Temperature–dependence in sewer blockage frequency

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Tue Mar 3 04:08:11 2015

Methods

Data

Albuquerque Bernalillo County Water Utility Authority (ABCWUA) responds to SSB events after discovery by maintenance workers or reports of blockages from the public. This study used an anonymised dataset of SSB dates, along with engineers' estimates of blockage cause. In total, 913 SSB reports from the period 2009-01-06 to 2013-02-01 (inclusive) were used in this study. The frequency of sanitary sewer blockages is the primary focus of this work.

Various testing is performed to verify cost-effective chemical odor control on three north-south interceptor sewers in the ABCWUA system, which are shown in Figure S1. The testing includes grab samples obtained by the chemical treatment vendor at 15 manholes on the three treated interceptors. The sewage grab sample measurements were obtained, typically bi-weekly, using a Cooper Atkins DPP400W Waterproof Pen Style thermometer with an accuracy range of +/- 1 C° (from -10° to 100°C) in a liquid sample collected from the manhole.
In total, 1871 SGST measurements from the period 2005-10-04 to 2012-12-19 (inclusive) were used in this study.

Mean daily air temperature (MDAT) was obtained from the Albuquerque International airport's (KABQ) automated METAR data collection system (available from \url{http://www.wunderground.com/history/airport/KABQ}) spanning the entire period of study noted above.

Since most days had no SSB events, the total number of SSB events per week (W-SSB) was computed and used in subsequent analysis. For comparison with SSB data, MDAT measurements were averaged by week to yield mean weekly MDAT (MW-MDAT). In addition, SGST measurements were averaged by week (all interceptors were combined), yielding mean weekly SGST (MW-SGST). In all analyses that included MW-SGST, weeks without SGST measurements were excluded.

Linear models

First, we used ordinary linear models to estimate the response of MW-SGST to MW-MDAT, interceptor identity, and manhole identity. For final selection of linear model specifications, both Bayes'information criterion (BIC) and parsimony considerations were employed. In favor of parsimony, and due to the small effect sizes and/or statistical non-significance, interceptor and manhole identity were excluded from subsequent models.

Next, we used generalized linear models (GLM) to estimate the response of W-SSB to

either MW-SGST or MW-MDAT.

We also used a GLM to estimate the response of W-SSB to both MW-MDAT and blockage cause. Due to low sample numbers, the response of W-SSB to both MW-SGST and blockage cause was not estimated.

All analysis was conducted with the R statistical programming environment \parencite{cran}.

Results

Air temperature (MW–MDAT) and sewage temperature (MW–SGST)
We found that sewage temperature increased with air temperature (Figure \ref{fig:sewweathplot}). Indeed, the best-ranked model of the response of MW-SGST to MW-MDAT (Table \ref{tab:bestlin}) explained the majority of variation in MW-SGST (R^2 = 0.757). However, as air temperature fells below freezing, little further decrease in sewage temperatures was observed (Figure \ref{fig:sewweathplot}).

For reference, all candidate models (ranked by BIC) are shown in Table \ref{tab:bictab}. All high-ranked models (low BIC) show a small but statistically significant effect of interceptors identity on sewage temperature. On the other hand, all models that included manhole identity ranked lower than the null model (which included only MW-MDAT and MW-SGST).
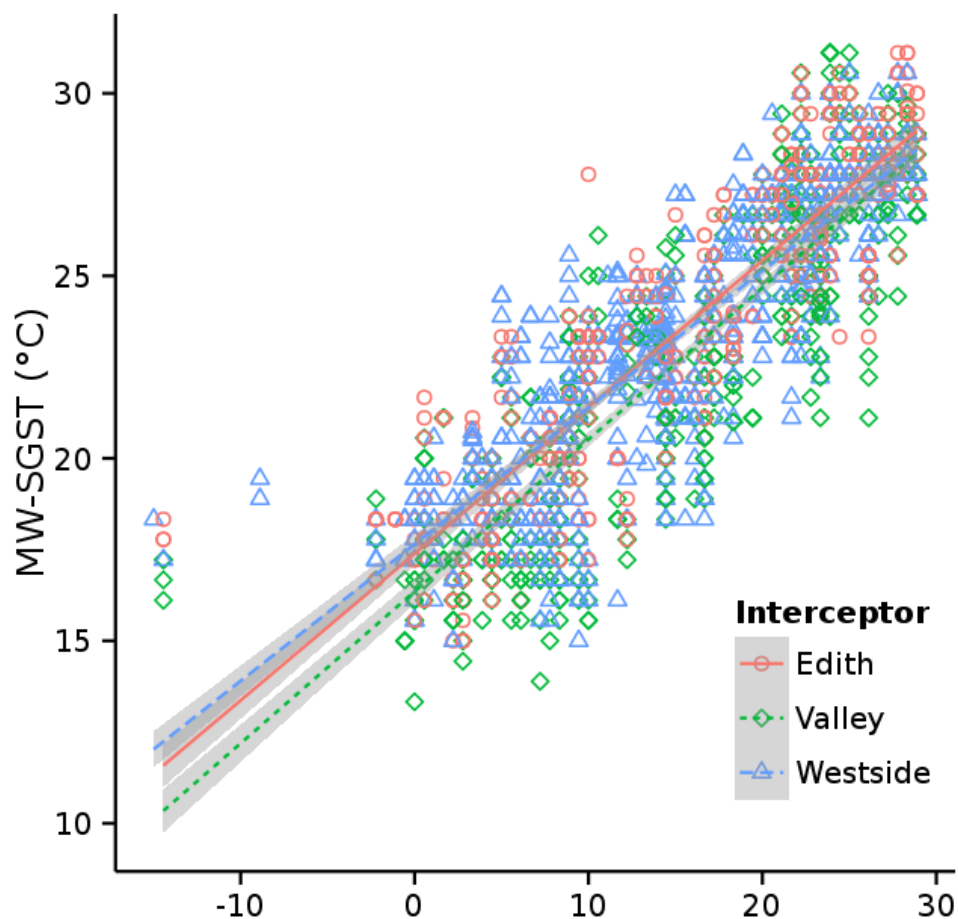
MW-MDAT (°C)

Figure 2: Sewage temperature (MW-SGST) increased with air temperature (MW-MDAT). The response of sewage temperature to air temperature differed slightly between sewer system interceptors. Overall, as air temperature dropped below freezing, no further decrease in sewage temperature was observed.

Sewage temperature (MW–SGST), air temperature (MW–MDAT), and sewer blockage frequency (W–SSB)

Overall, we found that sewer blockages occured more frequently during weeks with lower sewage temperatures (Figure \ref{fig:multiblockplot}A). We employed a Poisson GLM, with mean weekly temperature and cause predicting weekly blockage frequency.

The final model showed a highly statistically significant relationship between sewage temperature (MW-SGST) and sewer blockage frequency (W-SSB) (p < 0.001; Table \ref{tab:tempandblock}), R^2 statistics are not available for GLM, though the proportional reduction in deviance (D) provides an analogous measure of the model's explanatory power \parencite{zheng2000summarizing}. For the final model, we find that D = 0.199.

As with sewage temperature, we found low air temperature was associated with more sewer blockages. MW-MDAT was a highly significant predictor of W-SSB (Table \ref{tab:sewnb}; Figure \ref{fig:multiblockplot}B).

Causes of sewer blockage frequency (W–SSB)

Above, we see that sanitary sewer blockage frequency (W-SSB) is weakly correlated with both air and sewage temperature. While both sewage and air temperature are poor predictors, sewage temperature is somewhat better. Yet sewage temperature measurements are expensive and labor-intensive, and thus sparse relative to automated air temperature measurements. As such, a direct comparison between models is not possible.

This dataset includes 749 total blockages where grease was the estimated blockage cause, representing 178.8\% of total incidents during the study period. We constructed a Poisson GLM using both air temperature (MW-MDAT) and blockage cause (grease vs not grease) as predictor variables. Here, both air temperature and blockage cause are highly significant predictors of blockage frequency (Figure \ref{fig:block.airtemp} and Table \ref{tab:greasetab}). Again, there is a strong interaction between temperature and blockage cause, with grease-caused blocks responding more strongly to temperature. The full model explains a sizable proportion of variation in blockage frequency (D = 0.152), particularly for grease-caused blockages (Figure \ref{fig:block.airtemp}A).
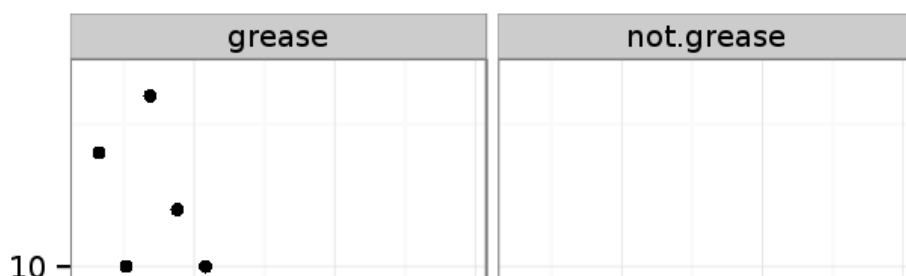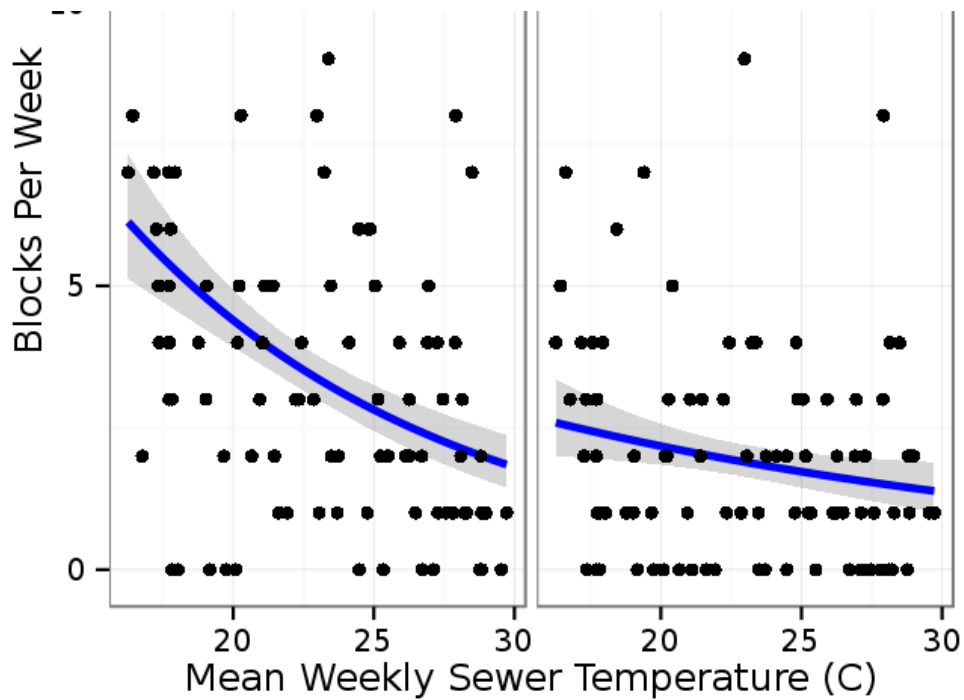
Figure 3: Mean weekly sewer temperature predicts blockages caused by grease, and is a poor predictor of blockages due to other causes. 94 weeks total, pseudo-R2: D=0.199. See Table ?? for model details.
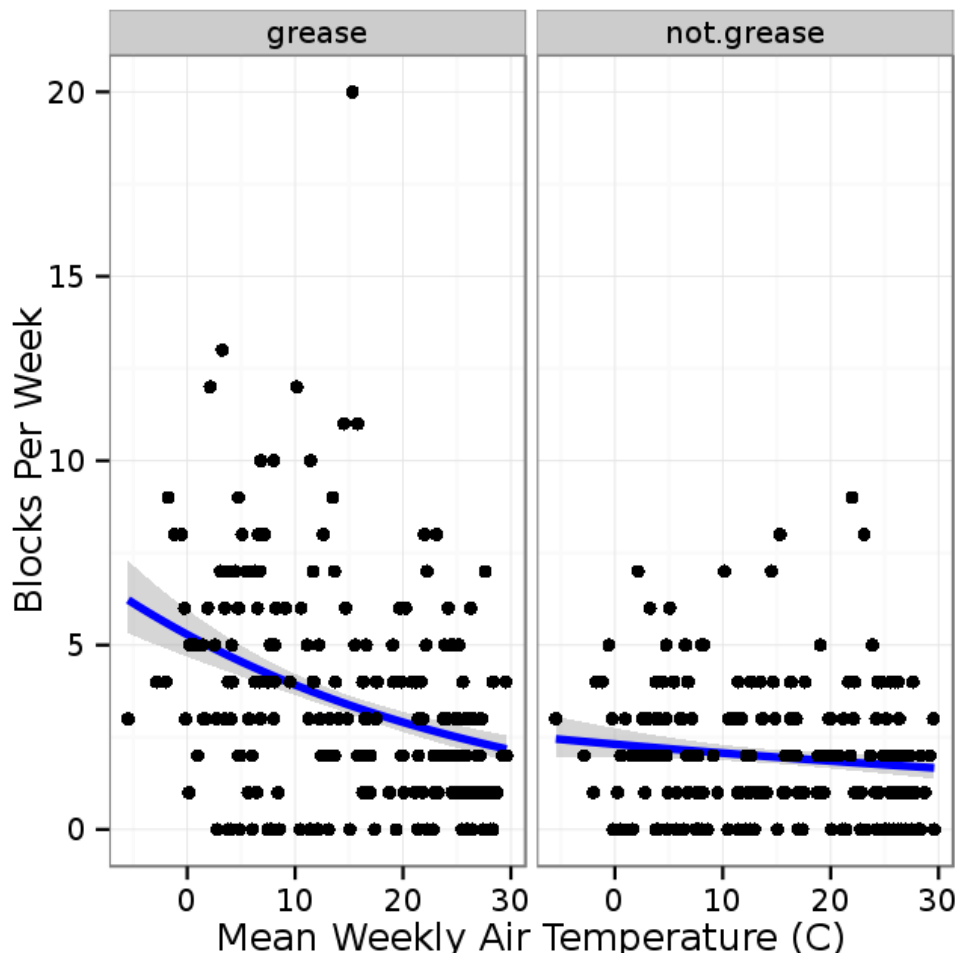
Figure 4: Mean weekly air temperature predicts blockages caused by grease (A: 749 total blocks), and is a poor predictor of blockages due to other causes (B: 419 total blocks). 212 weeks total, pseudo-R2: D=0.152. See Table ?? for model details.

Discussion

Notes / todo: ??both sewer temp and air temp are signif predictors, sewer temp is better ??likely that the reponse of sewer temp to air temp is dependent on local local climate and sewer configuration (mark?), warrants testing in different locales. ABQ diurnal temp, elevation gradient and cold air drainage. ??if municipalities are already collecting SGST, it would be an appropriate addition to system maintainance planning

Air temperature data, which are widely and freely available, have modest utility in predicting sewer blockages over weekly timescales. It is useful for practitioners to understand variables impacting SSOs, even with a weak relationship. Consideration could be given in sewer design to select locations subject to higher winter temperatures, either through greater depth or under asphalt pavement. These results also suggest that areas experiencing increasing average temperatures may find that this trend alleviates the pressure placed on sewage systems by FOG deposits. Similarly, weather forecasts and real-time weather observations may prove useful for predicting and responding rapidly to blockages, reducing the threat to property and public health.

Data from sewer measurements are a slightly more accurate predictor of blocking frequency. Where these data are regularly collected and rapidly analysed, they could be used in place of air temperature to anticipate problems in sanitation infrastructure and plan system maintenance.

Both sewage and air temperature are significant predictors of SSOs, with sewage temperature being the superior predictor. The sewage temperature is understood to be primarily driven by soil temperatures (author's communication with Dr. Jes Vollertsen, 2014). Literature is available (e.g., \cite{Hasfurther1972}) to predict soil temperature from air temperature in a non-urban area. The relationship between air and soil temperature is likely to be mediated by groundwater levels. The difference in predictive ability between sewage and air temperature may reflect the variable groundwater levels during the seasonal cycle in Albuquerque. Similarly, differences between interceptors and manholes may reflect elevation and land use, via their effects on groundwater temperature. Models including precipitation patterns and/or local physical characteristics (e.g. water table height, land use, sewer configuration, soil type, geology) could test this hypothesis.

Because lower temperatures occur coincidental to the Thanksgiving and Christmas season in the Northern Hemisphere, it is possible that FOG related SSOs increase during the holiday season but not due to higher levels of holiday generated FOG. Further study of SSO rates versus holiday seasons for Southern Hemisphere utilities may be enlightening. Further study may be appropriate of temperature impacts to FOG transformations in the sewer and to seasonal variations in FOG levels.

With continuing population rise and urbanisation, efficient operation of urban waste-water infrastructure is an increasingly important issue for global public health. \cite{Sato2013} recently highlighted the importance of more research into efficacy of waste-water treatment techniques, particularly in the developing world. The data in this study were not collected specially for research purposes. Rather, this study used data already collected by industry as part of standard operations, married with publicly accessible weather data available online. This demonstrates the potential usefulness of historic industry datasets for addressing future challenges.

Tables

??Need table numbers.

Weekly mean sewage temperature and blockage cause predict weekly blockage frequency (Poisson GLM, n=94 weeks, D=0.199)

	Dependent variable:
	value
SewTempC	-0.074***
	(0.011)
variablenot.grease	-0.625***
	(0.092)
Constant	2.932***
	(0.246)
Observations	188
Log Likelihood	-408.800
Akaike Inf. Crit.	823.700
Note:	*p<0.1; **p<0.05; ***p<0.01

Weekly mean air temperature and blockage cause predicts weekly blockage frequency (Poisson GLM, n=212 weeks, D=0.152)

	Dependent variable:
	value

MeanTempC	-0.030***
	(0.004)
variablenot.grease	-0.827***
	(0.108)
MeanTempC:variablenot.grease	0.019***
	(0.007)
Constant	1.665***
	(0.062)
Observations	424
Log Likelihood	-929.200
Akaike Inf. Crit.	1,866.000
Note:	*p<0.1; **p<0.05; ***p<0.01

#References

Supplemental Information