Cluster Analysis of Air Quality Data for CCOS Study Domain

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3 Purposes of Presentation

1. Summary of clustering work for CCOS domain
   – 6 subdomains: Bay Area, San Joaquin Valley (North, Central, and South), Sacramento Valley & Mountain Counties
   – Separate clusterings of wind & O$_3$ measurements

2. Domain-wide analysis
   – Qualitative agreement of results between subdomains
     • Similar synoptic influences for all subdomains
     • Example episodic scenario affecting entire domain
   – Quantitative analysis not feasible
     • Data limitations

3. Extensions of methods
   – Practical applications for modeling (simulation) efforts
   – Proofs of concept demonstrated for SFBA
Work Plan Tasks

1. Wind field clustering for 6 CCOS subdomains
   ✔ Collect data
     ✔ Non-contracted but necessary quality assurance delayed overall contract progress
   ✔ Perform 6 independent clusterings: SFBA, N/C/S SJV, SV, MC
   ✔ Interpret clustering results

2. \( \text{O}_3 \) clustering for 6 CCOS subdomains
   ✔ Collect data
   ✔ Test alternative algorithms for SFBA
   ✔ Perform clusterings for other 5 subregions: N/C/S SJV, SV, MC
   ✔ Interpret clustering results

3. Sequencing of dynamic cluster patterns
   ✔ Attempt to relate wind and \( \text{O}_3 \) clusterings
   ✔ Identify recurring upper-atmospheric transitions
   ✔ Consider dynamics at other time scales

4. Domain-wide synopsis of wind field clusterings
   ☐ Data limitations precluded quantification of these results
Lessons Learned

• Wind field clustering & sequencing contribute significant information
  – Provide physical insight for CCOS domain ozone episodes
  – Can provide increased representativeness and confidence in modeling (simulation) efforts
  – Methods useful for winter PM analysis (ongoing BAAQMD contract)

• Multi-scale nature of CCOS domain ozone variability
  – Mesoscale flow features further refine synoptically oriented clusters
  – Sources of inter-annual variability are not easily resolved

• Complexity of meteorology varies by basin
  – SFBA least complex
    • Slight amount of marine ventilation inhibits ozone buildup
  – Sacramento Valley most complex
    • Bi-directional flows along valley major axis
    • Small changes in marine ventilation (not affecting other basins) may strongly impact ozone levels
  – SJV has considerable spatial variability
    • Thermal flows stronger deeper south into SJV; marine influences stronger toward north
    • Fresno Eddy generates very complex but localized flow patterns

• Novel quality assurance methods were developed and applied to significantly enhance the results

• O$_3$ measurements clustering is not very useful

• Data limitations unknown at project outset precluded quantitative domain-wide analysis
  – Study could have been designed to focus on domain-wide patterns at expense of lost detail for individual subdomains
**Consistent clusters for 5 subdomains**

Number of days (and % NAAQS 8-hr O₃ exceedances) for each cluster, by subdomain.

<table>
<thead>
<tr>
<th></th>
<th>SFBA</th>
<th>N-SJV</th>
<th>C-SJV</th>
<th>S-SJV</th>
<th>SV</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>86 (13%)</td>
<td>264 (19%)</td>
<td>370 (60%)</td>
<td>404 (61%)</td>
<td>302 (35%)</td>
</tr>
<tr>
<td>H</td>
<td>353 (13%)</td>
<td>179 (42%)</td>
<td>229 (89%)</td>
<td>429 (58%)</td>
<td>397 (28%)</td>
</tr>
<tr>
<td>H/V</td>
<td>---</td>
<td>212 (25%)</td>
<td>184 (64%)</td>
<td>249 (63%)</td>
<td>203 (17%)</td>
</tr>
<tr>
<td>V or V1</td>
<td>309 (0%)</td>
<td>299 (12%)</td>
<td>299 (42%)</td>
<td>193 (38%)</td>
<td>228 (3%)</td>
</tr>
<tr>
<td>V/I or V2</td>
<td>341 (0%)</td>
<td>108 (6%)</td>
<td>396 (32%)</td>
<td>335 (22%)</td>
<td>171 (12%)</td>
</tr>
<tr>
<td>V/R</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>200 (3%)</td>
</tr>
</tbody>
</table>
“Static” cluster patterns (500-hPa)

Similar synoptic influences for all subdomains, but surface flows vary considerably.
“Dynamic” cluster sequences (500-hPa)

Example: $V \rightarrow R \rightarrow H$ captures eastward sweeping Rossby wave

1800 UTC 06 Sep 2002

- Trough along coast buffers CCOS domain from effects of offshore high pressure systems

1800 UTC 08 Sep 2002

- Trough dissipates as offshore high pressure advances eastward

1800 UTC 10 Sep 2002

- Ridge forms along coast from high pressure of offshore origin
“Dynamic” cluster sequences (surface)
## Domain-wide Hypothetical Example

<table>
<thead>
<tr>
<th>SFBA label</th>
<th>NSJV label</th>
<th>CSJV label</th>
<th>SSJV label</th>
<th>SV label</th>
<th>All labels present?</th>
</tr>
</thead>
<tbody>
<tr>
<td>day 1</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 2</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 3</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 4</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>H/V</td>
<td>YES</td>
</tr>
<tr>
<td>day 5</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 6</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>day 7</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>day 8</td>
<td>H</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>YES</td>
</tr>
<tr>
<td>day 9</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>R</td>
<td>YES</td>
</tr>
<tr>
<td>day 10</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td></td>
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<tr>
<td>day 11</td>
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<tr>
<td>day 12</td>
<td>H</td>
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<td>H</td>
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</tr>
<tr>
<td>day 13</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td></td>
</tr>
</tbody>
</table>

Tradeoff between spatial and temporal resolution for each subdomain. Only 452 of 1656 days in cluster analysis have labels for all subdomains! Lowered spatial resolution could increase domain-wide sample sizes.
Practical Extensions of Clustering

• Winter PM season clustering & sequencing
  – BAAQMD contract with UC Davis provides proof of concept
  – Initial results useful for modeling efforts
• Meteorological & Air Quality Model (AQM) validation
  – Classify simulated winds among known patterns
  – Determine if simulated data (classification) are labeled consistently with observations (clustering)
    • Prevailing conditions
    • Upper-atmospheric transitions
  – Expect better AQM performance when met. modeled accurately
  – Determine if seasonal met model can explain air quality variability
    • Proof of concept for MM5 winter 2000-01 simulation at BAAQMD
    • Compare MM5 performance to different met. models (WRF, CALMET)
• Selection of representative conditions for future simulations
• [blank slide]
MM5 validation: SFBA example

First half of CRPAQS episode: R1→R2→R3→R1 realistically simulated.

Second half of CRPAQS episode: persistent R2 inaccurately simulated as R1.

Simulated ventilation arrives 1-2 days early.

The 12/17/2000-1/7/2001 CRPAQS study period is simulated using MM5. This period was included in a previous UC Davis cluster analysis.
CMAQ performance evaluation

First half: adequate performance

Second half: PM levels underestimated.

Last day: PM levels decrease too early for eastern sites.

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