False Alarms and Missed Events: A Root Cause Analysis of Ozone Forecast Challenges for the Bay Area Air Quality Management District

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-Develop New Forecast Metrics to Enhance O_3 Forecast for the San Francisco Bay Area

About the Bay Area Air District

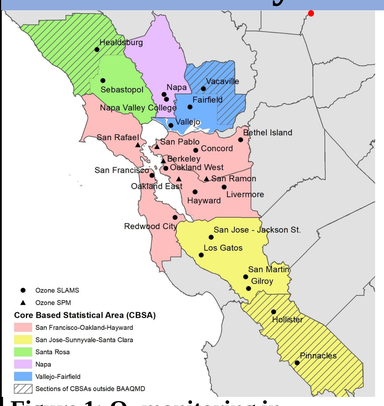

Figure 1: O_3 monitoring in the Bay Area

- Found in 1955
- 9 Bay Area counties
  - Napa, Sonoma, Marin, San Francisco, San Mateo, Santa Clara, Contra Costa, Alameda, and Solano
- Over 7 million residents
- 33 AQ and Met stations
  - 21 O_3 monitors
- All Criteria Air Pollutants
  - O_3 (May 1 to Oct 31)

More About O_3

AQI Category	Index Value
Good	0 to 50
Moderate	51 to 100
Unhealthy for Sensitive Group	101 to 150
Unhealthy	151 to 200
Very Unhealthy	201 to 300
Hazardous	301 and higher

Figure 2: Air Quality Index (EPA)

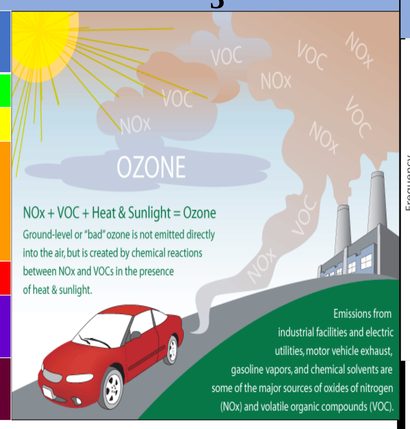

Figure 3: Ingredients for O_3 formation (EPA)

- National Standard:
  - **70 ppb** (8-hour average)
- Exceedance (USG):
  - $[O_3] \geq$ **71 ppb** (8-hour average)
  - **Spare the Air Alert** issued
- Health impact
  - Respiratory system, lung function, asthma
- Vulnerable population
  - Children, elderlies, people with respiratory diseases, active individuals
- Call to action
  - Limit outdoor activities, take public transit, carpool, bike

- Ozone Formation
  - Chemistry
    - NO_x & VOC
    - Motor vehicles exhaust
    - Industrial facilities emissions
    - Chemical solvents
  - **Meteorology**
    - **Heat**
      - Dependent on strength of onshore flow
    - Sunlight

Summertime Microclimates

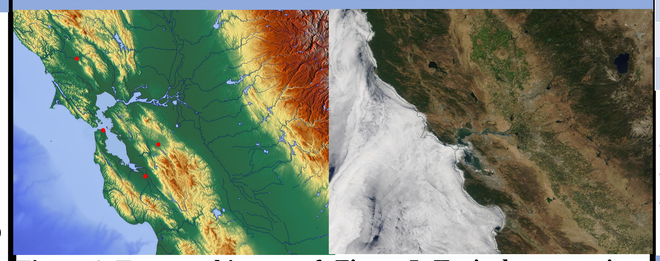

Figure 4: Topographic map of the Bay Area and Central Valley

- Coast & SST: 50s
- Bay: 60s & 70s
- Inland: 90s & 100s
- Difference: 50° F in 50 miles
- Thermal trough inland

Figure 5: Typical summertime marine stratus coverage

- Semi-permanent inversion aloft
- Daily PM sea breezes
- Marine stratus coverage reduces sunlight & UV

Base O_3 Forecast (2005-19)

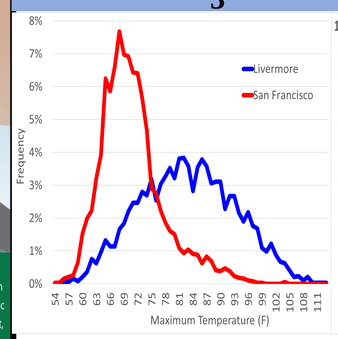

Figure 6: Max temperature comparison between Livermore and SF

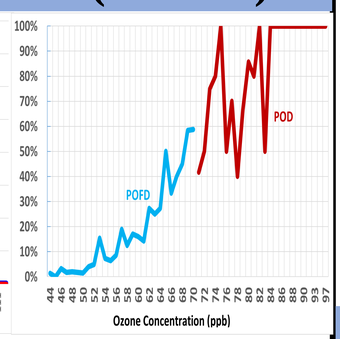

Figure 7: POD & POFD for the BAAQMD O_3 Forecast (2005 to 2019)

		Forecast	
		Yes	No
Observed	Yes	Hits	Misses
	No	False Alarms (FA)	Correct Negatives (CN)

Table 1: Forecast contingency table

POD (Probability of Detection) = Hits / (Hits + Misses)
POFD (Probability of False Detection) = FA / (FA + CN)
FAR (False Alarm Ratio) = FA / (Hits + FA)
CSI (Critical Success Index) = Hits / (Hits + Misses + FA)

- POD = 100% when $O_3 \geq 84$ ppb
- Misses occur when $O_3 \sim 71$ to 83 ppb
- POFD $\leq$ 10% when $O_3 \leq 56$ ppb
- POFD ~ 30 to 60% when O_3 between 65 and 70 ppb

	May	June	July	Aug	Sept	Oct	Total
F.A.	4	27	22	26	39	10	128
Miss	5	5	6	5	9	3	33
Hit	3	18	26	20	26	4	97

Table 2: Forecast verification by month

- September: False Alarms & Misses peaking
- More Hits in July & September
- Lull in August Hits

Project Objective

- Using data from 2005 to 2018 to develop new Forecast Metrics that optimizes skill score
  - Lower False Alarms and Misses
  - Higher Hits
- Apply new Forecast Metrics on 2019 data

Creating Forecast Metrics

Strong Factors

- Pressure Gradient
- Height of Inversion Bottom
- Maximum Temperature
- Time of Max Temperature
- 925-mb Wind Component
- Previous Day O_3

Weak Factors

- Same Day O_3 at High Elevation Station
- First 8-hour O_3 at High Elevation Station
- Inversion Strength
- Inversion Depth
- Height of Inversion Top
- Minimum Temperature
- 850-mb & 925-mb Temp

New Forecast Metrics

- New Forecast Metrics ➔ weak sea breeze

1. 2355Z SFO-SAC (Sacramento, CA) Pressure Gradient $\leq$ 2.3 mb (CSI = 0.550)
2. 12Z SFO-WMC (Winnemucca, NV) Pressure Gradient $\leq$ -2.0 mb (CSI = 0.547)
3. 12Z Oakland Sounding Height of Inversion Bottom $\leq$ 200 m (CSI = 0.530)
4. Max Temp at Livermore $\geq$ 95 F (CSI = 0.519)
5. Time of Max Temp at Livermore $\geq$ 2:30 pm (CSI = 0.517)
6. 12Z Oakland Sounding 925-mb Westerly Wind Component $\leq$ 8 KT (CSI = 0.507)
7. Previous Day District Max 8-hour $O_3 \geq$ 50 ppb (CSI = 0.500)

- Skill score optimized when 6 out of 7 Metrics fulfilled

	Base	New		Base Performance	New Performance
# of Forecasts	1826	229	**False Alarm Ratio**	57%	39% **(↓18%)**
False Alarms	128	64	**Probability of Detection**	75%	91% **(↑16%)**
Misses	33	10	**Probability of False Detection**	8%	54%
Hits	97	101	**Critical Success Index**	38%	58% **(↑20%)**

Table 3: Forecast verification statistics for Base O_3 Forecast and the new Forecast Metrics

Applying Metrics to 2019 Data

- 19 Cases
- Comparing new Forecast Metrics (FM) with:
  - 2017 In-House Regression (2017)
  - 2016 In-House Regression (2016)
  - NOAA CMAQ Model (NOAA)
  - BAAQMD Forecaster (FOR)

	2017 Equation	2016 Equation	NOAA Model	BAAQMD Forecaster	Forecast Metrics
False Alarm	4	8	0	10	**7**
Miss	5	5	5	2	**1**
Hit	4	4	4	7	**8**
CSI	31%	24%	44%	37%	**50%**

Table 4: Forecast verification for select forecast methods

- Forecast Metrics outperformed
- Forecast Metrics vs. BAAQMD Forecaster
  - Increase Hits by 1 count
  - Decrease Misses by 1 count
  - Decrease False Alarms by 3 counts
- Forecaster more skillful than regressions and NOAA CMAQ Model

Discussion

- Important to understand Microclimate in the Bay Area
  - Placement of the Thermal Trough
  - Microscale flow across the Bay Area (CANSAC WRF)
  - Maritime interface (Models too coarse to resolve)
  - Inversion profile
- O_3 production vs O_3 transport
  - Vertical mixing
  - Horizontal transport from Central Valley
- Misses vs. False Alarm
  - False Alarms are much better than Misses
- Varying forecaster personalities
- Changing forecast methods
- Human psychology
  - How do people response to **Spare the Air Alerts**
- Tightening National Ambient Air Quality Standards (NAAQS)
  - In 2015, NAAQS for O_3 was lowered to **70 ppb**.
  - In 2008, NAAQS for O_3 was **75 ppb**.
  - In 1997, NAAQS for O_3 was **80 ppb**.

Acknowledgement

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