.926013033021203]]]);

var imageCollection = ee.ImageCollection("NOAA/DMSP-OLS/NIGHTTIME_LIGHTS");
print(imageCollection);

// Load nightlights image inputs.
var nl1992 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101992')
  .select('stable_lights');
Map.addLayer(nl1992, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl1992');
var nl2012 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
Map.addLayer(nl2012, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl2012');

// Compute the nightlights decadal difference, without regions.
var nlDiff = nl2012.subtract(nl1992).clip(geometry);
print(nlDiff);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nlDiff');


var year = [1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012];

var meanDiffpixels = function(feature)
{
  var newFeature =ee.Feature(feature.geometry(),{'name':feature.get('name')});
  var stats = nlDiff.reduceRegion(
    {
  'reducer': ee.Reducer.mean(),
  'geometry': geometry(),
  'maxPixels': 207765900580,
  'crs': 'EPSG:4326',
  'scale': 30
  });
print(stats);
/*
newFeature =
newFeature.set(year,stats.get('stable_lights'));
}
return newFeature;
};
var NTLallChart = imageCollection.map(meanDiffpixels);
Export.table(NTLallChart);



/*
//Print mean reducer, difference in Cuba from 1992 to 2012
var stats = nlDiff.reduceRegion(
{
'reducer': ee.Reducer.mean(),
'geometry': CubaGeo,
```

```
//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var CubaGeo = /* color: 98ff00 */ee.Geometry.Polygon(
        [[[-85.23193359375, 21.6778482933475],
          [-76.53076171875, 19.08288436934017],
          [-74.6630859375, 19.476950206488425],
          [-73.71826171875, 20.550508894195637],
          [-75.87158203125, 21.963424936844223],
          [-80.15625, 23.664650731631614],
          [-85.10009765625, 23.926013033021203]]]);



// Load nightlights image inputs.
var nl2008 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152001')
  .select('stable_lights');
print(nl2008);
Map.addLayer(nl2008, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 43}, 'nl2008');

var nl2009 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182012')
  .select('stable_lights');
print(nl2009);
Map.addLayer(nl2009, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max':43}, 'nl2009');

// Compute the nightlights decadal difference
var nlDiff = nl2009.subtract(nl2008);
print(nlDiff);
Map.addLayer(nlDiff, {'bands': ['stable_lights'],'palette':'000000, FFFFFF', 'min':0, 'max': 23}, 'nlDiff');


//add fusion table with points
var Cuba5Points = ee.FeatureCollection('ft:1Iw9Vrx_F4iASB2FU1wHF4C4Dvdzyn9wYi5lZXIt5');
Map.addLayer(Cuba5Points.draw({'color': '000000', pointRadius:1}));

//Single Buffer
var createBuffer= function(feature)
{
var bufferedCuba = feature.buffer(75000);
return bufferedCuba;
};


var bufferAroundEachFeature = Cuba5Points.map(createBuffer);
print(bufferAroundEachFeature);
Map.addLayer(bufferAroundEachFeature,{'palette':'0000FF'});
Export.image(bufferAroundEachFeature, 'Figure3', {
  scale: 90,
  region: CubaGeo
});


//create a function that calculates the mean nlDiff within the buffer
var nlDiffmean = function(feature) {
var stats = nlDiff.reduceRegion(
{
'reducer': ee.Reducer.mean(),
'geometry': feature.geometry(),
'maxPixels': 1e9
});
//and creates a new property "nlDiffbyRegion" with this mean
return feature.set({'nlDiffbyRegion': stats});
};
print(nlDiffmean);

//then, we apply this function on each of the buffered mines
var meannlDiffperBuffer = bufferAroundEachFeature.map(nlDiffmean);
print(meannlDiffperBuffer);
//save the results of getInfo() to a variable: "features". Then, create a loop to print the mean nlDiff within the buffer
var features = meannlDiffperBuffer.getInfo().features;

for (var i = 0; i < features.length; ++i) {
var thisFeature = features[i].properties;
print(thisFeature.name + ': ' + thisFeature.nlDiffbyRegion.stable_lights);
}



//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var geometry = /* color: ff9999 */ee.Geometry.Polygon(
        [[[-85.27587890625, 22.492257220085193],
          [-84.375, 21.309846141087206],
          [-82.06787109375, 20.447602397594167],
          [-77.89306640625, 19.041348796589016],
          [-73.916015625, 19.352610894378635],
          [-73.8720703125, 20.776659051878816],
          [-79.34326171875, 23.56398712845123],
          [-84.287109375, 23.382598284178858]]]);

var imageCollection = ee.ImageCollection("NOAA/DMSP-OLS/NIGHTTIME_LIGHTS");
print(imageCollection);

// Load nightlights image inputs.
```

```
//Map Extent
Map.setCenter(-80.13, 21.38,7);

//Geometry
var geometry = /* color: ff0000 */ee.Geometry.Polygon(
        [[[-85.80322265625, 18.979025953255267],
          [-73.5205078125, 18.95824648598139],
          [-73.9599609375, 23.543845136505833],
          [-85.40771484375, 23.765236889758675]]]);


// Load nightlights image inputs.
var imageCollection = ee.ImageCollection("NOAA/DMSP-OLS/NIGHTTIME_LIGHTS");
print(imageCollection);

//Do abridged version for all images
// Load nightlights image inputs.

var nl1992 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101992')
  .select('stable_lights');

var nl1993 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F101993')
  .select('stable_lights');
var nlDiff1 = nl1993.subtract(nl1992);

var nl1994 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F121994')
  .select('stable_lights');
var nlDiff2 = nl1994.subtract(nl1993);

var nl1995 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F121995')
  .select('stable_lights');
var nlDiff3 = nl1995.subtract(nl1994);

var nl1996 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F121996')
  .select('stable_lights');
var nlDiff4 = nl1996.subtract(nl1995);

var nl1997 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F121997')
  .select('stable_lights');
var nlDiff5 = nl1997.subtract(nl1996);

var nl1998 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F121998')
  .select('stable_lights');
var nlDiff6 = nl1998.subtract(nl1997);

var nl1999 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F121999')
  .select('stable_lights');
var nlDiff7 = nl1999.subtract(nl1998);

var nl2000 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F142000')
  .select('stable_lights');
var nlDiff8 = nl2000.subtract(nl1999);

var nl2001 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F142001')
  .select('stable_lights');
var nlDiff9 = nl2001.subtract(nl2000);

var nl2002 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F142002')
  .select('stable_lights');
var nlDiff10 = nl2002.subtract(nl2001);

var nl2003 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F142003')
  .select('stable_lights');
var nlDiff11 = nl2003.subtract(nl2002);

var nl2004 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152004')
  .select('stable_lights');
var nlDiff12 = nl2004.subtract(nl2003);

var nl2005 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152005')
  .select('stable_lights');
var nlDiff13 = nl2005.subtract(nl2004);

var nl2006 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152006')
  .select('stable_lights');
var nlDiff14 = nl2006.subtract(nl2005);

var nl2007 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152007')
  .select('stable_lights');
var nlDiff15 = nl2007.subtract(nl2006);

var nl2008 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152008')
  .select('stable_lights');
var nlDiff16 = nl2008.subtract(nl2007);

var nl2009 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F162009')
  .select('stable_lights');
var nlDiff17 = nl2009.subtract(nl2009);

var nl2010 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182010')
  .select('stable_lights');
var nlDiff18 = nl2010.subtract(nl2009);

var nl2011 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182011')
  .select('stable_lights');
var nlDiff19 = nl2011.subtract(nl2010);
```