# Domestic U.S. Flight Evaluation Shiny Application

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Shiny for R provides a platform for developing web based graphical user interface (GUI) applications that implement customized data retrieval and analysis scripts written in R. Analytical results, in the form of standard R tables, graphs, lists, and so forth, are returned the user's browser in HTML that is formatted for effective presentation and interactive data analysis. An important feature of Shiny applications is referred to as *reactivity*. A reactive application dynamically binds GUI controls, such as selection lists, radio buttons, check boxes, and numeric range slider bars, to R function parameters, so that changes to on-screen controls trigger an immediate re-execution of associated R functions, followed by a refresh of results in the user's browser. Because Shiny is HTML based, a high degree of platform independence is achieved. Further, since no knowledge of R is required to execute and interact with a Shiny application, sophisticated analytical functions and models can be developed by domain experts with experience in R to be used by associates who are experts in their discipline, but may lack interest in or the time required for software development. A well designed Shiny application also promotes consistent execution of analytical functions since execution requires no modification of the structure or sequence of scripted instructions.

Following is a brief overview of an example Shiny application that graphically depicts the distribution of commercial air flights with departure and arrival at airports in the continental U.S.[1] Two styles of graph are used:

- A map of the continental U.S with arcs and arrows connecting destination and arrival airports, arcs sized and colored by proportion of all flights
- Distributions showing the density of departure delay caused by carrier and the difference in arrival delay and departure delay for all reasons (this is intended to measure the effectiveness of aircrew efforts to "make-up" for time lost waiting for departure

Each has a various GUI objects that control filtering and identification of flight categories such as carrier, month, weekday, proportion of flights, and delay status along with graph appearance controls such as for panel faceting, axis variable specification, axis limits, order of category appearance, categorical colors, arc size, airport labeling, alpha transparency, and appearance of vertical mean and median lines. Controls are reactive, so that changing them causes an "immediate" refresh of the on-screen graph. Due to the volume of arcs and airport labels on the flight map, "immediate" may actually be a lapse of one minute or more. However, using subtle adjustments, the analyst can progressively refine the appearance of a graph to highlight and contrast patterns identified in the data that are otherwise obscured.

[1]Data used are Carrier On-Time Performance records for January, April, July, and October 2018 as reported by the U.S. Bureau of Transportation Statistics (BTS). BTS requires major carriers to "report on-time data for flights they operate," which include "scheduled and actual departure and arrival times, canceled and diverted flights, taxi-out and taxi-in times, causes of delay and cancellation, air time, and non-stop distance." Additional information is available at `https://www.transtats.bts.gov/Tables.asp?DB_ID=120&DB_Name=Airline On-Time Performance Data&DB_Short_Name=On-Time`. Source data are available at `https://www.transtats.bts.gov/DL_SelectFields.asp`.

## U.S. Domestic Flight Map

Figure 1 contains a screen-shot of the flight graph. The origin and destination of each flight is connected by a directional arrow and connected airports are labeled. Due to the volume of traffic, conclusions using this graph are limited to crude observations such as an appearance of fewer routes in the northwest part of the map. To highlight patterns, differentiating colors, arc sizes, transparency, and paneling are needed. Graph controls appear at the top of the screen, including:

- Flight Proportion Threshold: This limits flights to those with a proportion of the total flights (in the data) greater than or equal to the specified value
- Airport Label Proportion Threshold: This limits airport labels to those with a proportion of total flights (departures or arrivals) greater than the specified value
- Color Low, Color Mid, Color High: This controls arc colors assigned to low, medium, and high proportion flights (these actually specify a continuous spectrum from low to high; the spectrum appears in the proportion flights legend to the right)
- Mid-color p Value: Specifies the centering proportion at which the mid-color is assigned (shifts the center of the low-high spectrum)
- Arc Size Range: Specifies the range of arc sizes assigned by relative proportion (low proportion flights are assigned values near the low end, high proportion flights from near the upper end)
- Arc Alpha Range: Specifies the range of alpha transparency values (low proportion assigned low alpha, or high transparency, high proportion flights are more opaque, from near the upper alpha range)
- Facet Variable: Specifies from which variable to subset the data; a separate panel (map) is rendered for each subset
- Carrier Delay Only: Checked limits flights to those identified as having been delayed due to the carrier (airline)
- Include Cancellations: Checked includes canceled flights

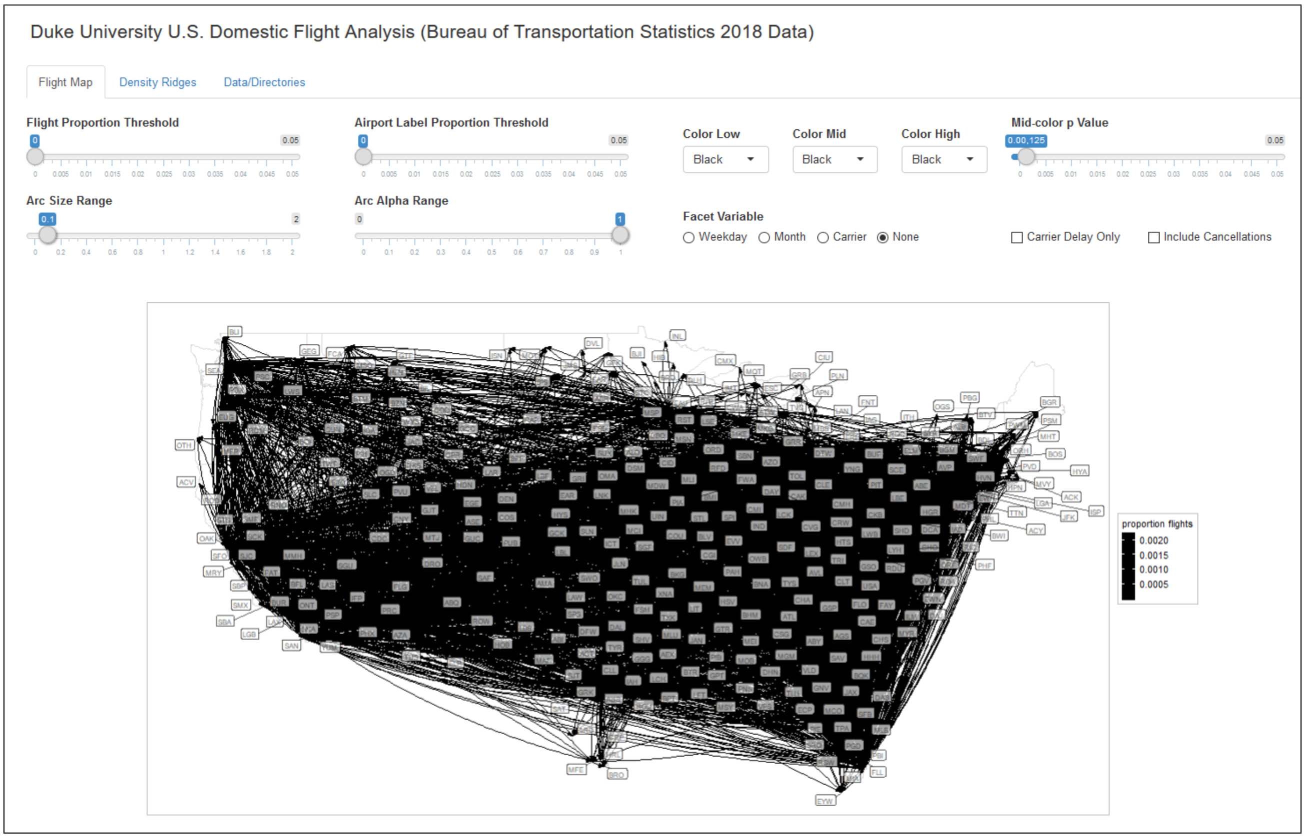


Figure 1: Single panel graph of all flights in data. No differentiating colors, transparency, or arc sizes employed.

Adjustments to proportions for flight appearance and airport labeling, arc colors, size, and transparency help to reveal high volume routes. Figure 2 shows adjustments to GUI controls along with the resulting graph.

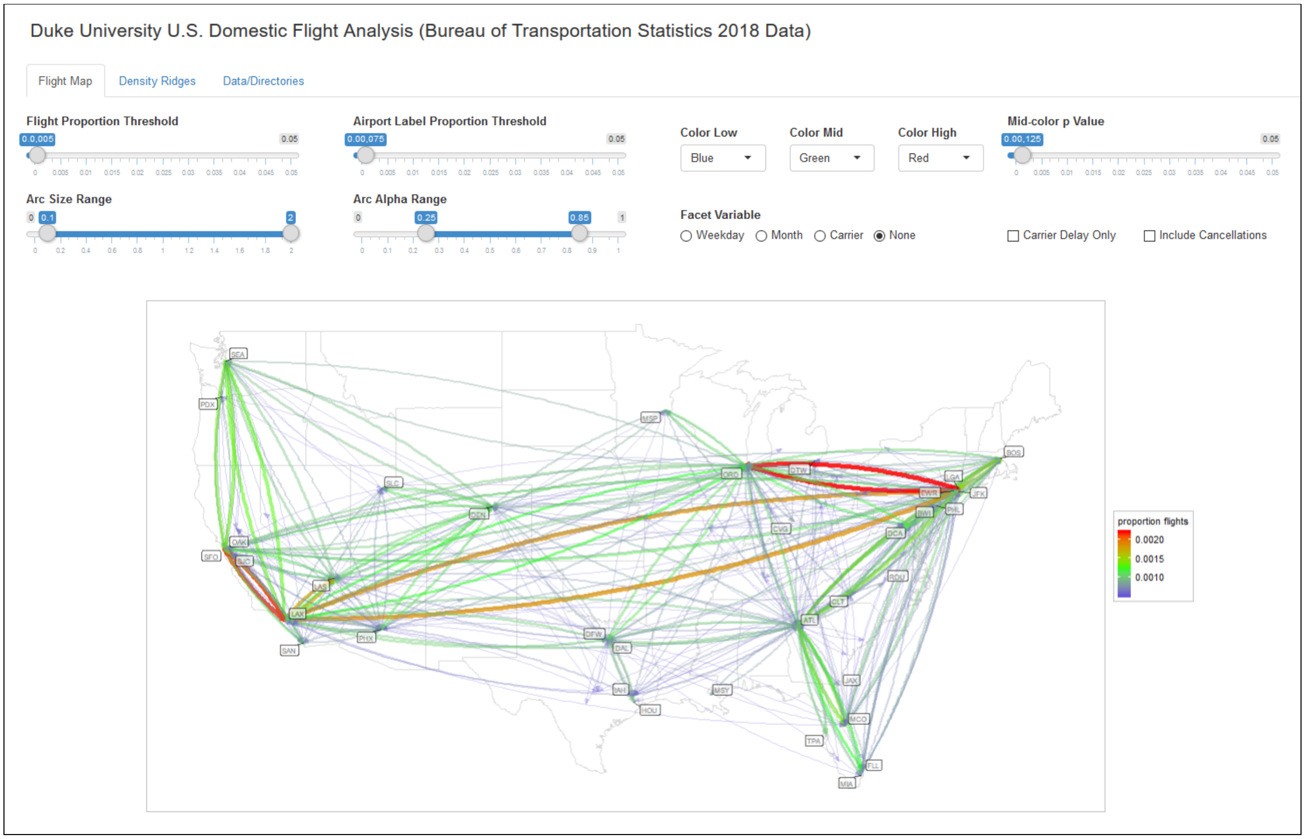


Figure 2: Single panel graph. Limited to high proportion flights and airports. Arc size (weight), color, and transparency proportional to observation mass in data.

Figure 2 represents all flights in the data set. Additional, more detailed patterns are made visible by subsetting the data and producing a panel of graphs, one for each subset. Figures 3, 4, and 5 panel graphs by weekday, month, and carrier. Significant patterns are clearly visible (for carriers and months represented in the data), such as

- LGA-ORD (both directions) and LAX-SFO (both directions) are high volume routes on weekdays, indicating that weekend traffic between all airports is more uniformly distributed than is weekday traffic
- The proportion of flights between LGA and LAX is greater in January and April than in July and October
- Regions and airports served by carrier are clearly identified

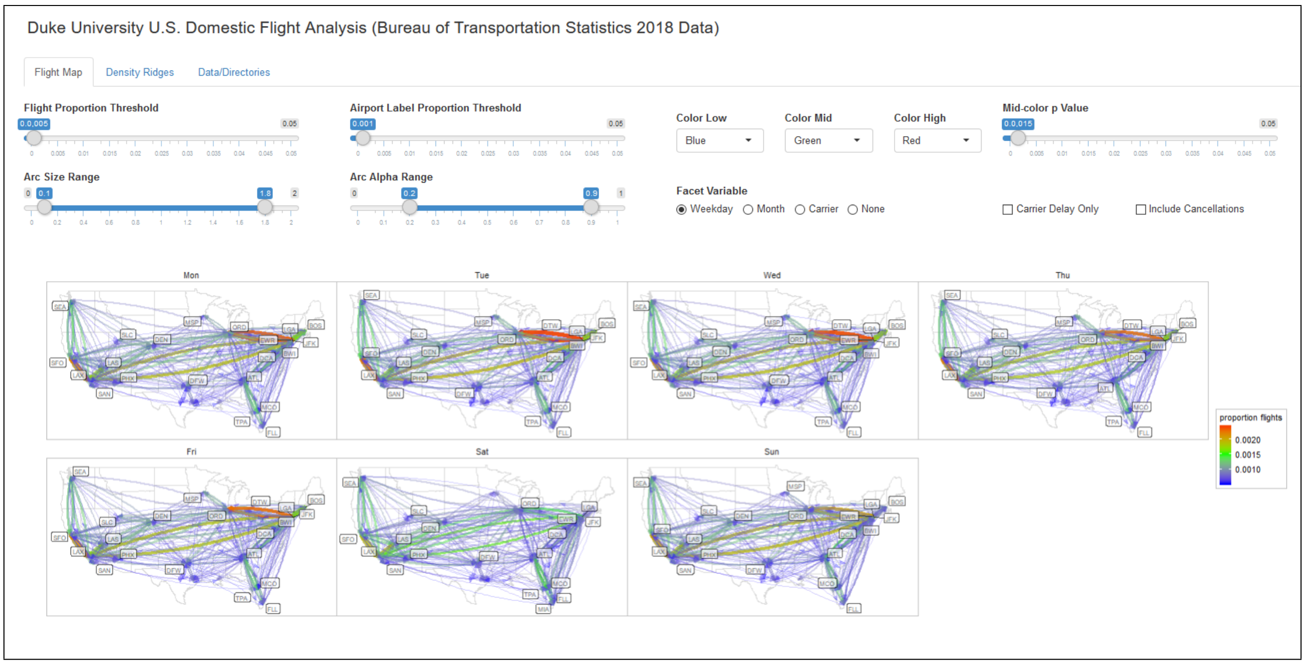


Figure 3: Multi-panel graph, by weekday. Proportions computed within panel subset. Flights and airports filtered by proportion. Arc size (weight), color, and transparency adjusted to highlight proportion contrasts.

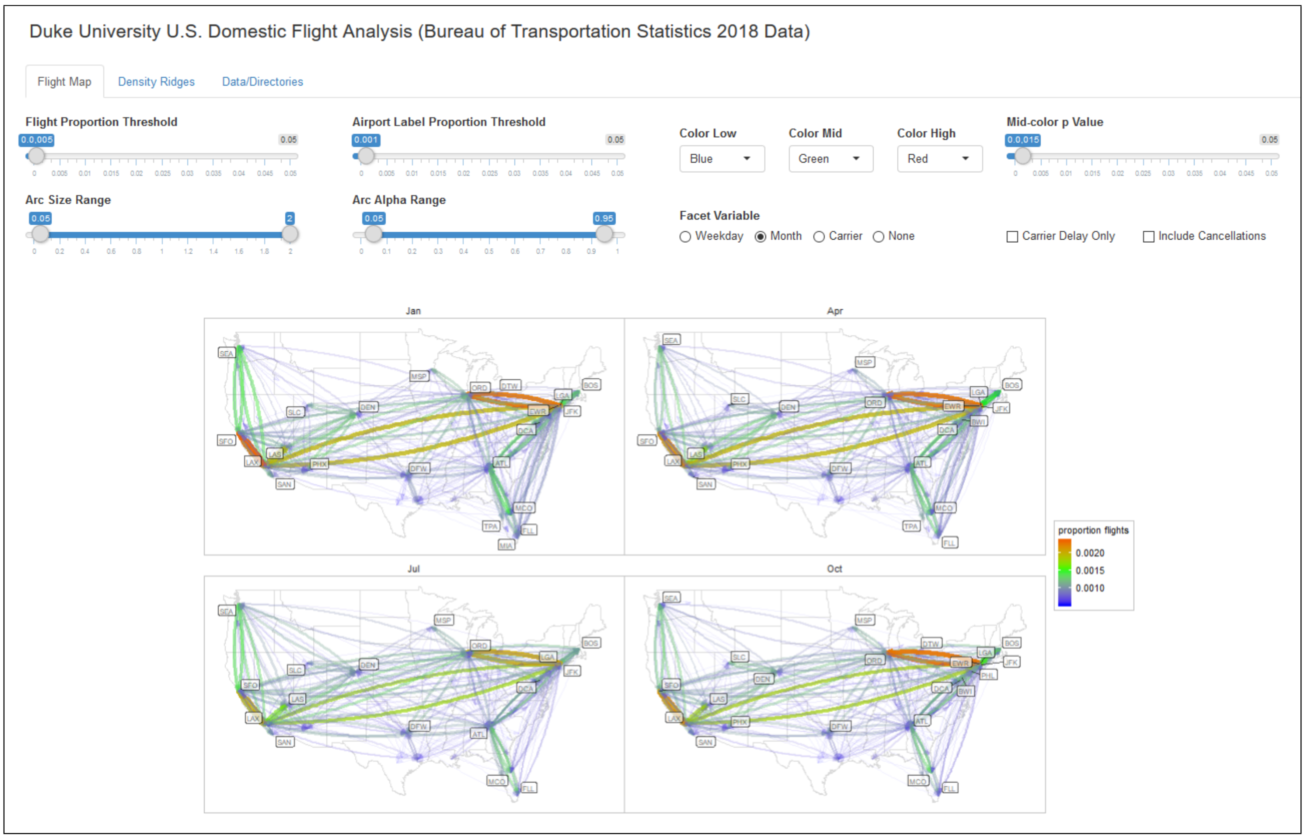


Figure 4: Multi-panel graph, by month. Proportions computed within panel subset. Flights and airports filtered by proportion. Arc size (weight), color, and transparency adjusted to highlight proportion contrasts.

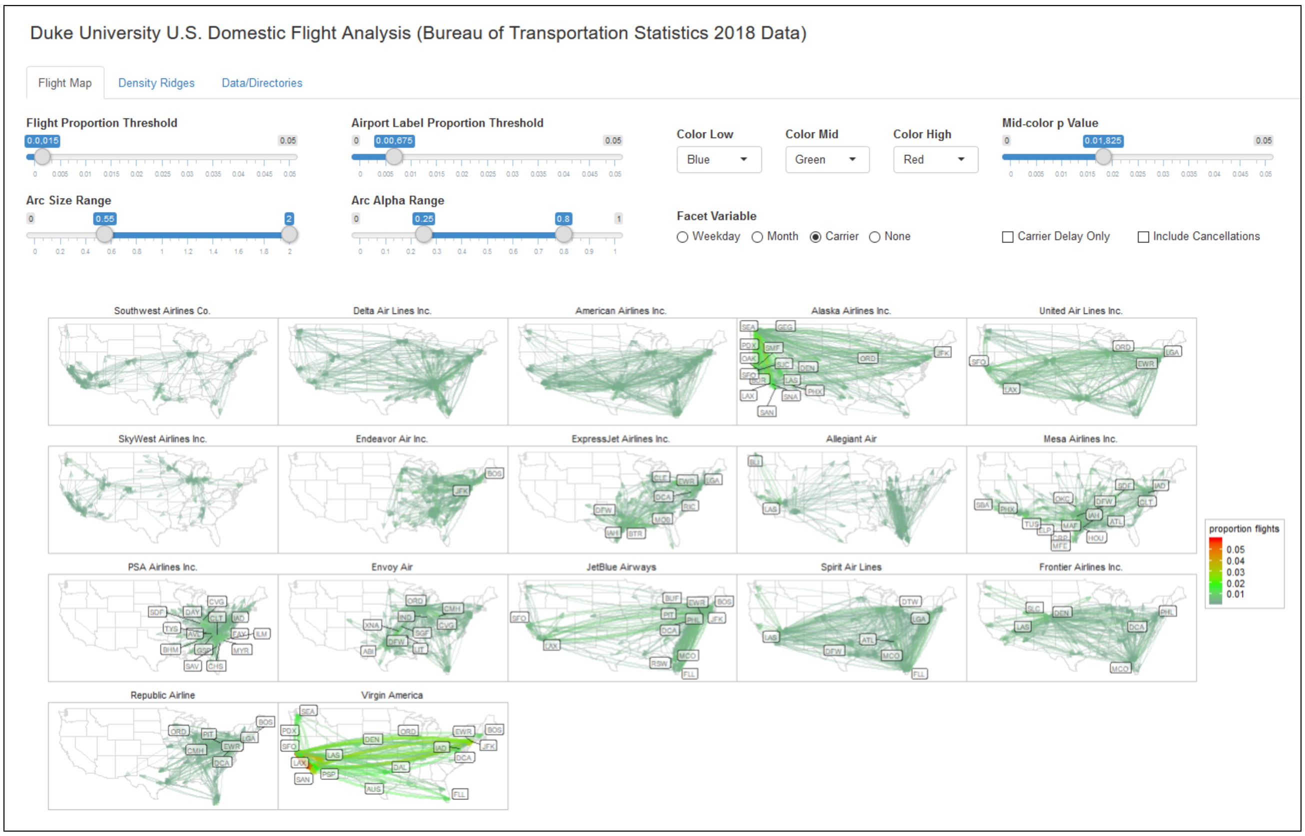


Figure 5: Multi-panel graph, by carrier. Proportions computed within panel subset. Flights and airports filtered by proportion. Arc size (weight), color, and transparency adjusted to highlight proportion contrasts.

Figure 6 shows flights delayed due to carrier reasons, paneled by weekday.

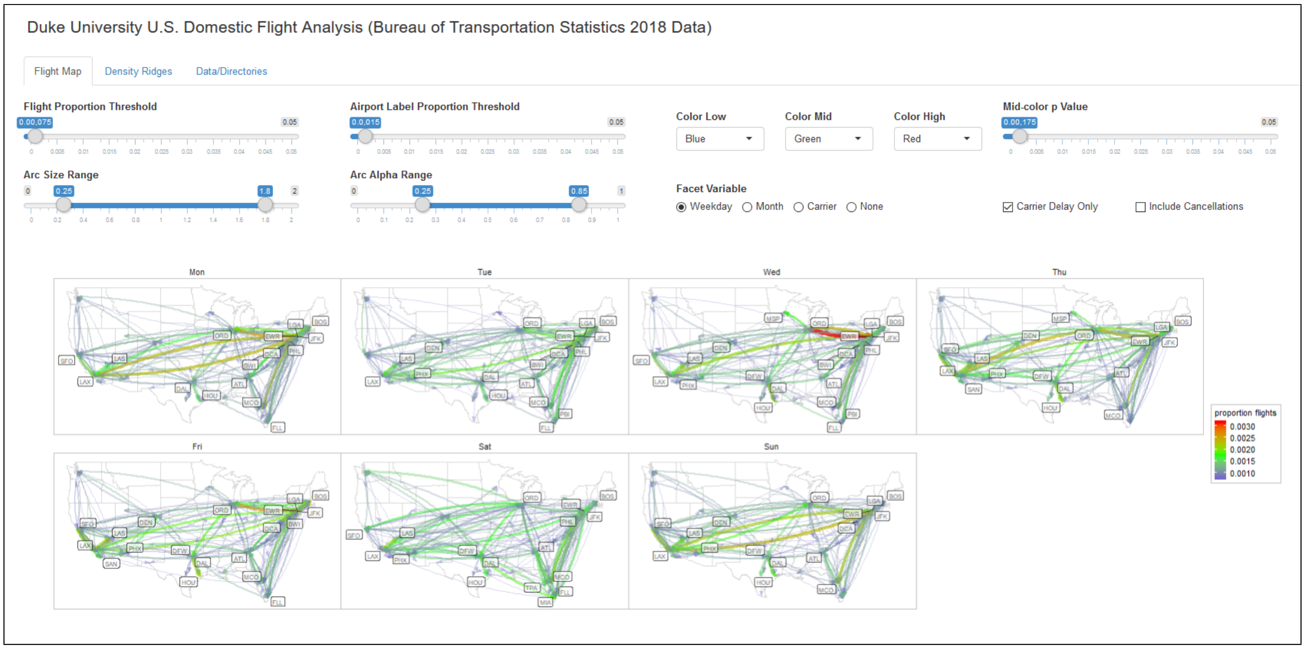


Figure 6: Multi-panel graph, by weekday. Limited to flights delayed due to carrier. Proportions computed within panel subset. Flights and airports filtered by proportion. Arc size (weight), color, and transparency adjusted to highlight proportion contrasts.

## Distribution of Carrier Delay and Difference in Arrival and Departure Delay

The previous section graphically presented the geographic distribution of flights. Also of interest is the distribution of important operational performance measures such as departure delay. Figure 7 contains a screen-shot of this distribution for each weekday. Graph controls appear at the top of the screen, including:

- x: The performance measure (departure delay or difference in arrival and departure delay) to be graphed on the x-axis
- x Limits: The lower and upper bounds of the x-axis
- y: The categorical variable from which to subset the data (weekday, month, or carrier); one distribution is displayed for each level of this variable
- y Order: Specifies the order (alphabetic, mean of x, or median of x) of categorical variable levels on the y-axis
- Color Low, Color High: Range of fill colors applied to y category distributions
- Reverse Color: Reverses the order of colors (low becomes high, high becomes low)
- Alpha: Controls transparency of distribution fill color
- Facet Variable: Variable by which to subset data (weekday, month, carrier); one set of graphs are generated for each level of the subset variable
- Vertical Lines: Specifies x values at which to draw vertical lines (mean, median, zero)


Figure 7: Distribution of carrier delay in minutes. Weekday on y-axis. No facet variable selected.

Figures 8 through 10 present various carrier departure delay results achieved by adjusting GUI controls. Increased detail of patterns of distribution should be noticed as the data are increasingly subset. Figure 11 compares distributions of the difference in arrival and departure delay, by weekday, within carrier. Vertical reference lines at zero enable comparison to a standard operating goal.

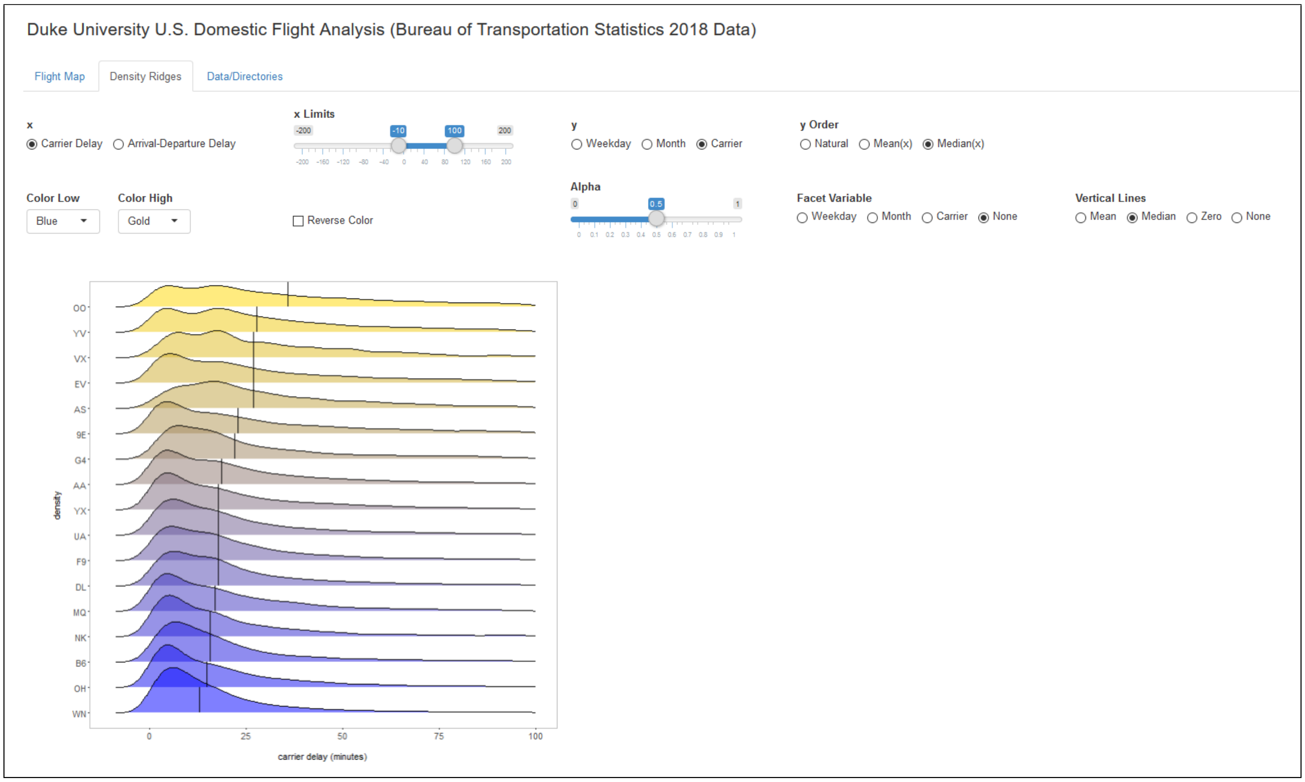


Figure 8: Distribution of carrier delay in minutes. Carrier on y-axis. y-axis levels in order of median delay. Median delay indicated by vertical lines.

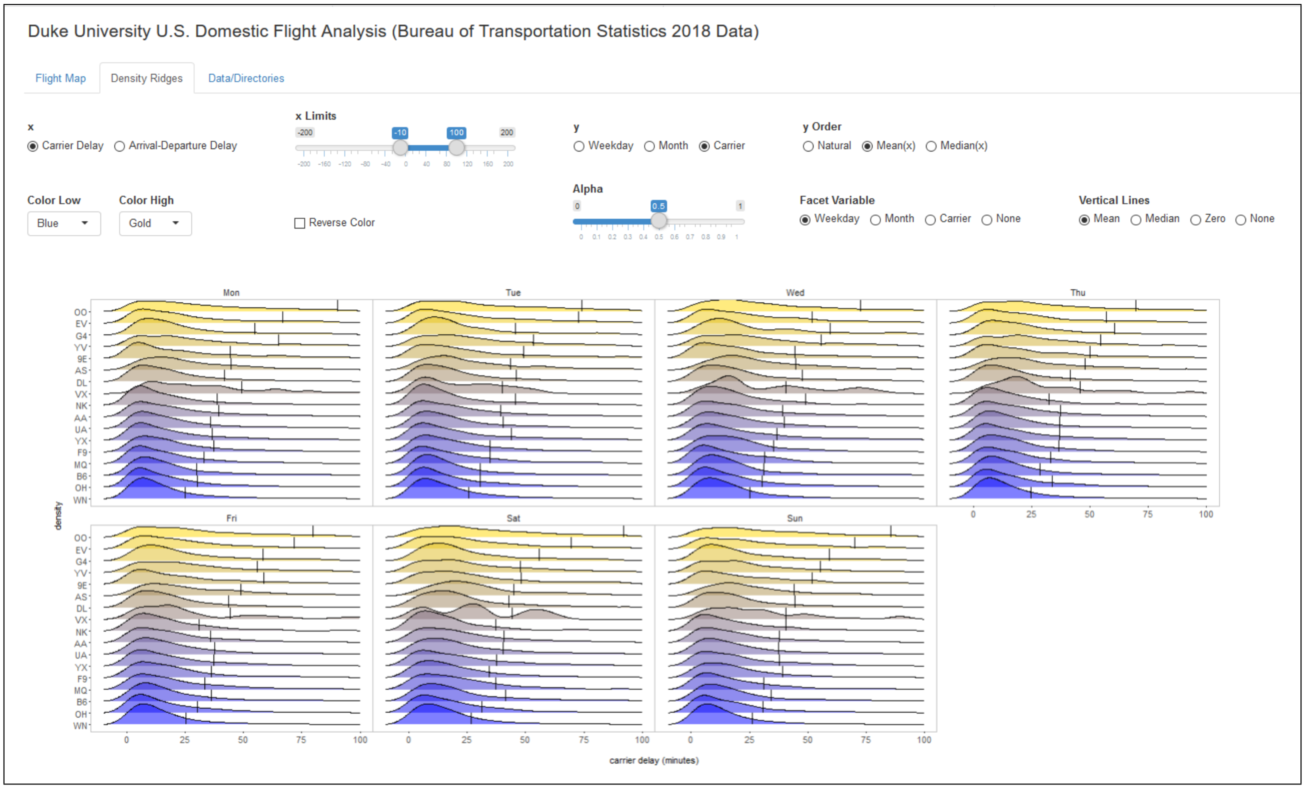


Figure 9: Distribution of carrier delay in minutes, by carrier within weekday. y-axis levels in order of mean delay. Mean delay indicated by vertical lines.

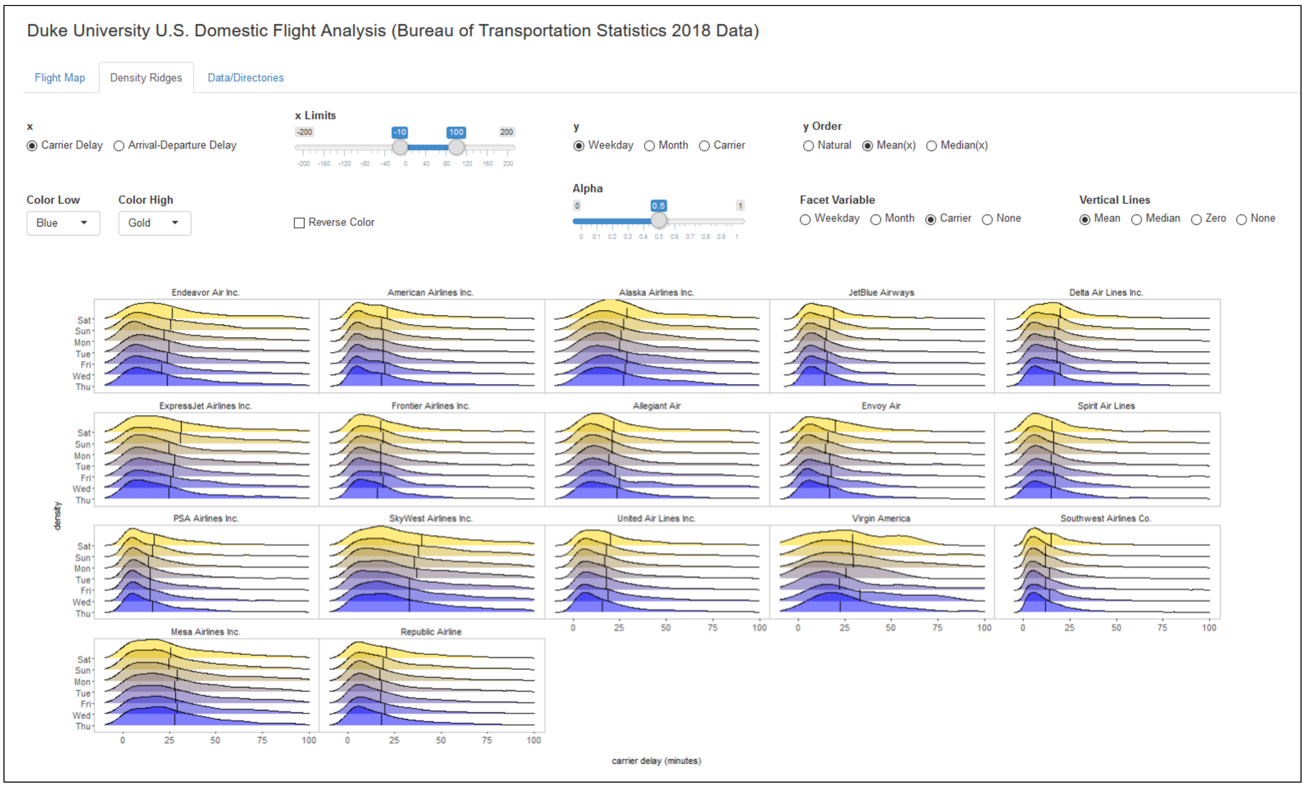


Figure 10: Distribution of carrier delay in minutes, by weekday within carrier. y-axis levels in order of mean delay. Mean delay indicated by vertical lines.

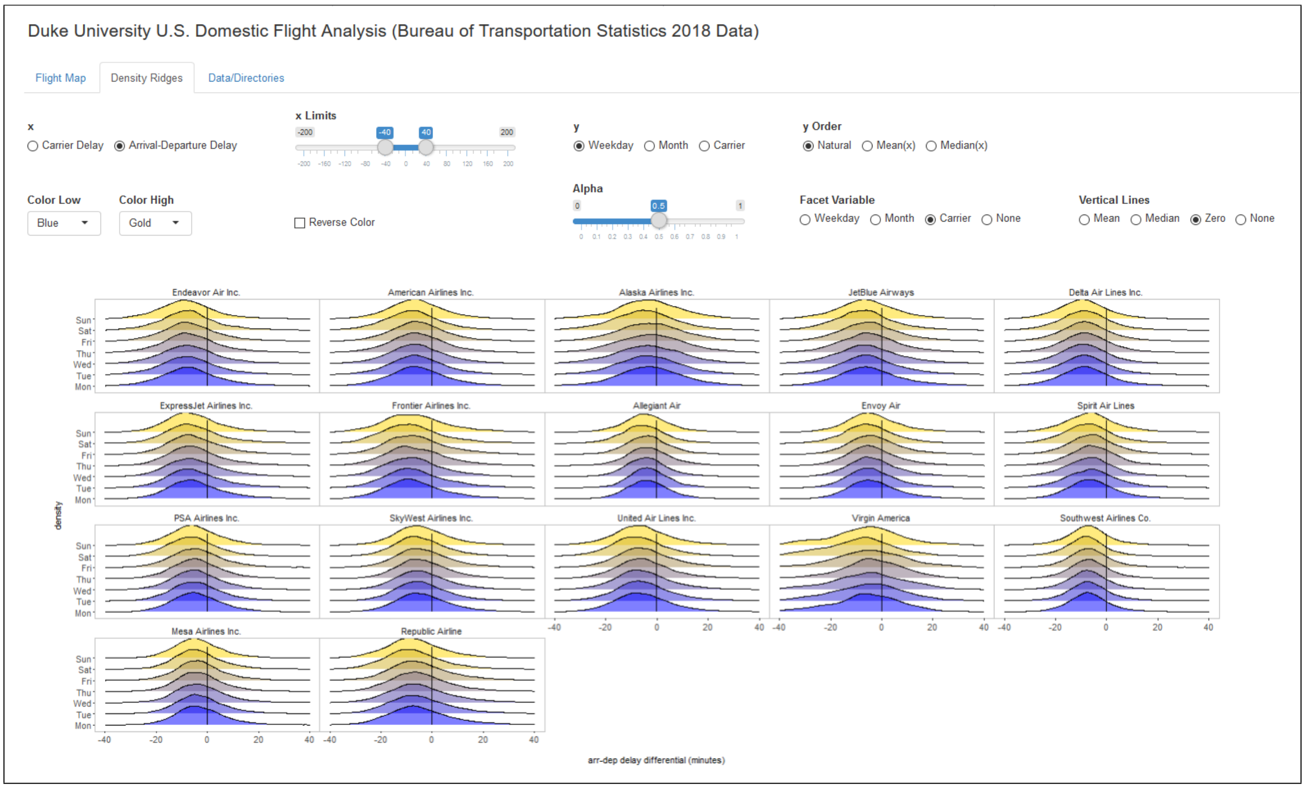


Figure 11: Distribution of difference in arrival and departure delay, in minutes, by weekday within carrier. y-axis levels in natural order. Vertical lines at zero for inter-carrier comparison to reference or goal.

## Supplement: Regression Models

Table 1 contains regression results for four fixed effects models fit to the domestic flight data from previous sections. Although generated using an R script, the table could be produced from within a Shiny application that executes corresponding R instructions. Model parameters, standard error types (clustered or homoscedastic), various table formats, and model analysis plots could be specified using Shiny GUI objects as previously demonstrated. Figure 12 shows mean predicted value vs. actual value for the independent variable, log(departure delay), using model 2 of table 1. Plots such as this can also be generated by executing appropriate R commands from within Shiny.

Table 1: Example regression models fit to domestic flight data. All standard errors clustered about aircraft tail number.

| parameter | model 1 | model 2 | model 3 | model 4 |
|---|---|---|---|---|
| b0 | 2.85337 | 2.94705 | 2.61346 | 2.63878 |
| SE | 0.00891 | 0.01023 | 0.00821 | 0.11631 |
| P(T > \|t\|) | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| distance | -0.00011 | -0.00011 | -0.00008 | -0.00011 |
| SE | 0.00001 | 0.00001 | 0.00000 | 0.00000 |
| P(T > \|t\|) | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| month(4) | -0.06780 | -0.06526 | -0.03527 | -0.04055 |
| SE | 0.00687 | 0.00688 | 0.00661 | 0.00652 |
| P(T > \|t\|) | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| month(7) | 0.11463 | 0.11886 | 0.13507 | 0.13746 |
| SE | 0.00688 | 0.00687 | 0.00640 | 0.00629 |
| P(T > \|t\|) | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| month(10) | -0.12785 | -0.12466 | -0.11058 | -0.11024 |
| SE | 0.00731 | 0.00730 | 0.00678 | 0.00670 |
| P(T > \|t\|) | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| weekday(2) | | -0.04492 | -0.03779 | -0.03750 |
| SE | | 0.00688 | 0.00682 | 0.00674 |
| P(T > \|t\|) | | 0.00000 | 0.00000 | 0.00000 |
| weekday(3) | | -0.16282 | -0.15227 | -0.15183 |
| SE | | 0.00733 | 0.00719 | 0.00712 |
| P(T > \|t\|) | | 0.00000 | 0.00000 | 0.00000 |
| weekday(4) | | -0.15968 | -0.14339 | -0.14060 |
| SE | | 0.00732 | 0.00720 | 0.00712 |
| P(T > \|t\|) | | 0.00000 | 0.00000 | 0.00000 |
| weekday(5) | | -0.05681 | -0.04377 | -0.04063 |
| SE | | 0.00711 | 0.00700 | 0.00692 |
| P(T > \|t\|) | | 0.00000 | 0.00000 | 0.00000 |
| weekday(6) | | -0.22247 | -0.21171 | -0.19899 |
| SE | | 0.00806 | 0.00786 | 0.00778 |
| P(T > \|t\|) | | 0.00000 | 0.00000 | 0.00000 |
| weekday(7) | | -0.11681 | -0.10753 | -0.10193 |
| SE | | 0.00717 | 0.00703 | 0.00695 |
| P(T > \|t\|) | | 0.00000 | 0.00000 | 0.00000 |
| airline FE | no | no | yes | yes |
| departing airport FE | no | no | no | yes |
| arriving airport FE | no | no | no | yes |

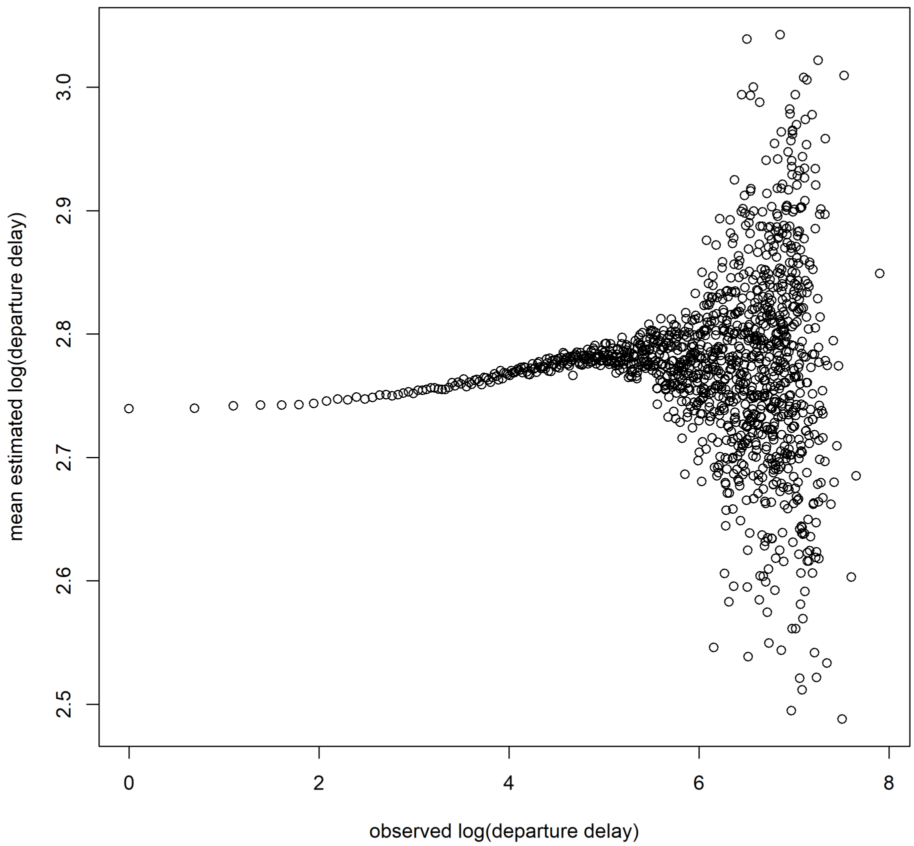


Figure 12: Plot of mean log(predicted departure delay) vs. observed log(departure delay) for model 2 of table 1.