# Empirical Orthogonal Teleconnection Analysis (?) of Daily Surface Ozone

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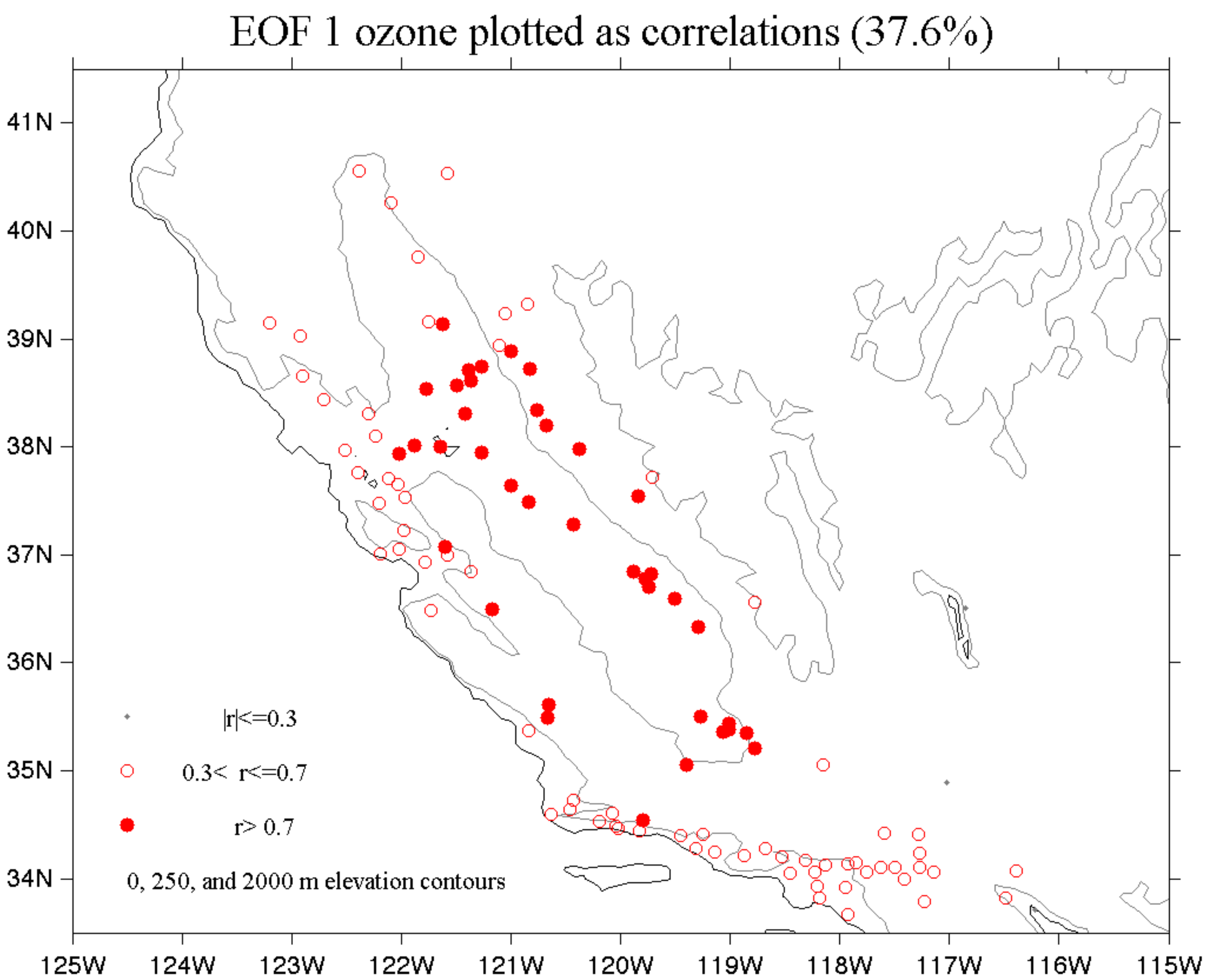
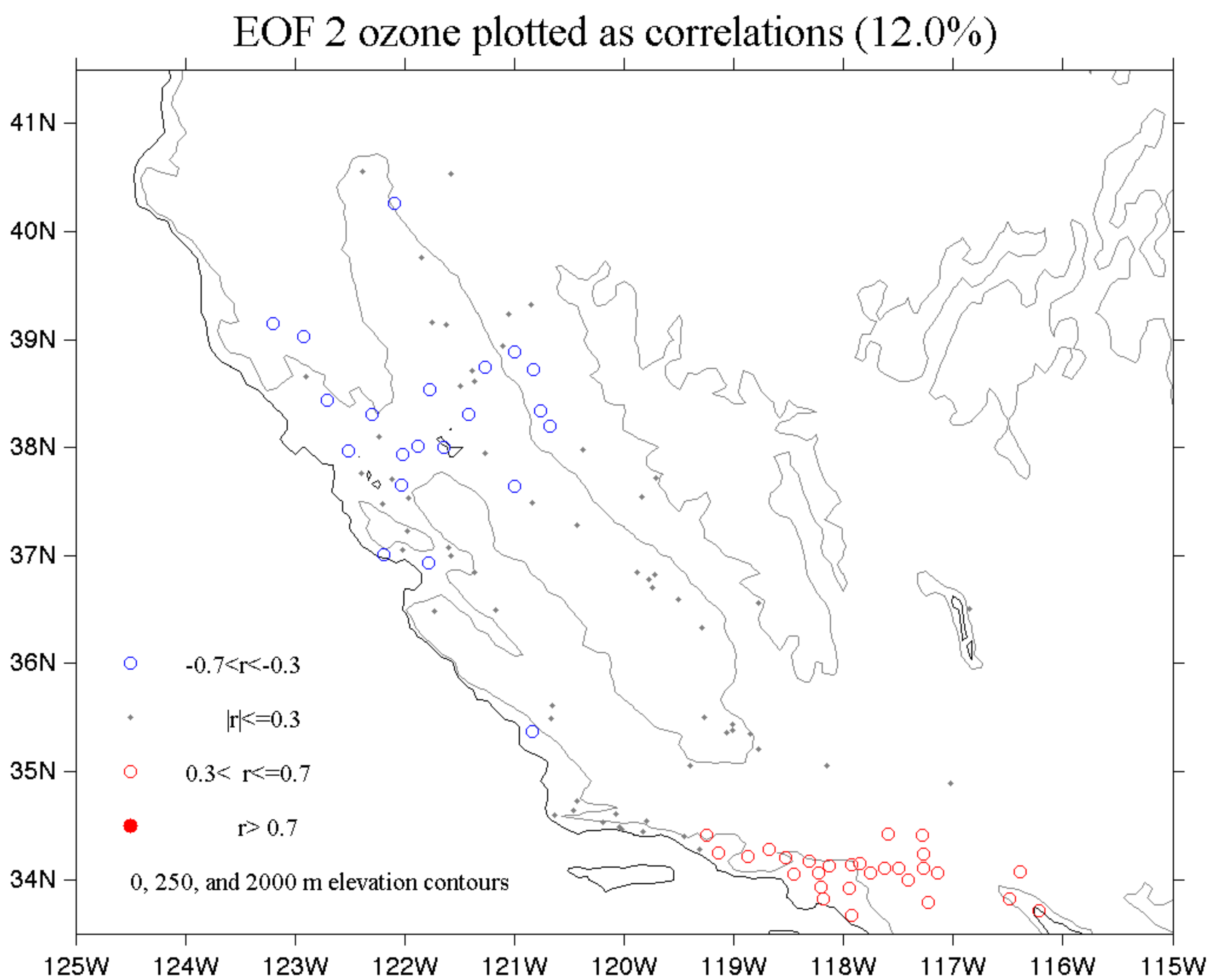
A common analysis problem is how to characterize the variability in a dataset.

Empirical Orthogonal Functions (EOFs) are very efficient, but the analysis is dominated by the leading EOF and there may be more variability in the data that you would like to explain.

# EOFs of California dailv surface ozone




EOF 2 ozone plotted as correlations (12.0%)
41N
40N
39N
38N
37N
36N
35N
34N
125W
124W
123W
122W
121W
120W
119W
118W
117W
116W
115W
-0.7<r<-0.3
|r|<=0.3
0.3< r<=0.7
r> 0.7
0, 250, and 2000 m elevation contours

- EOFs 1 and 2 explain 37 and 12% of the variability, and yet EOF 2 is a simple spatial harmonic of EOF 1. It doesn't look particularly physical.
- Empirical Orthogonal Teleconnections will yield more patterns and they will explain a larger percentage of variance in small areas. The patterns also tend to be more regional rather filling the spatial domain of the data.

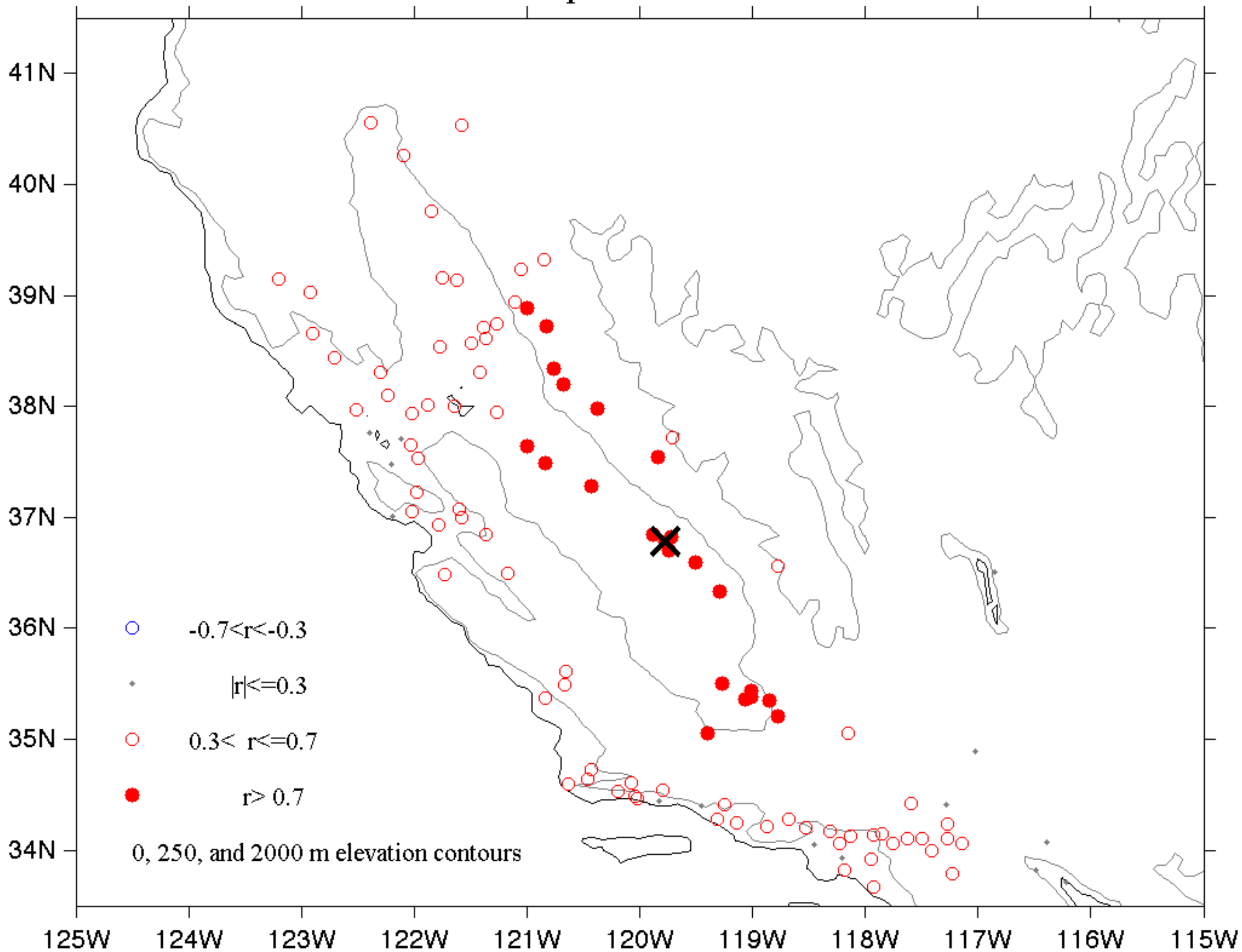
# The process to calculate EOTs is as follows:

- Data = A(x,t), where x is space and t time.
- For each spatial point, calculate the correlation with all of the gridpoints. Square and sum the correlation coefficients. Find the gridpoint whose time series explains the largest amount of variance in the dataset. That's EOT 1.
- Regress that timeseries onto all of the gridpoint timeseries, and remove that variability from the dataset.
- Repeat.

- Reference: Van den Dool et al. 2000, *J. Climate,* **13,** 1421-35.

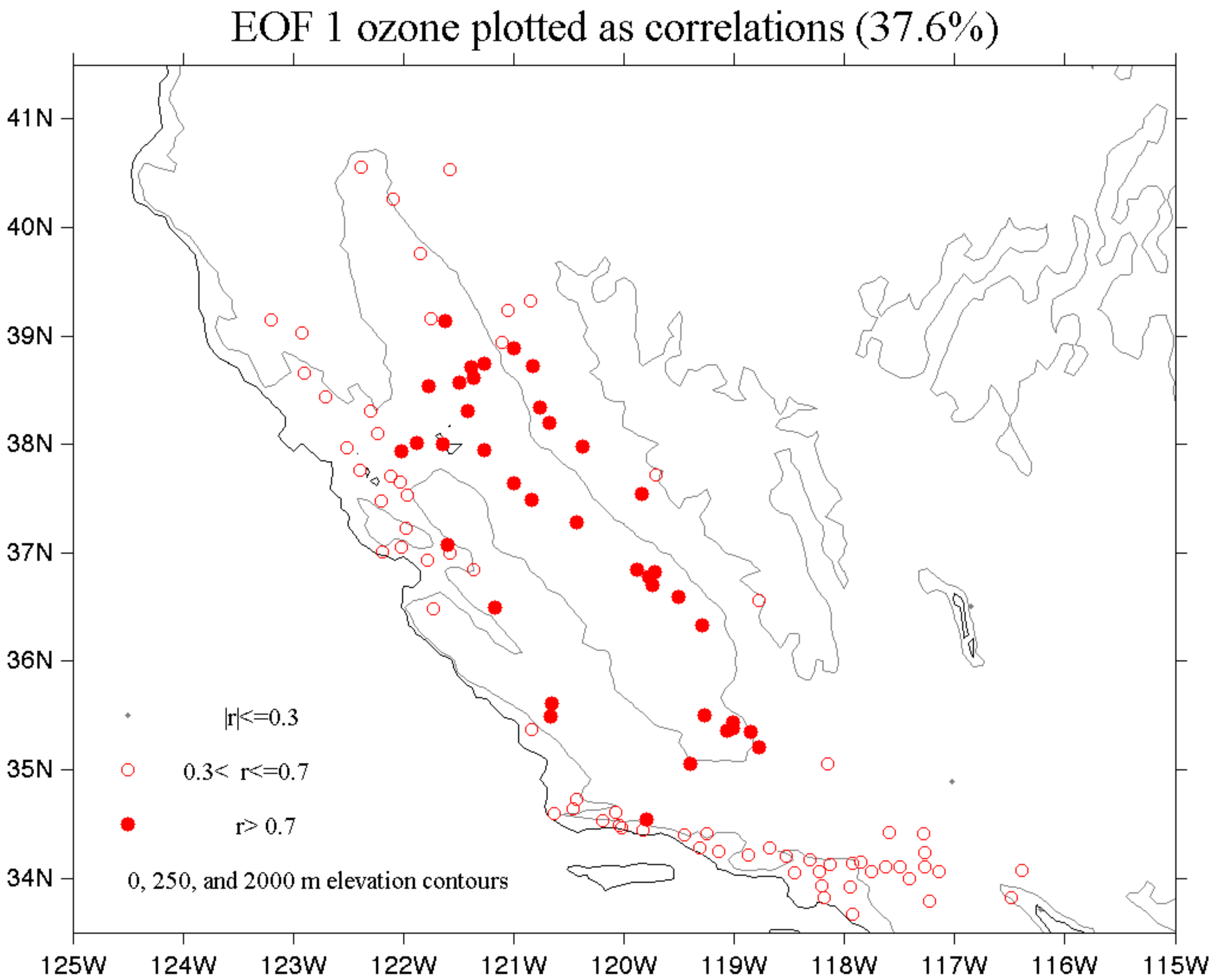
- The results are similar to what you get from rotated principal component analysis, but significantly less work!

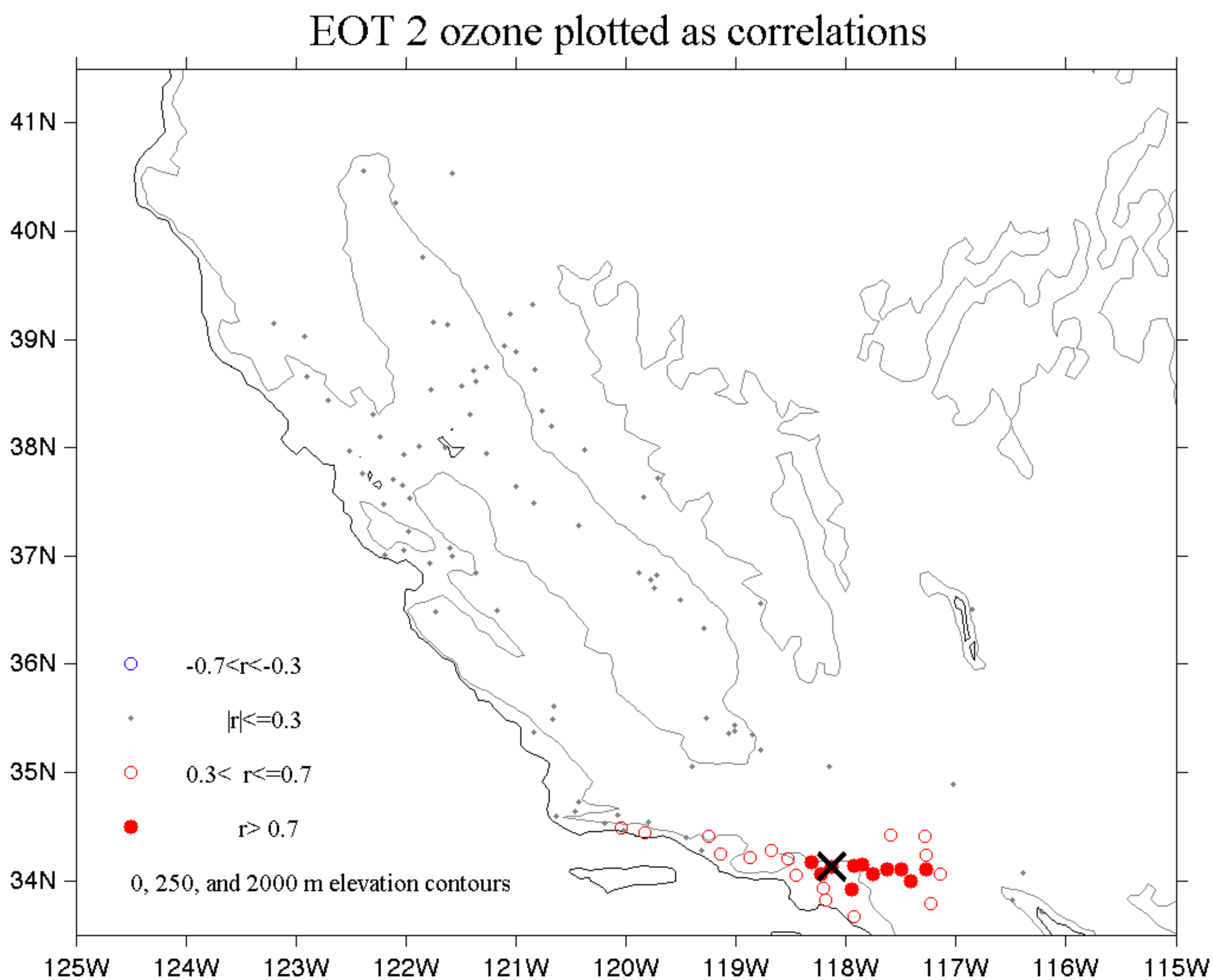
# EOT 1 ozone plotted as correlations




0.82 correlation with the EOF 1 timeseries.

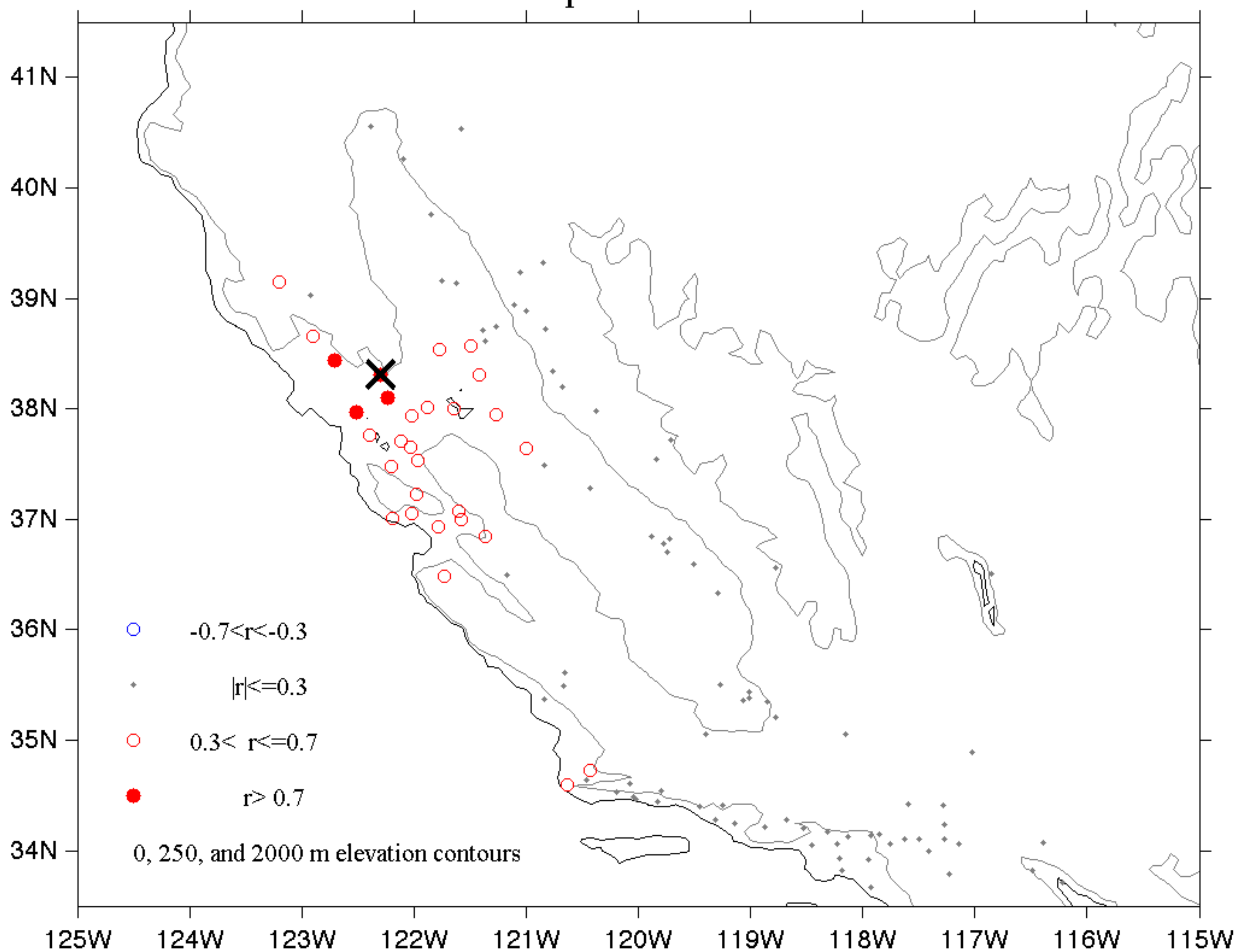
# EOFs of California dailv surface ozone



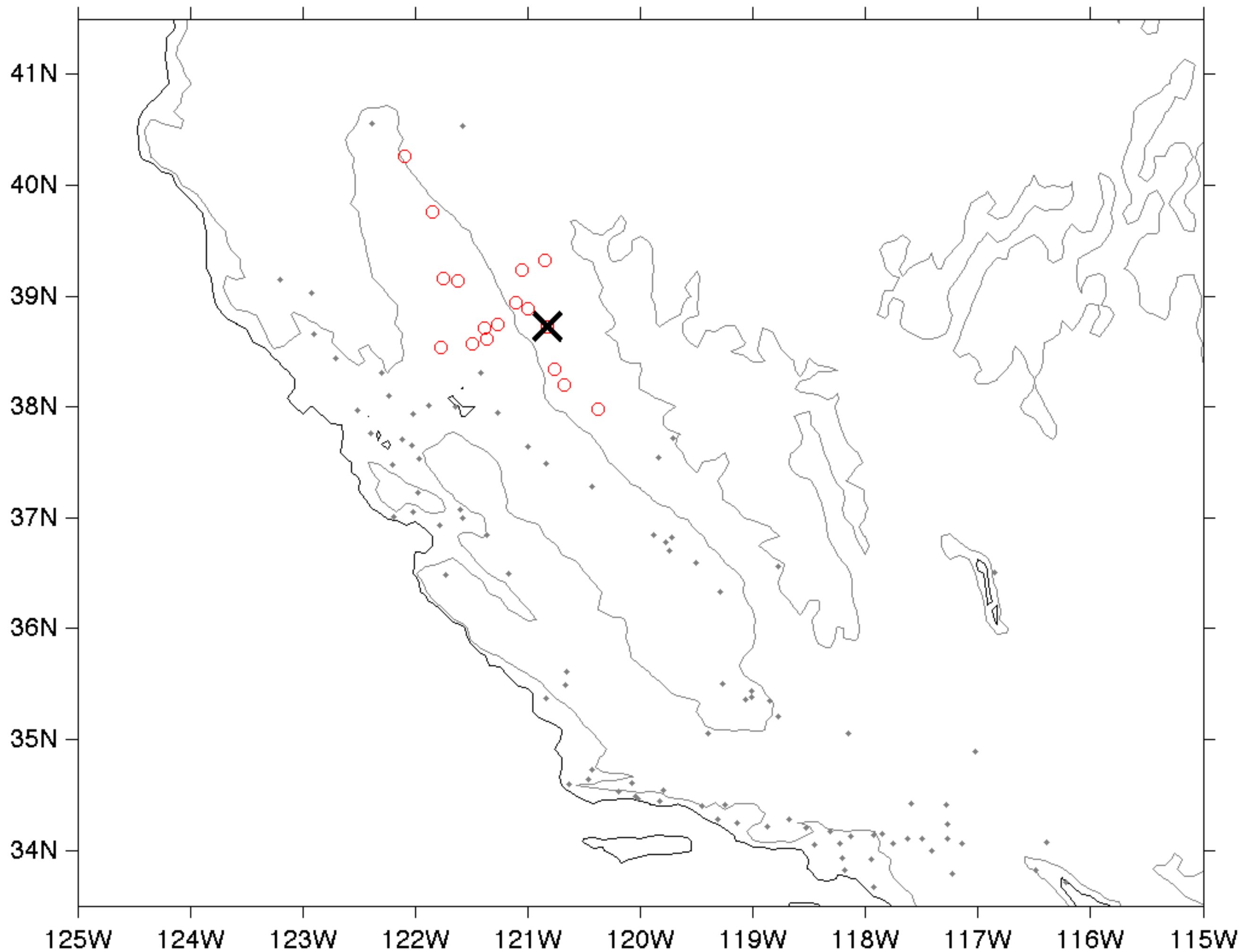



076 correlation with EOF 2 timeseries.

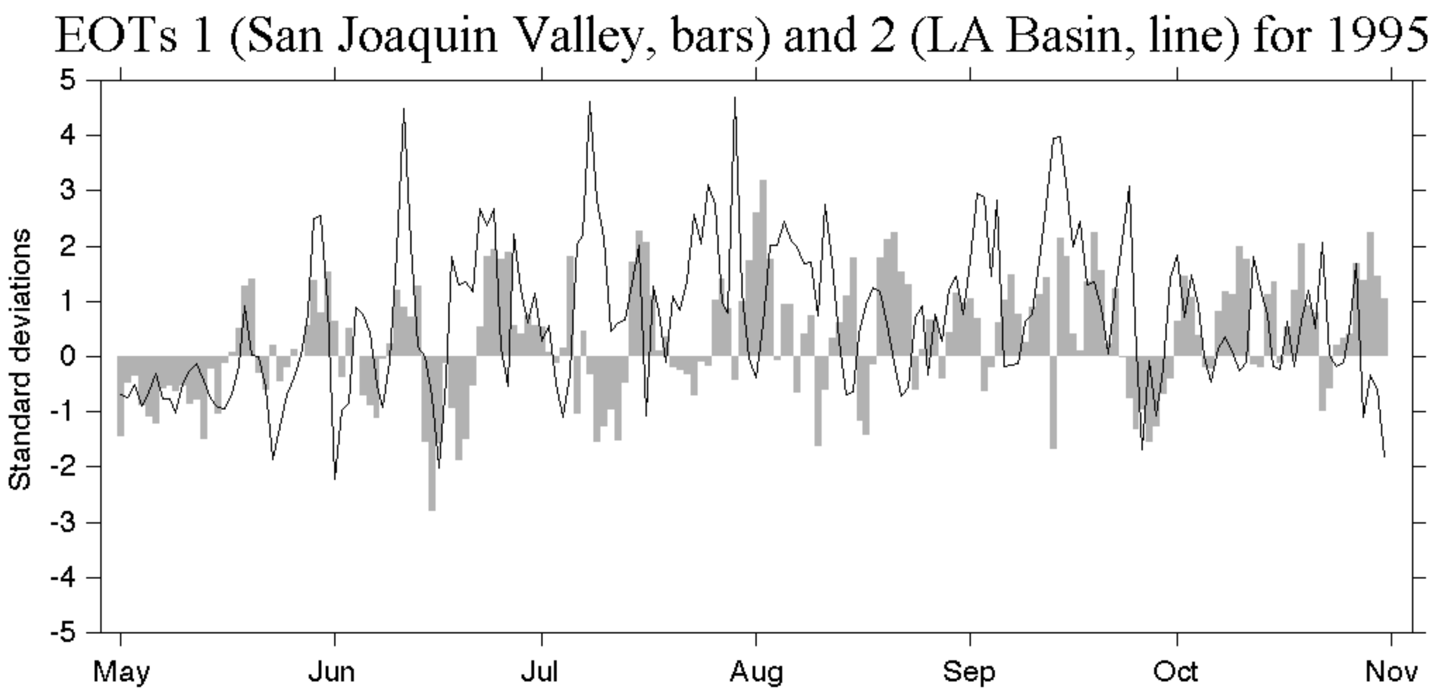
EOT 3 ozone plotted as correlations



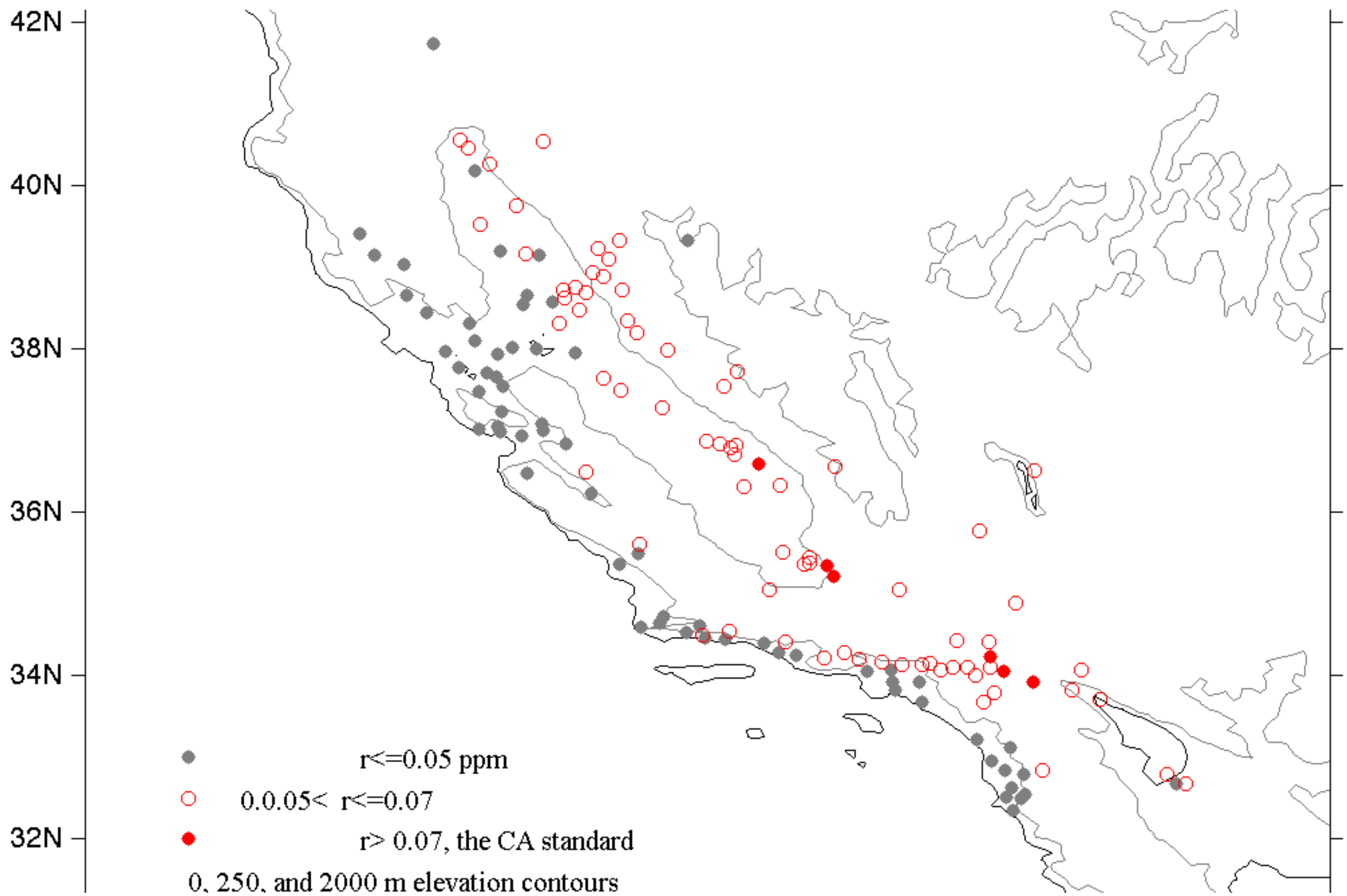
# EOT 4



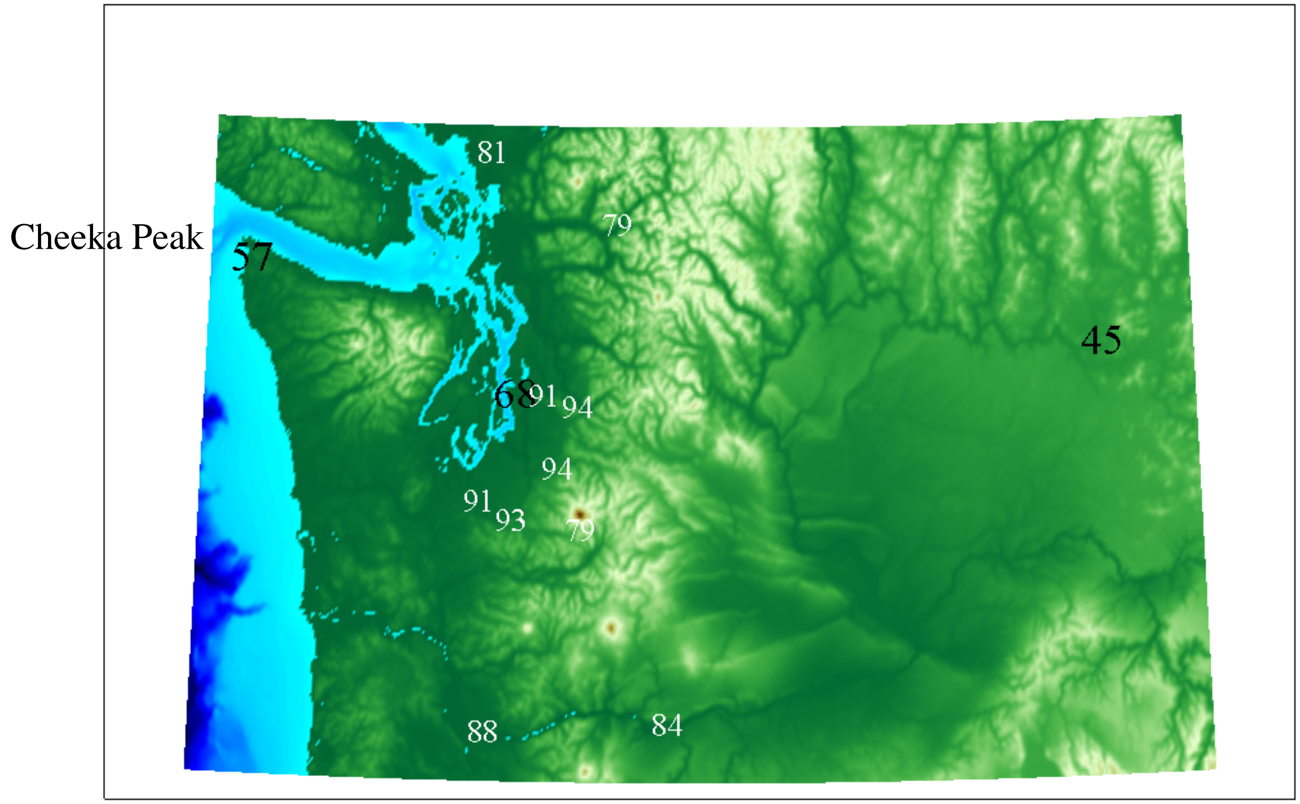
41N
40N
39N
38N
37N
36N
35N
34N
125W
124W
123W
122W
121W
120W
119W
118W
117W
116W
115W


EOTs 1 (San Joaquin Valley, bars) and 2 (LA Basin, line) for 1995
Standard deviations
5
4
3
2
1
0
-1
-2
-3
-4
-5
May
Jun
Jul
Aug
Sep
Oct
Nov

# California daily 8-hour maximum surface ozone



Correlation of daily summertime ozone with state average ozone, 1995-2009

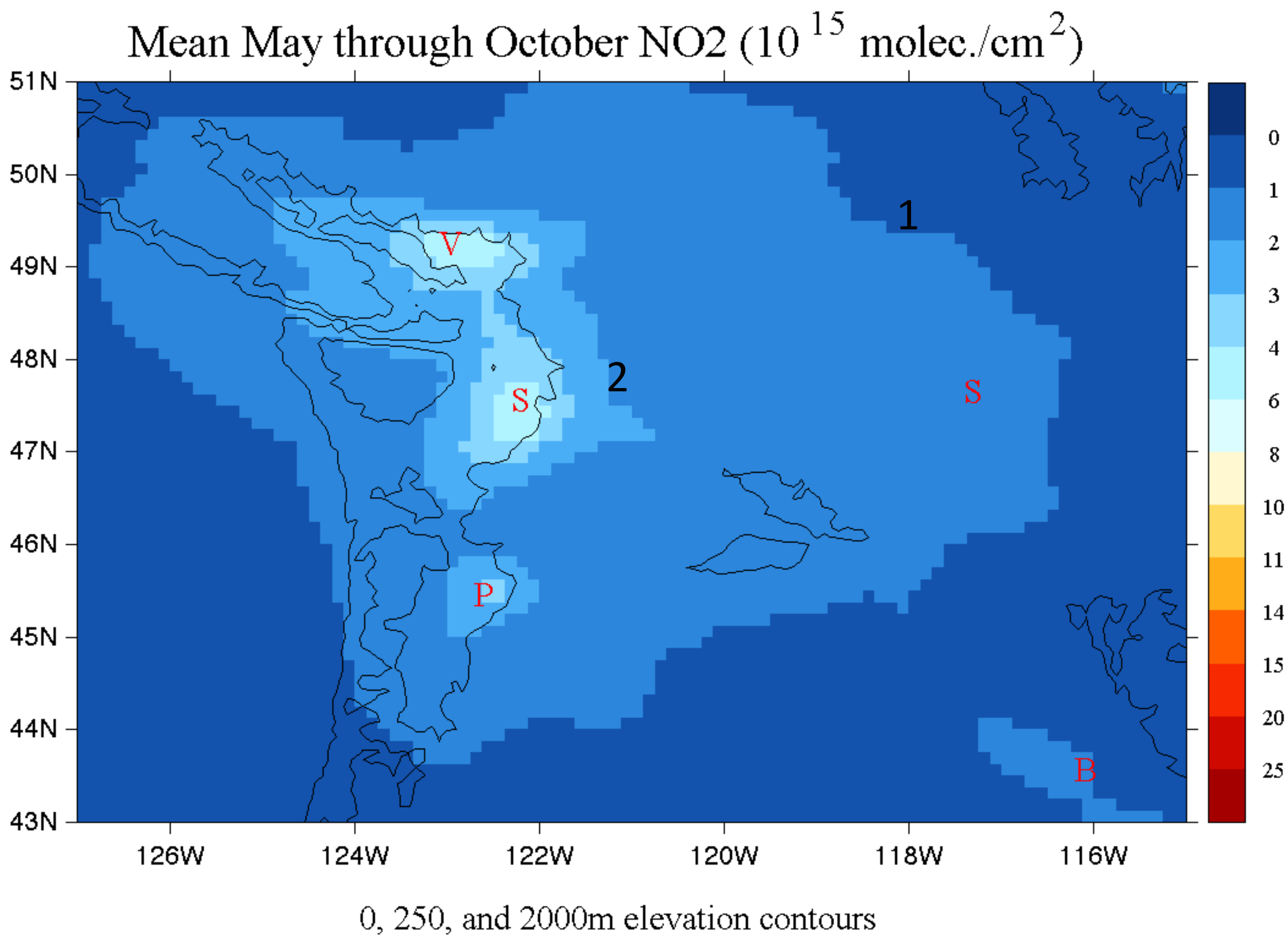



Mostly Washington State Department of Ecology measurements served by the Puget Sound  Clean Air Agency

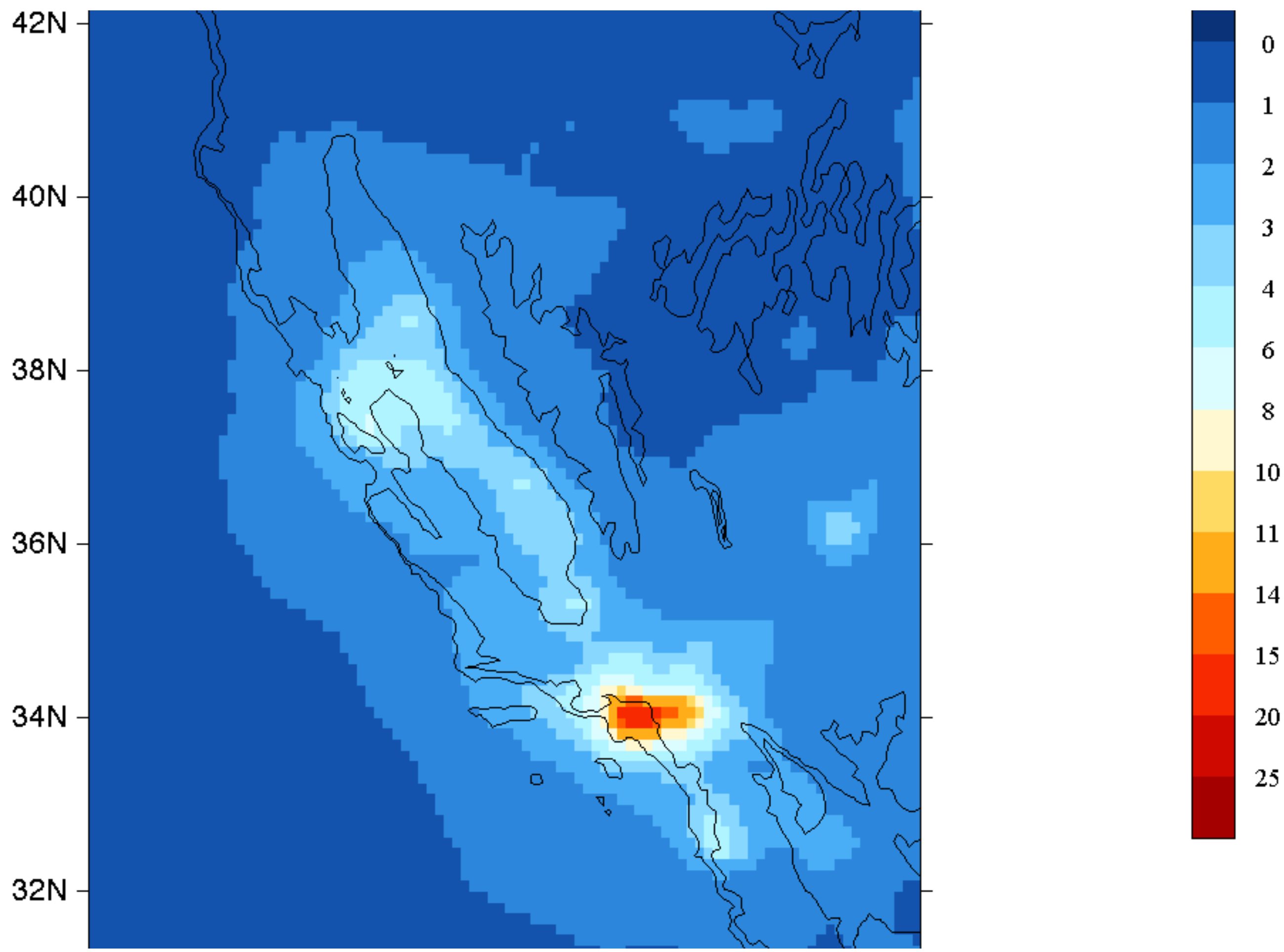
Now look at the daily variability of ozone, $NO_2$, and the atmospheric circulation.

*You can anticipate the affect on the Washington – Oregon ocean climate.*

# Dutch Ozone Monitoring Instrument $NO_2$ (DOMINO) tropospheric vertical column $NO_2$, began in 2005



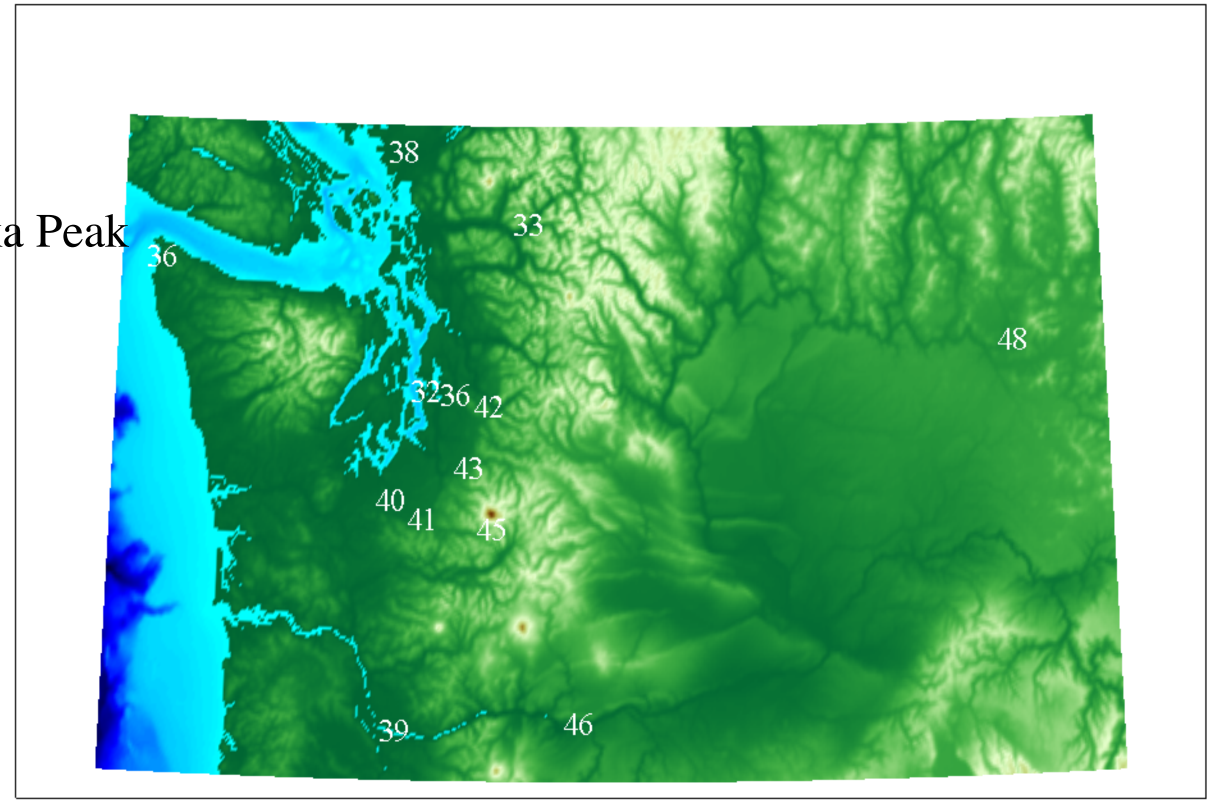
# Dutch Ozone Monitoring Instrument $NO_2$ (DOMINO)
# Tropospheric vertical column $NO_2$, began in 2005



*Thank you!*

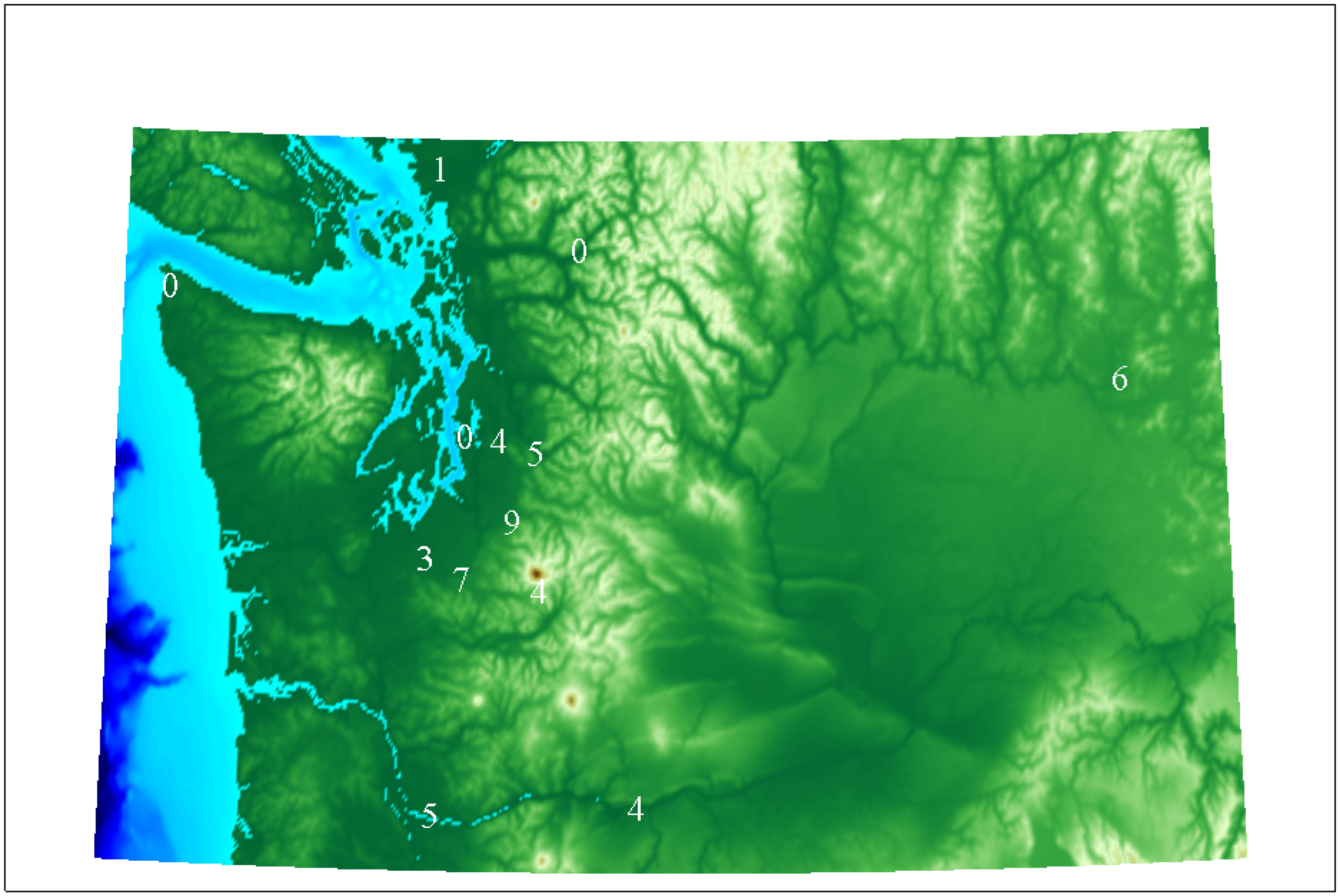
# Daily 8-hour maximum surface ozone

Mean May through October ozone (ppb) 1995-2009



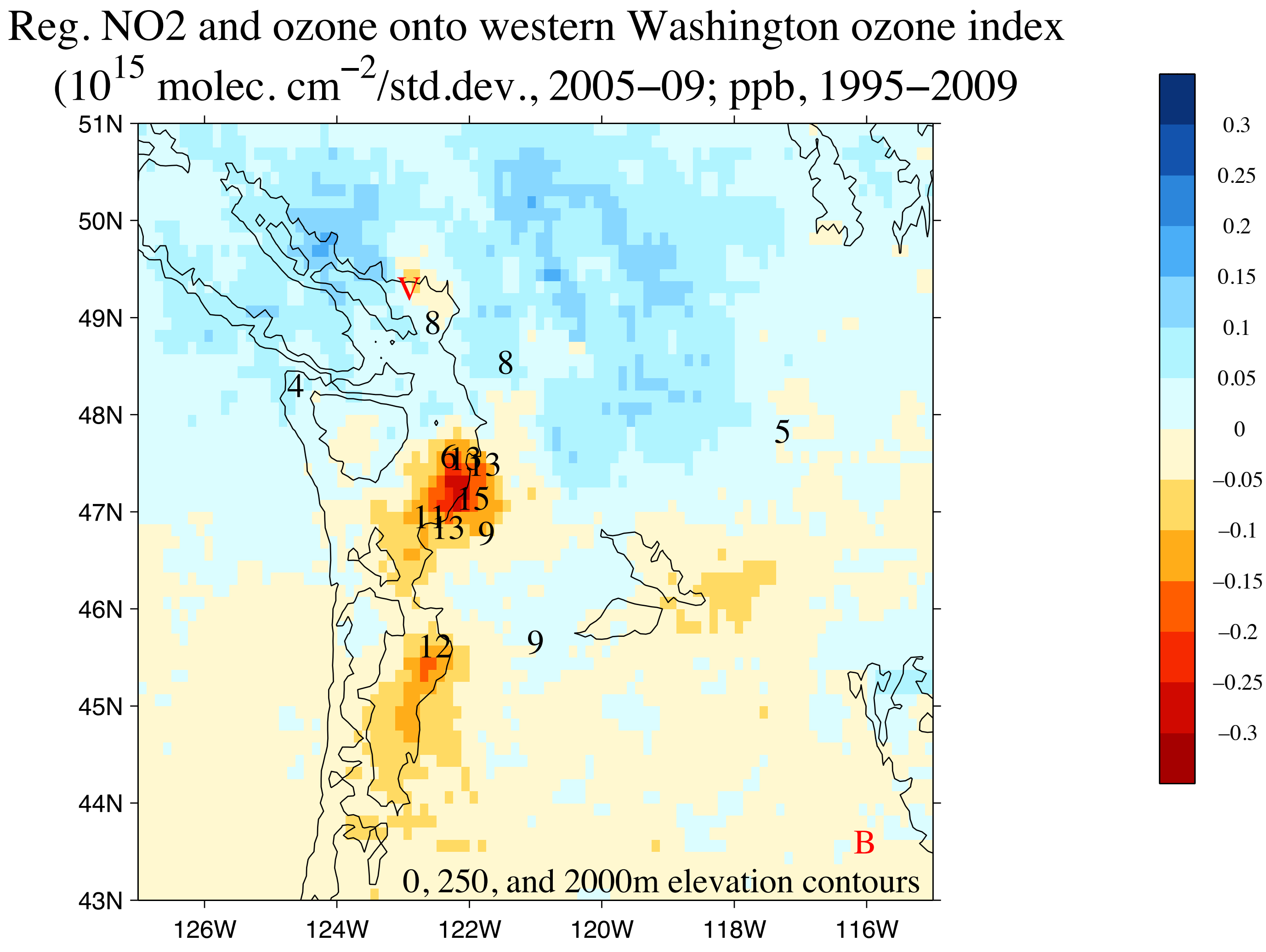

Mostly Washington State Department of Ecology measurements served by the Puget Sound  Clean Air Agency

# Percent May through October days when ozone > 70 ppb

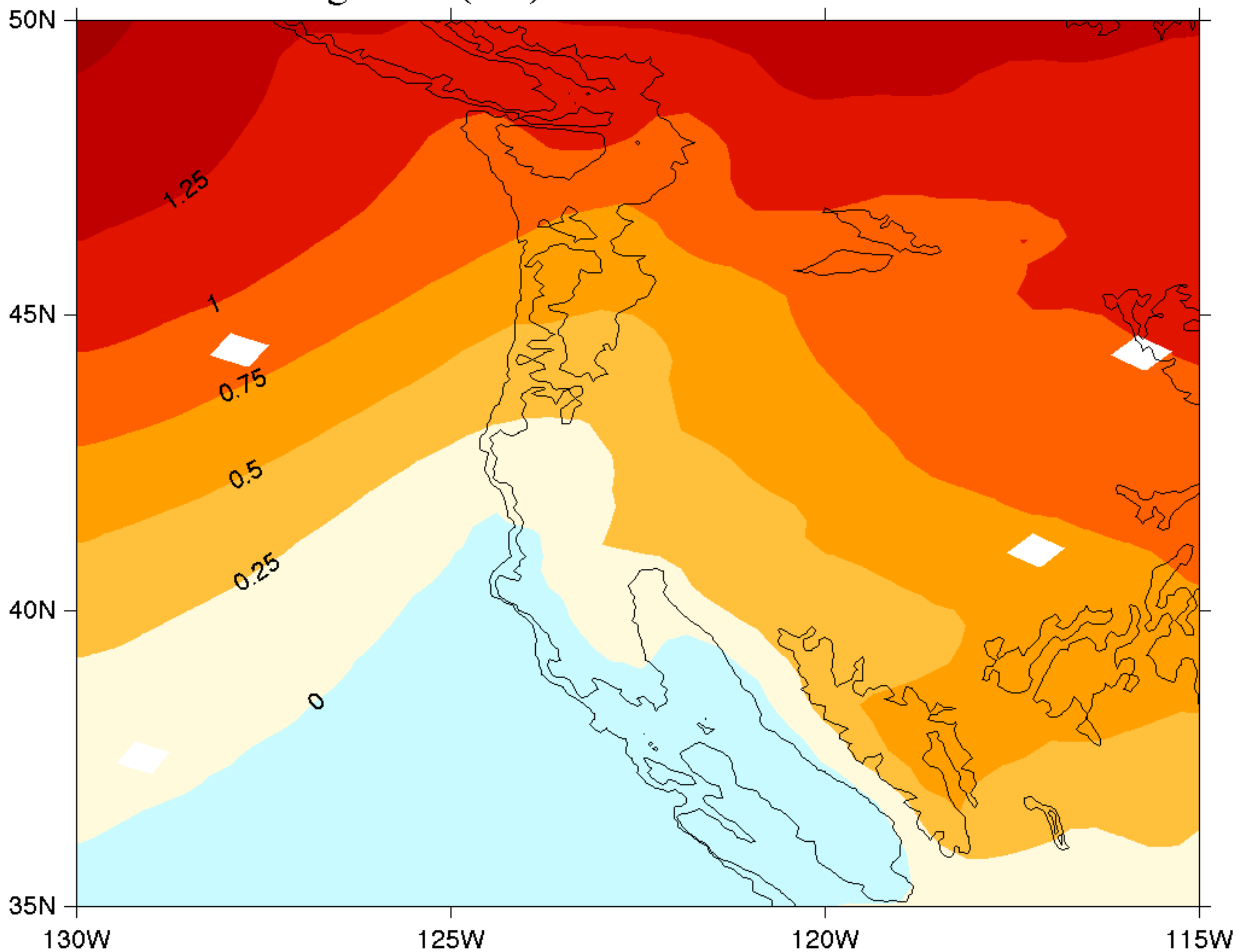


# The health consequences of surface ozone

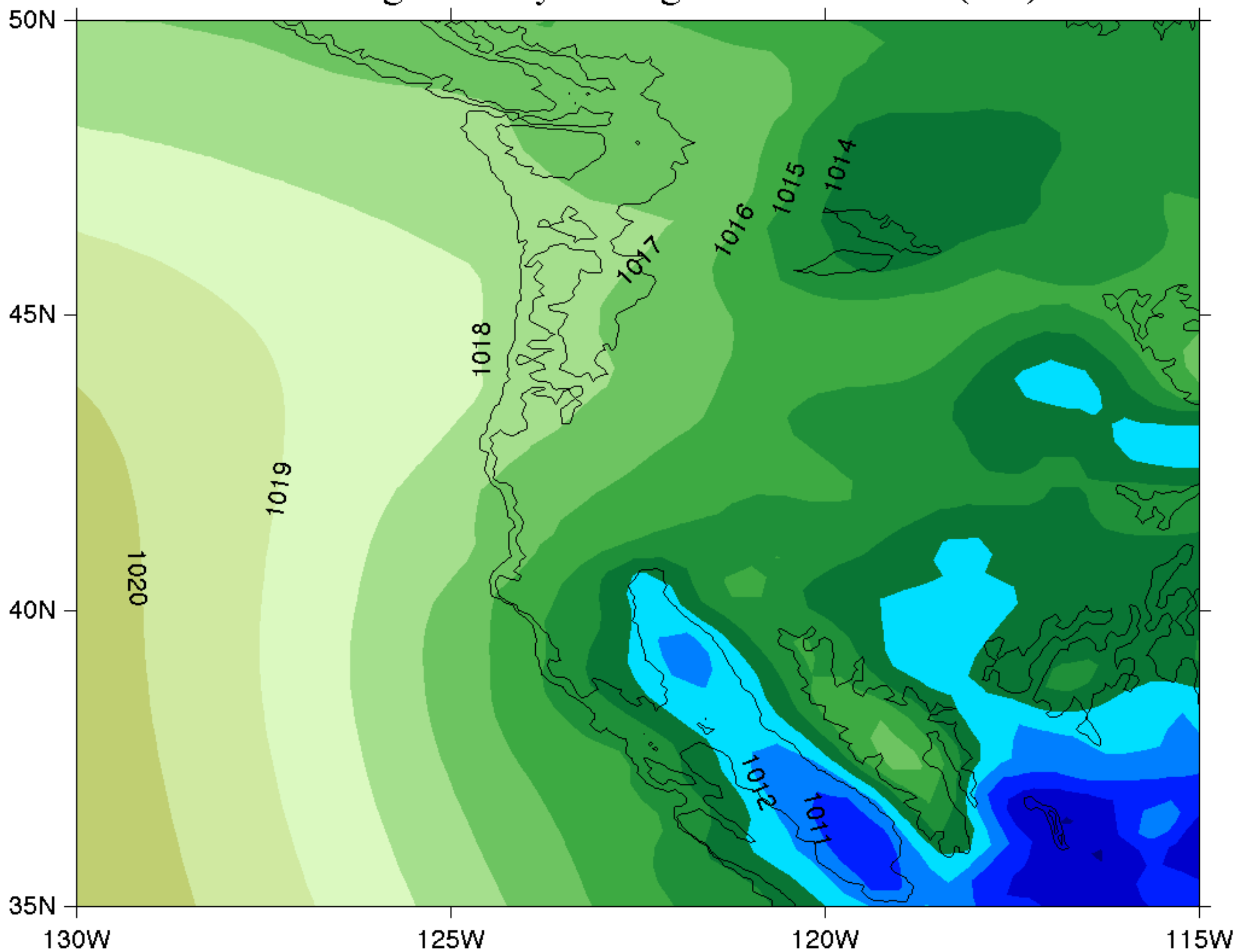
- Even relatively low levels of ozone can cause health effects.
- People with lung disease, children, older adults, and people who are active outdoors may be particularly sensitive to ozone.
- Children are at greatest risk from exposure to ozone because their lungs are still developing and they are more likely to be active outdoors when ozone levels are high, which increases their exposure.  Children are also more likely than adults to have asthma.
- It can worsen bronchitis, emphysema, and asthma. Ground level ozone also can reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue.

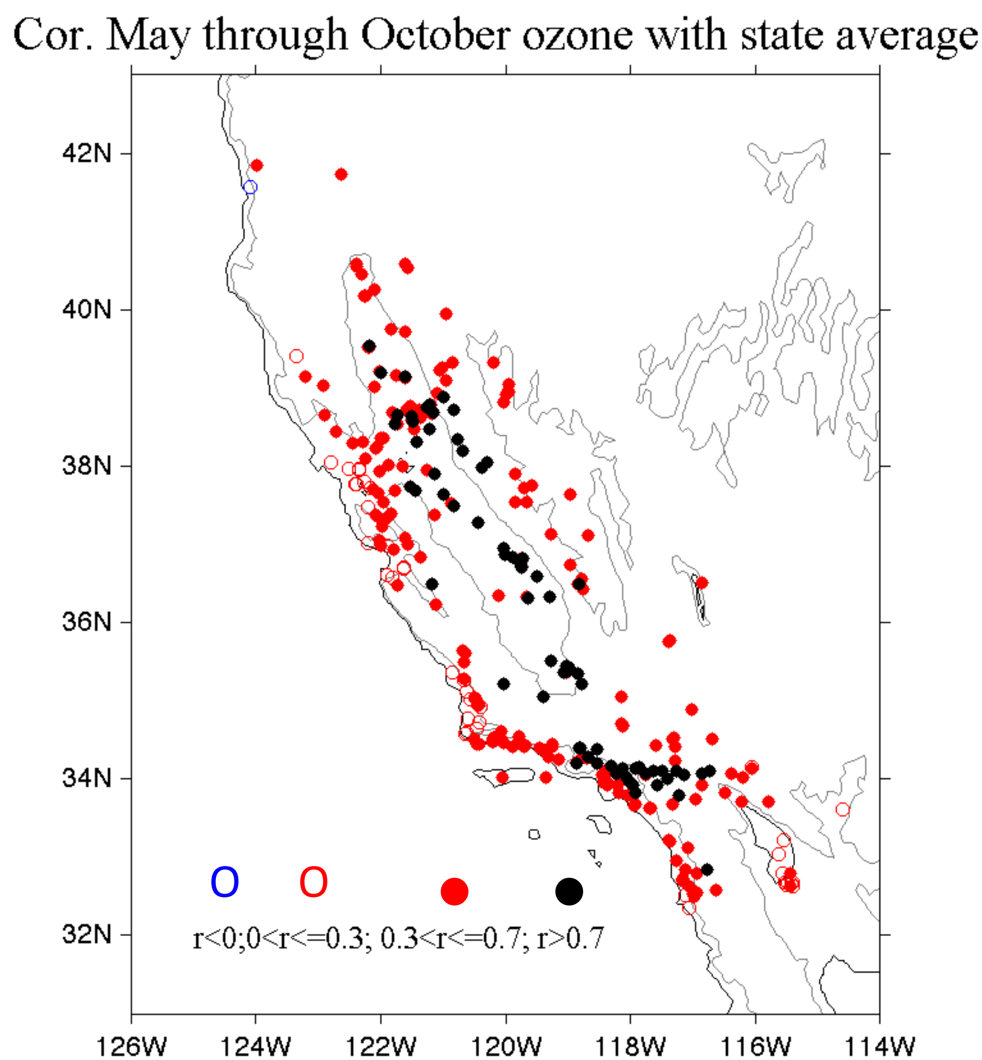

Reg. NO2 and ozone onto western Washington ozone index
(10^15 molec. cm^−2/std.dev., 2005−09; ppb, 1995−2009
51N
50N
49N
48N
47N
46N
45N
44N
43N
126W
124W
122W
120W
118W
116W
V
B
0, 250, and 2000m elevation contours
0.3
0.25
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25
−0.3

Reg. SLP (mb) onto western WA ozone

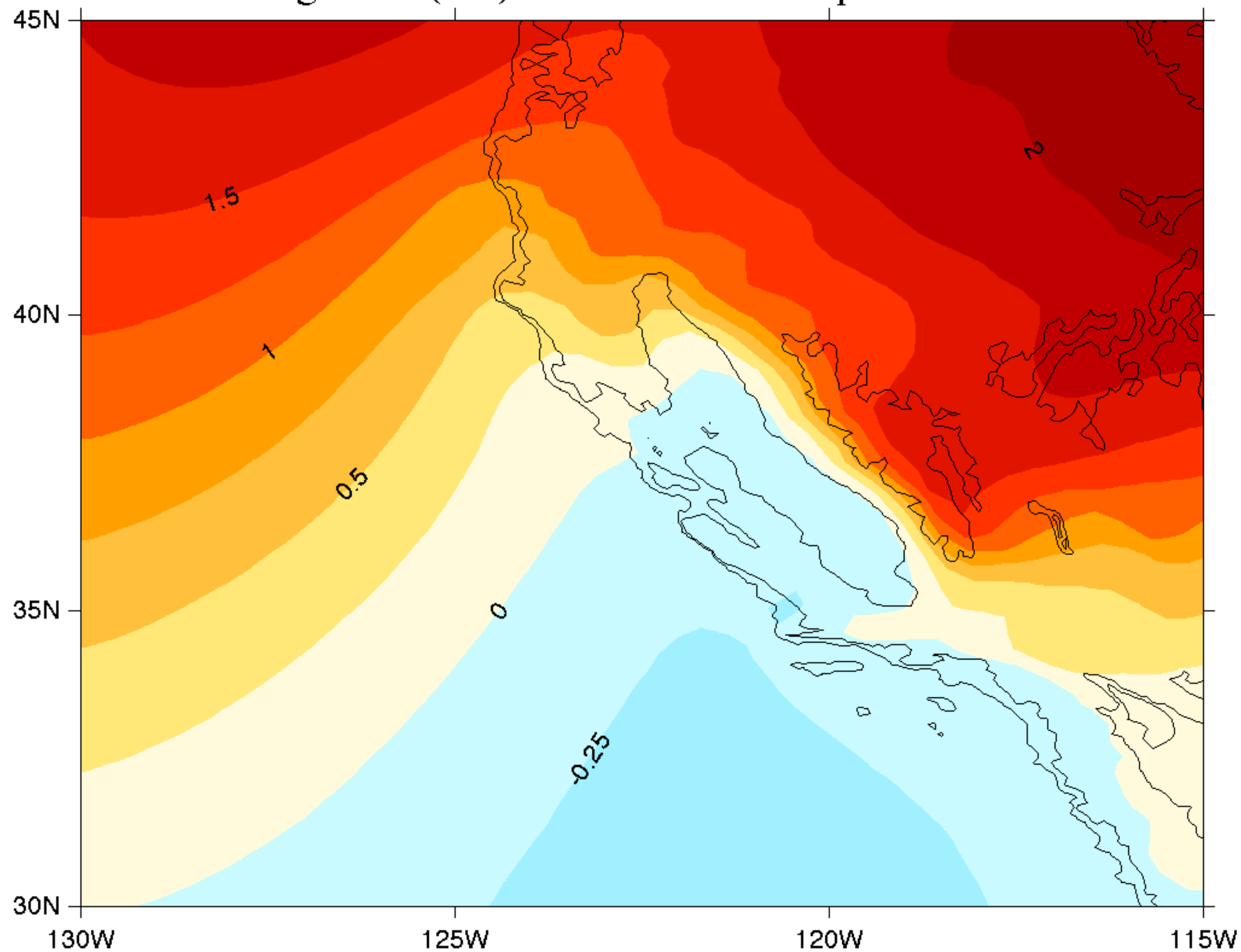


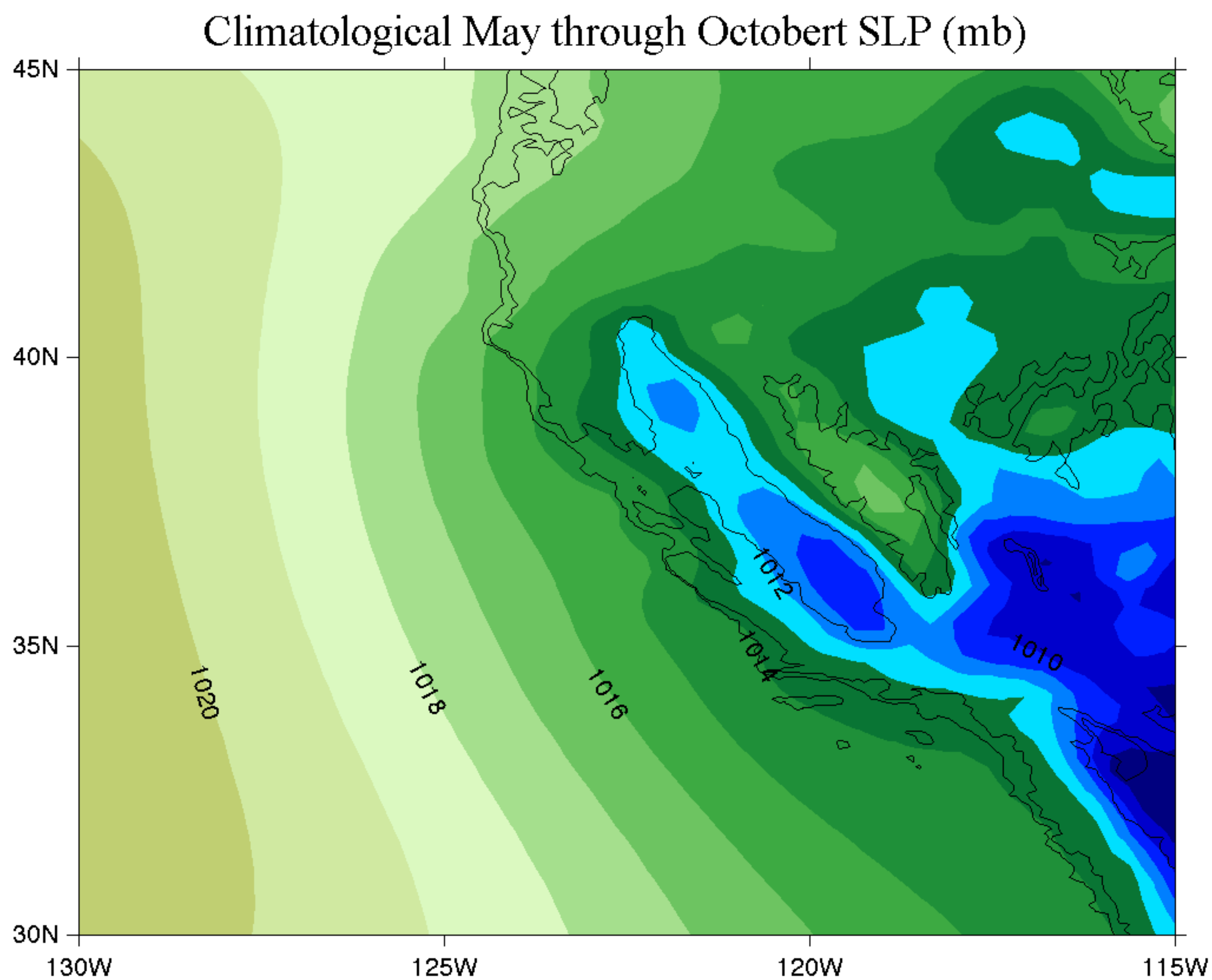
# Climatological May through October SLP (mb)




Cor. May through October ozone with state average
42N
40N
38N
36N
34N
32N
126W
124W
122W
120W
118W
116W
114W
O O
r<0;0<r<=0.3; 0.3<r<=0.7; r>0.7

## Reg. SLP (mb) onto Sac/San Joaquin ozone

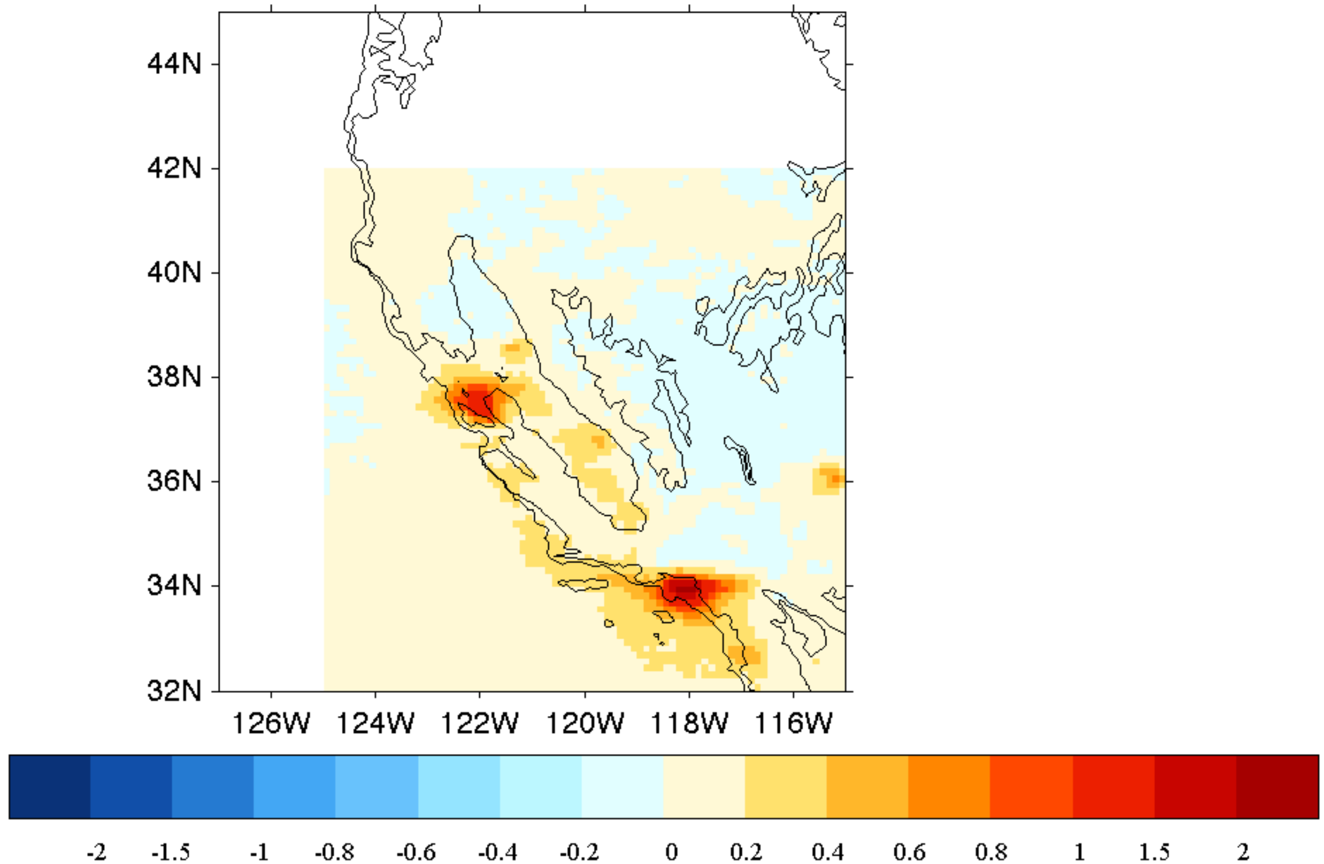




Climatological May through Octobert SLP (mb)
45N
40N
35N
30N
130W
125W
120W
115W
1020
1018
1016
1014
1012
1010

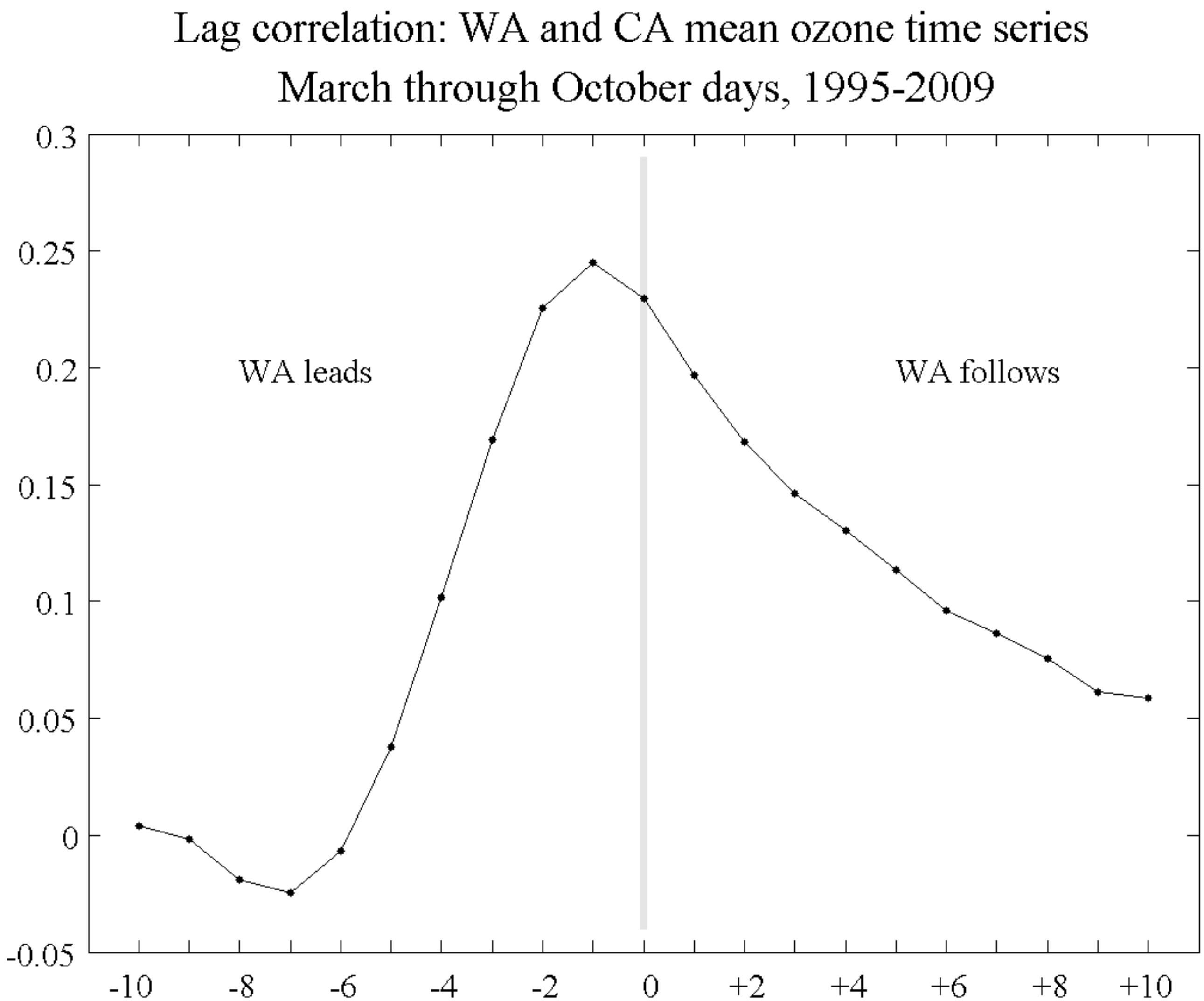
Reg weekday NO2 onto Sac/San Joaquin average Ozone

($10^{15}$ molec.cm$^{-2}$/std.dev.) 2005-09

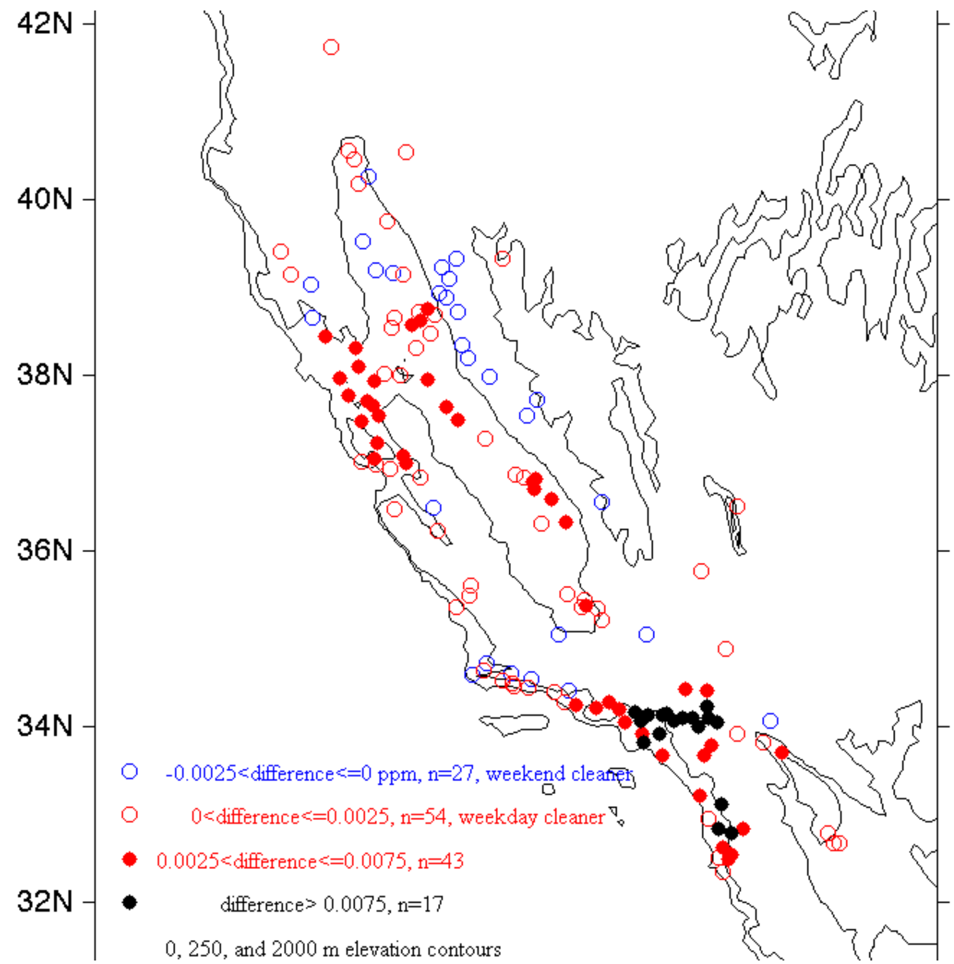


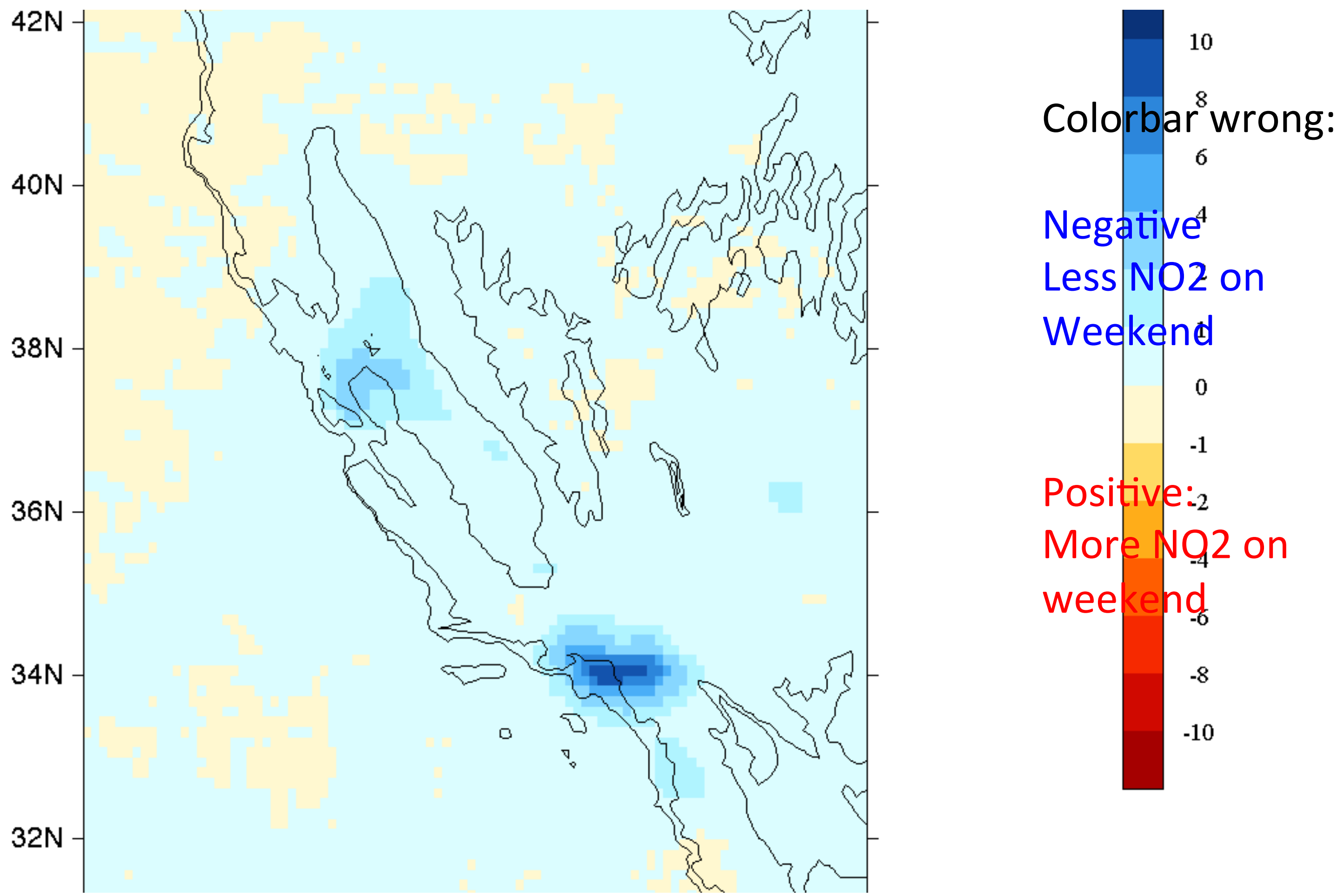
Similarity of the California and western Washington pressure anomaly patterns suggests that they are one in the same.

The California and western Washington daily mean ozone time series are correlated at 0.23 over 15 years.  This correlation suggests that there is some year to year coherence of ozone variations in the two regions.

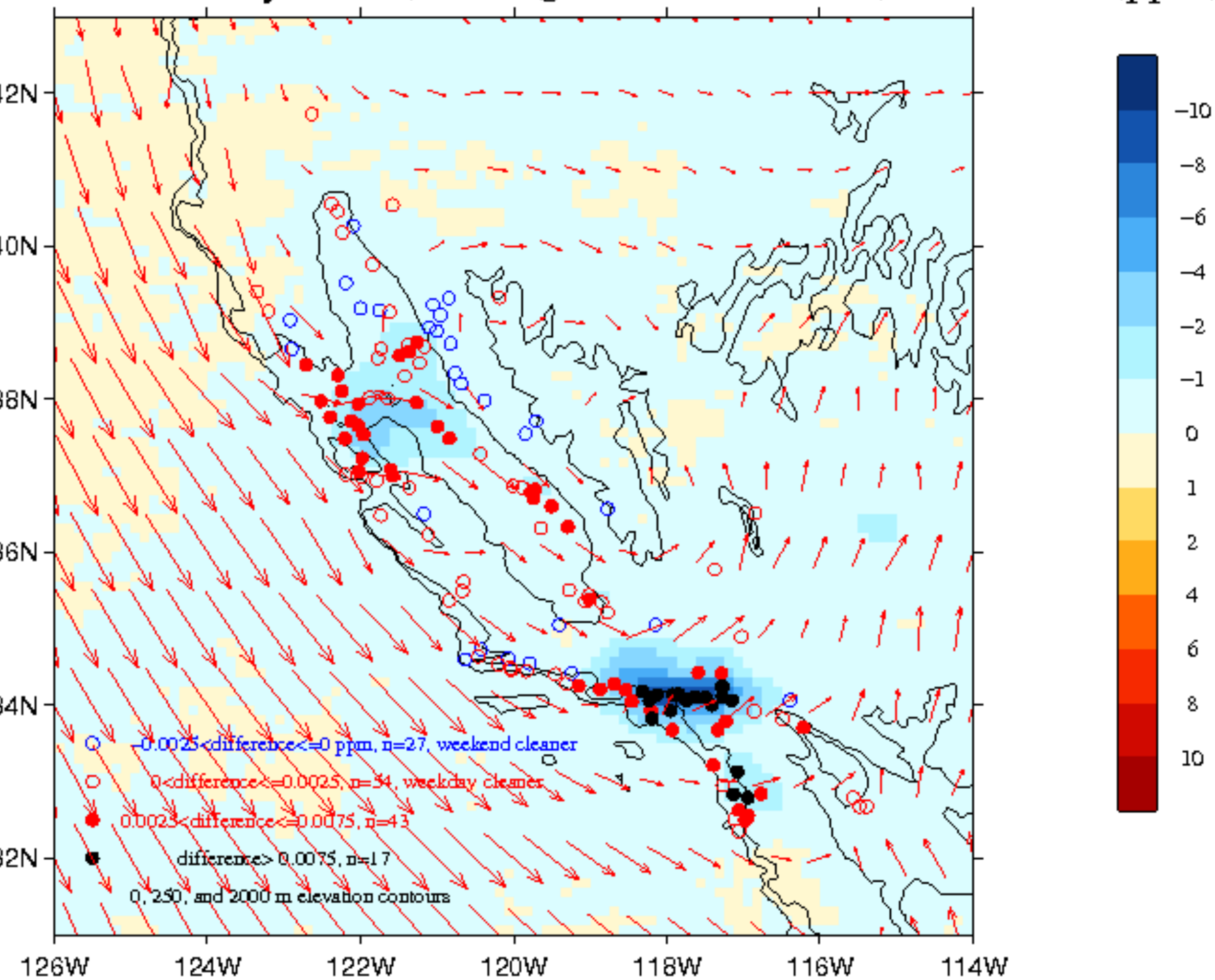

Lag correlation: WA and CA mean ozone time series
March through October days, 1995-2009
WA leads
WA follows
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-10
-8
-6
-4
-2
0
+2
+4
+6
+8
+10

# There is a significant weekday versus weekend signal in both ozone and $NO_2$




42N
40N
38N
36N
34N
32N
10
8
6
4
2
1
0
-1
-2
-4
-6
-8
-10
Colorbar wrong:
Negative
Less NO2 on
Weekend
Positive:
More NO2 on
weekend

Weekend minus weekday NO2 (shading, $10^{15}$ molec./cm$^2$) and ozone (ppm)



# Mean ozone versus Log10 NO2, stratified by weekend - weekday O3 difference