**Central America Health & Air Quality**

*Identifying Particulate Matter and Aerosols in Central America Using NASA Remote Sensing Data*

**Project Team**

***Project Team:***

Alejandro Soria (Project Lead)

Kaitlyn Bretz

Giancarlo DeMarco

Jay Oliver

***Advisors & Mentors:***

Dr. Kenton Ross (NASA Langley Research Center)

Dr. Travis Toth (NASA Langley Research Center)

Carlos Alberto Gonzalez (Representative of la Comisión Centroamerica de Ambiente y Desarollo (CCAD) and SICA representative)

**Project Overview**

***Project Synopsis:*** Central America’s dry season takes place between October and March, when fires and pyrotechnic events increase in frequency, releasing tiny airborne solid and liquid particles into the air. These aerosols and particulate matter (PM2.5) pose a serious threat to the region’s environment and public health. To better identify where PM2.5 is distributed, NASA Earth observations were used to find correlations between *in situ* PM2.5 data and remotely-sensed aerosols over Central America. To address community concerns, case studies were conducted to map PM2.5 distribution during air pollution events and images were created to establish PM2.5 baseline measurements.

***Abstract:*** Aerosols, fine particulate matter expelled into the atmosphere, have become a major concern due to associated negative health impacts. Aerosols are commonly created by anthropogenic activities such as biomass and fossil fuel burnings, pyrotechnics, vehicle congestion, and mining operations, or by natural sources such as dust and salt particles. These contributors often release aerosols with a diameter of 2.5μm or less (PM2.5) that degrade air quality, put populations at risk of adverse health effects, and can cause severe environmental problems. To assist policy makers in developing scientifically-based solutions to identify social and environmental issues relating to these aerosols, the Central America Health & Air Quality team partnered with organizations from El Salvador (*Ministerio de Medio Ambiente y Recursos Naturales (MARN*)), Guatemala (*MARN*), and Panama (*Universidad Technologica de Panama, La Universidad Autonoma de Ciriqui, and Instituto Especializado de Analisis de la Universidad de Panama*). Research was conducted using *in situ* PM2.5 data obtained from end users alongside NASA Earth observations, including Aqua and Terra Moderate Resolution Imaging Spectroradiometer (MODIS), Suomi National Polar-orbiting Partnership Visible Infrared Imaging Radiometer Suite (VIIRS), and CALIPSO Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP). The largest concentration of aerosols from 2008 – 2019 occurred during the transition from dry to wet season, particularly in the months of April and May. Data analysis identified associations between AOD and PM2.5 levels, fire events, and related health risks. Results indicate a significant correlation between AOD and PM2.5 for all three nations *(P-value < 0.05*), aerosols were positively correlated with increased fire occurrence, and a relationship was observed between AOD levels and the occurrence of health effects that are commonly associated with the presence of PM2.5.

***Keywords:***

Remote sensing, particulate matter, aerosols, biomass fires, air quality, health, SICA, regression analysis

***National Application Areas Addressed:*** Health & Air Quality, Disasters

***Study Location:*** Central American Integration System member states (SICA): El Salvador, Guatemala, Panama, Costa Rica, Dominican Republic, Belize, Honduras, and Nicaragua.

***Study Period:*** January2008 – September 2019

***Community Concerns:***

* Central America’s dry season is accompanied by an increase in fires. Smoke plumes from these fires severely degrade the region’s air quality by contributing to a higher concentration of PM2.5.
* Gunpowder associated with holiday-related pyrotechnics and celebrations causes degradation in air quality.
* The Cobre Panama copper mine is a large Central American mining operation and has been in use since January 2019. This operation has caused an increase in CO2 levels and dust output into the atmosphere, which contributes to high aerosol levels.
* Elevated levels of PM2.5 can cause serious health problems such as lung disease, asthma, diabetes, cancer, and heart problems.
* High concentrations of PM2.5 can contribute to the acidification of nearby water sources, deplete nutrients in the soil, change nutrient balance in coastal and large river basins, affect the diversity of ecosystems, and damage sensitive crops. PM2.5 can also damage man-made structures of cultural significance like monuments and statues.

***Project Objectives:***

* Quantify the relationship between PM2.5 and AOD through statistical analysis
* Conduct a case study to determine the air quality of SICA countries that have experienced intense air pollution events, such as fires
* Develop an AOD distribution map
* Demonstrate how NASA Earth observations data can be applied to the air quality interests of SICA countries
* Determine if a correlation exists between certain health conditions and high concentrations of aerosols

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Ministerio de Medio Ambiente y Recursos Naturales (MARN) (El Salvador)** | Telma Chavez, Remote Sensing Specialist | End User | No |
| **Ministerio de Medio Ambinente y Recursos Naturales (MARN) (Guatemala)** | Kenset Rosales, Coordinator, Environmental Information and Climate Change Unit | End User | No |
| **Universidad Technologica de Panama** | Orlando Aguilar, Air Quality Specialist | End User | No |
| **La Universidad Autonoma de Ciriqui** | Marco Tulio Guillen, Air Quality Specialist | End User | No |
| **Instituto Especializado de Analisis de la Universidad de Panama** | Hipólito Guerra, Head of Air Laboratory; Wilfredo Urriola, Head of Section | End User | No |

***Decision-Making Practices & Policies:*** In 1989, the SICA member states signed the Constitutive Agreement of the Central American Commission for Environment and Development. An objective of the agreement is to protect the environment from pollution through sensible use of natural resources. None of the end users currently apply NASA Earth observations to track aerosols or PM2.5. They rely on ground stations that predominantly capture urban areas. El Salvador, Guatemala, and Panama have provided air quality measurements sourced from San Salvador, Guatemala City, and Panama City, respectively. Representatives indicate that these ground stations are all in heavily urbanized areas and have spatial limitations. El Salvador and Guatemala's MARNs are government organizations, and consequently have the power to make policies dictating air quality regulations for the region. End users from Panama are associated with academic institutions and can serve as experts for policymakers when new regulations are developed.

***Project Benefit to End User:*** By using NASA Earth observations, SICA countries can closely monitor aerosols in the atmosphere to understand their distribution and potential effects on public health. In Panama, the largest Latin American mining operation, Cobre Panama copper mine, has been in use since January 2019. Providing stakeholders in Panama with before and after images of the mining operation will allow them to further develop research into air quality impacts of the mine. Fire distribution maps will allow the end users to visualize what areas are the most vulnerable and show the association between fires and aerosols. Monthly air quality maps were generated during the study period for El Salvador, Guatemala, and Panama to determine the time of year and areas most negatively impacted by high levels of aerosol concentration. Maps were developed to help determine the preliminary relationship between high AOD and negative health impacts associated with poor air quality conditions. This partnership offers the opportunity for participating SICA countries to use NASA Earth observations as an active data source and apply these methods to research within their own countries.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Aqua MODIS** | Aerosol Optical Depth,Active Fire Product | MODIS derived fire products (FIRMS) were used to identify fire events, and Aerosol Optical Depth acted as an air quality indicator. |
| **Terra MODIS** | Aerosol Optical Depth, Active Fire Product | MODIS derived fire products (FIRMS) were used to identify fire events, and Aerosol Optical Depth acted as an air quality indicator.  |
| **Suomi NPP VIIRS** | Aerosol Optical Thickness, Active Fire Product | VIIRS derived fire products (FIRMS) were used to identify fire events, and Aerosol Optical Thickness acted as an air quality indicator. |
| **CALIPSO CALIOP** | Aerosol profiles | CALIPSO products were used for validation of MODIS and VIIRS air quality products.  |

***Ancillary Datasets:***

* Republica de Panama Ministerio de Salud Direccion de Planificacion Departamento de Registros y Estadisticas de Salud – Boletin Estadistico (2017) – health data used to analyze correlation between respiratory and cardiovascular conditions and occurrence of high AOD in Panama
* MARN El Salvador Health Statistics – health data used to analyze correlation between respiratory and cardiovascular conditions and occurrence of high AOD in El Salvador

***Software & Scripting:***

* R – calculation of the relationship between AOD and PM2.5 , generation of statistical charts
* Python – calculation of the relationship between AOD and PM2.5, extraction of MOD08 and MYD08 from LAADS DAAC
* ENVI – extraction of MYD04 and MOD04 sub-datasets, remote sensing analysis
* QGIS – map generation
* ESRI ArcGIS Pro – geodatabase creation, map generation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Monthly Air Quality Indicator Maps** | Aqua MODISTerra MODISSuomi NPP VIIRSCALIPSO CALIOP | Maps illustrate the average AOD and PM2.5 concentration and distribution across SICA countries and will help end users better understand the spatial and temporal distribution of aerosols. | N/A |
| **Geodatabase of Anthropogenic and Natural Fire Events** | Aqua MODISTerra MODISSuomi NPP VIIRS | Databases will provide end users with the ability to analyze fire-related data with their own software. End users will be able to add to this database and expand it as more data becomes available. | N/A |
| **Geodatabase of AOD Distribution** | Aqua MODISTerra MODIS | Geodatabase includes all AOD measurements obtained from MODIS. End users can use this information to evaluate AOD distribution across space and time in their own analyses. | N/A |
| **Tutorial of Methods** | N/A | A tutorial walking through the project’s workflow will be provided to end users for continued analysis. | N/A |

**Project Handoff Package**

***Transition Plan:*** The complete handoff package was sent via NASA Large File Transfer (LFT) to our partners at the Ministerio de Medio Ambiente y Recursos Naturales in El Salvador, MARN in Guatemala, Universidad Technologica de Panama, La Universidad Autonoma de Ciriqui, Instituto Especializado de Analisis de la Universidad de Panama, and to SICA representatives duringthe last week of the term. A follow up meeting regarding questions and concerns from the end users was held following the term to answer any remaining questions.

***Team POC:*** Alejandro Soria, alejandro.soria@ssaihq.com

***Partner POC:***

Sean McCartney, Sean.McCartney@nasa.gov

Telma Chavez, tchavez@marn.gob.sv

Kenset Rosales, krriveiro@marn.gob.gt

Hipólito Guerra, hipolito.guerra@up.ac.pa

Wilfredo Urriola, wilfredo.urriola@up.ac.pa

Orlando Aguilar, orlando.aguilar@utp.ac.pa

Marco Tulio Guillen, marcoguillen11@hotmail.com

***Handoff Package:***

* Monthly Air Quality Indicator Maps
* Geodatabase of Anthropogenic and Natural Fire Events
* Geodatabase of AOD Distribution
* Tutorial of Methods
* Poster
* Presentation
* Project Summary
* Technical Paper

**References**

Health and Environmental Effects of Particulate Matter (PM). (2018, June 20). Retrieved from https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm

Ministerio de Medio Ambiente y Recursos Naturales. (2019). Retrieved from http://www.marn.gob.sv/

SICA in Brief. (2019). Retrieved from https://www.sica.int/sica/sica\_breve\_en.aspx