**Great Salt Lake Health & Air Quality**

*Monitoring Lakebed Exposure and its Impact on Air Quality and Environmental Hazards in the Great Salt Lake Watershed*

**Project Team**

***Project Team:***

Piper Christian (Project Lead)

Fiona Summers

Yoana Vargas Magana

Andrea Delgado

***Advisors & Mentors:***

Dr. Travis Toth (NASA Langley Research Center)

Dr. Kenton Ross (NASA Langley Research Center)

Lauren Childs-Gleason (NASA Langley Research Center)

Dr. Bonnie Baxter (Westminster College, Great Salt Lake Institute)

Dr. Maura Hahnenberger (Dust^2 (Dust Across a Desert-Urban-Summit Transect and Salt Lake Community College)

***Fellow:***

Julianne Liu (Virtual Environmental Justice)

***Team Contact:*** Piper Christian, [laurenpchristian@gmail.com](mailto:laurenpchristian@gmail.com)

***Partner Contacts:*** Chris Pennell, [cpennell@utah.gov](mailto:cpennell@utah.gov); Rachel Edie, [redie@utah.gov;](mailto:redie@utah.gov) Marisa Weinberg, [mweinberg@utah.gov](mailto:mweinberg@utah.gov)

**Project Overview**

***Project Synopsis:***

Water flow into the Great Salt Lake has declined rapidly over the past forty years due to human withdrawals and climate change. With over 50% of the lakebed now exposed, airborne toxic dust threatens to exacerbate already dangerous air quality conditions for the entirety of Northern Utah, especially for communities of color and low socioeconomic status living in closest proximity in West Salt Lake City. By leveraging data from Earth observations, the DEVELOP team created air quality vulnerability maps to inform the Utah Departments of Natural Resources and Environmental Quality’s dust mitigation and management strategies.

***Abstract:***

Water flow into the Great Salt Lake has declined rapidly over the last forty years due to human withdrawals and climate change. As a result of declining lake levels, over 50% of the lakebed is now exposed. Dust storms may grow in frequency and intensity across Northern Utah as lakebed dust becomes airborne under specific meteorological conditions. In our research project, we utilized satellite imagery from Terra and Aqua, Sentinel-5P, CALIPSO, Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI-2, Suomi NPP, ground sensor environmental data, and demographic data to understand the relationship between lake desiccation and dust, and the impact of pollution upon the communities surrounding the Great Salt Lake. By plotting changes in Lake Surface Area against Aerosol Optical Depth (AOD) over our study period (2010-2022), we found an inverse relationship (R2=0.3423) between lake surface area and dust levels within our study area. We conducted a Vertical Feature Mask (VFM) and Extinction Coefficient Plot, from which we identified that during dust events, the aerosol type is mainly polluted dust and the aerosol height is 200 meters from the surface. Lastly, we created bivariate choropleth maps, which demonstrate which census tracts within our study area are most vulnerable to AOD (a proxy for PM2.5 from dust), NO2 and HCHO (precursors to ozone). In summary, our findings revealed that declining lake levels are associated with an increase in intensity of dust events, and these dust events will particularly impact residents of Tooele County and the west side of Salt Lake City. Project resources support partner needs by informing targeted air monitoring efforts, lakebed management practices, and advocacy efforts for GSL stewardship.

***Key Terms:***

aerosol optical depth (AOD), particulate matter (PM), terminal saline lake, CALIOP, MAIAC, vertical feature mask, carbon monoxide, nitrogen dioxide

***National Application Area Addressed:*** Health & Air Quality

***Study Location:*** Great Salt Lake Watershed, UT (Box Elder, Cache, Rich, Morgan, Summit, Utah, and Wasatch counties, with emphasis on Weber, Tooele, Davis, and Salt Lake counties)

***Study Period:*** 2010 to 2022

***Community Concerns:***

* The community’s core concerns are climate change, air pollution, and public health and how air quality impacts from the drying Great Salt Lake may exacerbate existing environmental health inequities.
* In Salt Lake City, residents who live in previously redlined areas on the West side of the city are exposed to pollution sources at a higher concentration when compared to their majority white counterparts on the East side.
* The exposed lakebed, containing toxic heavy metals, poses a health risk for the surrounding community and has the potential to exacerbate air pollution exposure for communities already impacted by numerous point-source pollutants.

***Project Objectives:***

* Use Earth observations to quantify the relationship between dust, air quality, and lakebed exposure concerning the GSL, alongside community vulnerability by census tract and county
* Calculate seasonal trends in lake levels and dust and air quality indicators, including AOD, NO2, and HCHO
* Produce case studies depicting aerosol height and type for Dust Event Days (DEDs)
* Create dust and air quality vulnerability maps to depict relationships between pollution and social vulnerability
* Support advocacy efforts for GSL Stewardship which target air monitoring efforts lakebed management practices

**Partner Overview**

***Partner Organization(s):***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** | **Sector** |
| **Utah Department of Natural Resources, Division of Forestry, Fires, and State Lands** | Marisa Weinberg, interim Great Salt Lake Coordinator | End User | State Government |
| **Utah Department of Environmental Quality, Division of Air Quality** | Christopher Pennell, Technical Analysis Manager  Rachel Edie, Environmental Scientist | End User | State Government |
| **Westminster College, Great Salt Lake Institute** | Carly Biedul, Coordinator | Collaborator | Academic |
| **Dust^2** | Dr. Maura Hahnenberger, Principal Investigator | Collaborator | Academic |
| **Great Salt Lake Coalition** | Alex Veilleux, Policy Associate (HEAL Utah) | Collaborator | Non-Profit |
| **Utah Physicians for Healthy Environment** | Jonny Vasic, Executive Director; Dr. Brian Moench, MD, Board President | Collaborator | Non-Profit |
| **Westside Coalition** | Terry Marasco, Board Member | Collaborator | Non-Profit |

***Decision-Making Practices & Policies:***

TheUtah Department of Natural Resources, Division of Forestry, Fires, and State Lands (FFSL) is responsible for managing forest health, wildland fires, and sovereign land. They are primarily concerned with management of the GSL lakebed, and thus are interested in the relationship between lakebed exposure and associated air pollution. While FFSL uses remote sensing regularly, they do not currently use any NASA Earth observation-derived products. They will use project findings to inform their management practices of lakebed development, specifically regarding the identification of dust hotspots. Another partner, the Utah Department of Environmental Quality, Division of Air Quality (DAQ) is responsible for ensuring the state compliance of federal and state air quality standards to protect and improve the health of the state’s air, land, and water resources. DAQ is interested in integrating current instrumentation and Earth observations to better analyze emissions, high wind events, and lakebed-derived dust transport.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Terra and Aqua MODIS** | Atmospheric Properties | The Multi-angle Implementation of Atmospheric Correction (MAIAC) processes Terra and Aqua MODIS together. These product layers allow for aerosol sensing of aerosol optical depth (AOD), a proxy for dust particulate matter. This data was used in the sensing of lakebed dust over space and time and additional air quality analysis. |
| **Sentinel-5P TROPOMI** | Atmospheric Gases | The atmospheric gas parameters allowed the monitoring of various gases, including the spatial and temporal distribution of NO2 and HCHO for pollution vulnerability mapping, and CO for distinguishing high AOD caused by lakebed dust from wildfire smoke events. All indicators were incorporated into air quality analysis. |
| **CALIPSO CALIOP** | Aerosols | CALIPSO CALIOP’s high resolution, vertical data was used to determine aerosol type and height in the atmosphere during our Dust Event Day (DED) case study. |
| **Landsat 5 TM** | Lake Surface Area | We used Joint Research Center (JRC) Yearly Water Classification History, v1.4 from 2010-2022 to calculate surface area change of the Great Salt Lake over time. |
| **Landsat 7 ETM+** | Lake Surface Area | We used Joint Research Center (JRC) Yearly Water Classification History, v1.4 from 2010-2022 to calculate surface area change of the Great Salt Lake over time. |
| **Landsat 8 OLI and TIRS** | Lake Surface Area | We used Joint Research Center (JRC) Yearly Water Classification History, v1.4 from 2010-2022 to calculate surface area change of the Great Salt Lake over time. |

***Ancillary Datasets:***

* National Land Cover Database (NLCD) – Input for land cover and land cover change data for the extent of the Great Salt Lake
* EPA EJScreen Data – Utilized data from the 5-year American Community Survey from 2016-2020 on proportion of census tracts in Northern Utah that were people of color, low income, above the age of 65, and under the age of 5 for social vulnerability maps. We also utilized mapping of asthma preponderance by census tract to compare to our vulnerability maps
* HOLC Neighborhood Redlining Grades – Boundaries of historically redlined areas for analysis of connections between air quality and redlining. Digitized HOLC neighborhood grade vectors from the 1938 HOLC were used to overlay historic redlining maps on contemporary Salt Lake City boundaries
* USGS Great Salt Lake Gauge Station Data – Input for lake depth and lakebed exposure to validate satellite imagery of lake surface area
* Utah Department of Environmental Quality’s Utah Air Monitoring Program Archive – Input for historical air quality data, such as PM2.5, NO2, and O3 to validate satellite-derived air pollution data
* Aerosol Robotic Network (AERONET) – Ground-based validation of MODIS AOD readings

***Software & Scripting:***

* Google Earth Engine – Processing of Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI, TROPOMI, and MODIS-derived datasets
* R 4.2.2 – Principal component analysis for vulnerability index
* Python 3.10 – Vertical Feature Mask and Extinction Profile Coefficient for Aerosol Height and Type
* ArcGIS Pro 3.1.0 – Zonal statistics of demographic and pollution data by census tract and bivariate mapping for pollution vulnerability maps
* QGIS 3.28.2 – Attribute table join of demographic and pollution datasets

***End Products:***

|  |  |  |
| --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** |
| **Dust and Air Quality Seasonal Trends Package** | Terra and Aqua MODIS  Sentinel 5-P TROPOMI  Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI and TIRS | Our maps and plots show patterns in lake levels and dust concentrations from 2010-2022 and the relationship between these variables. This will help partners discern how lake levels and dust have changed over time and what regions of the state are worst impacted by pollution. |
| **Case Study of Dust Event Day** | CALIPSO CALIOP | These diagrams show the type of aerosols that are present and where they are in the atmosphere during a Dust Event Day, which will help partners understand the health risks associated with dust events.Aerosol subtype and extinction coefficient value and derived aerosol height & thickness on July 9th, 2021. |
| **Pollution Exposure and Vulnerability Map Package** | Terra and Aqua MODIS  Sentinel 5-P TROPOMI  Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI and TIRS | Our maps display how health-harming air pollutant concentrations are distributed across census tracts, showing which areas are worst impacted by air pollution. By adding maps on the distribution of social vulnerability by age, race, and income, we show how pollution and demographic characteristics compound upon each other to result in census tracts that are most vulnerable to air pollution. This may inform targeted advocacy, resource, or monitoring interventions in the worst impacted census tracts. |
| **Dust and**  **Air Quality Maps Methodology Tutorial** | N/A | We created a tutorial to enhance partners’ understanding of the technical aspects of the pollution and vulnerability maps, as well as to expand their capacities in ArcGIS and remote sensing processing to replicate similar procedures for future analysis. |
| **1-Page Flyer** | Terra and Aqua MODIS  Sentinel 5-P TROPOMI  CALIPSO CALIOP | Our one-page flyer will be used to raise awareness with partners, the public, and policymakers about our research on the Great Salt Lake and air pollution in Northern Utah. |

***Product Benefit to End User:***

Our community partners intend to use our maps, figures, and visuals to inform the public and policymakers through targeted advocacy about the environmental and social impacts of airborne dust from the drying GSL. By identifying census tracts that are particularly vulnerable to dust and other air pollutants, our end-user and collaborator partners can direct air quality and environmental health interventions where they are needed most. Our maps of dust, air quality, and social indicators will support targeted air monitoring efforts and lakebed management practices, and our tutorial will build local capacity to use earth observations to track changes in the GSL in the future.

**References**

Jones, E. N. (2021, May). *Environmental Racism in a Growing City: Investigating Demographic Shifts in Salt Lake City's Polluted Neighborhoods.* Awarded bachelor’s thesis, Utah State University, Undergraduate Honors Capstone Projects. 699. <https://doi.org/10.26076/06b4-4805>