An Analysis of Air-Mass Effects on the Use of Rail Transit Systems

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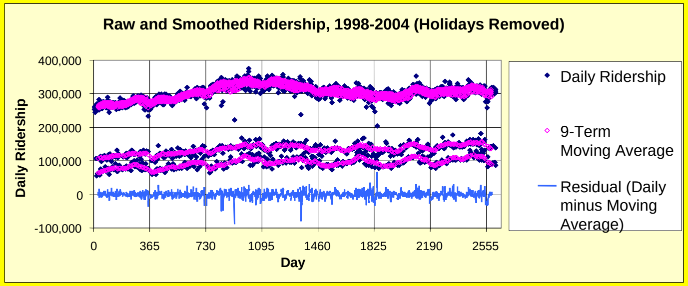
Introduction and Background

With a new light-rail system connecting Phoenix, Tempe, and Mesa scheduled to open in 2008, we were curious how daily weather influences ridership of rail transit systems. Previous research by Kuby, Barranda, and Upchurch (2004) found ridership to be significantly higher in milder climates, and Chagnon (1996) found that rain reduced transit ridership in the summer. Spatial synoptic classification of daily weather conditions into air mass categories has been linked to human health, but rarely to human behavior. We therefore chose to study the effects of synoptic air masses on ridership of rail systems. We obtained daily ridership data for the BART system in the San Francisco Bay area, the El in Chicago, and the light-rail in Newark, NJ. Using one-way ANOVA, we found a significant relationship between daily synoptic air mass conditions and daily ridership.

This APCG poster presents our results for the BART system only.

References

- Sheridan, S. & Kalkstein L. (1999) Redevelopment of a spatial synoptic classification for year round application, Proceeding, 11th Conference on Applied Climatology, American Meteorological Society.
- Chagnon, S. (1996) Effects of summer precipitation on urban transportation, Climate Change, Vol. 32: 481-494.
- Kuby, M. Garranda, A. & Upchurch, C. (2003) Factors Influencing Light Rail Station Boardings in the United States, Transportation Research Part A: Policy and Practice.



As the dependent variable, we use the difference between the actual daily ridership and a smoothed ridership variable. The smoothed variable controls for ridership fluctuations by day of week and by season of year.

We smoothed the ridership data by applying a 9-term moving average. The nine terms in each moving average are the ridership totals for the same day of the week in the prior four weeks, the day in question (t), and the following four weeks. For example, the moving average for a given Monday is calculated from the Monday in question, the four Mondays before, and the four Mondays after.

The 9-term moving average is defined as:

$$r_t - \frac{\sum_{\tau=-4}^{4} r_{t+7\tau}}{9}$$

where:

r_t = ridership on day t

τ = index of weeks

We also removed days when ridership was impacted by major events unrelated to weather. These included major holidays, festivals, and the Giants-As World Series.

The dependent variable is calculated as the difference, or residual, between the daily ridership (r_t) and the 9-term moving average, calculated as a percentage of the moving average.

Air Mass Definitions

DM (dry moderate)

Mild and dry, found in eastern and central U.S. associated with zonal flow aloft.

Adiabatically-warmed and dried air moves eastward after crossing the Rocky Mountains.

Also found in the southeastern U.S. when polar air is advected around a surface anticyclone with a long trajectory over the Atlantic Ocean.

DP (dry polar) (cP)

Advected from Canada through circulation around a cold-core anticyclone.

Lowest temperatures observed in a region for a particular time of year, as well as clear, dry conditions.

DT (dry tropical) (cT)

Hottest and driest conditions found at any location.

Advected from the southwestern U.S. or Sonoran Desert of Mexico, **or**

Rapidly descending air, such as the Chinook or Santa Ana winds.

MM (moist moderate)

Warmer and more humid than MP.

Appears in a zone south of MP air, still in an area of overrunning but with the responsible front much nearer.

May persist for many days if frontal movement is particularly lethargic.

MP (moist polar) (subset of mP air mass)

Weather conditions are typically cloudy, humid, and cool.

Appears either by inland transport from a cool ocean, or as a result of frontal overrunning well to the south of the region.

MT (moist tropical) (mT)

Warm and very humid.

Found in warm sectors of frontal cyclones **or**

Gulf return flow on the western side of an anticyclone in the eastern and central U.S.

TR (transitional)

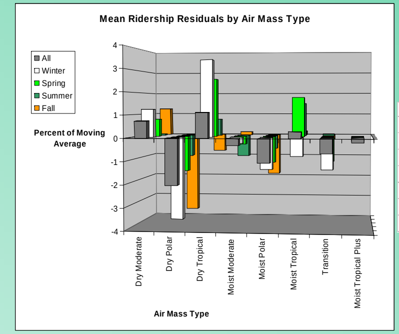
Identified on days when one air mass gives way to another.

MT+ (moist tropical plus - subset of mT)

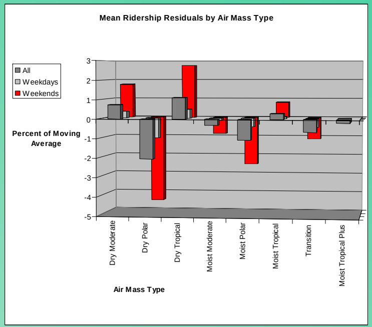
Used in heat research. MT day where both morning and afternoon temperatures are above seed day means

Captures the most "oppressive" quarter or so of MT days.

After http://sheridan.geog.kent.edu/ssc.html, Spatial Synoptic Classification homepage



	Total D.F.	F Test	Significance
All	2268	5.653	0.000
Winter	520	2.019	0.051
Spring	611	4.349	0.000
Summer	554	2.000	0.064
Fall	580	2.239	0.038
Weekdays	1632	3.011	0.004
Weekends	635	3.793	0.001



Discussion of Results

We used one-way analysis of variance (ANOVA) to compare the mean ridership residuals among the different air mass types. Over all seasons (see graph), the air masses with the highest ridership relative to the same day-of-week moving average were dry tropical (1.1% above avg.) and dry moderate (0.7% above avg.), while moist polar days had the lowest ridership (1.1% below avg.). These air masses affected ridership in a fairly consistent way in separate analyses of each season (see charts). For instance, a dry tropical day in San Francisco in February averages a 1PM temperature of 63F, a dew point of 34F, and 10% cloud cover. As a result, winter BART ridership on dry tropical days averages 3.4% above the moving average.

Another finding is that the effect of air mass on ridership is exaggerated on weekends. For instance, moist polar days on weekends reduce ridership by 2.5%, compared with only a 0.4% decline on weekdays, while dry moderate days increase ridership by 1.7% on weekends versus 0.3% on weekdays. We hypothesize that this is due to the fact that many weekend transit trips are discretionary.

For the ANOVA test, the null hypothesis is that the mean ridership residuals of the air mass types are equal and there is no effect on ridership by air mass. ANOVAs were significant at the .05 level, and we rejected the null hypothesis, for all seasons except summer when it was significant at the .10 level. The significance is higher for the weekend data than for the weekdays, despite there being a much smaller sample size. Our results support the alternate hypothesis that air mass classification significantly affects rail transit ridership on the BART system.

Preliminary results are similar for Newark and Chicago.