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SUBJECT: TIME SERIES ANALYSIS AND FORECASTING OF VENTURA COUNTY NONFUMIGANT PESTICIDE VOLATILE ORGANIC COMPOUND OZONE SEASON EMISSIONS–2010 UPDATE

INTRODUCTION

Time series modeling has been used to forecast annual emission of volatile organic compound from nonfumigant (VOC_{NF}) in Ventura County (Spurlock, 2009; Tao, 2009). The method yielded better predictions than the original procedure of using VOC_{NF} from 2 years prior as a forecast for the current year (Spurlock, 2009). The time series model parameters are updated every year by modeling the most recently available VOC data. Tao (2009) forecasted 2009 VOC_{NF} emission in Ventura County based on VOC_{NF} data of 1990–2008. The Department of Pesticide Regulation (DPR) calculated the actual 2009 VOC_{NF} emission recently. This calculation was compared with the previous forecasting to examine the accuracy and prediction capacity of the estimated time series model. In addition, the renewed VOC_{NF} data were modeled to update the time series model components, which were used to predict the 2010 and 2011 VOC_{NF} emission in Ventura County.

As shown in Tao (2009), the time series model was developed for the VOC_{NF} data by classical decomposition algorithm method using statistical software package R:

$$X_t = m_t + s_t + y_t \quad (1)$$

Where X_t is the monthly VOC_{NF} over the time, which is 1990-2008 in Tao (2009) and 1990-2009 in the updated modeling this year;

m_t is the trend estimated from the linear regression of deseasonalized VOC_{NF} on t;

s_t is the seasonal component, monthly in this study with $\sum_{j=1}^{12} s_j = 0$. The detrended VOC_{NF} were averaged for each month over the analyzed time and then centered to obtain the estimate;

y_t is residues fitted with autoregressive integrated moving average (ARIMA) process
t is the year as time index.

The notation used to denote a specific seasonal ARIMA model is

$$ARIMA(p,d,q) \times (P,D,Q)_L$$

where:

p = order of nonseasonal autoregressive component
d = order of nonseasonal differencing
q = order of the nonseasonal moving average process
P = order of seasonal autoregressive component
D = order of seasonal differencing
Q = order of the seasonal moving average process
L = seasonal length

COMPARISON OF ACTUAL DATA AND FORECAST

The 2009 monthly VOC_{NF} emissions in Ventura County were predicted by Eq 1 using 1990–2008 data. The seasonal component and linear trend model were estimated in Tao (2009). ARIMA $(1,0,0) \times (0,1,1)_{12}$ and ARIMA $(0,0,2) \times (0,1,1)_{12}$ were residue models respectively chosen by Tao (2009) and Spurlock (2009), both of which were used to calculate the predictions here. The actual VOC_{NF} data and the predictions with each of two residue models were compared in Table 1. The difference of the total emission between the forecast and the actual data was 10.2–10.3% for the entire year. The difference of the total emission during the ozone season (May - October) was lower (3.6-3.7 %). The two sets of residue models showed similar results. The average absolute percent difference of monthly prediction with the actual data was 18.1 using ARIMA $(1,0,0) \times (0,1,1)_{12}$ and 18.0 using ARIMA $(0,0,2) \times (0,1,1)_{12}$.

UPDATE TIME SERIES MODEL

The actual 2009 data were appended to the 1990–2008 data to develop time series model for the prediction of 2010 and 2011 VOC_{NF} emission in Ventura County. In the new modeling process, X_t in Eq. 1 was the monthly VOC_{NF} over 1990-2009.

The linear regression model $\{m_t\}$ was estimated as:

$$m_t = 823078.2 - 399.0 \times t \quad (2)$$

R^2 of the model was 0.16, which suggested that the regression model accounts for 16% of the variation in the deseasonalized data, higher than 7% of last year's estimate. The absolute value of slope increased, compared to the last year estimate (-377.1). This change indicated that the VOC_{NF} emission in Ventura County may be decreasing faster in recent years.

The seasonal component was shown in Figure 1b, which exhibited the similar pattern with last year estimate (Figure 1a) except for June. November was not a month counted in the ozone season but showed a higher contribution to VOC_{NF} emission than each month of May–August.

Table 1. Comparison of actual data and prediction of Ventura County VOC_{NF} emission (lbs) in 2009

Month	Actual Data	Model Prediction ARIMA (1,0,0) × $(0,1,1)_{12}$	Percent Difference[a]	Model Prediction ARIMA (0,0,2) × $(0,1,1)_{12}$	Percent Difference
1	9463.36	8540.39	-9.8	8468.33	-10.5
2	8626.57	11728.78	36.0	11550.91	33.9
3	13106.41	17161.27	30.9	17042.08	30.0
4	12714.77	16814.17	32.2	16633.60	30.8
5	27870.17	24094.68	-13.5	23967.96	-14.0
6	23491.32	28327.60	20.6	28320.35	20.6
7	20007.65	18702.47	-6.5	18751.80	-6.3
8	24380.82	27025.07	10.8	27121.42	11.2
9	34186.41	35727.28	4.5	35783.41	4.7
10	35485.86	37507.29	5.7	37561.81	5.9
11	23877.77	30850.50	29.2	31009.29	29.9
12	11077.38	12971.31	17.1	13082.57	18.1
Total	244288.5	269450.8	10.3	269293.5	10.2
Ozone Season Total[b]	165422.2	171384.4	3.6	171506.8	3.7

a. Percent Difference = (prediction–actual data)/actual data
b. Ozone Season Total = sum of emission during May–October

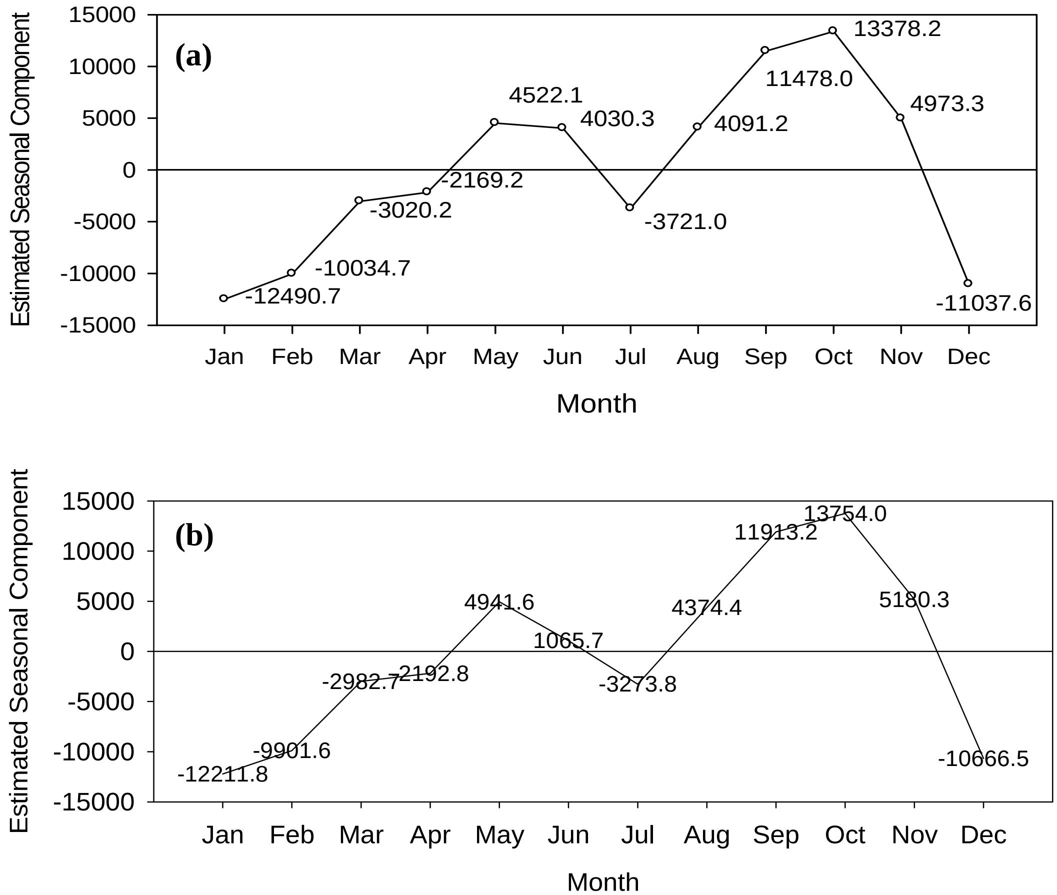

Figure 1. The estimate of seasonal component (lbs) in the VOC_{NF} series of (a) 1990 – 2008 and (b) 1990 – 2009

Five ARIMA model were fitted and compared: ARIMA (1,0,0) × $(0,1,1)_{12}$, ARIMA (0,0,1) × $(0,1,1)_{12}$, ARIMA (1,0,1) × $(0,1,1)_{12}$, ARIMA (2,0,0) × $(0,1,1)_{12}$, and ARIMA (0,0,2) × $(0,1,1)_{12}$. The Box-pierce test yielded large p-values, indicating that the residuals of the models were stationary (Table 2). ARIMA(0,0,2) × $(0,1,1)_{12}$ was the best choice with the highest P-value and lowest AICC. Its equation is:

$$y_t = \delta + w_t - \theta_1 w_{t-1} - \theta_2 w_{t-2} - \theta_{s,1} w_{t-12} - \theta_{s,1}\theta_1 w_{t-13} - \theta_{s,1}\theta_2 w_{t-14} \qquad (3)$$

Where δ is a constant, $\theta_{S,1}$ is the seasonal moving average coefficient, estimated as -0.746, θ_1 and θ_2 are the nonseasonal moving average coefficient, estimated as 0.241 and 0.232, and w_t is a Gaussian white noise term assumed $N(0, \sigma_{wt}^2 = 26114031)$.

Table 2. Summary of Box-pierce test and AICC on ARIMA models

Model	**Box-pierce test p-value**	**npar**	**AICC**
ARIMA $(1,0,0) \times (0,1,1)_{12}$	0.40	4	4563.58
ARIMA $(0,0,1) \times (0,1,1)_{12}$	0.15	4	4568.71
ARIMA $(1,0,1) \times (0,1,1)_{12}$	0.62	5	4563.25
ARIMA $(2,0,0) \times (0,1,1)_{12}$	0.86	5	4561.00
ARIMA $(0,0,2) \times (0,1,1)_{12}$	0.98	5	4558.98

PREDICTION USING THE UPDATED MODEL

With the estimates of three components, the time series model X_t for the VOC_{NF} data was built by the combination of the seasonality s_t (Figure 1b), the trend m_t (Eq. 2) and the ARIMA $(0,0,2) \times (0,1,1)_{12}$ (Eq. 3) for y_t as Eq.1. The estimates of entire year VOC emission from nonfumigant in Ventura were 250,713.9 lbs in 2010 and 247,186.2 lbs in 2011. The prediction data for ozone season in these two years were reported in Table 3.

Table 3. The prediction of VOC_{NF} monthly emission (lbs) in 2010 and 2011 ozone season

Monthly Prediction	**Year**	
	2010	**2011**
May	24,073.1	23,674.1
June	22,567.6	22,168.6
July	18,653.0	18,254.0
August	26,181.5	25,782.5
September	35,000.0	34,601.0
October	36,542.3	36,143.4
Total	**163,017.4**	**160,623.6**

CONCLUSION

The time series model were developed for the nonfumigant VOC emission in Ventura. The predicted total emission showed a difference around 10% relative to the actual 2009 data. The model yielded better predictions during the ozone season (May–October) with a difference of

3.6–3.7% between the forecast and the actual data. After updating the time series model with the new 2009 VOC_{NF}, the predictions of VOC_{NF} emission in Ventura County were 163,017.4 lbs in 2010 ozone season and 160,623.6 lbs in 2011 ozone season.

REFERENCE

Spurlock, F. 2009. Time Series Analysis and Forecasting of Ventura County Nonfumigant Pesticide Volatile Organic Compound Emissions. July 16, 2009. Memorandum to Randy Segawa.

Tao, J. 2009. Time Series Analysis and Forecasting of Ventura County Nonfumigant Pesticide Volatile Organic Compound Emissions–2009 Update. December 23, 2009. Memorandum to Randy Segawa.