Analysis of geographical patterns in weather-related flight delays

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Contents

Data Information

- Airline on time data from the Bureau of Transportation Statistics for all US States
- Weather-related flight delays data from June 2003 to December 2013

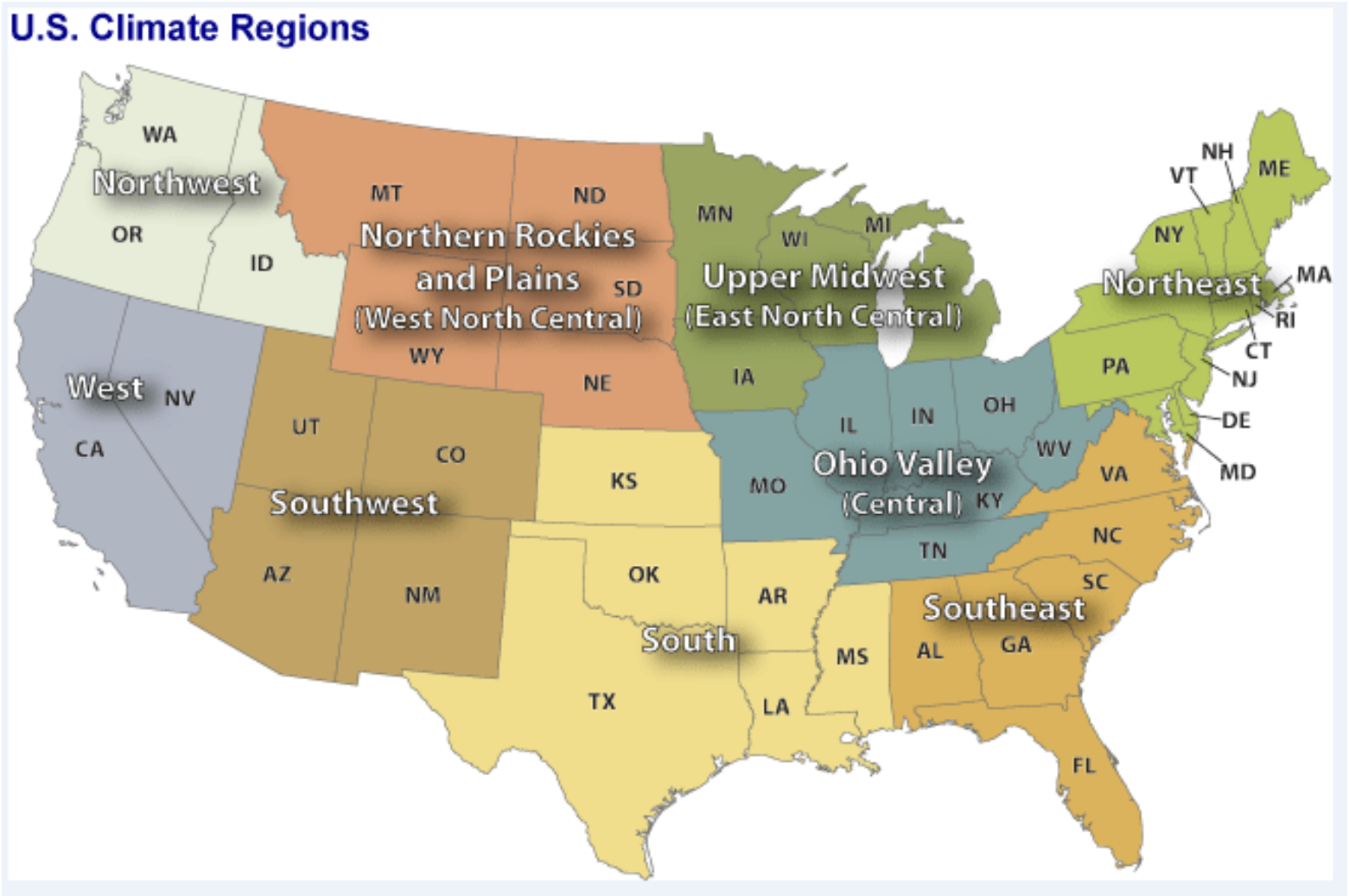
Question of Interest

Are there geographical patterns in weather-related flight delays, and do these change over time?

Assumptions

- NA $\rightarrow$ No Delay
- For Proportion
  - Weather delay value greater than 0 $\rightarrow$ 'Delayed' regardless of severity
  - Denominator $\rightarrow$ count of all flights including NA
- Weather within a month is 'reasonably consistent'
- Defined regions using National Oceanic and Atmospheric Administration (NOAA) map
  - Added Alaska and Hawaii as their own region
  - Lumped unlinked airports into an 'Other' region
- Weather is similar in climate regions
- Analysis done on origin airport. Assumes delay on origin side.

NOAA Map of Regions



Population-based Results

- Aggregate to monthly basis
- Higher percentages of delayed flights are in winter
- Highest winter proportions are in Central region
  - Chicago: Major hub plus cold winters
- No month/region exceeds 4% in the proportion of delayed flights
- Bump in Jun, Jul and August for the South, Southeast, Northeast and Upper Midwest
  - Tornado season?
- South is consistently above 1% across all months

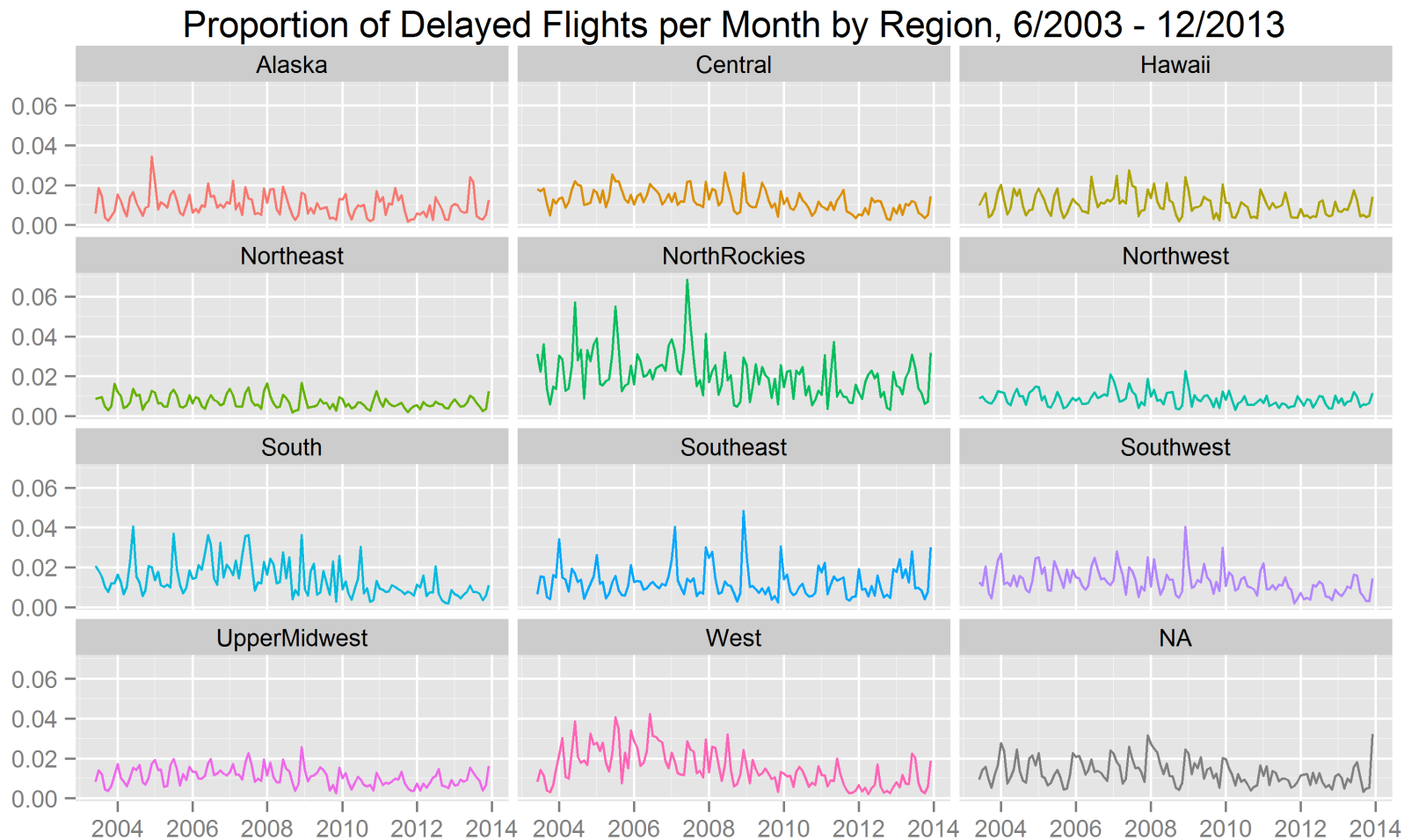
Proportion of Weather Delayed Flights, by Month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alaska	1.832%	1.353%	1.175%	0.517%	0.347%	0.319%	0.455%	0.661%	0.698%	0.865%	1.529%	1.768%
Central	3.155%	2.849%	1.740%	1.349%	1.614%	1.957%	1.733%	1.450%	0.809%	0.802%	1.129%	3.385%
Hawaii	0.108%	0.114%	0.113%	0.029%	0.056%	0.021%	0.030%	0.116%	0.013%	0.051%	0.091%	0.344%
Northeast	2.007%	1.853%	1.422%	1.038%	1.185%	1.992%	2.011%	1.710%	0.872%	0.963%	0.971%	2.409%
NorthRockies	1.641%	1.321%	1.000%	0.725%	0.708%	0.830%	0.739%	0.707%	0.523%	0.636%	0.830%	2.071%
Northwest	1.367%	0.505%	0.422%	0.179%	0.151%	0.210%	0.202%	0.230%	0.182%	0.293%	0.667%	1.513%
Other	0.368%	0.270%	0.218%	0.275%	0.421%	0.514%	0.762%	0.612%	0.393%	0.510%	0.328%	0.329%
South	1.808%	1.939%	1.988%	1.938%	2.472%	3.236%	2.877%	2.173%	1.232%	1.494%	1.285%	2.356%
Southeast	1.177%	1.220%	1.133%	1.028%	1.252%	2.464%	2.475%	1.981%	1.065%	0.867%	0.783%	1.217%
Southwest	1.117%	0.741%	0.617%	0.540%	0.589%	0.961%	1.079%	0.904%	0.446%	0.519%	0.457%	1.378%
UpperMidwest	1.653%	1.913%	1.349%	1.045%	1.489%	1.965%	1.728%	1.262%	0.977%	0.914%	1.069%	2.266%
West	0.651%	0.497%	0.412%	0.303%	0.276%	0.319%	0.403%	0.383%	0.277%	0.430%	0.433%	0.729%

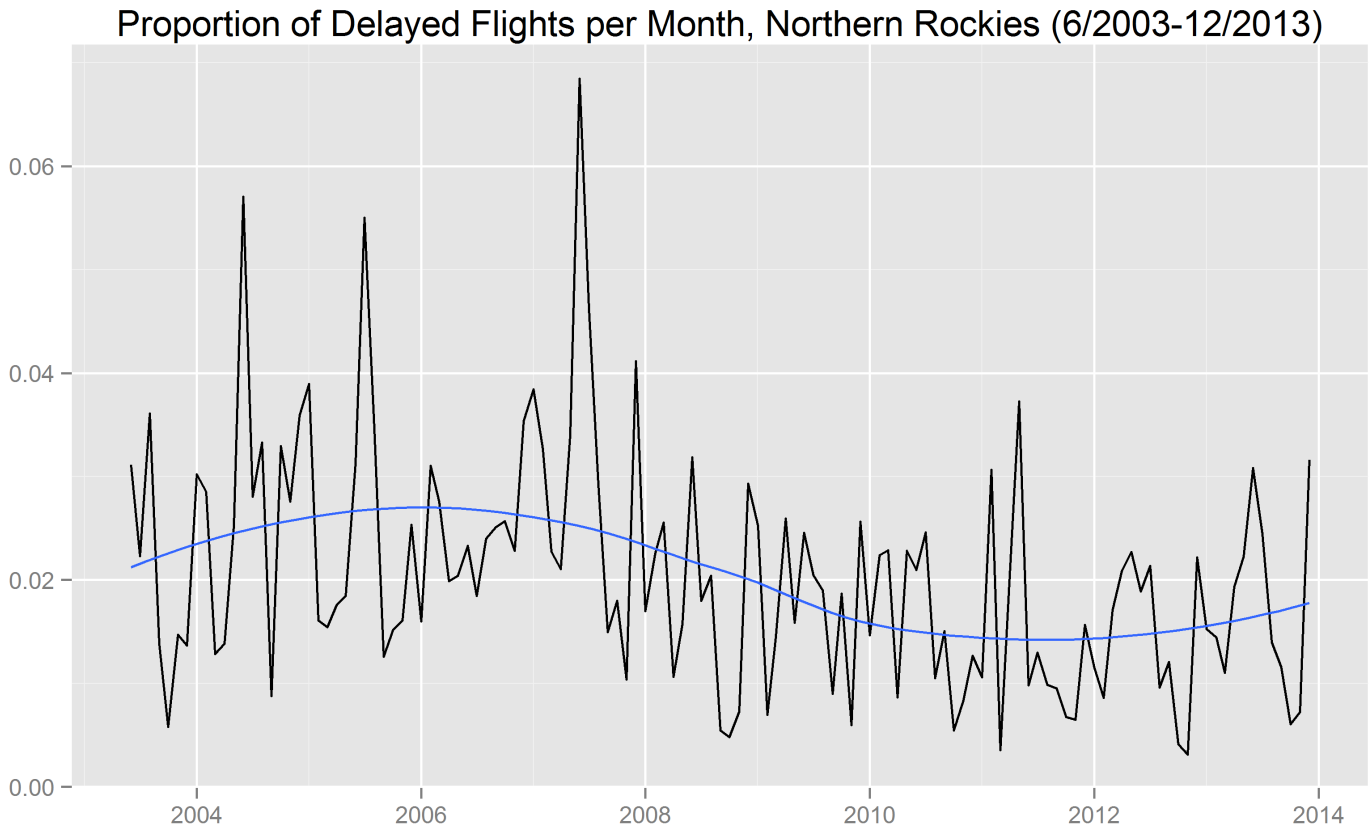
Population-based Results

- Across all years
- Northern Rockies show greatest fluctuation over the years
- Northwest region is the most consistent through time, with around 1% delays
- Northern Rockies alone:
  - No obvious seasonal patterns
  - Gradual change of mean level over the years

All Regions


Proportion of Delayed Flights per Month by Region, 6/2003 - 12/2013
Alaska
Central
Hawaii
Northeast
NorthRockies
Northwest
South
Southeast
Southwest
UpperMidwest
West
NA
0.06
0.04
0.02
0.00
2004
2006
2008
2010
2012
2014

Northern Rockies



Assumptions

Same as that of Population Based Analysis

Sampling Technique

- Strata $\rightarrow$ Single region for single month
- Number of flights per month ranging from an average of 3,000 in Alaska to an average of 115,000 in the Southwest
- Proportional sampling $\rightarrow$ sampled approximately 2.5% of the flights in each stratum

Sample-based Results

- Very similar to the population results
- Heat map of monthly proportions show the same pattern
  - Nothing over 4%
  - Same bump in the summer in the south
- Zero proportion in some strata, with very low population proportions
- Standard errors all below 0.5%, and generally below 0.25%

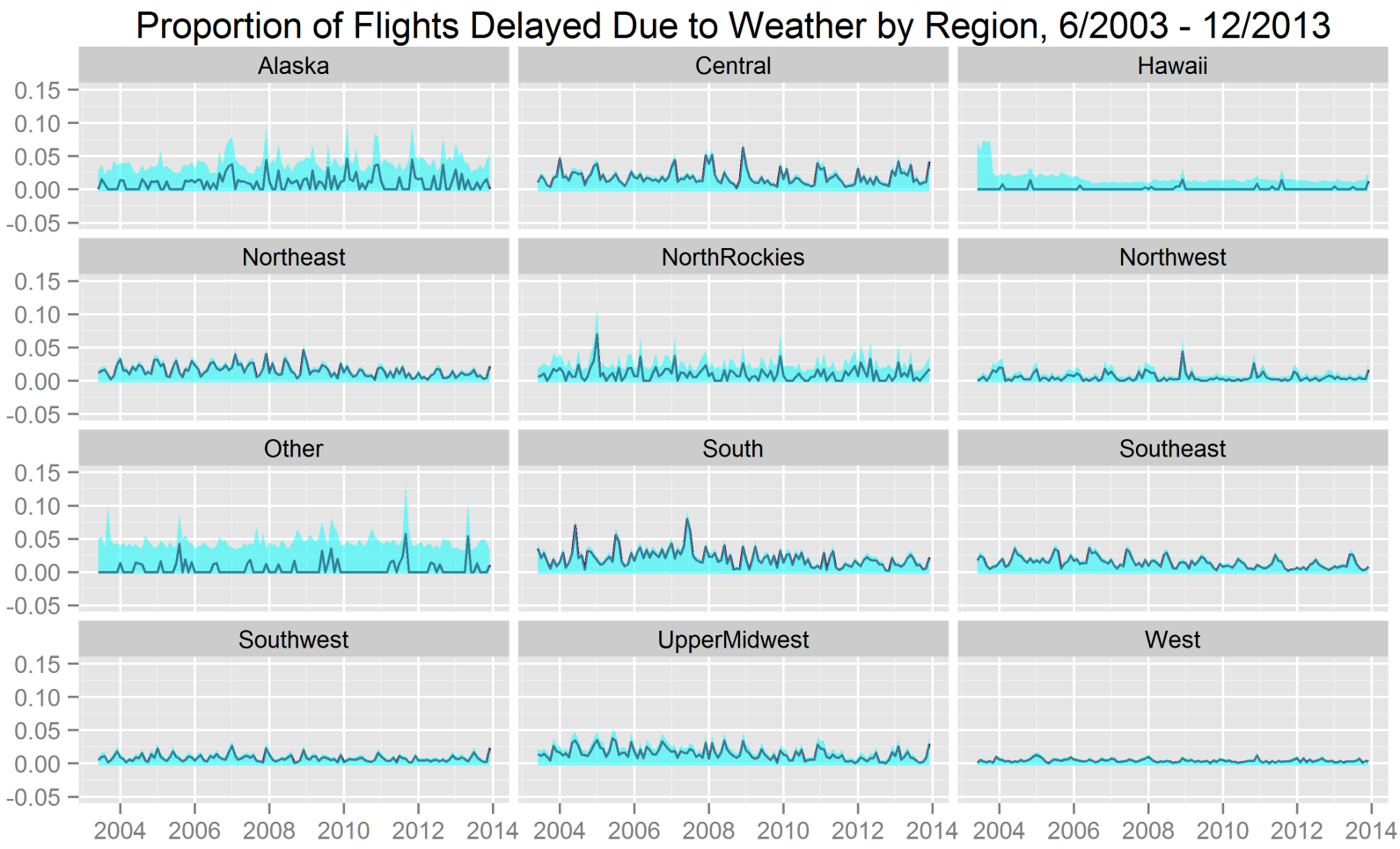
Proportion of Weather Delayed Flights, by Month

p (se(p))	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alaska	1.711%	0.939%	0.941%	0.650%	0.720%	0.334%	0.718%	0.649%	0.933%	0.728%	1.312%	1.820%
	(0.46%)	(0.38%)	(0.35%)	(0.29%)	(0.29%)	(0.16%)	(0.24%)	(0.23%)	(0.31%)	(0.27%)	(0.41%)	(0.46%)
Central	3.147%	2.795%	1.762%	1.349%	1.634%	1.963%	1.660%	1.468%	0.811%	0.870%	1.200%	3.323%
	(0.12%)	(0.12%)	(0.09%)	(0.08%)	(0.08%)	(0.09%)	(0.08%)	(0.08%)	(0.06%)	(0.06%)	(0.07%)	(0.12%)
Hawaii	0.047%	0.103%	0.048%	0.000%	0.045%	0.000%	0.039%	0.127%	0.000%	0.047%	0.137%	0.373%
	(0.05%)	(0.07%)	(0.05%)	(0.00%)	(0.04%)	(0.00%)	(0.04%)	(0.07%)	(0.00%)	(0.05%)	(0.08%)	(0.12%)
Northeast	2.029%	1.881%	1.382%	1.104%	1.065%	1.930%	2.159%	1.631%	0.799%	0.935%	0.982%	2.546%
	(0.10%)	(0.10%)	(0.08%)	(0.07%)	(0.07%)	(0.09%)	(0.10%)	(0.08%)	(0.06%)	(0.07%)	(0.07%)	(0.11%)
NorthRockies	1.519%	1.527%	0.758%	0.604%	0.799%	0.862%	0.763%	0.798%	0.474%	0.637%	1.372%	2.015%
	(0.31%)	(0.32%)	(0.22%)	(0.20%)	(0.22%)	(0.21%)	(0.19%)	(0.19%)	(0.17%)	(0.19%)	(0.29%)	(0.33%)
Northwest	1.079%	0.735%	0.519%	0.187%	0.086%	0.262%	0.219%	0.291%	0.179%	0.426%	0.885%	1.343%
	(0.16%)	(0.14%)	(0.11%)	(0.07%)	(0.04%)	(0.07%)	(0.06%)	(0.07%)	(0.06%)	(0.09%)	(0.14%)	(0.16%)
Other	0.135%	0.141%	0.000%	0.265%	0.878%	0.617%	0.711%	1.167%	0.864%	0.160%	0.146%	0.360%
	(0.13%)	(0.14%)	(0.00%)	(0.18%)	(0.35%)	(0.27%)	(0.29%)	(0.36%)	(0.38%)	(0.16%)	(0.14%)	(0.21%)
South	1.797%	1.948%	1.919%	1.979%	2.568%	3.235%	2.767%	2.229%	1.321%	1.387%	1.214%	2.477%
	(0.09%)	(0.10%)	(0.10%)	(0.10%)	(0.11%)	(0.12%)	(0.11%)	(0.10%)	(0.08%)	(0.08%)	(0.08%)	(0.11%)
Southeast	1.232%	1.114%	1.122%	1.038%	1.227%	2.568%	2.484%	1.944%	1.043%	0.845%	0.921%	1.235%
	(0.06%)	(0.06%)	(0.06%)	(0.06%)	(0.06%)	(0.09%)	(0.08%)	(0.08%)	(0.06%)	(0.05%)	(0.05%)	(0.06%)
Southwest	1.107%	0.695%	0.645%	0.560%	0.594%	0.852%	0.942%	0.939%	0.442%	0.354%	0.561%	1.569%
	(0.09%)	(0.07%)	(0.07%)	(0.06%)	(0.07%)	(0.07%)	(0.08%)	(0.08%)	(0.06%)	(0.05%)	(0.06%)	(0.10%)
UpperMidwest	1.645%	1.800%	1.190%	0.893%	1.765%	2.008%	1.795%	1.080%	0.877%	1.008%	1.155%	2.436%
	(0.14%)	(0.15%)	(0.12%)	(0.10%)	(0.14%)	(0.14%)	(0.13%)	(0.11%)	(0.10%)	(0.10%)	(0.11%)	(0.16%)
West	0.656%	0.475%	0.435%	0.214%	0.288%	0.276%	0.385%	0.351%	0.327%	0.388%	0.396%	0.716%
	(0.06%)	(0.05%)	(0.05%)	(0.03%)	(0.04%)	(0.03%)	(0.04%)	(0.04%)	(0.04%)	(0.04%)	(0.04%)	(0.06%)

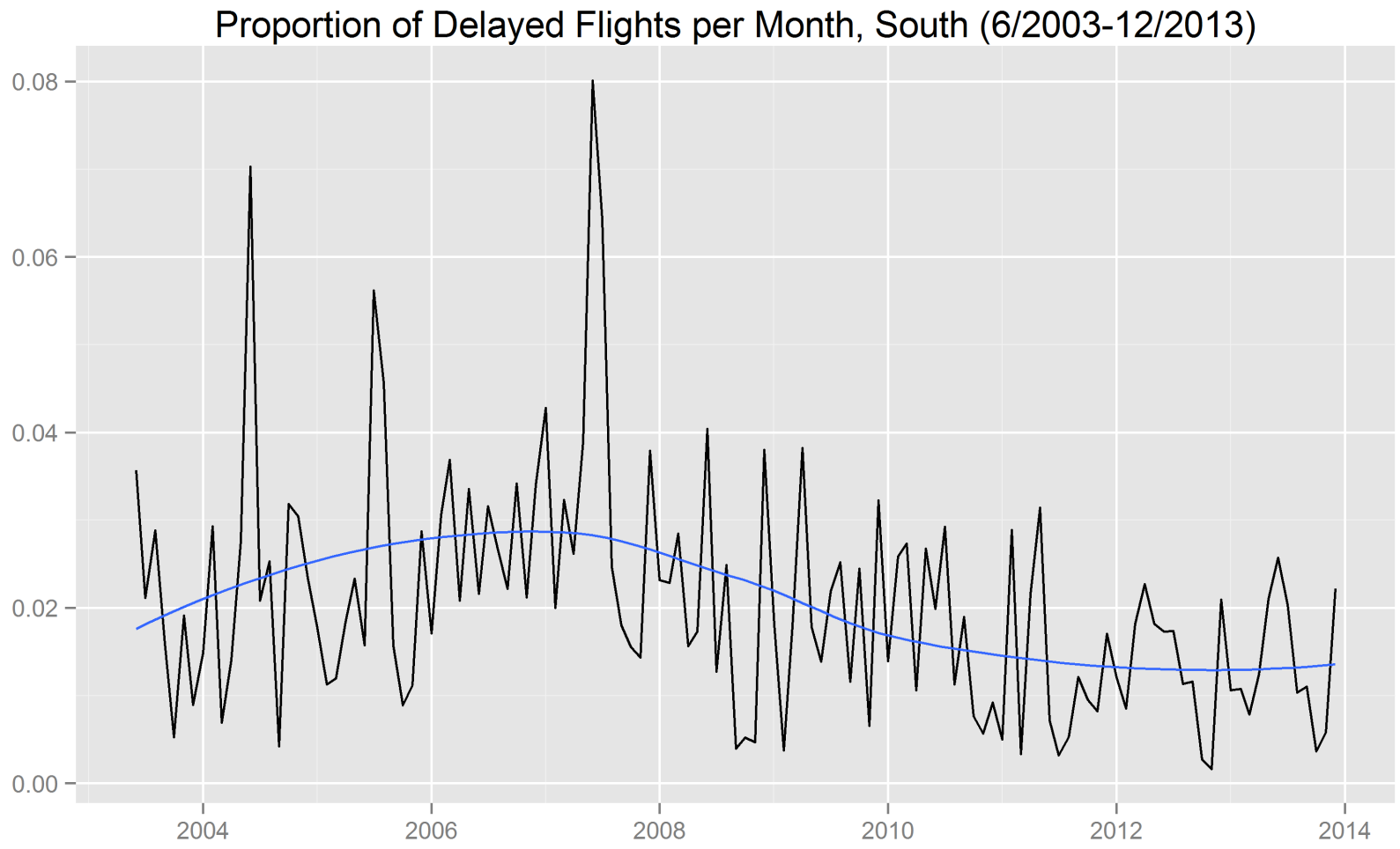
Sample-based Analysis

- Proportions with point-wise confidence intervals
- Regions Alaska, Hawaii and Other have greater margins of error
  - Small sample sizes
- No apparent trend over the years for most regions, except for the South
- South alone:
  - No obvious seasonal patterns
  - Bump at the end of 2006/beginning of 2007

All Regions


Proportion of Flights Delayed Due to Weather by Region, 6/2003 - 12/2013
Alaska
Central
Hawaii
Northeast
NorthRockies
Northwest
Other
South
Southeast
Southwest
UpperMidwest
West
0.15
0.10
0.05
0.00
-0.05
2004
2006
2008
2010
2012
2014

Southern Area



Discussion

- **Expecting**: seasonal differences (more delays in winter)
- **Not expecting**: large amount of summer delays, especially in South and Southeast
- Observed regional differences in amount of delays
- No significant shift in regional differences over time

Population and Sample Monthly Proportions

Population Data: Monthly Proportion of Delayed Flights by Region (6/2003 - 12/2013)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alaska	1.832%	1.353%	1.175%	0.517%	0.347%	0.319%	0.455%	0.661%	0.698%	0.865%	1.529%	1.768%
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Data was grouped by Month & Region, (n delay flights)/(n flights) for each of the 144 combinations.

p
(se(p))

Sample Data: Monthly Proportion of Delayed Flights by Region (6/2003 - 12/2013)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alaska	1.711%	0.939%	0.941%	0.650%	0.720%	0.334%	0.718%	0.649%	0.933%	0.728%	1.312%	1.820%
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Southwest	1.107%	0.695%	0.645%	0.560%	0.594%	0.852%	0.942%	0.939%	0.442%	0.354%	0.561%	1.569%
UpperMidwest	1.645%	1.800%	1.190%	0.893%	1.765%	2.008%	1.795%	1.080%	0.877%	1.008%	1.155%	2.436%
West	0.656%	0.475%	0.435%	0.214%	0.288%	0.276%	0.385%	0.351%	0.327%	0.388%	0.396%	0.716%

Obstacles and Solutions

- Defining regions & assigning regions to flights
  - `left_join` of DPLYR was very helpful
  - Saved the IATA, State and Region for all airports in a .csv file for easy use
- Five IATA codes in the data not documented in the Data Expo .csv file
  - Googled it!

Obstacles and Solutions

- Figuring out how to sample by our strata (region/month/year)
  - Define list of vectors:
    ```
    ak.list <- [All Alaska Airport Codes]
    c.list <- [All Central Airport Codes]
    ...
    r.list <- list(ak.list, c.list,...)
    ```
  - Within loop, assign one vector from list to a variable:
    ```
    o.list = r.list[[k]]
    ```
  - Within filter, use %in% statement and list variable:
    ```
    filter(...,origin %in% o.list,...)
    ```

Obstacles and Solutions

- Confidence intervals for zero proportions
  - Rule of Three: $3/n_h$ gives upper bound of 95% CI
- "Other" region: military bases and protectorates, not geographically consistent
  - Included in summary but no conclusions drawn from it