Ozone Metrics Based on the 8-Hour Attainment Test

Houston/Galveston/Brazoria Photochemical Modeling Technical Committee

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Question

- How can we use model output to show predicted improvements in:
  - Area of exceedance of the 8-hour ozone standard?
  - Population in exceedance of the 8-hour ozone standard?
  - Other measures of air quality?

Issue

- With the 1-hour standard, the attainment test consisted of comparing the highest modeled value in each grid cell with the 125 ppb standard.

- Metrics such as area of exceedance or population in exceedance could easily be calculated by just counting grid cells where future-case predicted peak ozone was > 125 ppb.

Issue (cont.)

- With the 8-hour standard, the attainment test consists of calculating a future design value at each monitor, then comparing that value with the 85 ppb 8-hour standard.

- The new attainment test does not provide information about attainment in grid cells other than those containing a monitor.

Issue (cont.)

- How then do we predict which grid cells will exceed the 8-hour standard?

Spatial Interpolation

- Spatial interpolation can be used to estimate values across a grid based on a relatively small number of data points.

- Several methods are available; the method of choice for geostatistical applications is known as kriging.

Spatial Interpolation

- Simplest method to “fill in” the grid is to interpolate (krige) the future design values (DV_Fs).
- But monitoring locations are mostly urban, hence don’t represent ozone concentrations in more rural locations.
- So simply kriging observed DV_Fs will tend to over-estimate DV_Fs outside the urban areas.

Spatial Interpolation (cont.)

- Best estimate of ozone concentrations away from monitors is probably the photochemical model.

- Is there some way to use model results together with a spatial interpolation scheme to provide a better estimate of DV_Fs across the nonattainment area?

A Combined Approach

- EPA has indicated that its BenMap software will employ model output in a spatial interpolation scheme to use in a “unmonitored area attainment test”, but has not yet released it.

- As an alternative, we have developed a procedure which performs a similar function and appears to work well in HGB.

A Combined Approach (cont.)

- Instead of kriging the design values themselves, we kriged the **ratios** of **baseline design values** to **average modeled baseline ozone concentrations** at the monitor locations.

- The ratios can be used to adjust the modeled averages to estimate what design values would be across the modeling domain, if everyone had a monitor in his/her back yard.

- Note that differences between the baseline modeled average concentrations and the baseline design values should not be interpreted as "errors" in the model – they simply represent two different (albeit closely related) things.

Some Math

Let DVC_K = Baseline (current) DV at monitor location k. (1)

As per EPA 8-hour attainment demonstration guidance, DVc is a 3-year center-weighted average of the 3 DVs which include the baseline (current) year.

Let MC_K = Baseline (current) avg. modeled conc. at monitor location k. (2)

Let MF_K = Baseline (current) avg. modeled conc. at monitor location k. (3)

These are actually peak of the average modeled concentrations within an array of grid cells "near" the monitoring site.

The Future Design Value at monitor location k is then defined as:

$$DVF_K = DVC_K \times \frac{MF_K}{MC_K} \quad (4)$$

which can be rewritten as:

$$DVF_K = MF_K \times \frac{DVC_K}{MC_K} \quad (5)$$

Some Math (cont.)

Let $R_K = \dfrac{DVC_K}{MC_K}$ (6)

so $DVF_K = MF_K \times R_K$. (7)

Now MF_K can be calculated for any grid cell K, but R_K is only defined for monitor locations. Using a spatial interpolation such as kriging can be used to find a value for R_K at every grid cell K.

Let R'_K = interpolated ratio at an arbitrary grid cell K. (8)

Note that R'_K will not necessarily exactly equal R_K when kriging is used to perform the interpolation.

Finally, we can estimate a future DV in any grid cell K by

$$DVF'_K = MF_K \times R'_K \quad (9)$$

Some Math (cont.)

Note that at the monitor locations, DV'_F will equal DV_F except for some variation induced by the spatial interpolation.

For comparison, it is also useful to estimate baseline (current) design values at every grid cell as follows:

$$DVC'_K = MC_K \times R'_K \qquad (10)$$

Ratios of DV_Cs to Modeled Averages

Site	Baseline DV (DVc)*	Modeled Average*	Ratio
Bayland Park	107	86.0	1.24
Clinton Drive	93	89.1	1.04
Clute	90	92.3	0.97
Conroe	91	84.4	1.08
Deer Park	107	89.9	1.19
Galveston	98	97.2	1.01
Aldine	108	85.7	1.26
Croquet	102	88.6	1.15
Lang	83	83.3	1.00
NW Harris Co.	104	79.3	1.31
Houston East	102	88.7	1.15
Regional Office	95	88.5	1.07
Monroe	90	88.7	1.02
Wayside	89	85.7	1.04
Shell Westhollow	95	85.7	1.11
La Marque	90	96.2	0.94

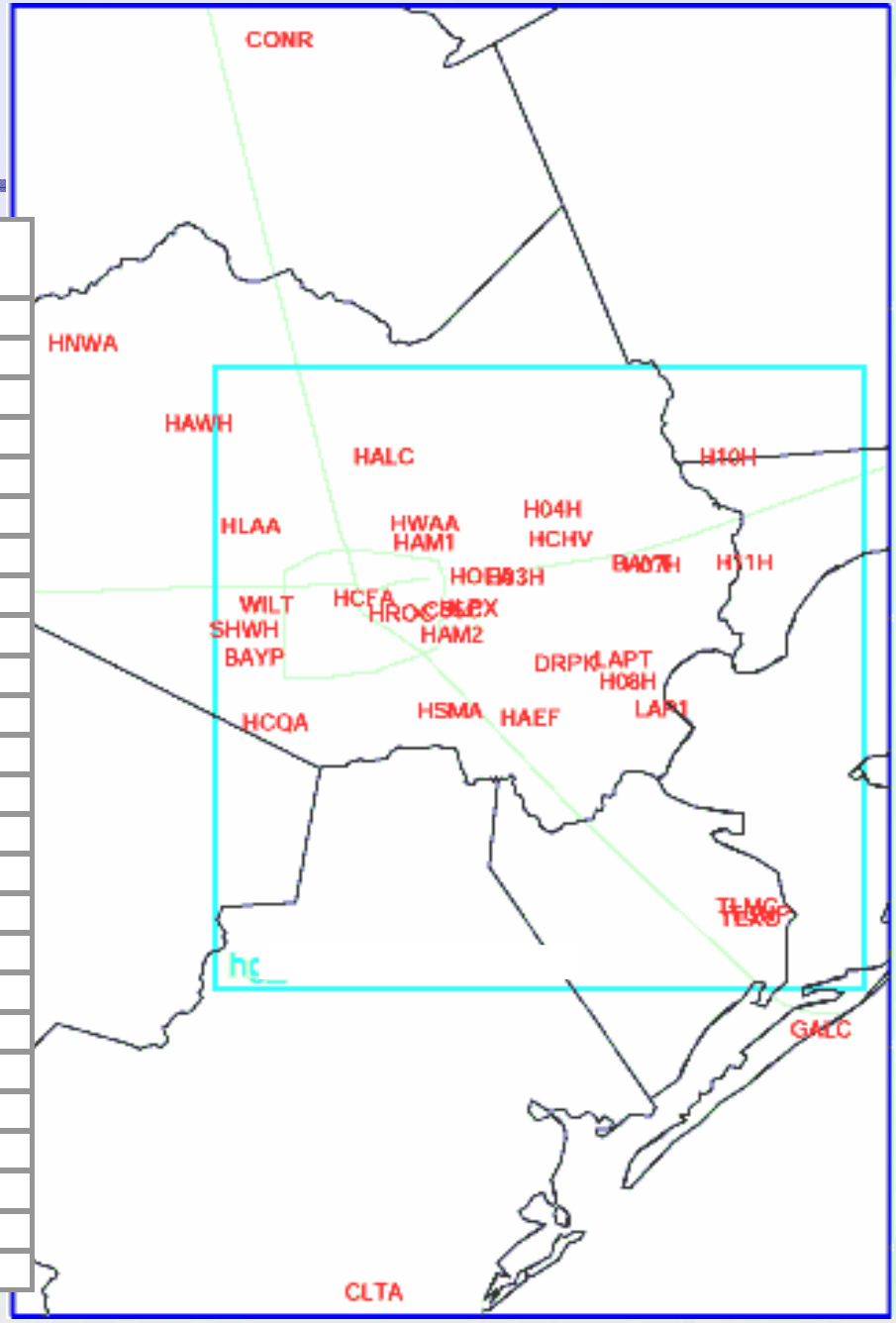
*Notes: The 2000 Baseline (current) DV, or DV_C is actually the average of three years' DVs (2000, 2001, & 2002), as per EPA Guidance. This is the value used in calculating future DVs for the attainment test.

The Modeled Average is the average of the highest modeled 8-hour concentrations "near" the monitoring site. It excludes values < 70 ppb.

For details, see the EPA 8-Hour Attainment Demonstration Guidance

Monitor Site Codes and Locations

Site Code	Site Info
BAYP	Bayland Park, Harris Co., TX
C35C	Clinton, Harris Co., TX
CLTA	Clute, Brazoria Co., TX
CONR	Conroe, Montgomery Co., TX
DRPK	Deer Park, Harris Co., TX
GALC	Galveston, Galveston Co., TX
H03H	HRM Site 3, Houston, Harris Co., TX
H04H	HRM Site 4, Houston, Harris Co., TX
H07H	HRM Site 7, West Baytown, Harris Co., TX
H08H	HRM Site 8, Houston, Harris Co., TX
H10H	HRM Site 10, Mont Belvieu, Chambers Co., TX
H11H	HRM Site 11, Chambers Co., TX
HALC	Aldine, Houston, Harris Co., TX
HCFA	Crawford, Houston, Harris Co., TX
HCQA	Croquet, Houston, Harris Co., TX
HLAA	Lang, Houston, Harris Co., TX
HNWA	NW Harris, Tomball, Harris Co., TX
HOEA	Houston East, Houston, Harris Co., TX
HROC	TCEQ Houston Regional Office, Harris Co., TX
HSMA	Swiss & Monroe, Houston, Harris Co., TX
HWAA	North Wayside, Houston, Harris Co., TX
SHWH	Westhollow, Houston, Harris Co., TX
TLMC	Texas City, Galveston Co., TX
LAPT	La Porte, Harris Co., TX
WILT	Top of Williams Tower (254m AGL), Harris Co., TX



Ratio: 'Avg 2000-2001-2002 DVc' / Baseline

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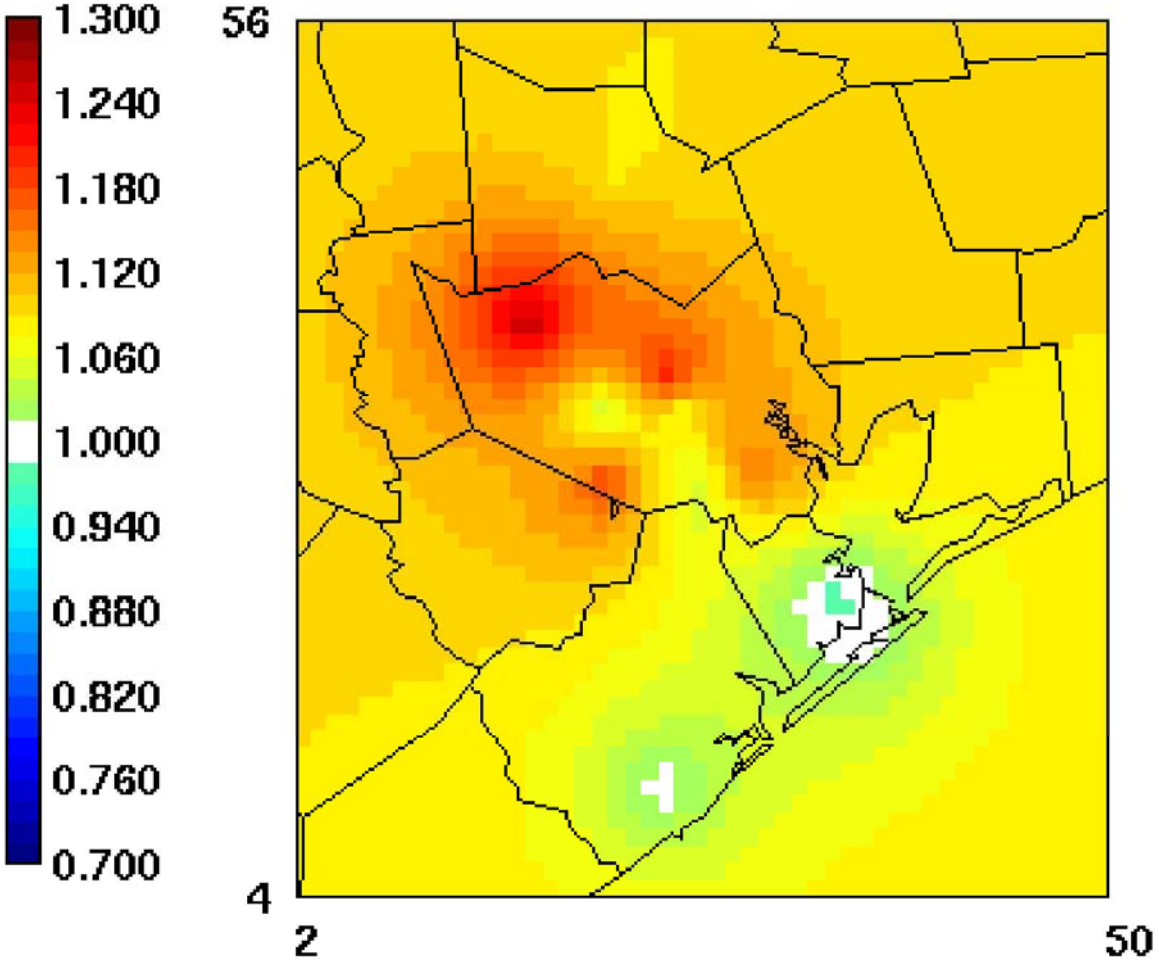


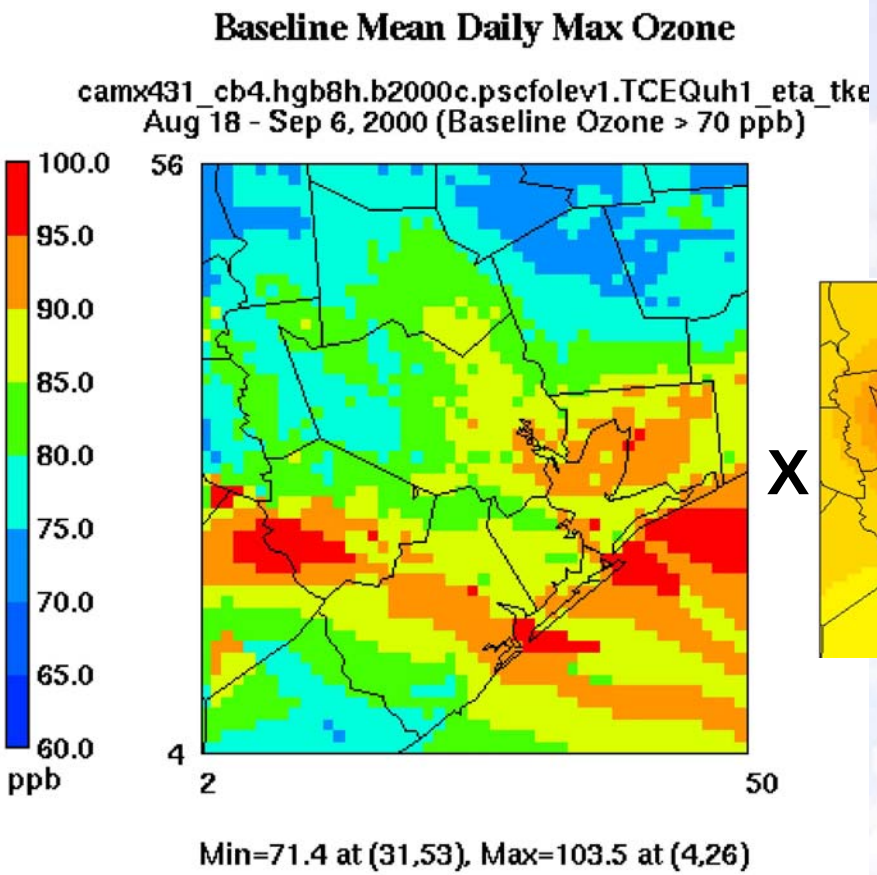
Min=0.979 at (34,21), Max=1.245 at (15,38)

A Combined Approach (cont.)

- The gridded ratios are then multiplied by the modeled average future concentrations across the nonattainment area to produce an estimated DV_F in every grid cell.

- We can also estimate baseline (current) design values at each grid cell by multiplying the ratios by the modeled average baseline concentrations.

Baseline Modeled Average Ozone Concentrations and Baseline Ozone DV (DV_C) for Each Grid Cell



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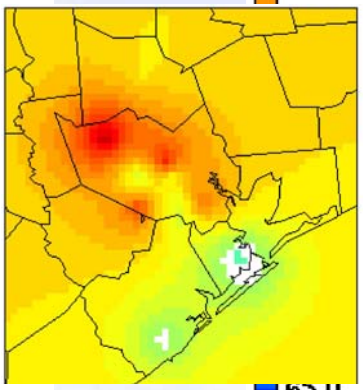

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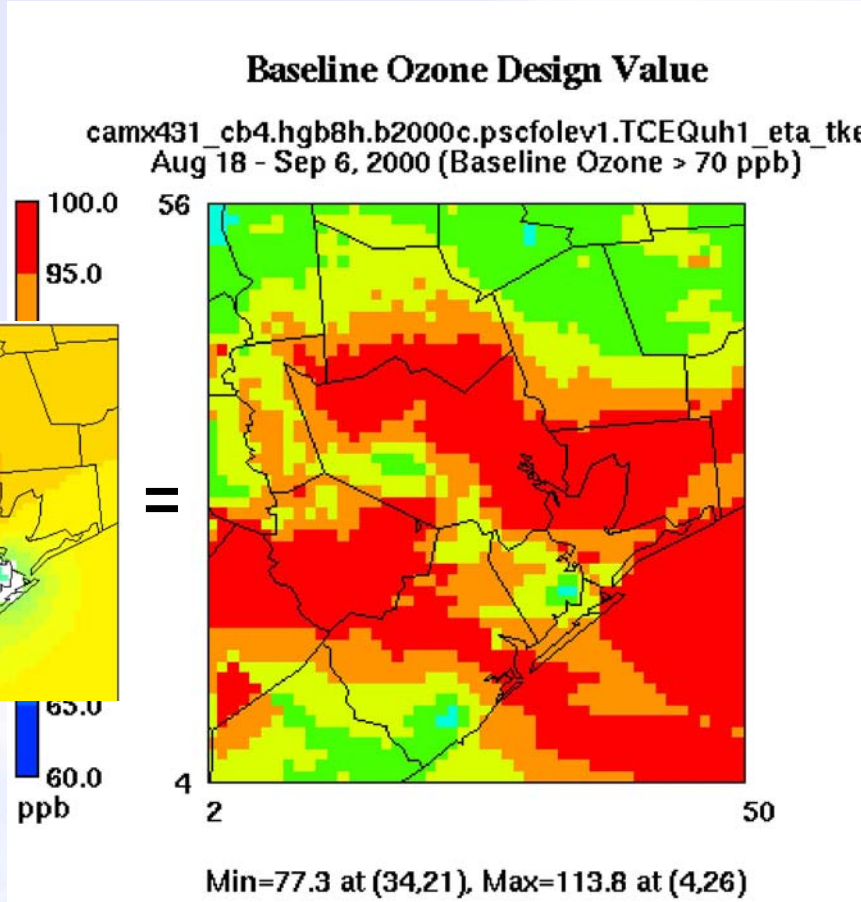
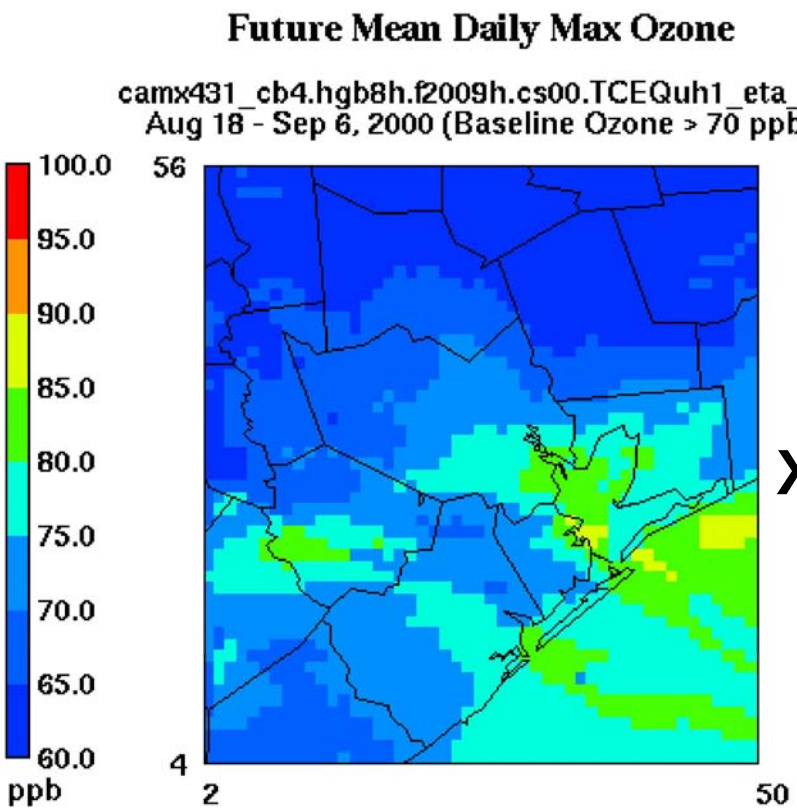


Future Modeled Average Ozone Concentrations and Future Ozone DV (DV_F) for Each Grid Cell



Min=57.7 at (30,51), Max=86.7 at (37,24)

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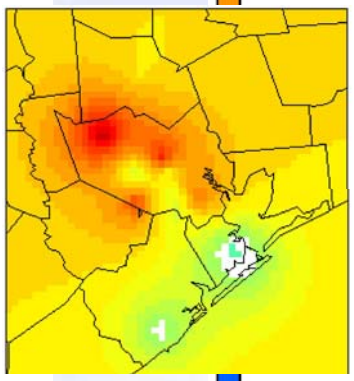

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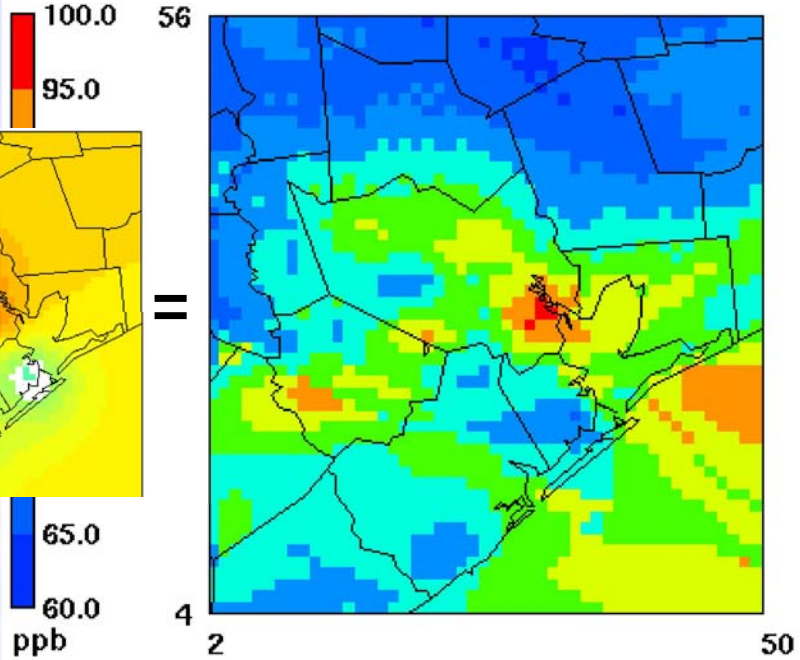
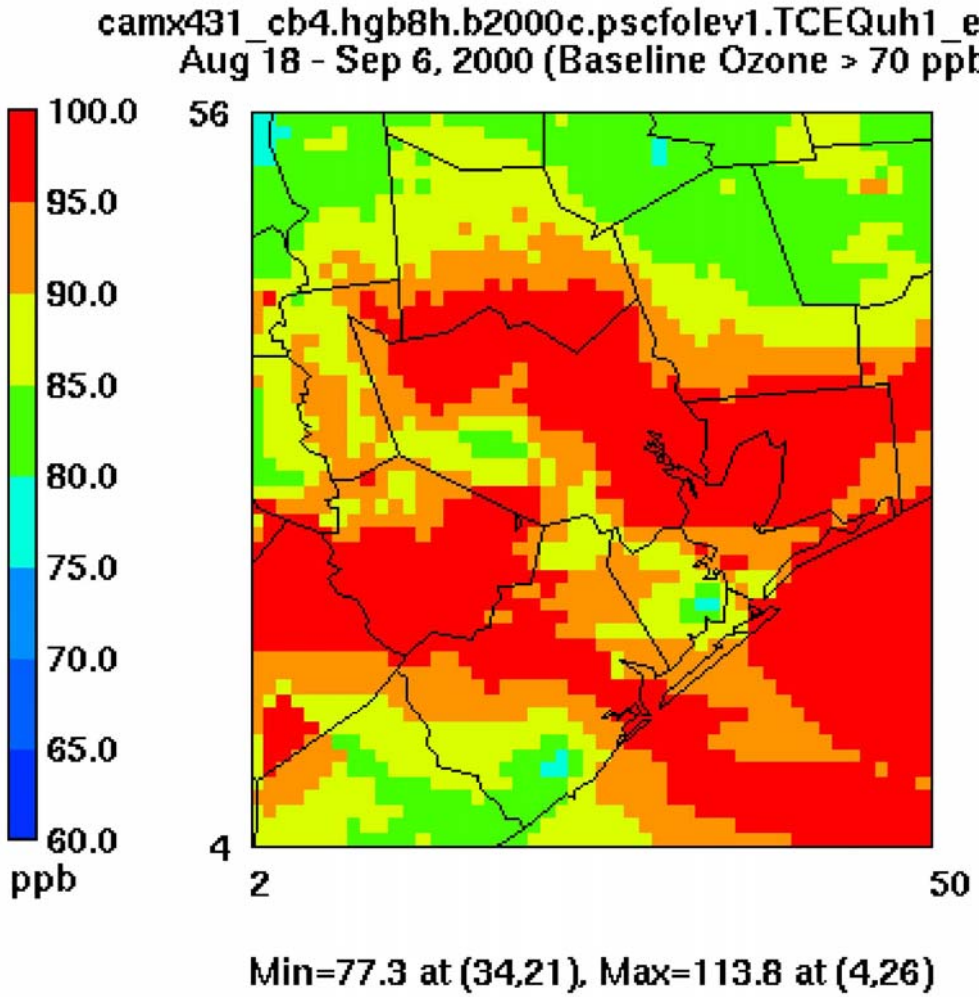


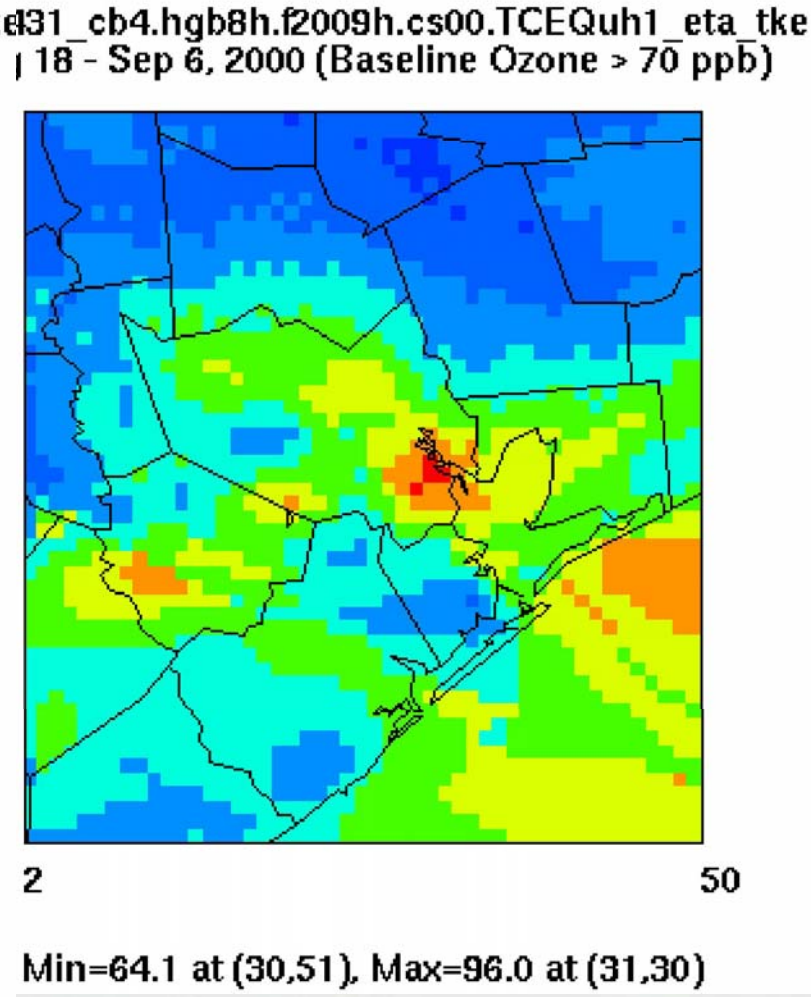
Min=64.1 at (30,51), Max=96.0 at (31,30)

Baseline Ozone DV (DV_C) Compared With 2009 Future Ozone DV (DV_F)

1999 Baseline Ozone Design Value

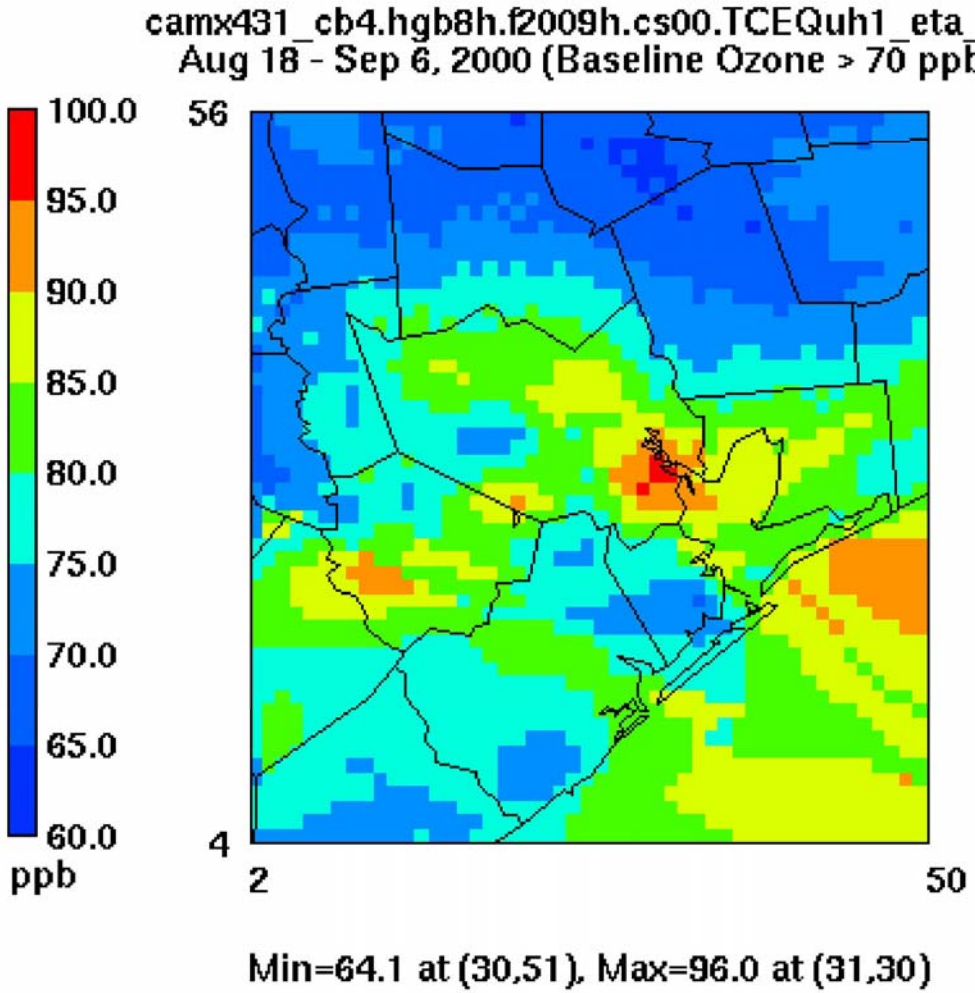


2009 Future Ozone Design Value

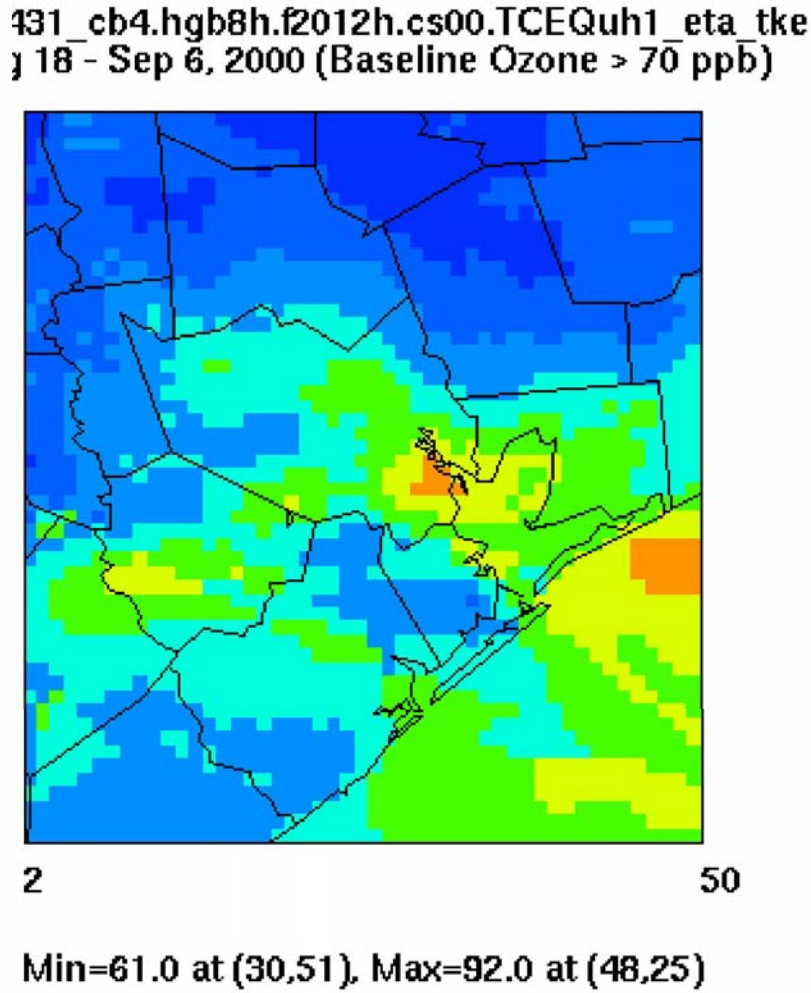


Comparison of 2009 DV_F with 2012 DV_F

2009 Future Ozone Design Value



2012 Future Ozone Design Value



Notes

- This procedure is mathematically equivalent to the standard DV_F calculations at the monitoring sites, however
- The spatial interpolation does not reproduce exactly the input values, so
- Values of DV_C and DV_F in the plots are approximately the same as those seen in the usual DV_F calculation, but are not exact.

Notes (Cont.)

- No spatial interpolation methodology is capable of extrapolating values beyond the area covered by observational data (e.g. outside the monitoring network). Results in these areas must be interpreted cautiously.

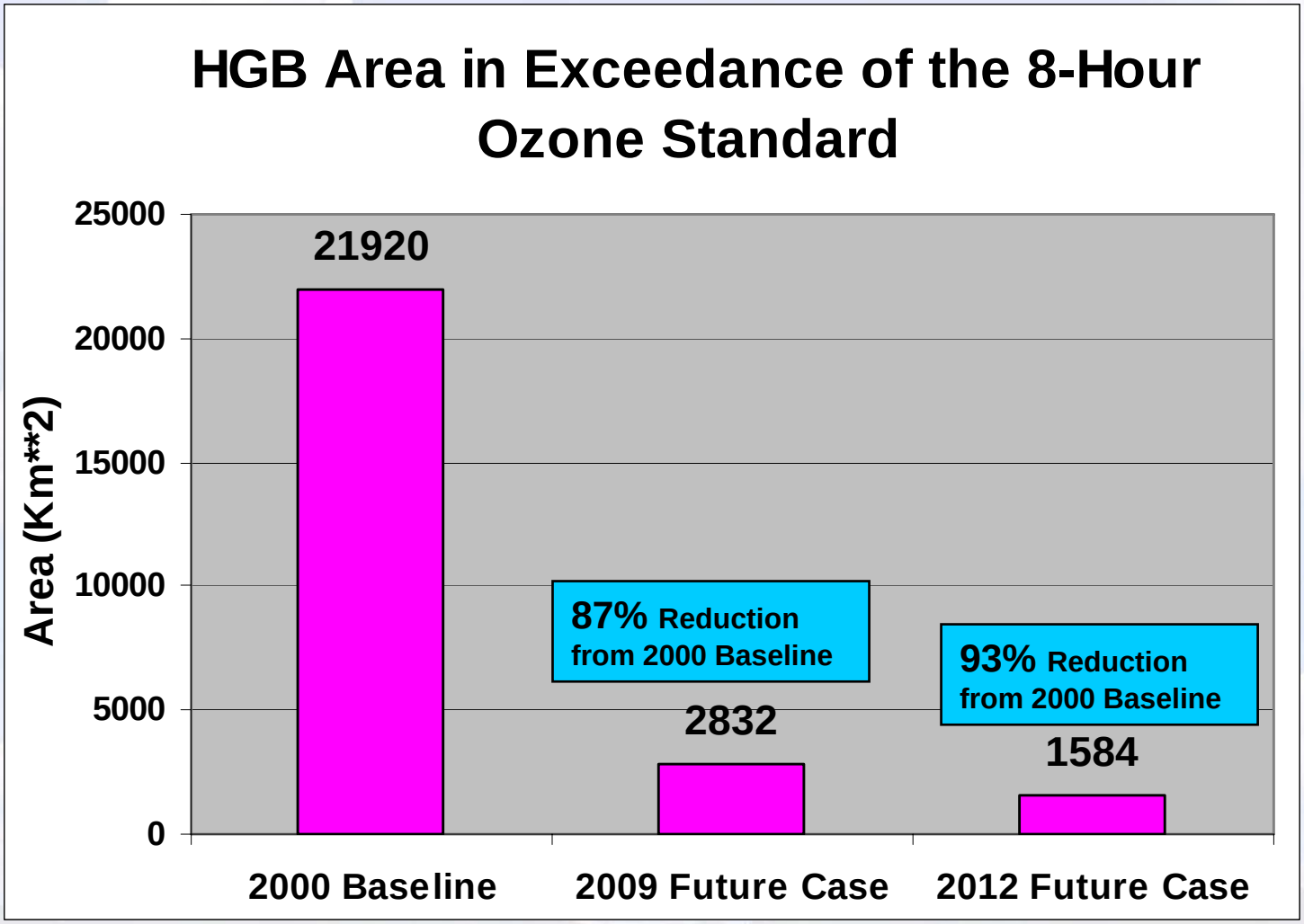
- The attainment area analysis performed here provides useful information until EPA provides explicit guidance on how to perform an Unmonitored Area Attainment Test.

Ozone Metrics

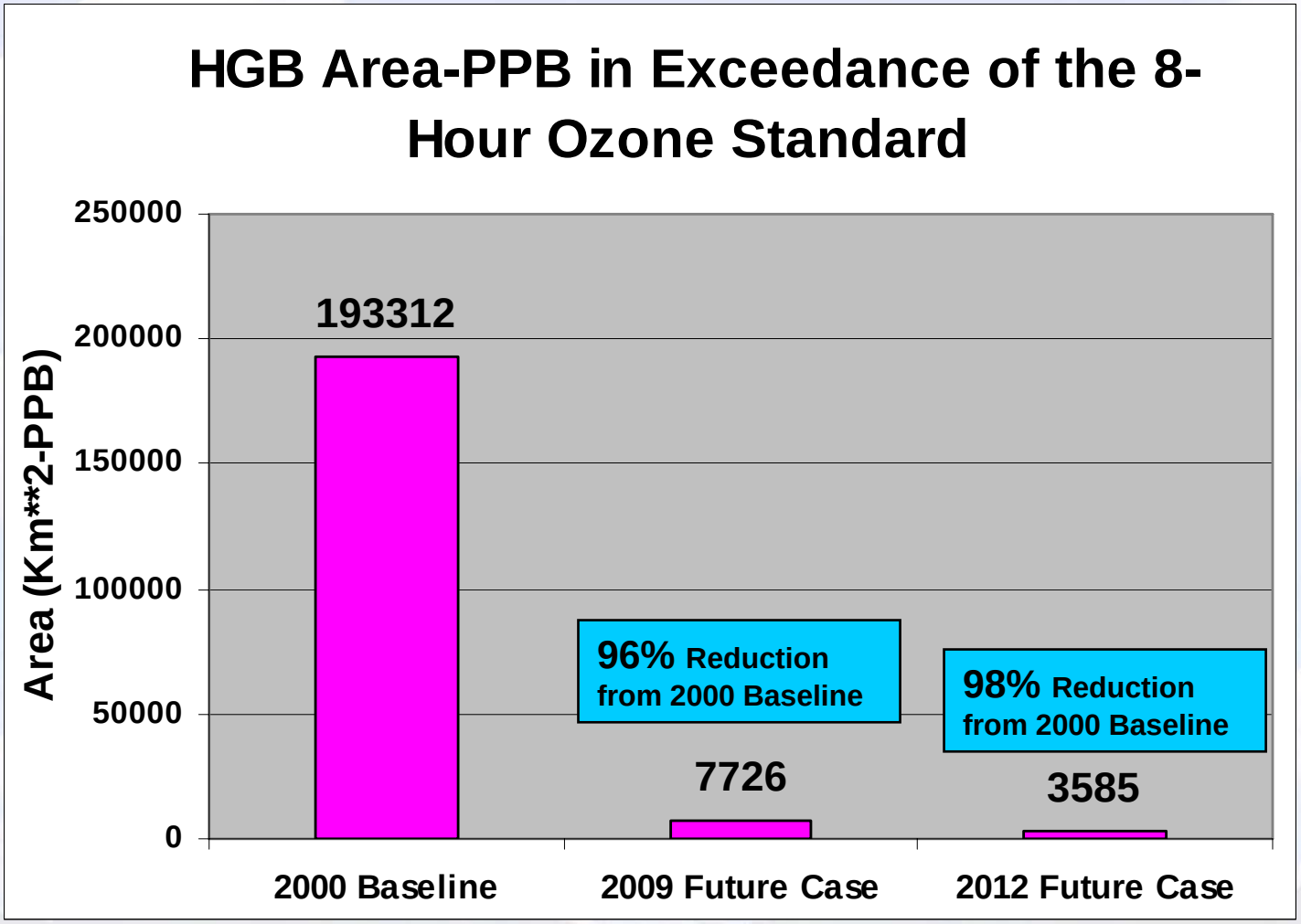
- Now that we have gridded values for baseline and future DVs, we can calculate the land area and population exposed to ozone concentrations over the 8-hour standard.

- Also we can calculate some more comprehensive ozone metrics: area-ppb and population ppb which factor in level of exposure above the standard.

Some Ozone Metrics



Some Ozone Metrics



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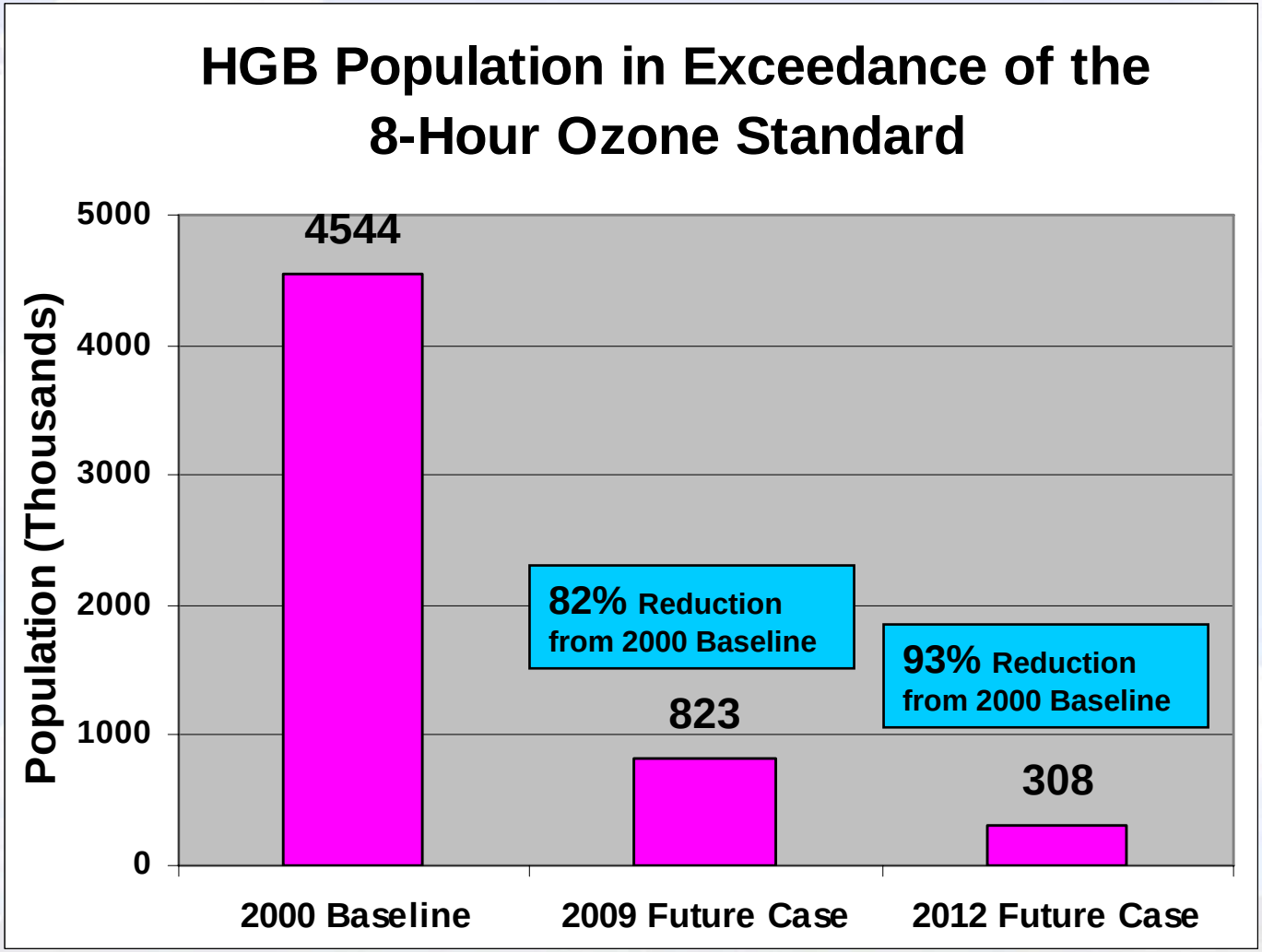

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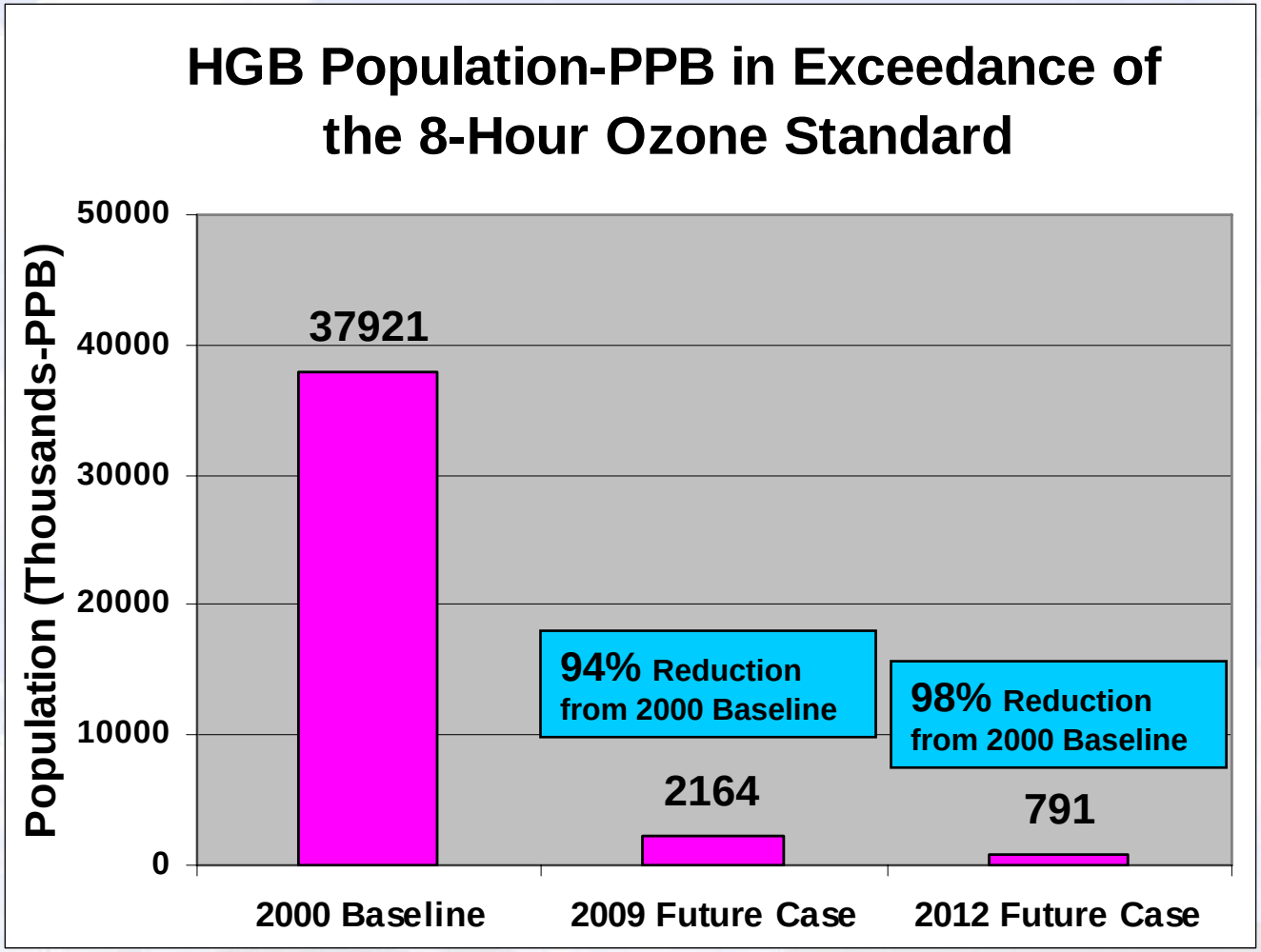

Possible Future Work

- Other spatial interpolation schemes –
  - Splines, nearest monitor, $1/R^N$.
- Evaluate BenMap when it becomes available.
- Repeat analysis for other nonattainment areas.