# Evaluation of Meteorological Factors and Trends Contributing to Recent Poor Air Quality in the South Coast Air Basin

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## Motivation

The South Coast Air Basin of California (SoCAB) is well-known for its historically poor air quality. In recent years, the Basin has seen tremendous progress due to the implementation of effective emissions mitigation strategies. In the past five decades, the level of air pollutants (particulate matter (PM), NOx, ozone) has been reduced. However, in the last five years, the ozone concentrations in the SoCAB shows the inverse trend despite the continuous reduction of emissions. To answer the question, we need to investigate not only how ozone responds to emissions, but also how concentrations are impacted by meteorological factors (i.e., wind speed, temperature, relative humidity, pressure). It is difficult given the complexities of accurately tracking emission changes, characterizing all meteorological variables that can impact ozone, simulating the complexities of the formation and fate of ozone and PM, and isolating the role of long-range transport of pollutants impacting the region.


**Figure 1**: Tasks mapped to study objectives.

## Objectives

**Overall Objective:** To understand the relationship of ozone and meteorology over the past 30 years.

1. Determine a set of meteorological factors which contribute to high ozone and $PM_{2.5}$ episodes, respectively
2. Analyze the recent meteorological and air quality trends
3. Project directions of recent air quality trends

## UCR Tasks

1. **Task 3:** Machine learning to determine air quality, meteorology, and regional climate drivers of high ozone
2. **Task 4:** Chemical transport modeling and sensitivity analyses to quantify VOC and NOx contributions to ozone and $PM_{2.5}$

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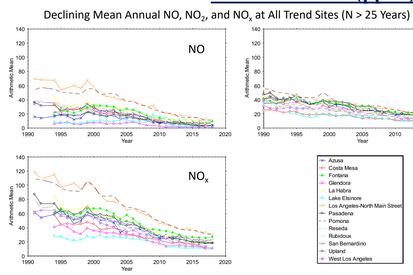
## Meteorological Study

### Concentrations (ppbv)




- $NO_x$ has steadily decreased in the last 27 years from 1990 to 2017 in all cities in Southern California
- SCAQMD emission control strategies have been effective

### Ozone Trends

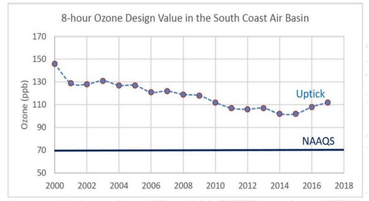
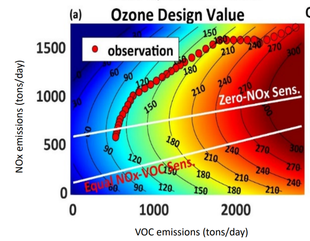



***Figure 1**: Ozone design value trends in the South Coast Air Basin, as reported by SCAQMD (P2019-08).*

- Due to the reduction of $NO_x$, ozone concentrations largely decreased from 2000-2014
- From 2014-present, ozone reversed its trend. An uptick of ozone concentrations occurred from 2014
- Ozone 1997 8-hr standard is 80 ppb, and the deadline to meet the standard is 2023
- Ozone 2008 8-hr standard is 70 ppb.

### NOx/VOCs Isopleths




- The isopleths are developed for LA/SoCAB areas
- In some locations of the isopleth, if the $NO_x$ decreases, ozone concentrations increase
- VOC controls can be a strategy to limit the production of ozone
- SoCAB has become less VOC limited over the past 40 years

Source: Qian et al., *ES&T Letters*, **2019**

## Methods/Results

### Ozone Simulation using Generalized Additive Model




- Simulated ozone concentration for the with original and averaged meteorology from 1990 to 2018
- Blue line is daily maximum 8-hour ozone at Crestline
- Green line is the simulated ozone using the GAM model with the observed meteorology
- Red line is the simulated ozone using the GAM model with averaged meteorology

### Meteorological Analysis

- Upon visual inspection, the distributions indicate that ozone exceedances are associated with lower $NO_2$ and NO concentrations, higher air and dew point temperature, better visibility, and more narrow distributions for relative humidity, wind speed and wind direction
- Lower NO and $NO_2$ concentration is associated with higher 8-hr ozone exceedance hours
- Higher temperature, dew point temperature are associated with the 8-hr ozone exceedance hours
- Exceedances peak around relative humidity of 40 percent
- Exceedances peak near wind speeds of 6 mph
- Wind direction during exceedances is westerly (from the Pacific ocean)




Comparison of 70 ppb ozone exceedance hours and non-exceedance hours and the corresponding meteorological or air quality measurement for 1998-2018 from 12pm-5pm

### Machine Learning

**Algorithm:** Random forest regression (RFR) method

- Predict the output based on training data
- Training data – observed measurements
- Open source – SciKitLearn library, 10000 nodes on each tree and 16 trees

**Input Data:** Datasets are from MesoWest and NOAA, 80% for training, 20% for model testing and evaluation

**Training features:** air temperature, relative humidity, pressure, wind direction, wind speed, dew point temperature, $NO_2$, NO

**Prediction model for 70 ppb standard:** Peak ozone hours from 12pm-5pm to reasonably simulate the meteorological distributions for exceedance and non-exceedance hours




- **Overall Objective:** To understand the time-dependent meteorological influences on ambient ozone concentrations and predict the relationship between ozone precursors and meteorology for future cases
- **Tasks:** Use machine learning to study the sensitivity of ozone to changes in temperature, relative humidity, emissions (NOx), etc. over time and to predict the future ozone concentrations under future meteorology and emissions scenarios

### Machine Learning Predictions




Actual and predicted 8-hr ozone exceedance with the sensitivity to the change in temperature

- Actual (left) and RFR predicted (right) distributions of exceedances and non-exceedances with respect to 12:00 PM to 5:00 PM $NO_2$ concentration
- Periods shown: 1998-2002, 2003-2007, 2008-2012, and 2013- 2018.
- RFR algorithm used 9 input features
- Prediction has a good agreement with the observation data. However, prediction slightly underestimates the exceedance of ozone concentrations
- From 1998 – 2018, on every five-year increment plot, exceedances are associated with higher temperatures in later years

## Conclusion

- Machine learning using the RFR algorithm well describes the trends of ozone due to the variations of other features
- Meteorology significantly affects ozone exceedances
- Slightly lower $NO_2$ and NO concentrations promote the exceedance hours of ozone
- Emphasis was given to the role of meteorology that has adversely influenced the observed trends of ozone and $PM_{2.5}$ in the SoCAB in recent years and the projection of such trends to the near-term

## Future Work

- Apply machine learning to test the sensitivity of ozone to changes in meteorology. We will use similar methods to build the regression models for particulate matter mass and species, CO, $NO_x$, and $SO_2$
- Use machine learning to predict future ozone concentrations for different cases (i.e., increasing temperature, decreasing $NO_x$)
- Use CMAQ to simulate the summer 2017 and 2023 cases

## References

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