Air Quality Extreme Events and Projected Trends for the Southwestern United States

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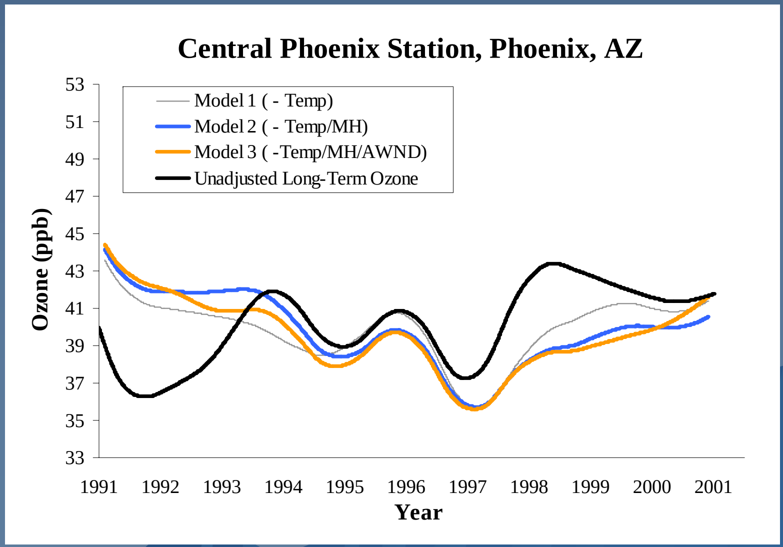
Project Context

- Established to assess impacts of climate variability and change on human and natural systems in the Southwest

CLIMAS
Climate Assessment Project for the Southwest

- Air quality initiative: help air quality planners and managers understand links between climate and pollutants to improve decision-making capabilities

- Previous study: meteorologically-adjusted, long-term trends (Wise and Comrie 2005)



Research Needs

Source: Liverman and Merideth 2002

- Focus on ozone and PM
  - NAAQS regulations
  - Known detrimental effects (health, environment, visibility)
- Cities in the Southwest are often close to violating federal standards
  - Local climate and weather conditions often determine whether levels are exceeded
- Probabilities of exceedances, now and in the future

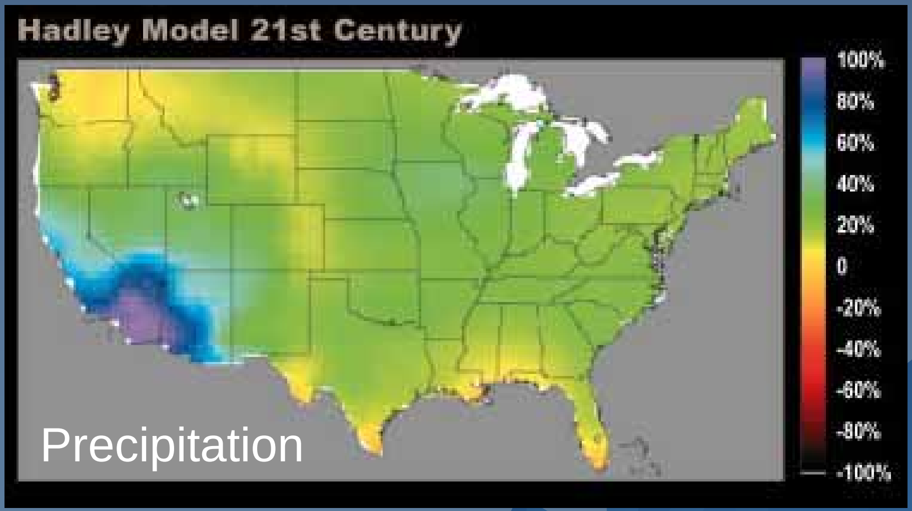
Objectives

Meet research needs regarding extreme events and future conditions by:

- Characterizing ozone and PM air quality exceedances under current conditions using extreme value methods
- Downscaling climate model scenarios to determine probable changes in ozone/PM meteorology and resulting changes in return levels

Background: Predicted Changes

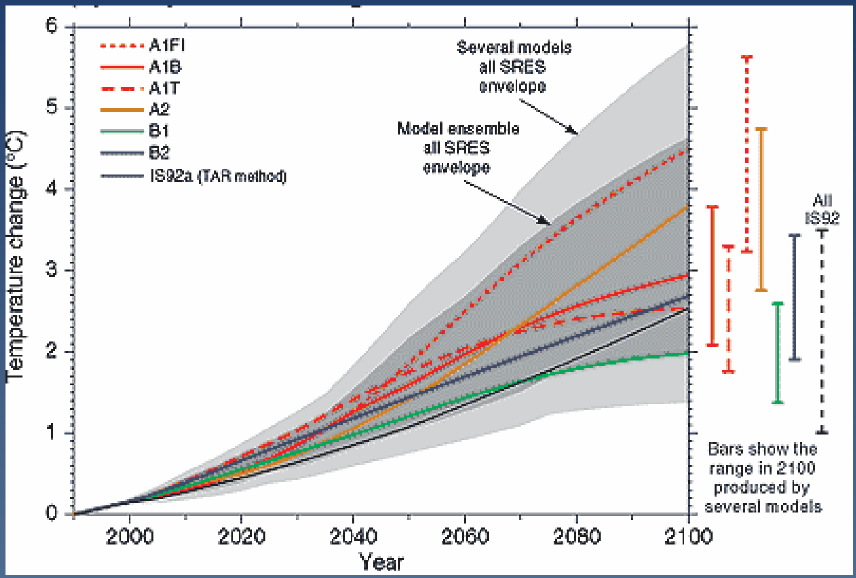
- Climate
  - Warmer: 5-6°C projected for West by 2100
  - Less certainty with precipitation; more model-dependent
- Air quality
  - Ozone-focused
  - Globally: uncertain
  - Western US: higher ozone
    (Prather et al. 2002; Leung and Gustafson 2005)



www.usgcrp.gov

Data

- Ozone and PM data
  - Local, state, and federal environmental agencies
  - Ozone: maximum daily 8-hr average
  - PM: 24-hour average PM_{10}



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- GCM scenarios: Hadley Centre's HadCM3; SRES A2 and B2 scenarios
- NCEP reanalysis meteorological variables
- Tucson, AZ

Methods: Extreme Values

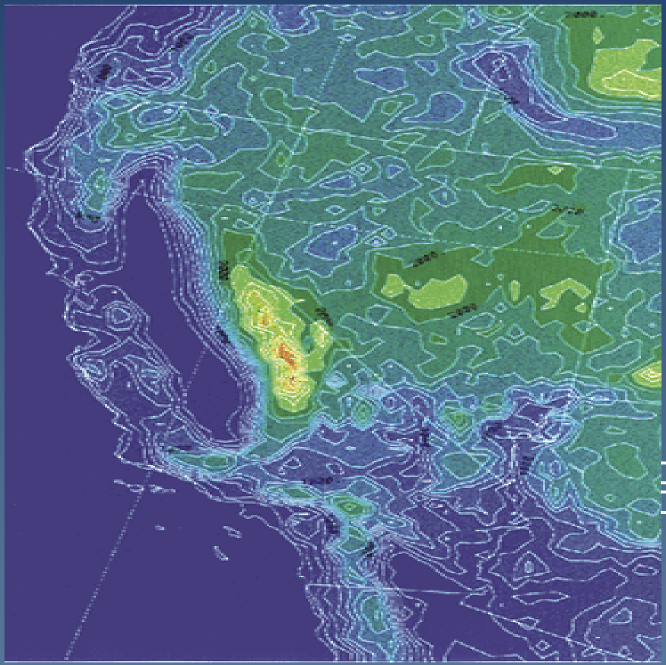
- Central Limit vs. Extreme Types Theorem
  - Normal vs. GEV/GP distributions
- Used to estimate:
  - Return Period
    - Probability that threshold is exceeded in a given time period
  - Return Level
    - Magnitude of the return period

www.isse.ucar.edu

- Applied using R-source ExtRemes
  (Gilleland and Katz 2004 / NCAR)

Methods: Statistical DownScaling Model (SDSM - Wilby et al. 2002)

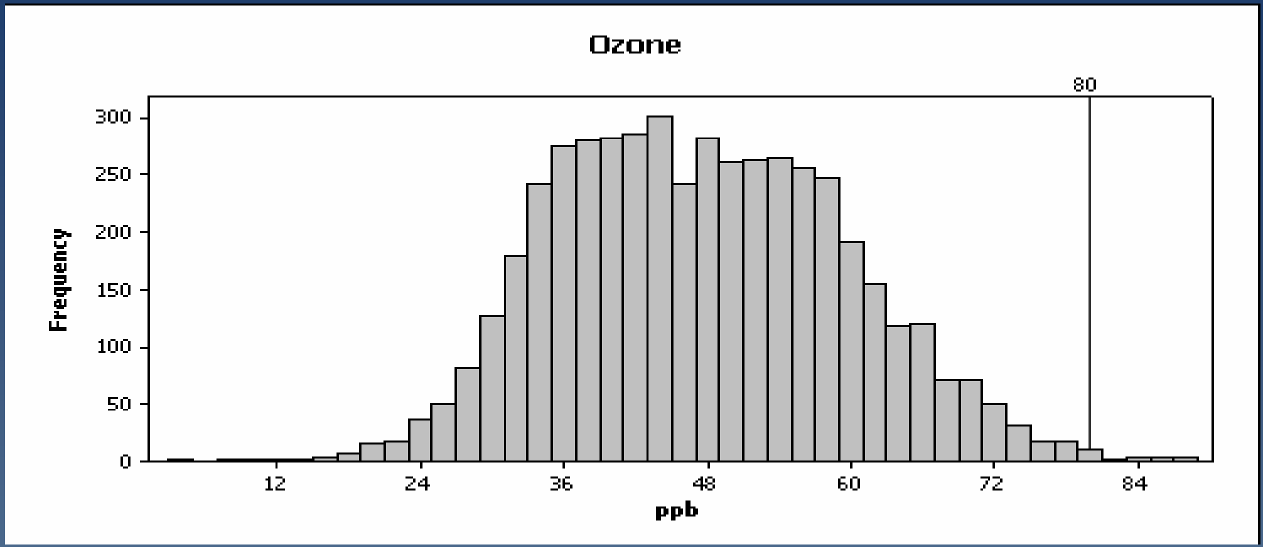
- Combines stochastic weather generator and regression-based approaches
- Model calibrated using observational predictors / predictand



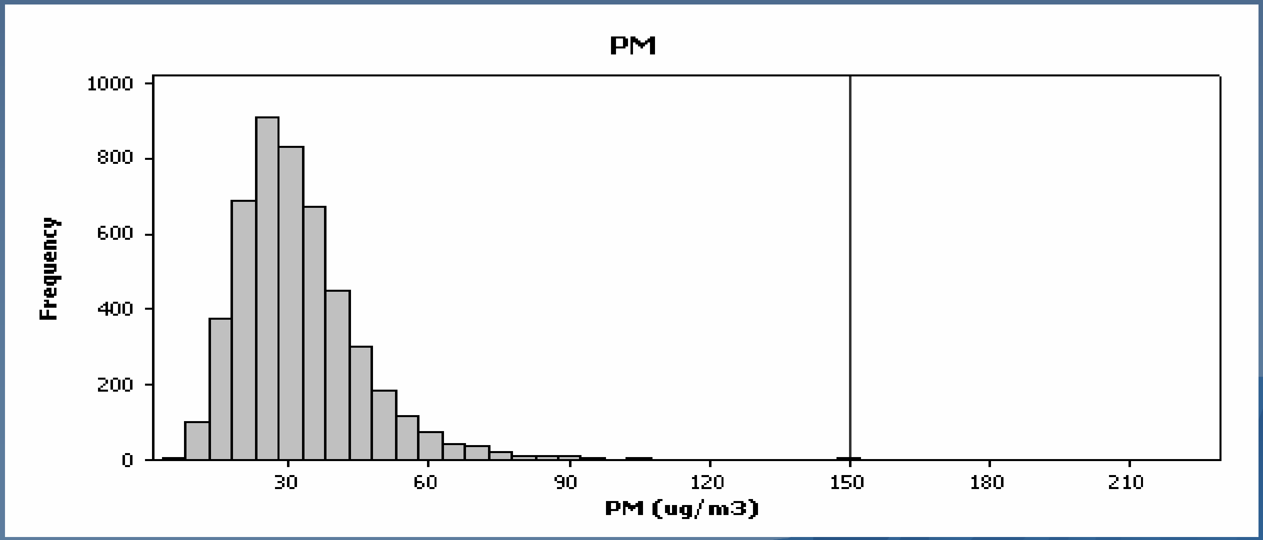
www-esd.lbl.gov

- Modeled relationships and GCM predictors generate future scenarios
- 1990-2001 / 2002-2050 / 2051-2099

Results: Observed Extremes

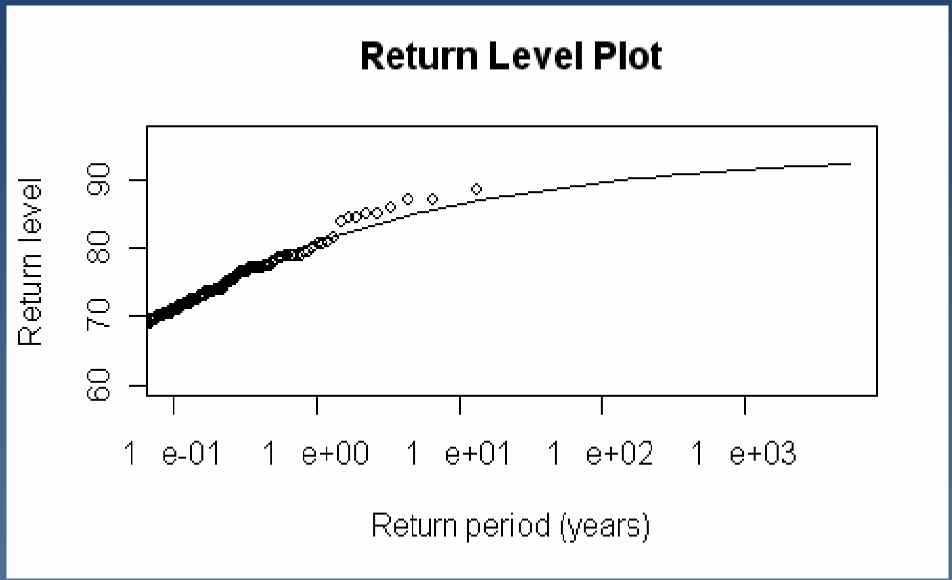


Shape parameter = -0.24 (beta)



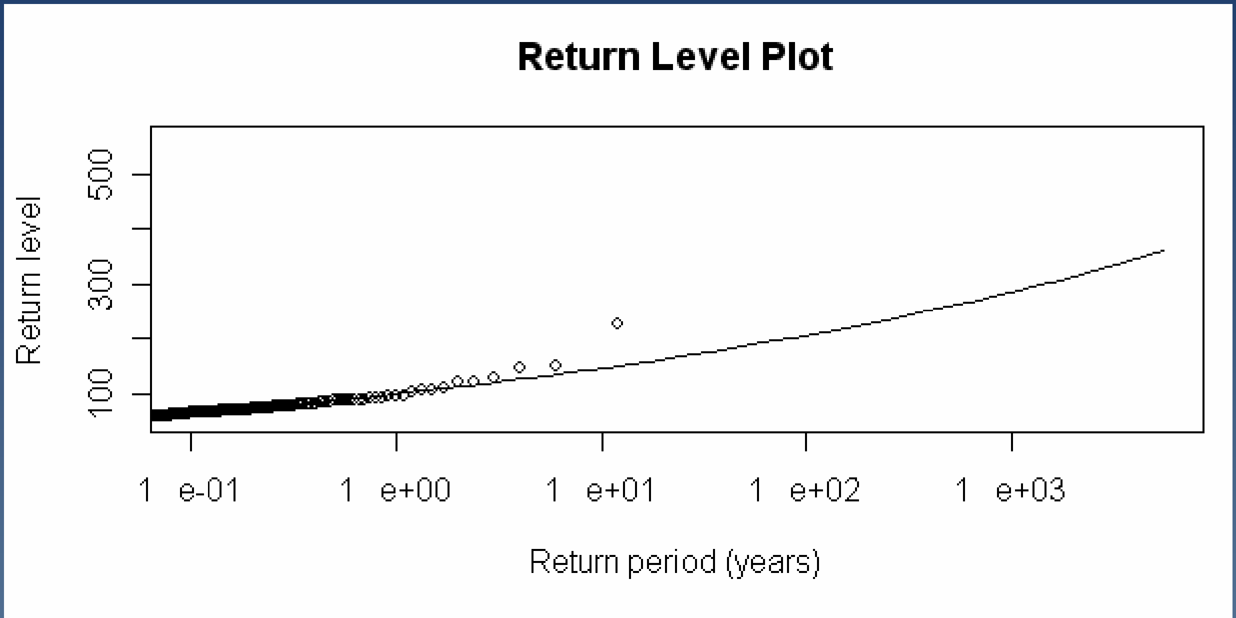
Shape parameter = 0.12 (Pareto)

Results: Ozone Return Levels (Current Conditions)



Return Period (yrs)	Return Level (ppb)	Confidence Interval (ppb)
1	81	80-82
10	86	85-89
100	90	87-93

Results: PM Return Levels (Current Conditions)



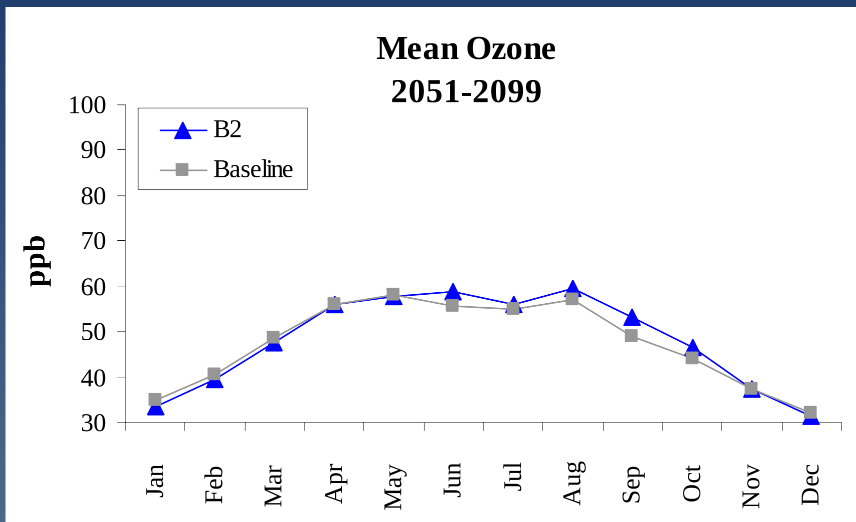
Return Period (yrs)	Return Level (µg/m3)	Confidence Interval (µg/m3)
1	100	93-109
10	146	128-167
100	207	173-241

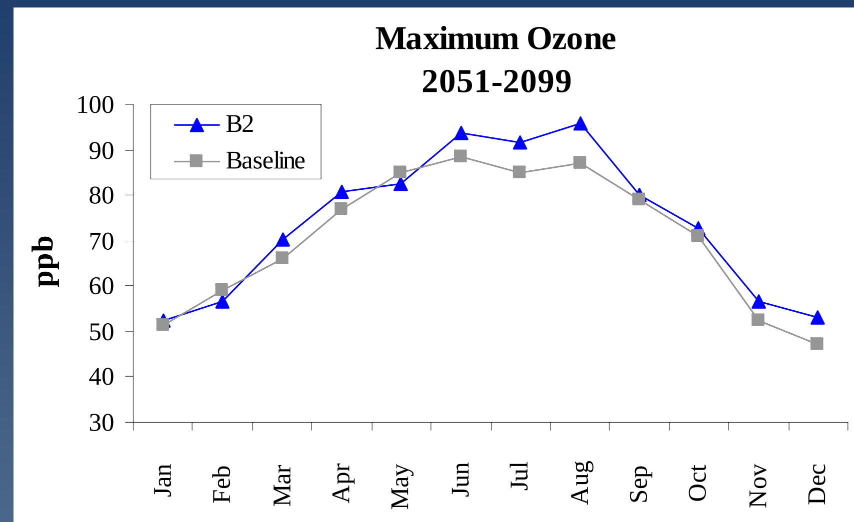
Results: SDSM Calibration and Verification

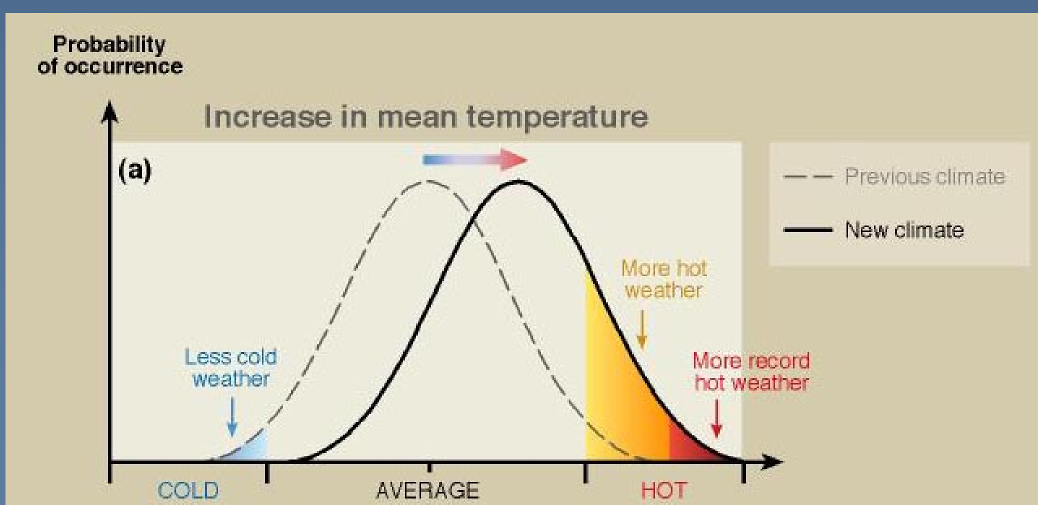
- Calibration: 1990-1995
  - Observed predictand (ozone/PM) and NCEP climate predictors
- Verification: 1996-2001
  - Observed and modeled output

	Tucson Ozone	**Tucson PM**
NCEP Predictor Variables	500 hPa divergence 850 hPa airflow strength Relative humidity at 500hPa Near surface relative humidity Surface specific humidity Mean temp at 2m	Mean sea level pressure 500 hPa geopotential height Relative humidity at 850hPa Near surface relative humidity
R^2	0.348	0.277

Results: Modeled Future Ozone







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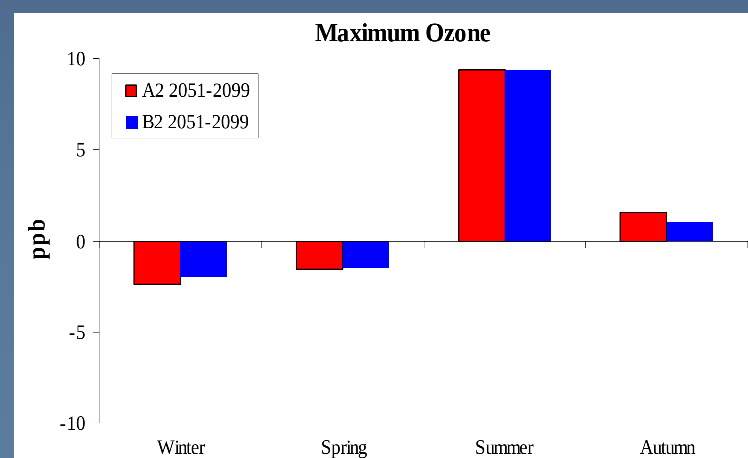
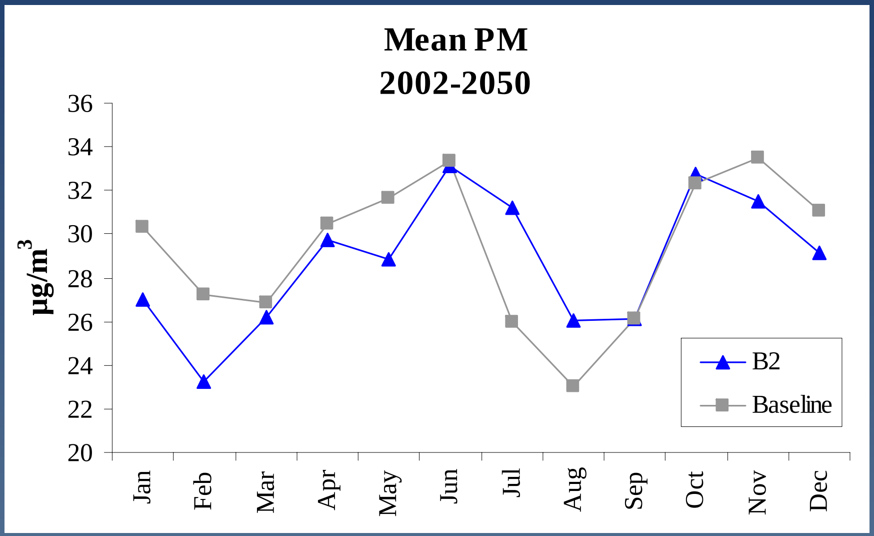
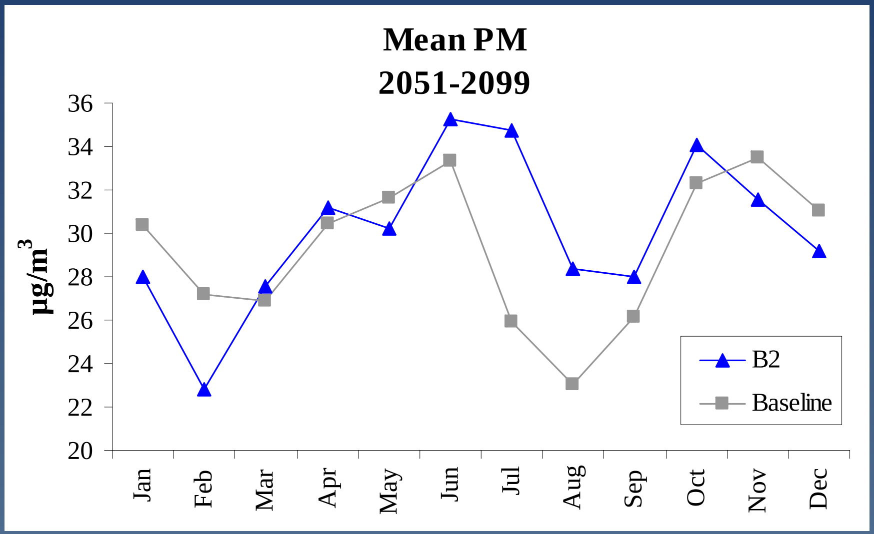
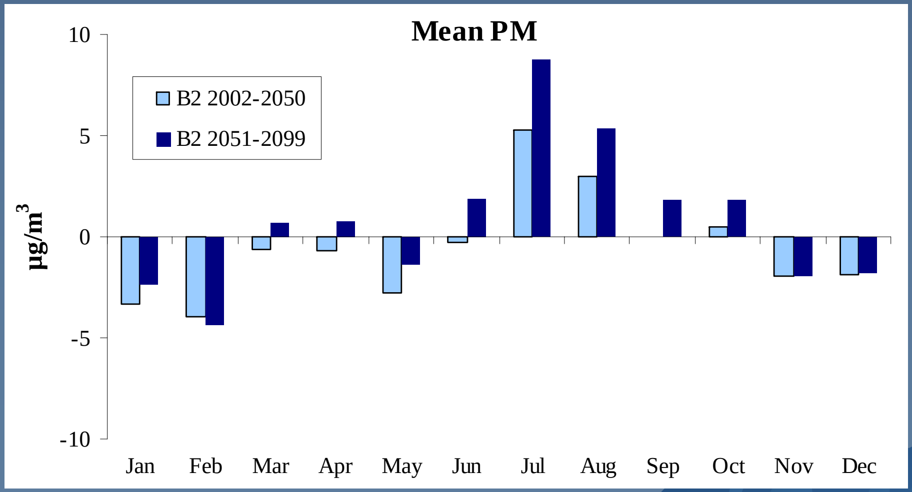


Results: Modeled Future PM





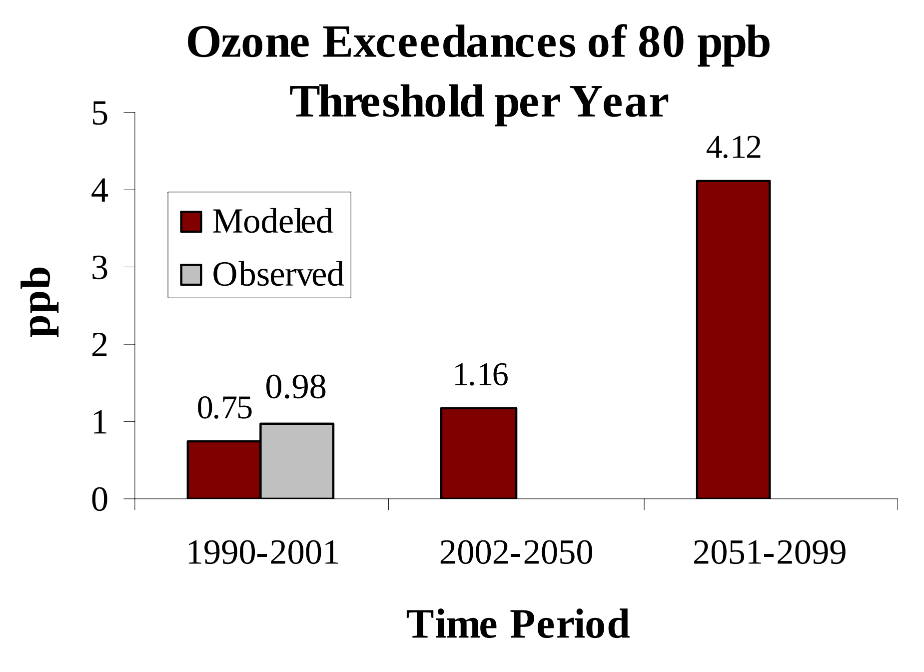


Results: Modeled Ozone Extremes

Return Period (yrs)	1990-2001 Return Level (CI)	2002-2050 Return Level (CI)	2051-2099 Return Level (CI)
1	79 (78-80)	81 (81-82)	87 (86-88)
10	85 (83-87)	89 (88-91)	96 (94-98)
100	88 (86-92)	95 (92-97)	103 (100-106)

parts per billion

Return Period (yrs)	2002-2050 Return Level Increase from Baseline	2051-2099 Return Level Increase from Baseline
1	2.53%	10.13%
10	4.71%	12.94%
100	7.95%	17.05%



Results: Modeled PM Extremes

Return Period (yrs)	1990-2001 Return Level (CI)	2002-2050 Return Level (CI)	2051-2099 Return Level (CI)
1	85 (79-94)	81 (79-83)	83 (82-86)
10	132 (110-155)	105 (99-115)	107 (101-114)
100	213 (168-258)	133 (118-148)	131 (120-143)

$\mu g/m^3$

Conclusions

Characterization of air quality exceedances under current climate conditions:

- Ozone:
  - 1-yr return period for exceedances (80 ppb)
  - 100-yr return level = 90 ppb
- PM:
  - 10-yr return period for exceedances (150 ug/m3)
  - 100-yr return level = 207 $\mu g/m^3$

Conclusions

Downscaled GCM projections applied to air quality:

- SDSM models correspond well with observed validation period air quality
  - Mean, max ozone
  - Mean PM
- Ozone
  - Monthly means increase 4-5 ppb in summer and autumn
  - Increases in summer seasonal max up to 10 ppb
- PM
  - Summer monthly mean increases up to 9 μg/m^3
  - Winter decreases (but within confidence interval)

Conclusions

Modeled climate influence on future extreme events:

- Ozone
  - Increases in return levels at 1-yr (10%), 10-yr (13%), and 100-yr (17%) return periods by 2099
  - Quadrupling of exceedance rate/yr by 2099

- PM
  - Projected decreases from 1990-2001 to 2002-2050
  - No change 2002-2050 to 2051-2099
  - 21st-century 100-yr return levels below NAAQS

Future Research

- Compare return levels and climate sensitivity with other Southwest cities
- Modification of PM calibration period, statistical methods, or threshold for better simulation of extremes

seattlepi.nwsource.com

- Incorporation of emissions scenarios / chemical transport

Thank You!

Acknowledgments:

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