Photochemical Modeling Investigation of the Effect of Ship Emission Control on Central California

Jinyou Liang[1], Ajith Kaduwela[1,2], Kemal Gürer[1], and Paul D. Allen[1]

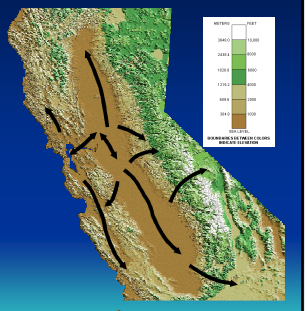
1. Air Resources Board, California Environmental Protection Agency
2. Department of Land, Air, and Water Resources, University of California at Davis

Outline

- Central California and CRPAQS
- CMAQ Model Setup
  - Domain & Resolution
  - CRPAQS winter episode
- Model Evaluation
  - Meteorological Input
  - Gas and PM Output
- Results
  - SO2 and PM Sulfate
  - SECA Effects

The San Joaquin Valley

- One of the most productive agricultural regions in the world – Cadillac Dessert
- Major goods movement corridors
- Oil production in the southern Valley
- Air Quality: Second most polluted area in the US and second most studied area in the world
- Ozone pollution in the summer and PM pollution in the winter



Prof. John Watson, DRI

Major field studies

- 1970: Project Lo-Jet (identified summertime low-level jet and Fresno eddy)
- 1972: Aerosol Characterization Experiment (ACHEX, first TSP chemical composition and size distributions)
- 1979-1980: Inhalable Particulate Network (first long-term $PM_{2.5}$ and PM_{15} mass and elemental measurements in Bay Area, Five Points)
- 1978: Central California Aerosol and Meteorological Study (seasonal TSP elemental composition, seasonal transport patterns)
- 1979-1982: Westside Operators (first TSP sulfate and nitrate compositions in western Kern County)
- 1984: Southern SJV ozone study (first major characterization of O_3 and meteorology in Kern County)
- 1986-1988: California Source Characterization Study (quantified chemical composition of source emissions)
- 1988-89: Valley Air Quality Study (first spatially diverse, chemical characterized, annual and 24-hour $PM_{2.5}$ and PM_{10} seasonal)
- Summer 1990: San Joaquin Valley Air Quality Study/Atmospheric Utilities Signatures Predictions and Experiments (SJVAQS/AUSPEX, first central California regional study of O_3 and $PM_{2.5}$) – Also known as SARMAP (SJVAQS/AUSPEX Regional Modeling Adaptation Project)
- Winter 1995: CRPAQS Pilot Study (IMS95, first sub-regional winter study)
- December 1999 to February 2001: CRPAQS and CCOS (first year-long, regional-scale effort)
- December 1999 to present: Fresno Supersite (first multi-year experiment with advanced monitoring technology)

CMAQ Model Domain

162 Air Quality Stations

365 Meteorology Stations

Modeling Approach

- California Regional PM10/PM2.5 Air Quality Study (CRPAQS) 2000-2001 winter PM episode
  - www.arb.ca.gov/ccaqs
- MM5 meteorology with NWS analysis
- ARB/UC Davis emission inventory
- CMAQ v4.5

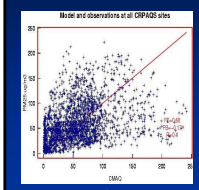
Meteorology Model Performance

	MB	MGE
Wind speed (m s^{-1})	0.49 (0.5)	1.53 (0.5)
Wind direction (º)	3.54 (10)	57.21 (30)
Temperature (K)	0.76 (0.5)	2.5 (2)

ARB CMAQ Model Setup

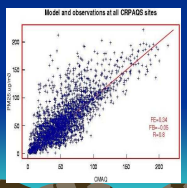
- (185x185) (4x4) km^2 horizontal grids with 15 expanding layers up to 10 km
- Internal mixture, 3-modal approach, SAPRC99_ae3_aq
- Some code modifications
- ~22-day run on 16-CPU Linux cluster in ~2 days

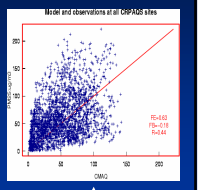
$PM_{2.5}$ Mass



Grid Cell

Best Match within 49 Cells





49-Cell Average

PM Mass and Key Components

	mFE		mFB		R	
	n=0	n=3	n=0	n=3	n=0	n=3
NH_4^+	0.73	0.44	-0.19	-0.14	0.44	0.59
NO_3^-	0.79	0.49	0.05	0.09	0.44	0.63
$SO_4^=$	0.77	0.45	-0.54	-0.33	0.18	0.63
TC	0.83	0.45	-0.71	-0.37	0.71	0.82
PM_{25}	0.68	0.37	-0.26	-0.09	0.41	0.74
PM_{10}	0.78	0.53	-0.21	-0.18	0.55	0.78

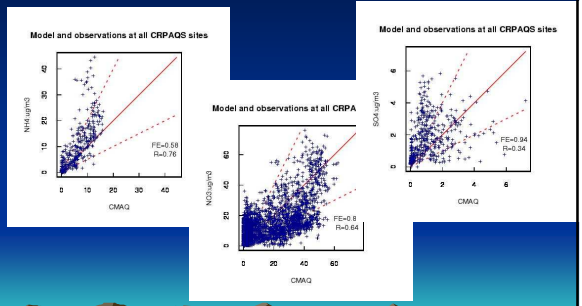
Inorganic Gas Species

	mFE		mFB		R	
	n=0	n=3	n=0	n=3	n=0	n=3
CO	0.85	0.59	-0.73	-0.48	0.39	0.57
HNO3	***0.90***	***0.75***	***-0.63***	***-0.61***	***0.14***	***0.33***
NH_3	0.94	0.54	0.07	0.10	0.23	0.84
NO_2	0.77	0.33	-0.37	-0.16	0.46	0.80
NO	***1.30***	***0.90***	***-0.90***	***-0.67***	***0.23***	***0.55***
O_3	0.79	0.49	0.50	0.33	0.49	0.76
SO_2	0.96	0.39	-0.57	-0.20	0.06	0.76

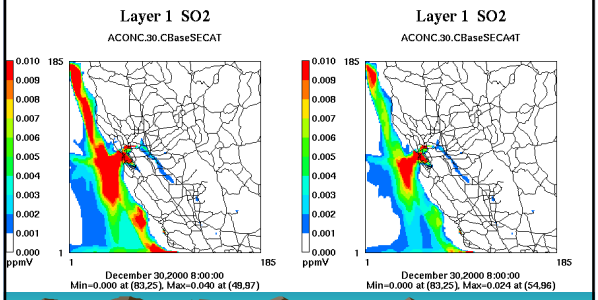
Organic Gas Species

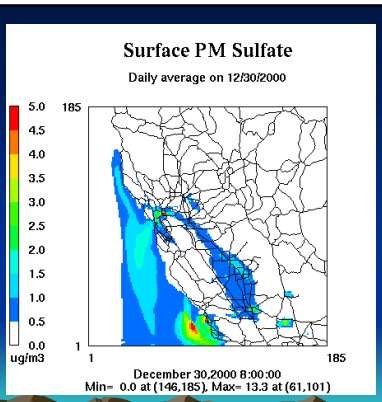
	mFE		mFB		R	
	n=0	n=3	n=0	n=3	n=0	n=3
ALK1	0.75	0.26	0.23	0.09	0.42	0.77
ALK2	***1.60***	***1.30***	***-1.60***	***-1.30***	***0.44***	***0.54***
ALK3	1.10	0.53	-1.00	-0.52	0.56	0.71
ALK4	0.87	0.33	-0.73	-0.31	0.42	0.59
ALK5	0.67	0.23	-0.12	-0.04	0.54	0.84
ARO1	0.90	0.37	-0.78	-0.36	0.48	0.65
ARO2	0.94	0.40	-0.82	-0.38	0.53	0.68
OLE1	0.81	0.24	-0.27	-0.15	0.68	0.95
OLE2	1.10	0.36	-0.65	-0.32	0.40	0.61
TERP	0.37	0.05	-0.24	-0.02	0.64	0.99

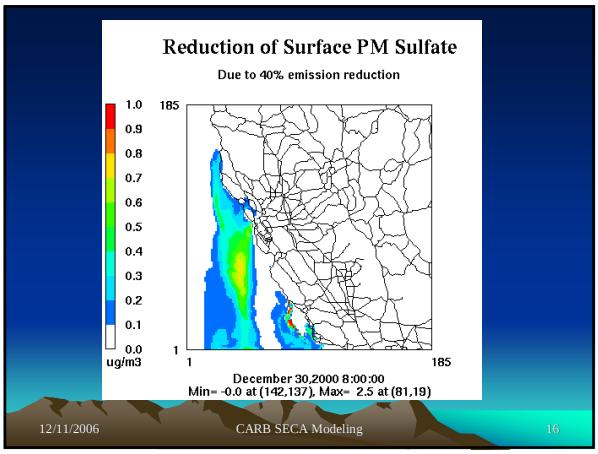
Individual Components



Simulated Surface SO2







Conclusion

- A winter PM episode was simulated over central California using observational constraints
- The ship emission of sulfur compounds was shown to have little effects in coastal area and shipping lanes, no noticeable effect in San Joaquin Valley during the episode.