Observe the Eclipse from a Passenger Jet!

By Dr. Sten Odenwald (NASA/HEC)

Although many people plan to be on the path of totality to observe the August 21, 2017 total solar eclipse, there are other opportunities to see this rare event that may surprise you!

Regularly-scheduled passenger jets will be crossing the path of totality and for those who will be on these flights, they too will have the opportunity to look out their windows and see the eclipse in progress. At any given hour of the day, there are literally thousands of passenger jets in the air over the continental United States. Many of these flights will be crossing the path of totality at exactly the right moment…but which ones?

You can figure this out yourself with a bit of sleuthing and mathematics!

Airline scheduling is based on the takeoff and landing times given in the local time units which will be Pacific Standard Time, Mountain Standard Time, Central Standard Time or Eastern Standard Time.

These times are converted into the common Universal Time by adding the following time increments: PST+7h, MST+6h, CST+5h and EST+4h. The total solar eclipse starts at 17: 16 on the West Coast and ends at 18:49 on the East Coast. What you need to do is to search through all the flights and find those that leaves at the right time so that they will be flying over the path of totality at the time the total solar eclipse is in progress at that location. Because the lunar shadow travels at a speed of over 2000 km/hr, the timing has to be exact or you will miss the event completely. Since it only lasts a bit more than 2.5 minutes, any actual flight delays or minor route changes will be enough for you to arrive at the right geographic spot along the path, but either too late or too early!

Here's how to do it!

Through trial and error and some estimates, I found 100 scheduled flights in February 2017 that would be in the air over the path of totality around the time of the eclipse on August 21, 2017. I looked at the major hubs like Chicago, New York, Los Angeles, San Francisco, Denver, Atlanta and a dozen other popular cities, to search for incoming and outgoing flights that I estimated would be crossing the path around the right time to within an eyeball-accuracy of a few hours. Then from this sample, I did a detailed calculation of their flight paths and timings to see which of these flights would be potential viewing locations. Here is how I did this calculation.

1) For each flight, I determined the latitude and longitude of the endpoint cities
2) I converted the takeoff and landing times into Universal time.
3) From the difference in latitudes and the travel time in decimal hours, I calculated the latitude speed of the plane in degrees/hour. From the difference in longitudes I calculated the longitude

speed of the flight in degrees/hour. Example Delta flight 393 leaves Chicago for Atlanta with a flight time of 2h 11m (2.183hrs) where Chicago (41.878N, 87.63W) and Atlanta(33.75N, 84.388W). Traveling from Chicago to Atlanta the change in latitude is -8.129 degrees and in longitude it is -3.242 degrees. The latitude speed is then -8.129/2.183 = -3.724 deg/hr. In Longitude we have -3.242/2.183 = -1.485 deg/hr.

4) For each flight I created a pair of linear equations that predicted their straight-line path from their origin city to their destination city. I did not include earth curvature and 'geodesic' path corrections because the flights spanned only a few degrees and at this scale there is not a large expected correction….but it could amount to several minutes which would be enough to 'miss' the eclipse. However inflight speed changes also amount to several minutes so the eclipse forecast is only an approximation.

5) The pair of linear equations y = mT + b, were created by using the latitude and longitude of the origin city to set up the 'b' terms in decimal degrees, and the angular speeds from Step 3 above to set up the speed coefficients 'm'. From the example above in Step 3 we would get the two equations for the flight path where T is the time in decimal UT hours of

$$Latitude = -3.724\, T + 41.878 \qquad Longitude = -1.485\, T + 87.63$$

6) The total eclipse lasts from 17.2664 UT to 18.817 UT.

7) To compare the flight path with the path of totality, I used a quadratic fit to the latitude and longitude locations of the path of totality given by the following formulae:
$Lat = -3.4312T^2 + 115.95T - 934.38$ *and* $Long = 10.666T^2 - 414.05T + 4095.1$ where T is the decimal Universal Time. For example at T = 17.3 UT the predicted latitude for totality is 44.63 North and the longitude is 124.26 West.

8) I created an Excel Spreadsheet in which each row was a separate flight along with its information about geographic locations, flight duration, times for takeoff and landing, calculation for latitude and longitude angular speeds. I then programmed a set of 15 columns for each flight in which the eclipse UT times were given in intervals of 5 minutes. Each cell of the grid calculates the distance between the flight at that UT and the location of totality in degrees using the distance formula:

$$D = \text{sqrt}\ (xf-xe)^2 + (yf-ye)^2)$$

where yf is the predicted decimal latitude of the flight, xf is the predicted decimal longitude of the flight, ye is the predicted decimal latitude of the eclipse and xe is the predicted decimal longitude of the eclipse, all evaluated at the UT for the column.

9) The grid of distance numbers were created for all of the flights, and those flights for which the distance was '0 degrees' were identified. These would be the flights for which our simple

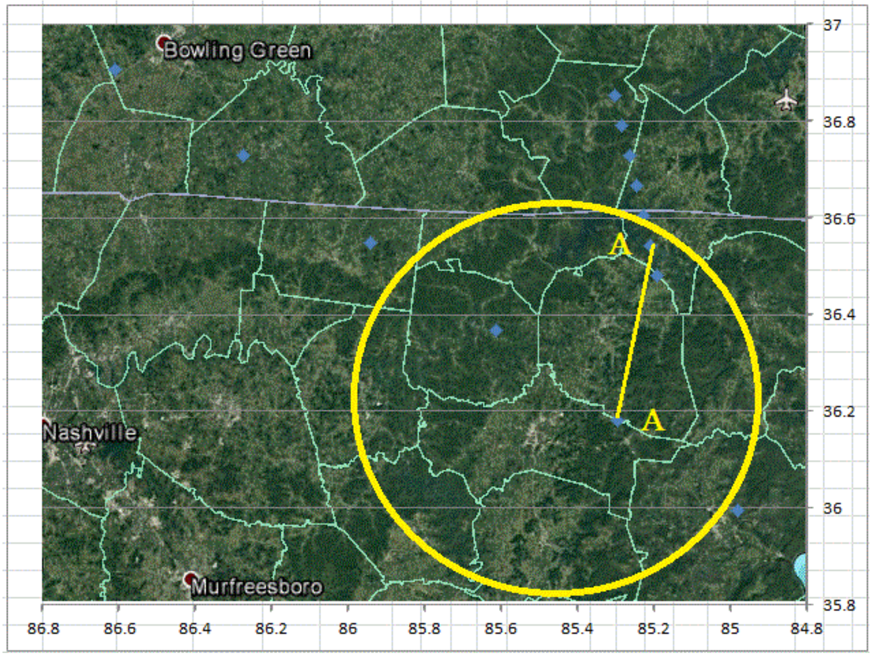
program predicted the flight would fly over the path of totality at the same time the eclipse was occurring there. A total of three commercial flights were found this way and these are:

Delta flight 2470 from Indianapolis to Atlanta, leaving Indianapolis at 12:40 pm
Spirit Airlines flight 446 from Las Vegas to Chicago, leaving Las Vegas at 8:23 am
American Airlines flight 242 from Miami to Chicago, leaving Miami at 12:15 pm.

10) But because the eclipse shadow is 110 km in diameter, corresponding to 1 degree in latitude / longitude, there are also a 20 other flights that come within 1 degree or less of the path of totality at about the right time. These flights are:

Delta-393	Chicago to Atlanta	leaving 12:15pm
Delta 926	Omaha to Atlanta	leaving 1:15pm
AA 1751	Philadelphia to Atlanta	leaving 12:55pm
AA 2512	Austin to Chicago	leaving 11:30am
United 1160	Houston to Chicago	leaving 11:30am
AA 4595	Houston to Chicago	leaving 11:30am
United 330	Miami to Chicago	leaving 12:24pm
AA 3624	Oklahoma City to Chicago	leaving 12:00pm
Delta 1586	Denver to Cincinnati	leaving 10:50am
AA 2325	Chicago to Dallas	leaving 12:10pm
AA 1118	Minneapolis to Dallas	leaving 11:10am
AA 2515	Chicago to Denver	leaving 12:00pm
United 5934	Cleveland to Denver	leaving 11:50am
Delta 2639	Minneapolis to Denver	leaving 11:37am
Delta 4503	Omaha to Denver	leaving 12:59pm
Delta 4956	Oklahoma City to Minneapolis	leaving 11:45am
Delta 2787	New York to Salt Lake City	leaving 11:15am
Delta 459	New York to San Francisco	leaving 11:45am
Alaska Air 1025	New York to San Francisco	leaving 11:55am
Virgin Air 25	New York to San Francisco	leaving 11:55am

11) The track map below is for Delta 2470 and shows the location of the shadow center (6 diamond points from top left to lower right), and the flight (6 diamond points from top to bottom just right of center) at 1 minute intervals from UT 18:27 to 18:33 corresponding to local times of 1:27pm to 1:33pm EST. The large circle gives the approximate size of the eclipse shadow at the time of closest flight approach, which occurs at 18:31 UT and 1:31 EST and is labeled by ‘A’. The distance between the A-A points is 0.4 degrees so at this time the flight would be just inside the edge of totality. But if the flight arrives a minute late, the eclipse would only be partial and last for a few seconds. In these calculations, the exact path of the flight and its actual timeline due to headwinds and other inflight adjustments can seriously affect these path predictions.



This sample of 23 flights constitutes the best candidates for seeing an in-flight total solar eclipse, but is not an exhaustive study of all 5,000 commercial flights that are likely to be in the air at the time, so there may be a number of additional candidates to consider in a more detailed study. Nevertheless, it is fun to consider that if you happened to be on just the right flight, you may be lucky enough to see at least part of the total solar eclipse, and certainly for the majority of these 5000 flights it is very likely that you will see at least a partial eclipse!

The Excel Spreadsheet from which these predictions were made can be downloaded from this link

http://spacemath.gsfc.nasa.gov/Airlines.xls