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Internship: Air Quality Management in Caribbeang SIDS

MSc Internship Proposal 1: Monitoring and Analysis of Air Quality in Caribbean SIDS

Motivation:

The Caribbean Small Island Developing States (SIDS) are experiencing escalating air quality challenges due to a combination of localized emissions and transboundary pollution events. Tropospheric Nitrogen Dioxide (NO_2) levels, a key indicator we of nitrogen oxide (NO_x) emissions, have been observed to peak in regions such as Hispaniola, ha hi Cuba, Jamaica, Puerto Rico, and the Lesser Antilles. These elevated concentrations are primarily attributed to vehicular emissions, industrial activities, and the burning of biomass. Additionally, the chiCaribbeanèvvcu is periodically affected by Saharan dust plumes, which can transport particulate matter ($PM_{2.5}$ and PM_{10}) across the Atlantic, exacerbating local air quality issues. For instance, in June 2020, a massive sSaharan dust event blanketed the Caribbean, leading to hazardous air quality levels and posing significant health risks to residents, particularly those with respiratory conditions . The Sentinel-5 Precursor (S5P) satellite's TROPOspheric Monitoring Instrument (TROPOMI) offers a unique opportunity to monitor NO_2 and other pollutants over the Caribbean region. By leveraging TROPOMI's high-resolution data, this study aims to provide a comprehensive assessment of air quality dynamics in Caribbean SIDS, facilitating informed decision-making for public health and environmental policies.

Problem Statement

Despite the growing concerns over air pollution in the Caribbean SIDS, there is a lack of comprehensive, region-wide assessments of NO_2 concentrations and their temporal and spatial variations. Traditional ground-based monitoring networks are sparse and often insufficient to capture the full extent of pollution across these islands. Furthermore, the influence of transboundary pollution events, such as Saharan dust intrusions, on local air quality remains inadequately understood. This knowledge gap hinders the development of effective mitigation strategies and public health interventions. Therefore, there is an urgent need to utilize satellite-based observations to fill this void and provide a robust analysis of air quality trends in the Caribbean SIDS.

Objective:

To investigate the spatiotemporal patterns of air pollutants, specifically NO_2, $PM_{2.5}$, and CO, in Caribbean Small Island Developing States (SIDS) using TROPOMI satellite data from May 2018 to December 2024.

Research Questions:

1. Which regions within Caribbean SIDS exhibit the highest levels of NO_2 and $PM_{2.5}$ pollution?
2. What are the temporal variations in NO_2 concentrations, and how do they correlate with temperature changes?
3. How can satellite-derived NO_2 data be validated against ground-based measurements?
4. What are the spatial and temporal patterns of CO concentrations in the region?

Tasks:

1. **Data Acquisition:**
    a. Retrieve daily TROPOMI NO_2, AAI, and CO datasets for the region of interest.
    b. Retrieve daily MODIS AOD datasets for the region of interest.
    c. Meteorological Data: Access wind speed and direction data from ECMWF ERA5 reanalysis to track dust transport patterns.
2. **Data Preprocessing:** Resample data to various spatial resolutions (1x1 km, 2x2 km, 3.5x3.5 km) for comparative analysis.
3. **Spatial Analysis:** Generate heatmaps and timeseries to identify pollution hotspots.
4. **Temporal Analysis:** Examine weekly cycles of NO_2 and CO levels to understand emission patterns.
5. **Validation:** Compare satellite-derived NO_2 data with available ground-based measurements to assess accuracy.

Opportunities for MSc Students

These internships offer MSc students a unique opportunity to engage in cutting-edge environmental research, focusing on air quality dynamics in the Caribbean region. Students will gain hands-on experience in analyzing satellite-derived data, applying advanced statistical methods like the Mann-Kendall test and time series decomposition. Through this project, students will develop expertise in environmental data analysis, statistical modeling, and geospatial technologies.

Contact: Dr. R. L. Curier for more information or discuss any research idea related to this topic.

MSc Internship Proposal 2: Assessing the Impact of Saharan Dust Events on Caribbean Air Quality Using TROPOMI Observations

Background and Motivation

The Caribbean region frequently experiences the transport of Saharan dust, a phenomenon known as the Saharan Air Layer (SAL). These dust events can significantly impact air quality, visibility, and public health. Traditional ground-based monitoring systems often lack the spatial coverage and temporal resolution needed to comprehensively assess these impacts. Satellite-based observations, such as those from the TROPOspheric Monitoring Instrument (TROPOMI) aboard the Sentinel-5 Precursor satellite, offer a promising alternative for monitoring atmospheric composition over large areas.

This internship aims to leverage TROPOMI data to analyze the effects of Saharan dust events on air quality in the Caribbean, focusing on parameters such as aerosol optical depth (AOD), particulate matter (PM10), and nitrogen dioxide (NO_2) concentrations.

Research Objectives

1. Identify and characterize Saharan dust events impacting the Caribbean region using TROPOMI data.
2. Assess the temporal and spatial variations in AOD, PM10, and NO_2 concentrations during these events.
3. Evaluate the correlation between dust event intensity and air quality parameters. How do long-range transport events, like Saharan dust, influence NO_2 concentrations in Caribbean SIDS?

Tasks

1. **Data Acquisition:**
   - 1.1. TROPOMI and MODIS Data: Obtain Level-2 aerosol and trace gas products, such AOD, NO_2, and CO, for the Caribbean region from the Copernicus Open Access Hub.
   - 1.2. Ground-Based Measurements: Collect PM10 concentration data from regional monitoring stations, such as those in Guadeloupe and Martinique, for validation purposes.
   - 1.3. Meteorological Data: Access wind speed and direction data from ECMWF ERA5 reanalysis to track dust transport patterns.
2. **Data Processing:**
   - 2.1. Preprocessing: Apply quality control measures to filter out invalid or low-confidence data points.
   - 2.2. Spatial Analysis: Map AOD, PM10, and NO_2 concentrations to identify regions most affected by dust events.
   - 2.3. Temporal Analysis: Analyze time series data to determine the duration and frequency of dust events.

3. **Statistical Analysis:**
    3.1. Correlation Analysis: Perform statistical tests (e.g., Pearson or Spearman correlation) to assess relationships between dust event intensity and air quality parameters.
    3.2. To identify and quantify significant trends in NO_2 concentrations across the Caribbean SIDS using robust statistical and decomposition methods.
        3.2.1. Mann-Kendall Test: Apply the Mann-Kendall (MK) test to assess the presence of monotonic trends in NO_2 time series data.
        3.2.2. Time Series Decomposition: Decompose the NO_2 time series into its constituent components: trend, seasonality, and residuals

Opportunities for MSc Students

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MSc Internship Proposal 3: Emission Inversion in Caribbean SIDS

Motivation:

The Caribbean Small Island Developing States (SIDS) are experiencing escalating air quality challenges due to a combination of localized emissions and transboundary pollution events. Tropospheric Nitrogen Dioxide (NO_2) levels, a key indicator of nitrogen oxide (NO_x) emissions, have been observed to peak in regions such as Hispaniola, Cuba, Jamaica, Puerto Rico, and the Lesser Antilles. These elevated concentrations are primarily attributed to vehicular emissions, industrial activities, and the burning of biomass. Additionally, the Caribbean is periodically affected by Saharan dust plumes, which can transport particulate matter ($PM_{2.5}$ and PM_{10}) across the Atlantic, exacerbating local air quality issues. For instance, in June 2020, a massive Saharan dust event blanketed the Caribbean, leading to hazardous air quality levels and posing significant health risks to residents, particularly those with respiratory conditions . The Sentinel-5 Precursor (S5P) satellite's TROPOspheric Monitoring Instrument (TROPOMI) offers a unique opportunity to monitor NO_2 and other pollutants over the Caribbean region. By leveraging TROPOMI's high-resolution data, this study aims to provide a comprehensive assessment of air quality dynamics in Caribbean SIDS, facilitating informed decision-making for public health and environmental policies.

Problem Statement

Despite the growing concerns over air pollution in the Caribbean SIDS, there is a lack of comprehensive, region-wide assessments of NO_2 concentrations and their temporal and spatial variations. Traditional ground-based monitoring networks are sparse and often insufficient to capture the full extent of pollution across these islands. Furthermore, the influence of transboundary pollution events, such as Saharan dust intrusions, on local air quality remains inadequately understood. This knowledge gap hinders the development of effective mitigation strategies and public health interventions. Therefore, there is an urgent need to utilize satellite-based observations to fill this void and provide a robust analysis of air quality trends in the Caribbean SIDS.

Objective:

To estimate NO_x emissions and assess the impact of long-range transport events, such as Saharan dust, on air quality in Caribbean SIDS using TROPOMI satellite data and atmospheric models.

Research Questions:

1. How can NO_x emissions be estimated from TROPOMI NO_2 data ?
2. What are the spatial and temporal variations in NO_x emissions across the region?

Task:

1. **Data Acquisition:**
   1.1. TROPOMI Data: Obtain Level-2 aerosol and trace gas products, such NO_2, for the Caribbean region from the Copernicus Open Access Hub.
   1.2. EDGAR and CAMS-GLOB-ANT dataset :.
   1.3. Meteorological Data: Access wind speed and direction data from ECMWF ERA5 reanalysis to track dust transport patterns.
2. **Data Preprocessing:**
   2.1. Resample data to various spatial resolutions (1x1 km, 2x2 km, 3.5x3.5 km) for comparative analysis.
   2.2. Resample Emission using monthly weekly, hourly emission profile
3. **Emission Estimation:** Apply methods like the exponentially modified Gaussian fitting function combined with wind rotation techniques to estimate NO_x emissions.
4. **Temporal Analysis:** Study seasonal and weekly variations in NO_x emissions to understand underlying patterns.

Opportunities for MSc Students

These internships offer MSc students a unique opportunity to engage in cutting-edge environmental research, focusing on air quality dynamics in the Caribbean region. Students will gain hands-on experience in analyzing satellite-derived data, applying advanced statistical methods like the Mann-Kendall test and time series decomposition. Through this project, students will develop expertise in environmental data analysis, statistical modeling, and geospatial technologies.

Contact: Dr. R. L. Curier for more information or discuss any research idea related to this topic.