Breathing the bad air or not ?

Ozone Effect on Mortality

A multi-site time series study

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Ozone & Morbidity/Mortality

- **Ozone acute effect: concentration > 1*ppm* (typical smoggy air) → resistance to breathing and headache, particularly to sensitive people.**
- **Repeated ozone exposure<0.25 *ppm* →pulmonary function decline**
- **Positive association has been found between respiratory admission & summer ozone exposure.**
- **Significant association has been found between daily mortality & previous day ozone level in Los Angeles, New York.**
- **Ozone exposure might be related to daily fluctuations in admissions for congestive heart failure in the elderly.**
- **Public health significance of these acute reversible effect remain uncertain.**

- **Audrey, Galizia, 1999; Delvin RB, 1991; Folinbee LJ, 1988; Kinney PL, 1996**
- **Richard Burnett, and etc, 1996, 1997.**
- **P.L. Kinney and H. Ozkaynak, 1991, Association bw/ ozone & daily mortality**

NMMAPS Data

(The national mortality morbidity Air pollution study)

- **Mortality (1987 – 1994)**
  -- National Center for Health Statistics
  - Total, CVD, RESP, Other cause specific, daily.
  - for three age groups (<65, 65-75, >75)
- **Air pollution (1987 – 1994)**
  -- Environmental Protection Agency
  - PM_{10}, O_3, CO, SO_2, and NO_2 , (daily)
- **Meteorology (1987 – 1994)**
  -- National Climatic Data Center
  - Temperature, dew point. (daily)
- **Summer months only (6,7,8,9), for 19 largest cities.**

Outcome & Covariates

- **Y: CVDRESP death = CVD + RESP**
- **Reasons:**
  - **People with respiratory diseases are more sensitive to ozone exposure.**
  - **Ozone exposure might be related to congestive heart failure in the elderly.**
  - **O3 exposure is likely not to be associated with other-cause related death.**
- **X: Primary interest: O_3, & Confounders:**
  - Meteorology confounders:
    - **Temperature, Dew point temperature**
  - Biologic confounders:
    - **Age, Time, Day of week.**
  - Confounding from other pollutants:
    - **PM_{10}, CO, SO_2, and NO_2**

O_3 formation (much simplified)

- NO_2  $NO + O_3$

$O + O2$

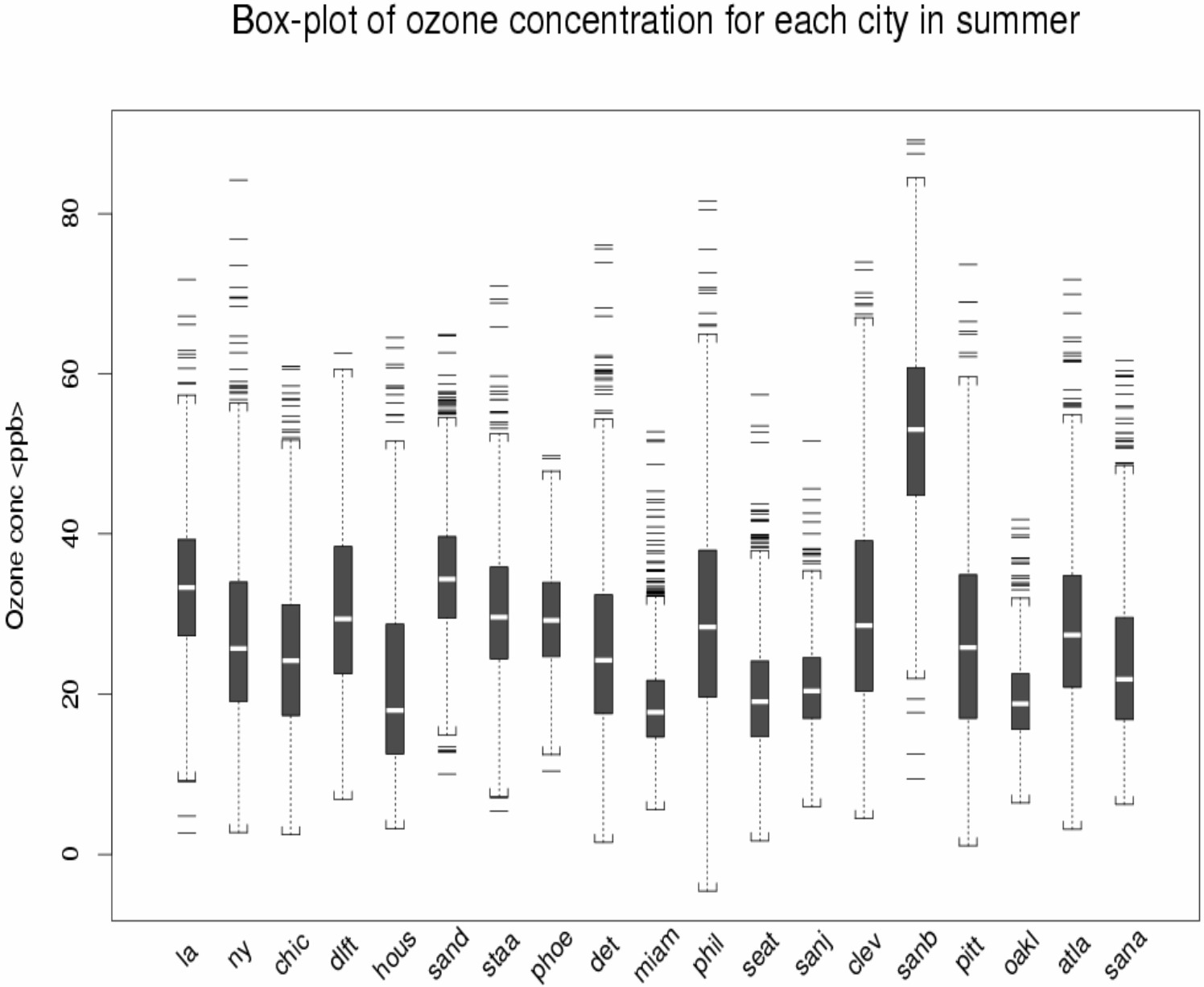
- Temperature is an imperfect surrogate measure of sunlight.
- Organic source: [VOC] / [NO_2]
- O3 → highly active oxidant, which might contribute to the formation airborne particles.

Study Aims

1. **EDA on the association between O_3 & mortality.**
2. **To estimate summer ozone exposure's city-specific and overall effect on relative rates of CVD & RESP mortality, combining information across the largest 20 US cities.**
3. **To explore the exposure-response time lag**
4. **To investigate the confounding effects of temperature, and other pollutants.**
5. **To explore the sensitivity of the results to the adjustment for time trends, & temperature thredhold of "moderate temperature".**

EDA result

- Range of ave([O_3]): 0~100*ppb*.
- Typical smoggy day: daily max([O_3]) $\approx$1000*ppb*
- Missing is not big problem for O_3. (19 cities, no minn)
- No statistical significant association between O_3 and other-cause specific mortality. (In appendix)
- Temperature and O_3 are associated to each other, and the association for below and above certain thredhold temperature is different.


Box-plot of ozone concentration for each city in summer
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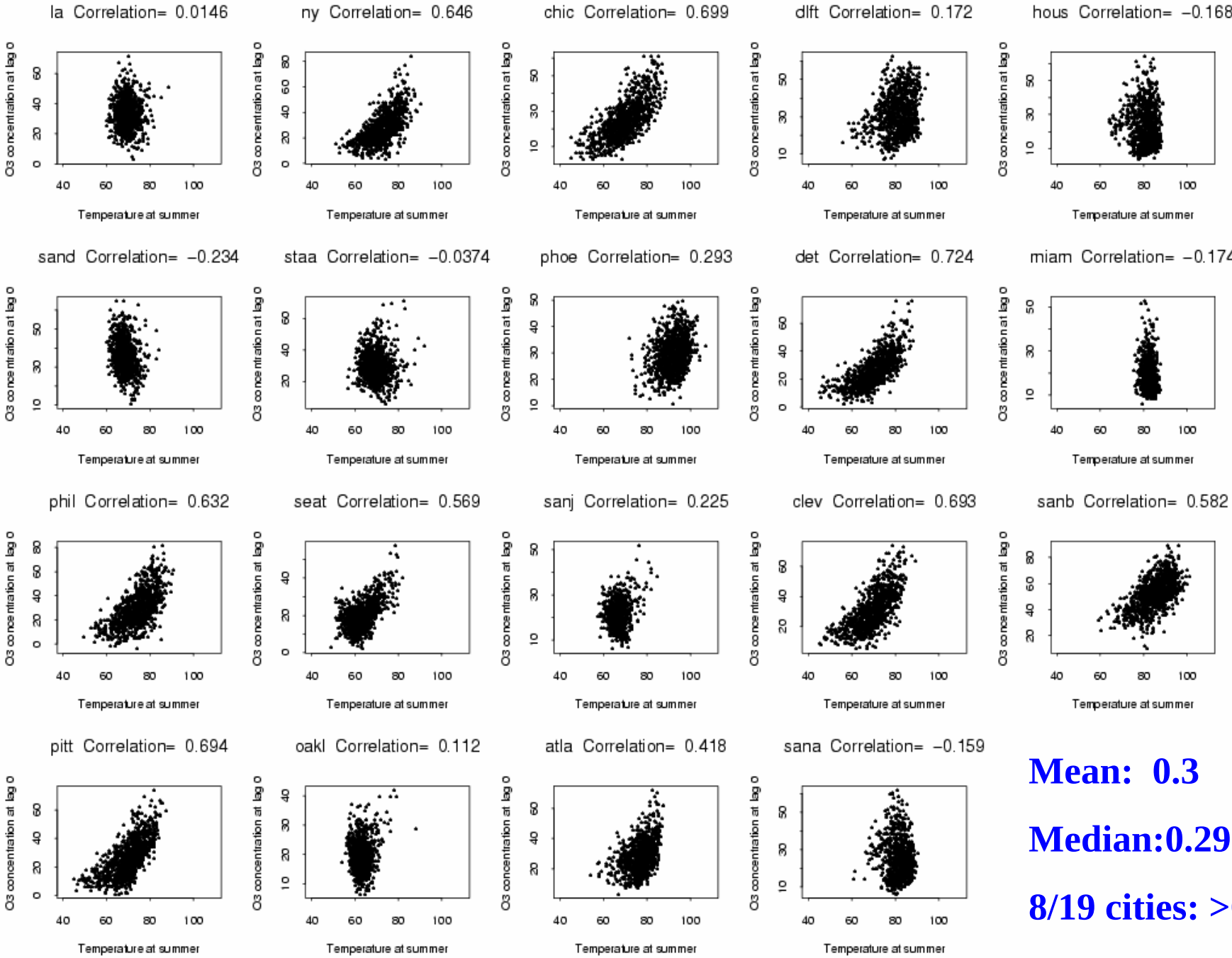
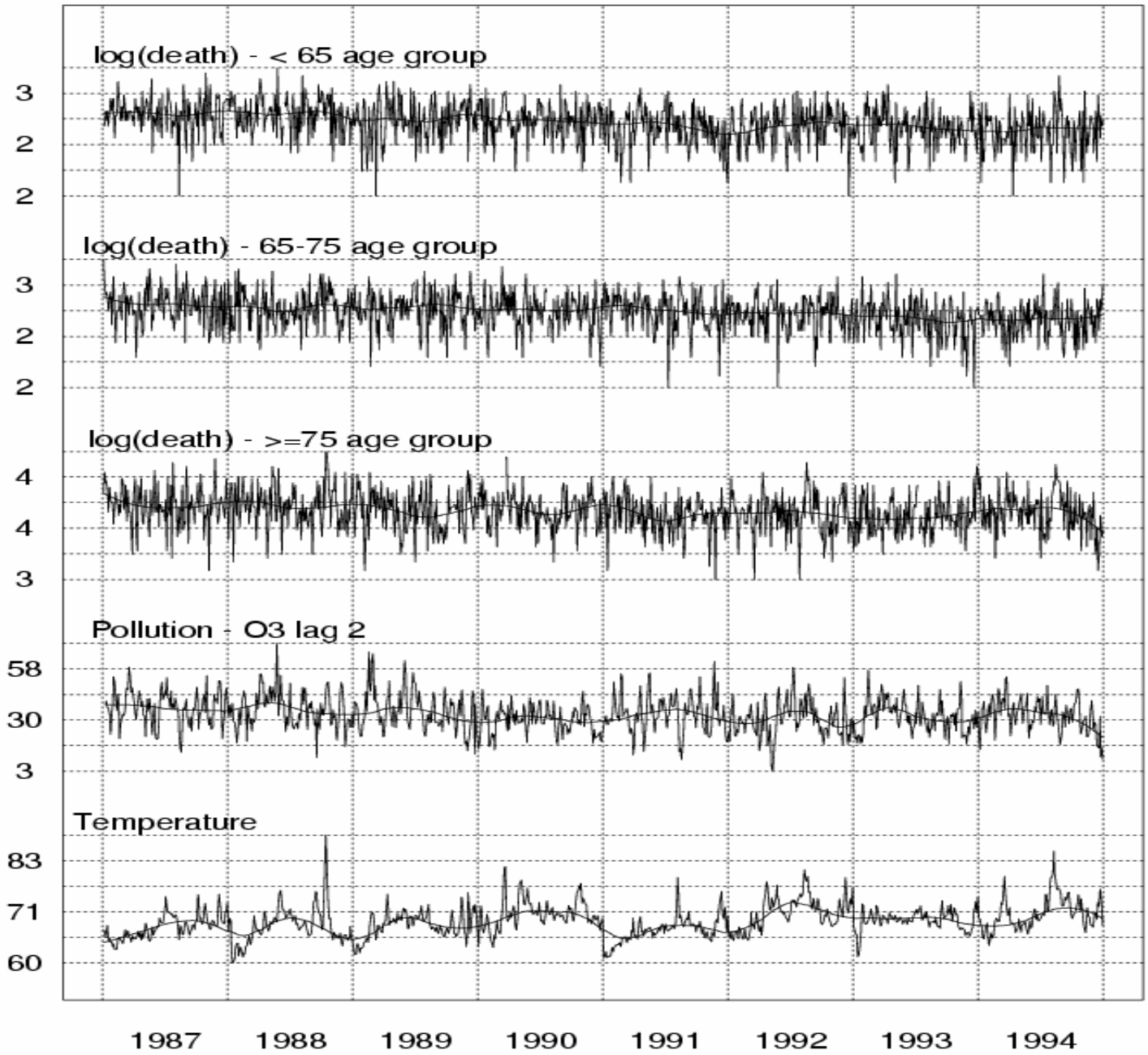


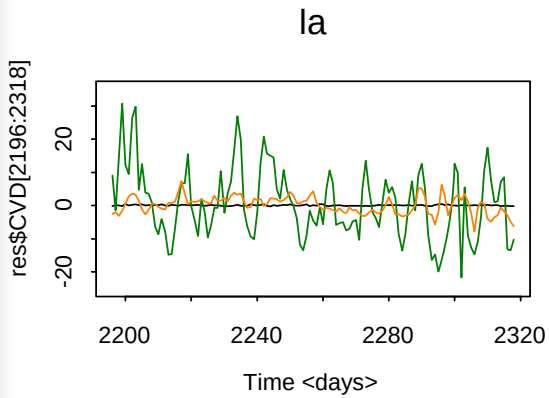
Mean: 0.3

Median:0.29

8/19 cities: >0.5

log(Motality), ozone, temperature, in three age groups

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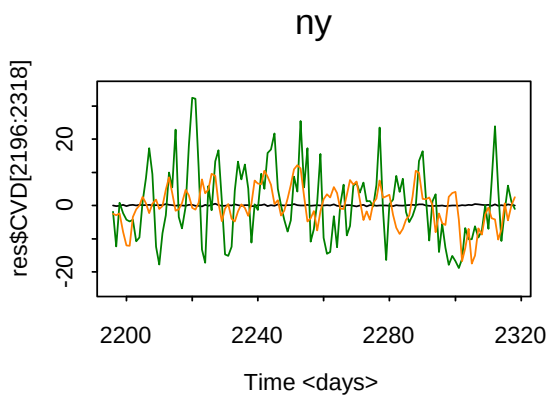
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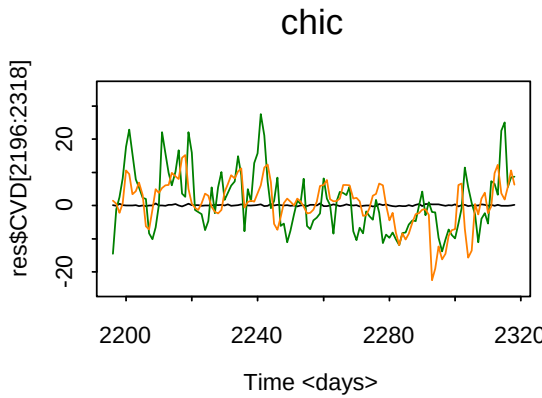
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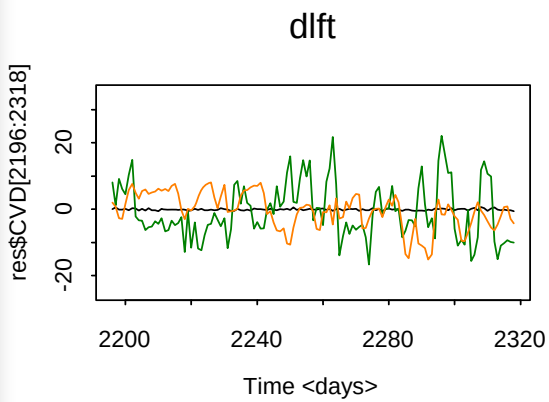
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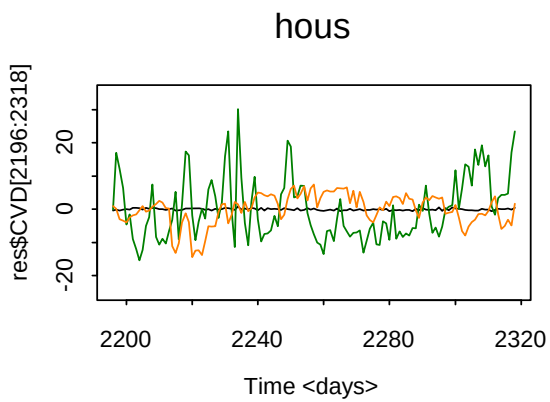
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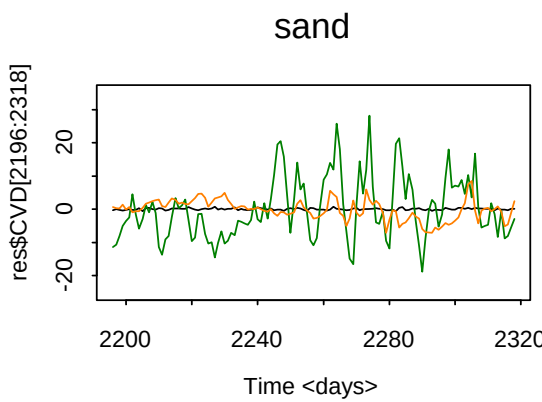
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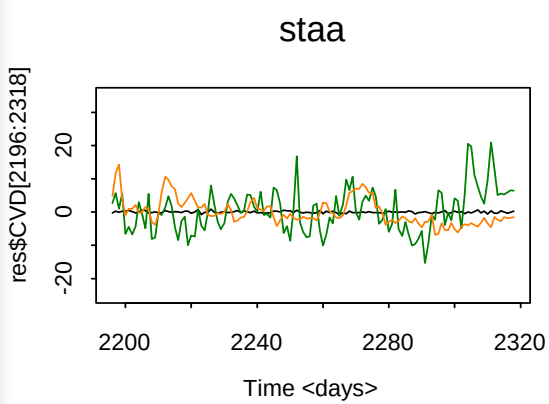
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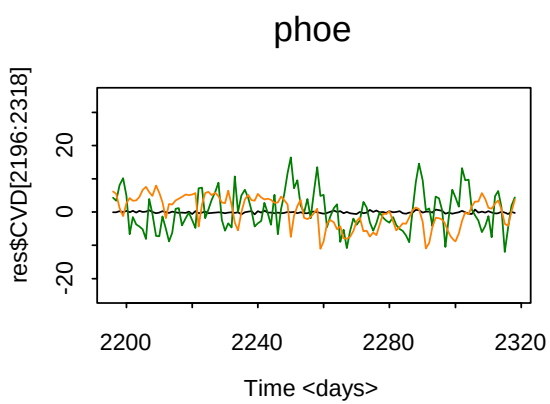
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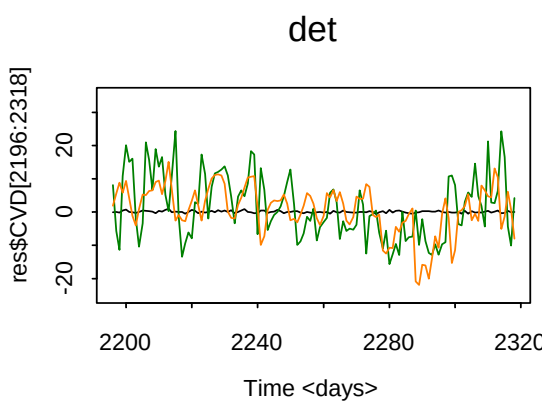
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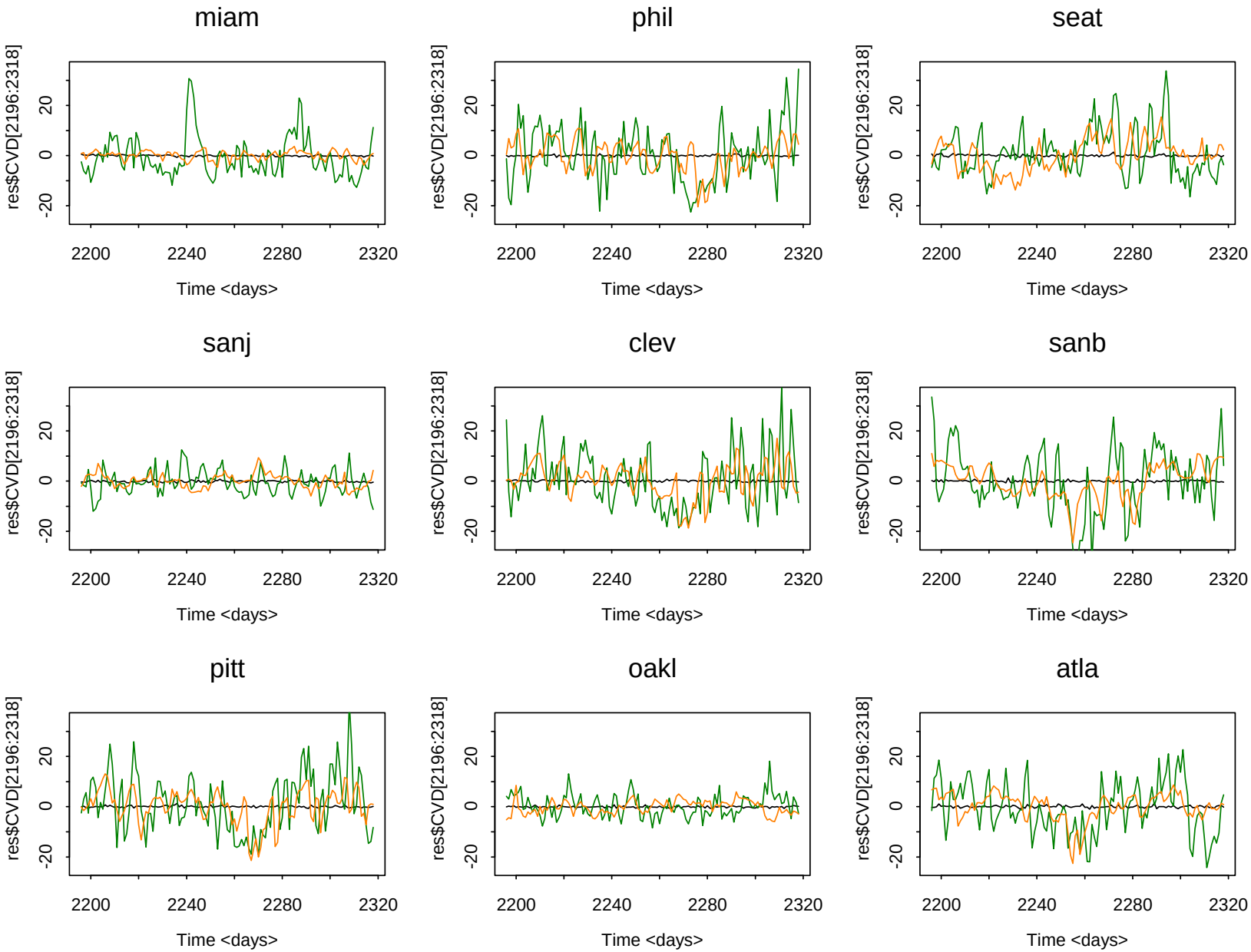
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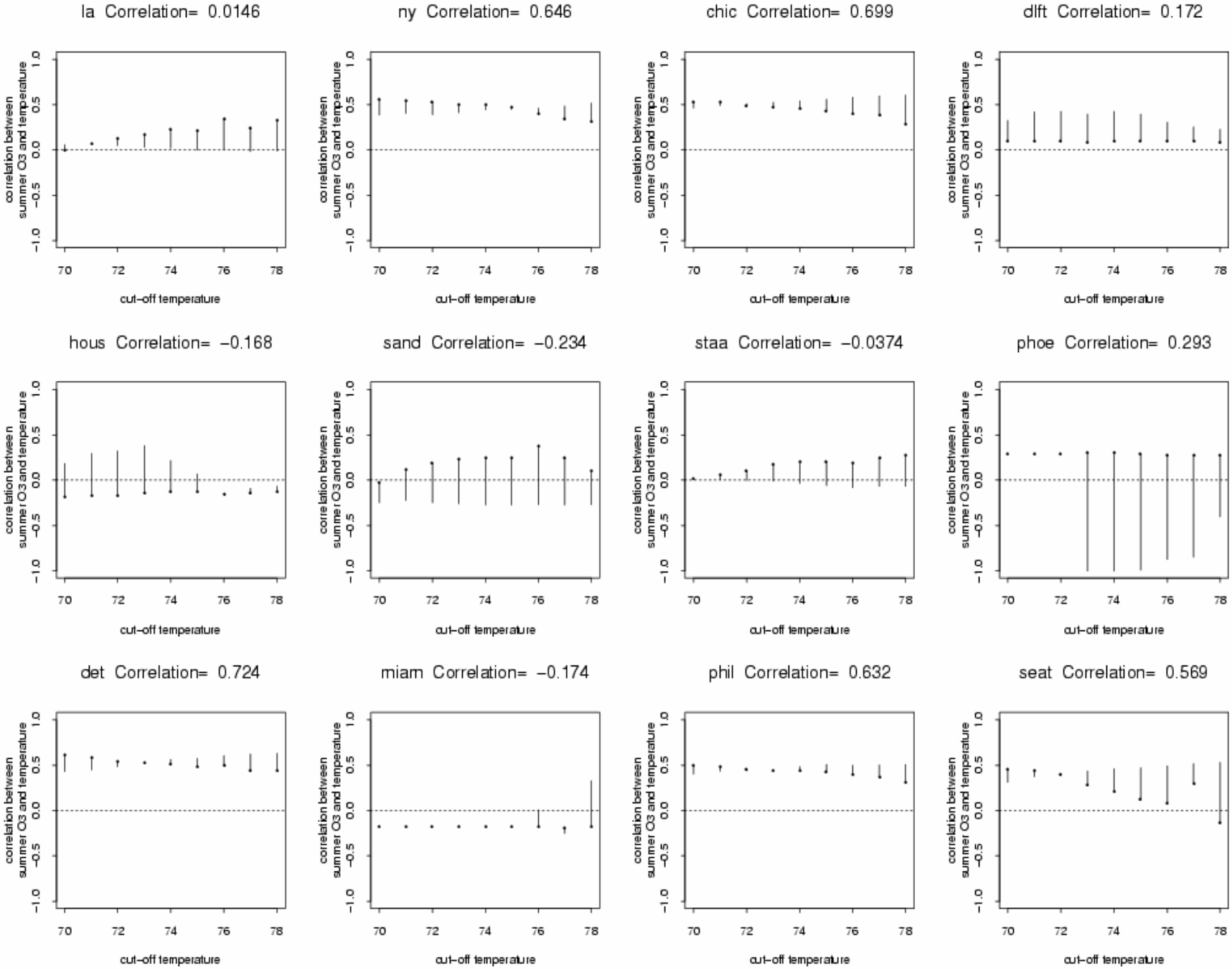
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correlation between summer O3 and temperature
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72
74
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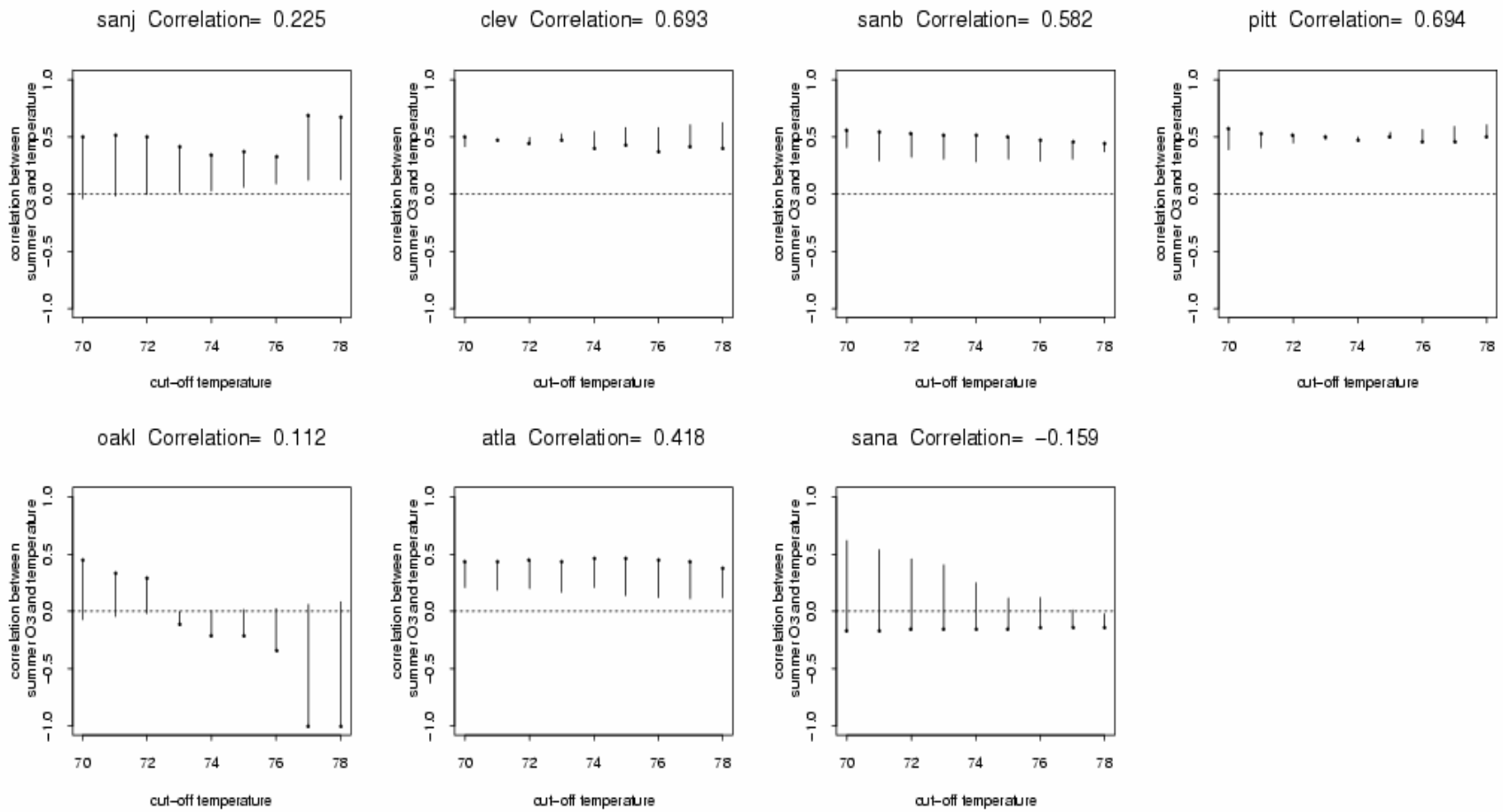


Current threshold for defining moderate temperature: 75 F.

The sensitivity study: threshold ranges from 70 F to 78 F, with step 1 F difference.

Method – Adjustment

- **City-specific effect (β_i^c) → Poisson regression by GLM.**
- **Model:**

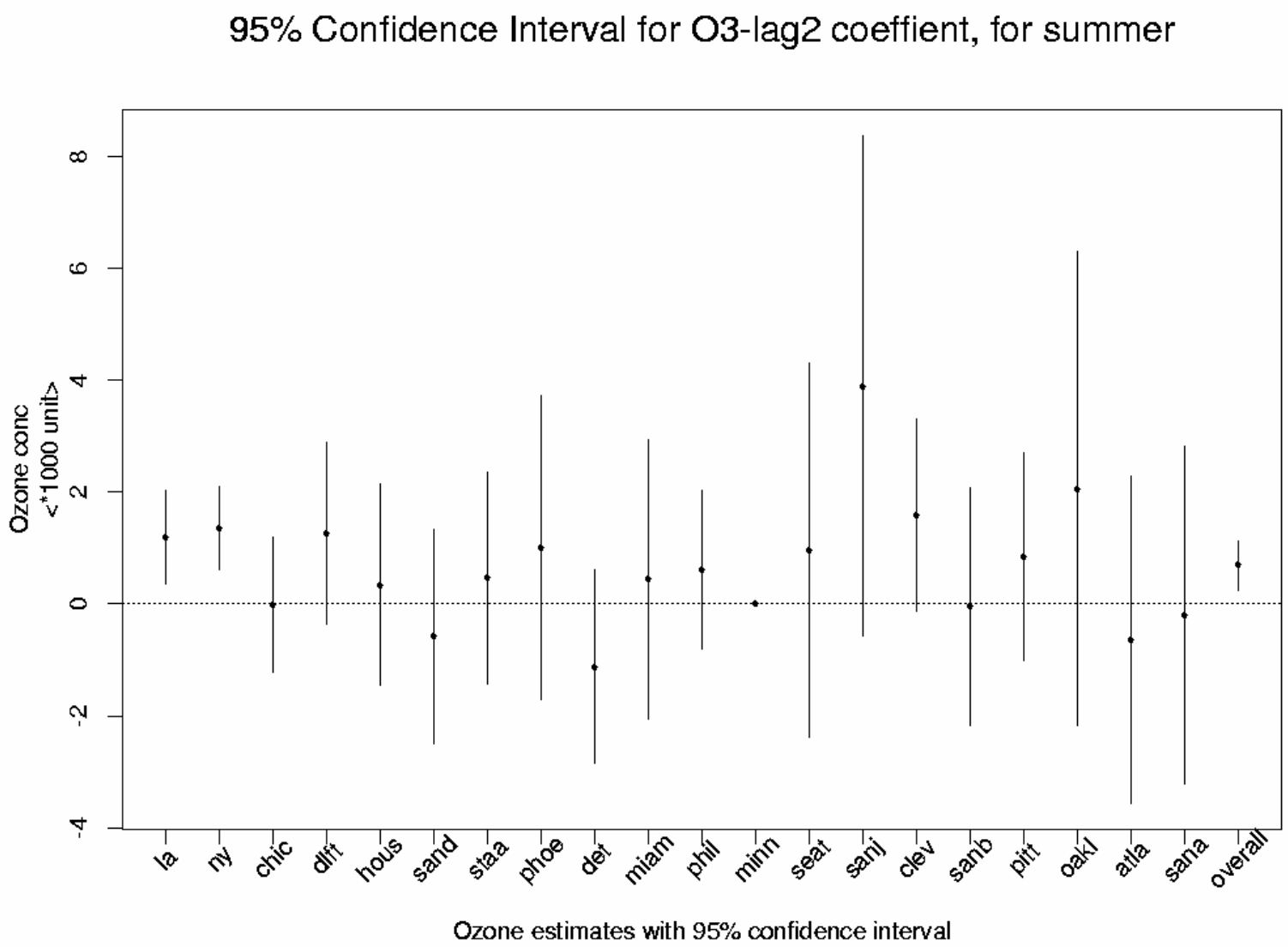
log (E[y]) ~ [O3] + age + dow + s(Time,8) + s(temperature, 8)

log (E[y]) ~ [O3] + [mix pollutant] + age + dow + s(Time, 8) + s(temperature, 8)

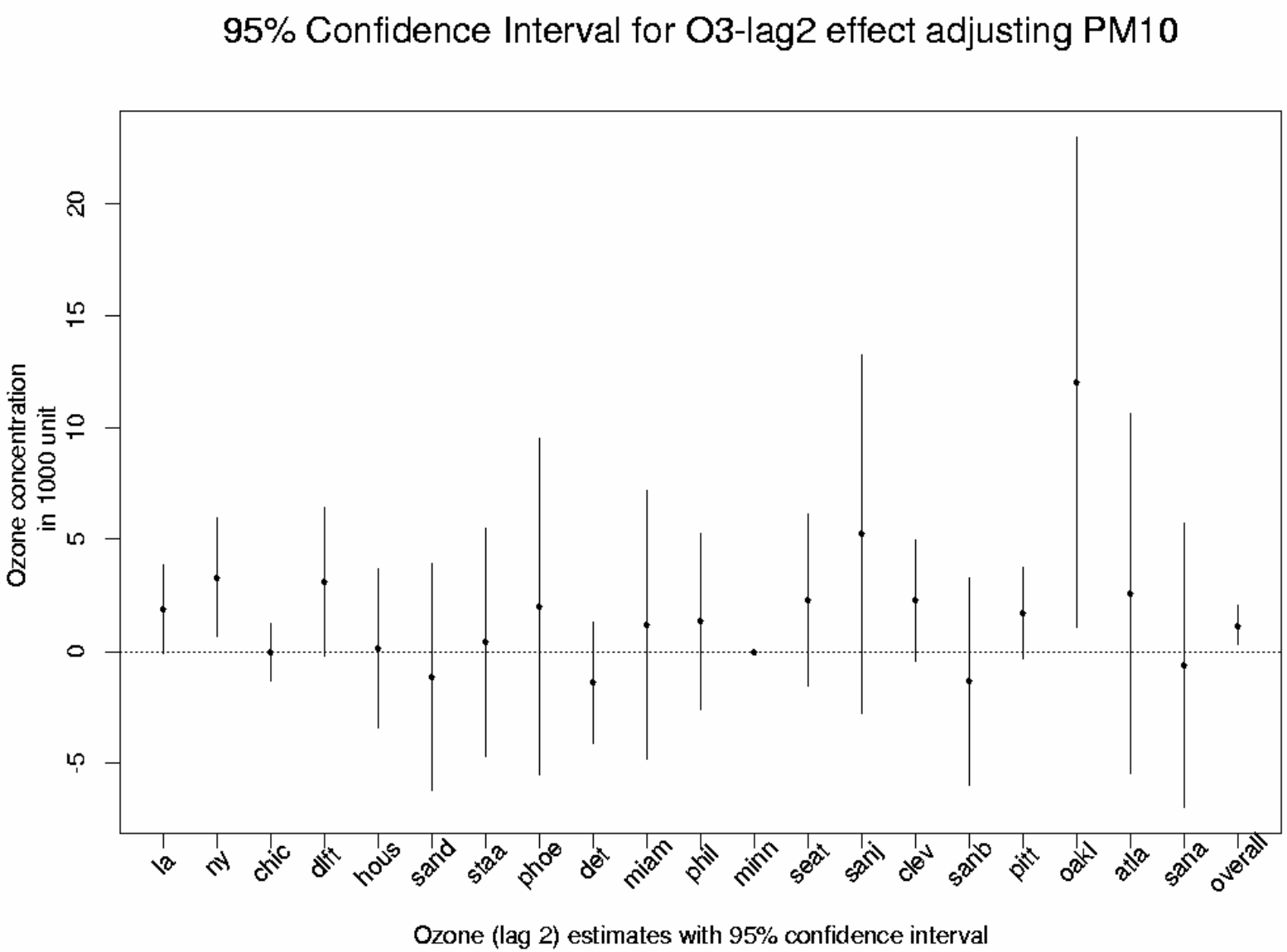
  - **[O3]: different lag --- lag 0/1/2**
  - **[mix pollutant]: PM_{10}, CO, SO_2, and NO_2**

- **Overall effect (μ) → Bayesian Hierarchical Model**
- **Model:** $\beta_i^c \sim N(\theta_i^c, \sigma_i^2)$, $\theta_i^c, \sim N(\mu, \tau^2)$
  - μ **(overall log odds ratio)** = overall summer ozone effect on CVD & RESP mortality, combining information across 20 largest cities.
  - Using **BUGS** for the analysis under non-informative prior.
- **Sensitivity Study → S(Time, a), a range 4 ~ 32 in 8 yr.**
  - **a= d.f. of global smooth function - confounding of long-term trend, like yearly trend, seasonal trend, and monthly trend. (step = 2)**

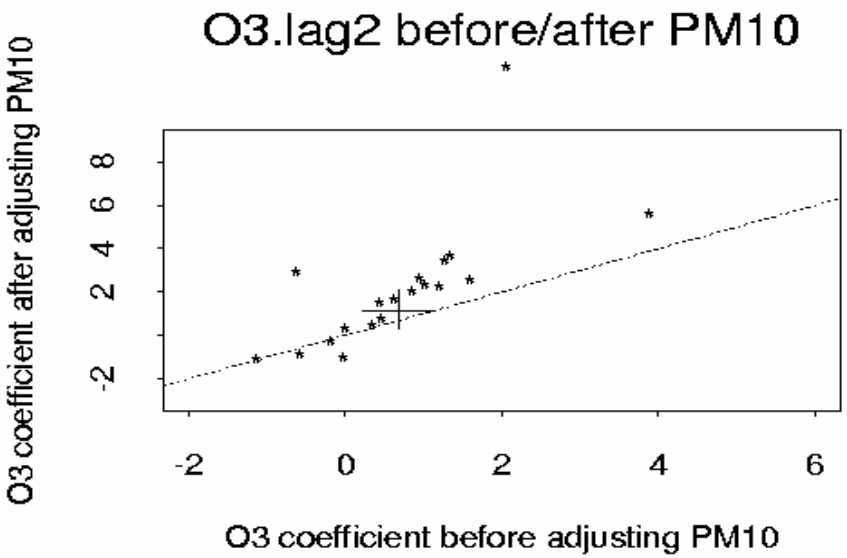
City-Specific Ozone Effect

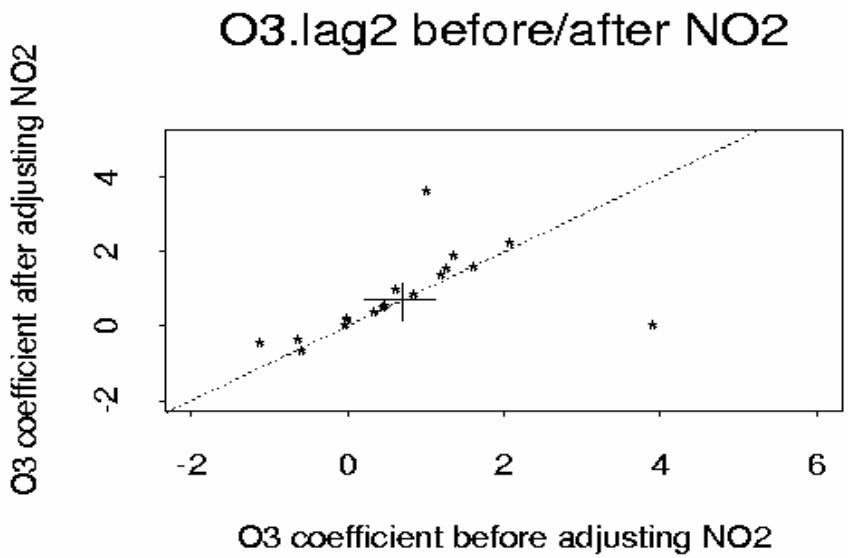


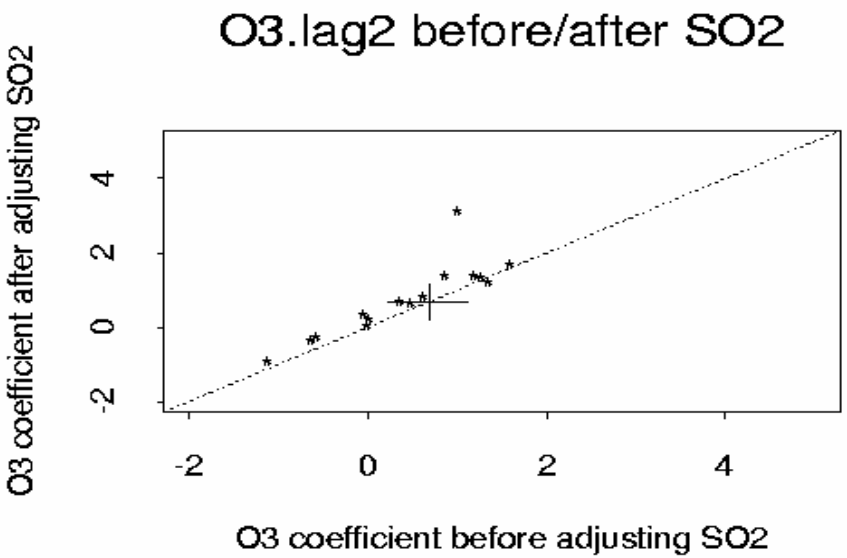
City-Specific Effect, w/ PM_{10}

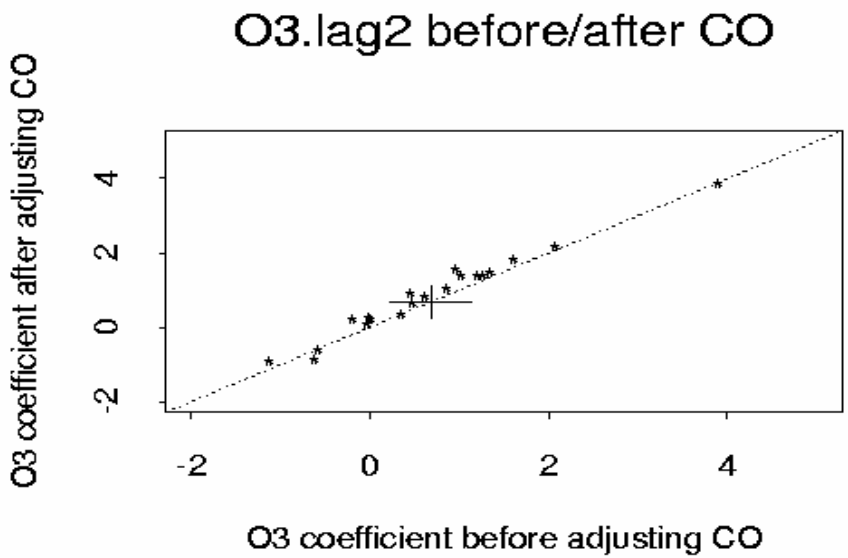


Confounding Effects of Pollutants





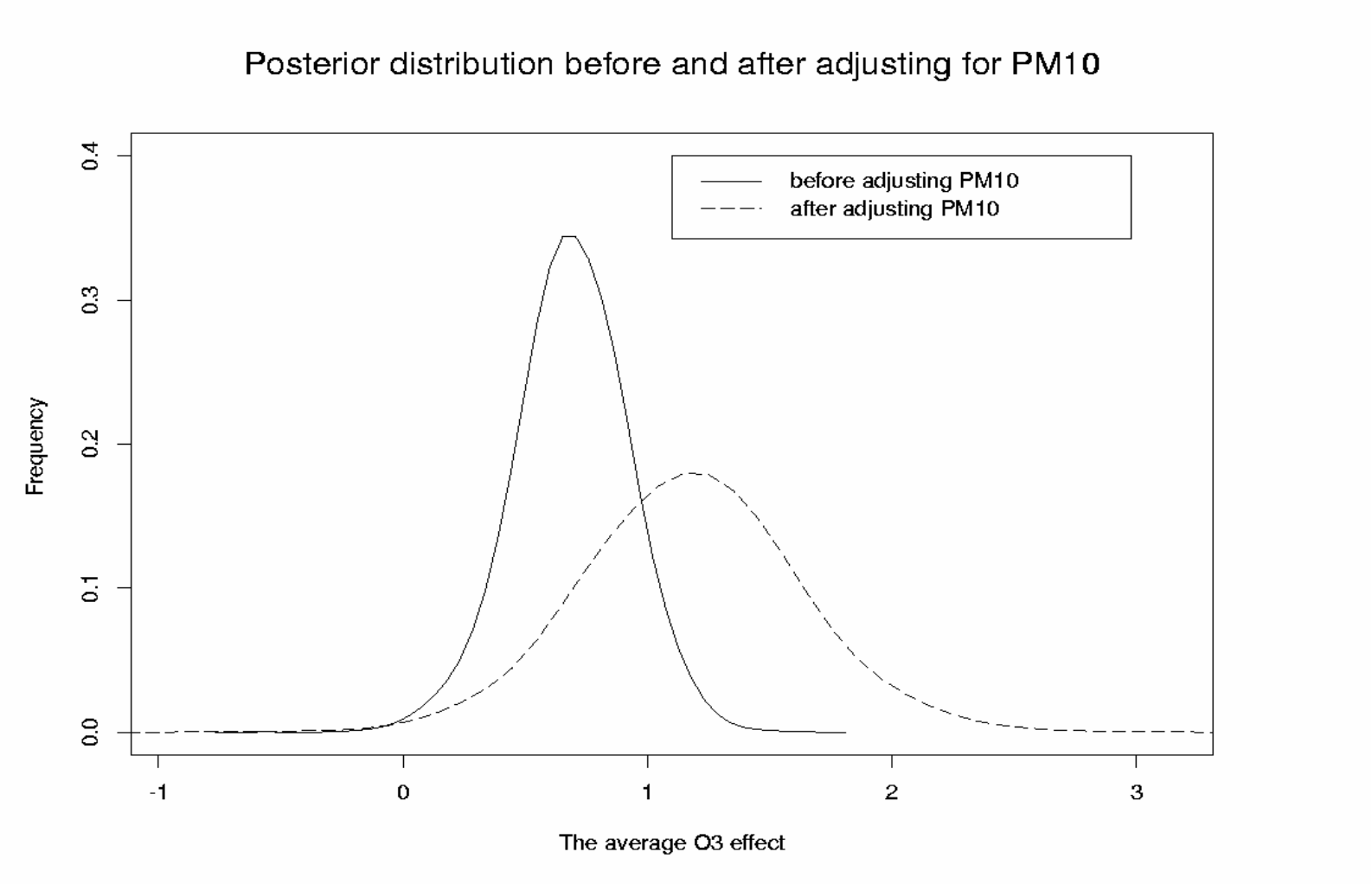


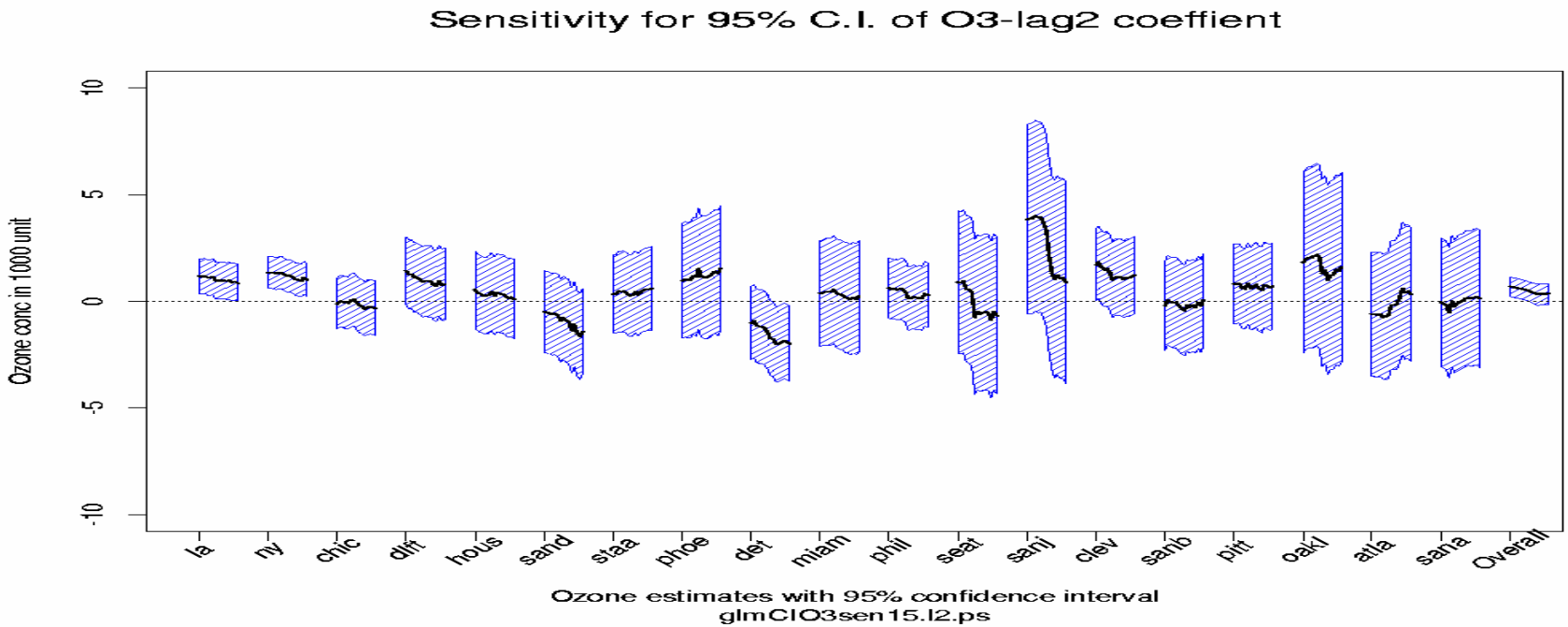


Overall ozone effect

Slope	O3 + PM_{10}	O3 +NO2	O3 + SO2	O3 + CO
O3 lag 0	After: 0.038 (-0.944, 1.032) Before: 0.391 (-0.105, 0.874)	0.346 (-0.157, 0.813) 0.391 (-0.105, 0.874)	0.320 (-0.223,0.824) 0.391 (-0.105,0.874)	0. 336 (-0.181, 0.821) 0.391 (-0.105, 0.874)
O3 lag1	- 0.421 (-1.457, 0.553) 0.580 (0.161, 0.975)	0.608 (0.065, 1.117) 0.580 (0.161, 0.975)	0.508 (0.040,0.979) 0.580 (0.161, 0.975)	0. 557 (0.114, 0.979) 0.580 (0.161, 0.975)
O3 lag2	1.149 (0.313, 2.073) 0.704 (0.240, 1.119)	0.694 (0.160, 1.164) 0.704 (0.240, 1.119)	0.689 (0.187, 1.144) 0.704 (0.240, 1.119)	0.679 (0.216, 1.098) 0.704 (0.240, 1.119)

Posterior-Dist. of μ (lag 2)




Sensitivity for 95% C.I. of O3-lag2 coeffient
Ozone conc in 1000 unit
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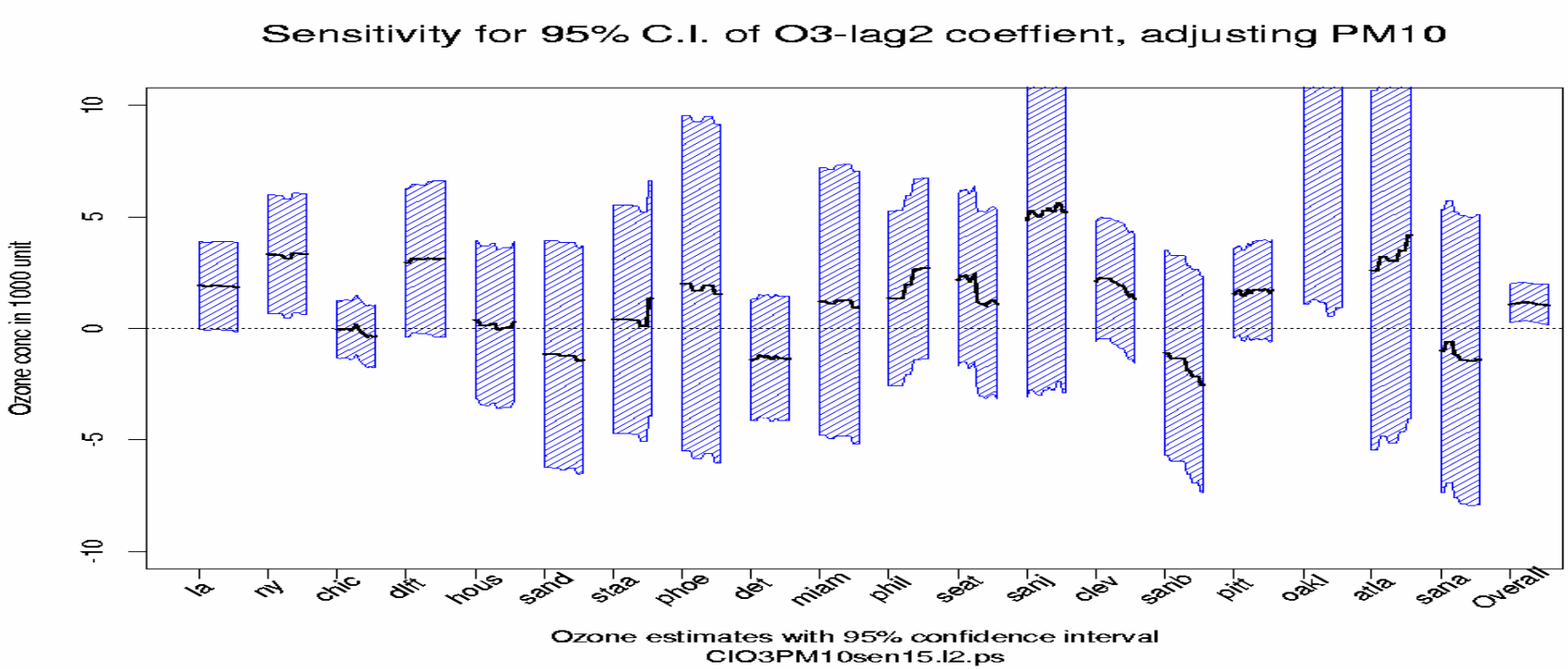
Overall
Ozone estimates with 95% confidence interval
glmClO3sen15.l2.ps


Sensitivity for 95% C.I. of O3-lag2 coeffient, adjusting PM10
Ozone conc in 1000 unit
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Overall
Ozone estimates with 95% confidence interval
ClO3PM10sen15.l2.ps

Conclusion

- **Overall, there is statistically significant positive association between ambient summer O3 and CVD & RESP mortality at lag 1 and lag 2.**

- **The association between mortality and summer ozone is confounded by PM_{10}, but not much confounded by CO, SO_2, and NO_2. (Further study is needed to control the confounding effect of PM_{10}.)**

- **The city-specific and overall ozone effects results under univ- & multi-pollutants models are not sensitive to the selection of the number of d.f. in the smooth function of time.**

Working in Progress

- Control the temperature effect by subclassification method
- Control the PM10 confounding effect by matching method

Method – Subclassification

- **City-specific effect (β_i^c) → Poisson regression by GLM.**
  - **Similar model for 19 cities, but only for the data with current day temperature below 75 F, after taking away yearly cycle (or any long-term trend > 4 months).**

- **Overall effect (μ) → Bayesian Hierarchical Model**
  - **Same model with new β_j^c :**

$$\beta_i^c \sim N(\theta_i^c, \sigma_i^2), \quad \theta_i^c, \sim N(\mu, \tau^2)$$

- **Sensitivity Study** →threshold temperature ("moderate temperature") change from 70 F to 78 F, with step 1 F increasing.

Matching – Control PM_{10} confounding

- LA & San Bernardino comparison

	CVD & RESP	Temp L0	Dew Temp	O_3 L2	PM_{10}	NO_2	SO_2	CO
LA	**25.75**	**69.2**	**60**	**33.3**	**45**	**37**	**1.1**	**1000**
Sanb	**3.2**	**85**	**44**	**53**	**41**	**30**	**0.04**	**945**

- Might over-simplify the problem to:
  - 2 correlated cities: same [PM_{10}], with different temperature and [O_3].
- Control population difference

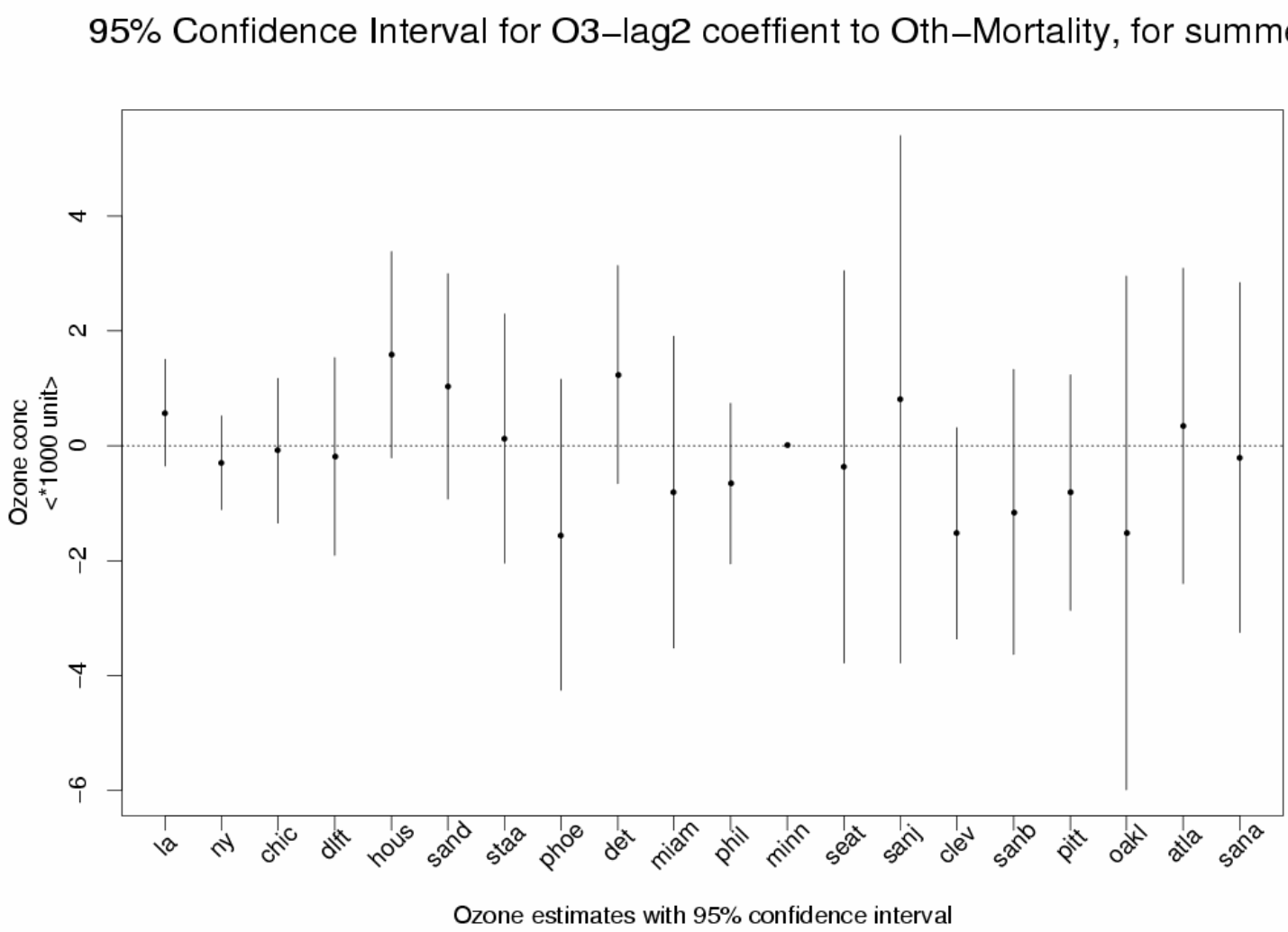
Discussion & Acknowledgment

- **Measurement error**
  - Personal summer ozone exposure?
- **Possible to control temperature effect?**
  - Clustering on synoptic whether.
- Is the association between ambient O3 and mortality **confounded by the unobserved** ultra-fine particle, or other pollutants?

- Thanks a lot for **-- Dr. Dominici and Dr. McDermott** help and guidance.
- Thank **Dr. Bandeen-Roche** for the help on confounding.

- Thank **you** for reaching this far.

Appendix-1



Total effect ≈ - 0.048, not sig.