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Mapping Air Population

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Abstract: "Air population" refers to the total number of people flying above the earth at any point in time. The total number of passengers can then be estimated by multiplying the number of seats for each aircraft by the current seat occupancy rate. Using this method, the estimated air population is determined by state for the airspace over the United States. In the interactive, real-time mapping system, maps are provided to show total air population, the density of air population (air population / area of state), and the ratio of air population to ground population.

Keywords: Air Traffic, Air Population, ADS-B, Real-time Population, Air/Ground Population Ratio

1. Introduction

Some population is ephemeral. For instance, central business districts in cities are said to have "high daytime populations." A number of studies have examined US Census Bureau American Community Survey data on daytime populations at the county level (Badhuri 2008, Laughlin, et al, MacKenzie, et al.). It was found that the population of Manhattan doubles to over 3.0 million during the day from a base of about 1.5 million (Badger 2013). While the ratio of daytime and nighttime population varies for cities throughout the world, all cities exhibit a commuter pattern that results in major diurnal shifts in population.

Another population shift takes shape in the sky everyday as people commute across large distances. For purposes of this study, air population is defined as the number of people who reside above the earth at a particular point in time. The purpose here is to map air population for the United States by state throughout the day.

2. Real-Time Air Population

Since 2007, private networks of receivers have facilitated the mapping of flights. The system is based on the Automatic Dependent Surveillance-Broadcast (ADS-B) that broadcasts the precise and instantaneous location of aircraft. Thousands of ground stations monitor these locations, sending their data to central servers. This data is used to estimate air populations.

2.1 Flight Tracking

Estimating air population starts with determining the instantaneous position of all aircraft. A number of companies such as FlightAware, FlightRadar24, and PlaneFinder now gather this data.

Data gathering is accomplished through different types of ADS-B receivers. The most popular of these receivers is based on a Raspberry Pi (Biggs 2013). Costing less than $50, the computer runs Debian – a specific version of the Linux operating system. Attached to the computer's USB port is a receiver originally designed to receive over-the-air television. The receiver is attached to an antenna to acquire the ADS-B broadcast. The device, costing less that $80, is pictured in Figure 1.

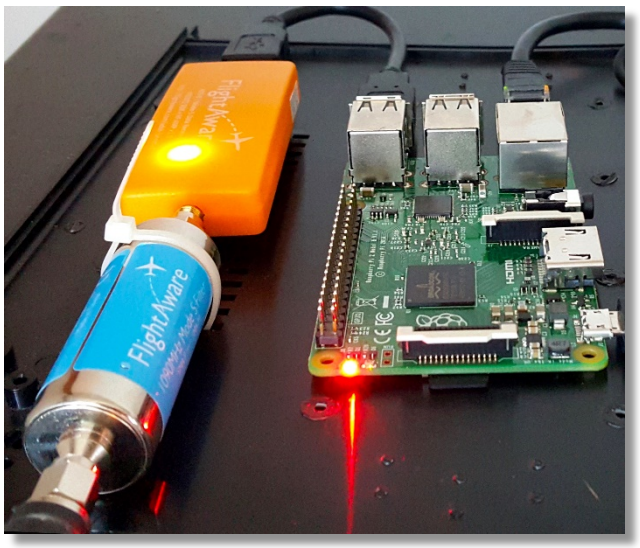

Fig. 1. FlightAware's PiAware ADS-B receiver based on a Raspberry Pi computer (right), ADS–B dongle (left-rear) and filter (left-front). Connected to an antenna, the $80 device monitors air traffic and sends data to FlightAware's servers. Over 7000 of these receivers have been placed throughout the world.

ADS-B sends a message every 30 seconds. A plot of aircraft from a single Raspberry Pi-based receiver is shown in Figure 2. A single aircraft and its route is shown in Figure 3 that depicts a flight from Toronto to Los Angeles.

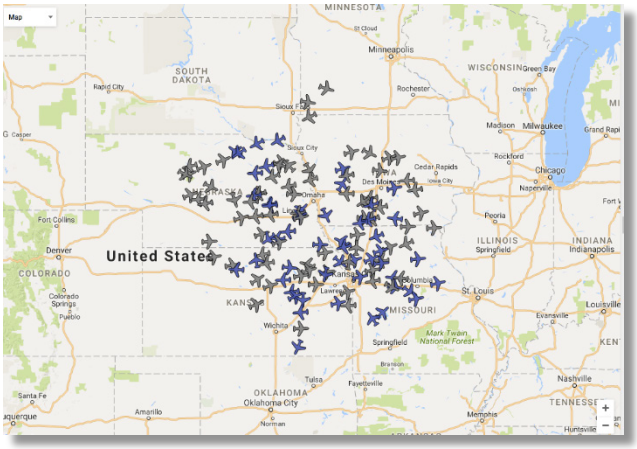

Fig. 2. Planes monitored by a single ADS-B receiver located at the University of Nebraska at Omaha. Reception is line-of-site. The maximum range equates to about 225 miles (402 miles) for aircraft flying at altitudes above 30,000 feet.

Fig. 3. A single flight flying above the state of Nebraska. Air Canada flight 789, a Boeing 767-300 jumbo jet, is flying at 34,000 feet (340) at a speed of 430 knots (796 km/h) from Toronto (CYYZ) to Los Angeles (KLAX) with an estimated arrival at 10:11 AM local time. An ADS-B receiver based on a Raspberry Pi located in Omaha, Nebraska, captured the flight.

Multiplying the number of seats in the airplane by the current airline occupancy rate, and adding the number of crewmembers, results in an estimate for the number of people on the aircraft. Summing these population estimates for all the airplanes flying over a state creates the state's air population.

Air populations vary dramatically by state. In the early afternoon, states like California and Texas will have air populations above 20,000 people. Other states like Idaho and North Dakota may only have a few hundred.

The overall air population for the 48-contiguous states plus the District of Colombia will vary between nighttime values of less than 30,000 to daytime highs over 300,000 people. With a US ground population of about 320 million, the daytime air population is nearly 0.1% of the total (300,000 / 320 million).

2.2 Mapping Air Population

Air population data are mapped using ESRI's ArcGIS API for JavaScript. This API includes the ability to perform spatial queries that allows features to be intersected based on geographic location.

Air population is mapped in a variety of ways. The map in Figure 4 depicts the population by state. The location of each aircraft can be placed on top of the map, as shown in Figure 5.

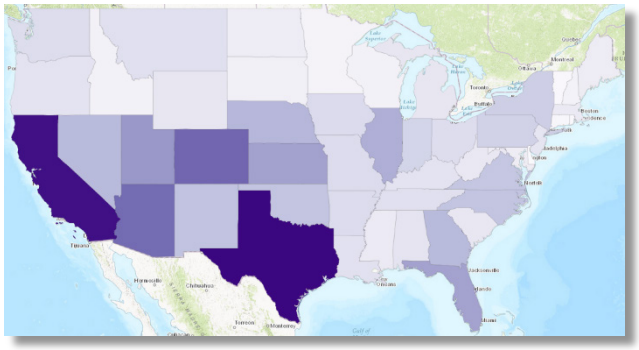

Fig. 4. A choropleth map showing absolute air population by state for the United States. Values range from a high of nearly 20,000 passengers for Texas to a low of 500 for Idaho.

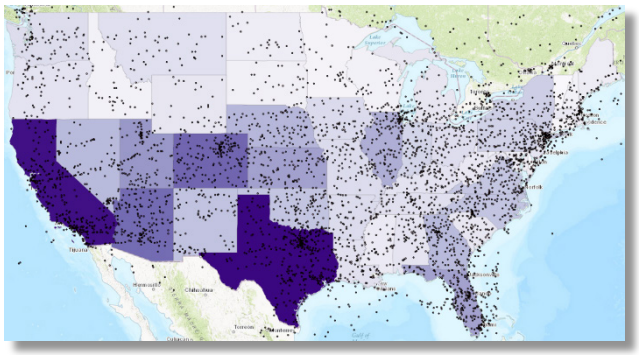

Fig. 5. Positions of aircraft super-imposed on the map of air population from Figure 4.

Air population is also mapped with the "heat map" approach that computes a density value per unit area (see Fig. 6). A triangle of sorts is visible between New England, Southern Florida and the San Francisco Bay area.

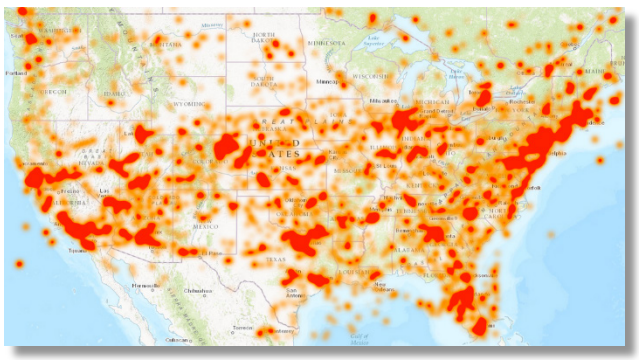

Fig. 6. A heat map of air population. The combination of coastal and transcontinental connections creates a triangle of air traffic across the country.

Air population density can also be mapped by dividing air population by the area of each state. Figure 7 shows the air population for the 48 states plus the District of Columbia. At only 68.34 sq. miles, Washington, DC, is the smallest of all entities mapped. A handful of flights over the district will skew the population density values

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so that, using the unclassed method, the remaining states will be barely shaded (see Fig. 8).

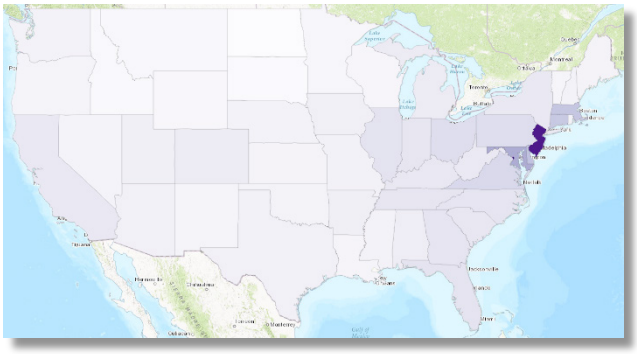

Fig. 7. Air population density map. Like ground population density, smaller states on the east coast also have higher air populations densities.

Fig. 8. Air population density map of the east coast of the United States. Depending upon current flight pattern, small areas like Washington, DC, will have very high air population densities. If planes are not directly above the small area that constitutes DC, then Rhode Island or New Jersey will usually have the highest air population density.

Figure 9 depicts the ratio of air population to ground population. Values range from a low of 0.00036 for New York State to a high of 0.007 for Wyoming. The ratio clearly defines what is commonly referred to as "flyover states."

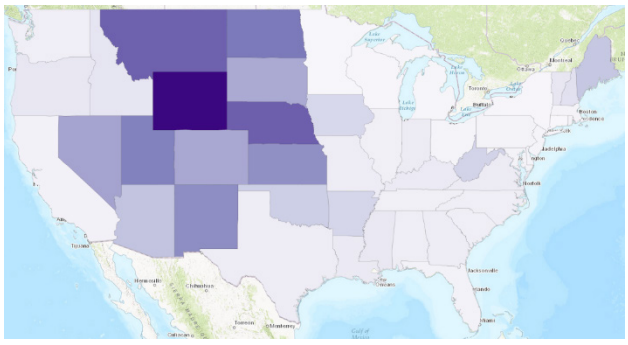

Fig. 9. The ratio of air to ground population.

3. Conclusions

Air population for the 48 states plus Washington, DC, regularly exceeds 300,000 during the early afternoon hours. Individual states like California and Texas have air populations that exceed 20,000. Air population density is generally highest in states like Maryland, Massachusetts, Washington, DC, and New Jersey.

The ratio of air-to-ground population clearly shows the so-called flyover states. The Great Plains and southwestern US are in the east-west flight corridor and generally have higher air-to-ground ratios than the rest of the country.

4. References

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