A New Technique for Forecasting Stratus in the San Francisco Bay Area

SJSU | DEPARTMENT OF METEOROLOGY AND CLIMATE SCIENCE

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ABSTRACT

San Francisco International Airport (SFO), one of the world's busiest airports, experiences frequent delays due to weather, mainly due to morning stratus that spreads from the Pacific Ocean and the Golden Gate Bridge. Meteorologists from the National Weather Service (NWS) in collaboration with the Federal Aviation Authority (FAA) have worked on methods to forecast the burn-off time for the stratus clouds, which is important for determining when arriving flights can use visual approaches and land on-time. However, these forecasts are primarily used by pilots; the FAA and NWS forecast is not available until 13Z when the stratus may have already formed. The goal of this project is to find a way to forecast the timing and duration of the flight delays by the previous night by analyzing historical daily weather and flight delay statistics. Consumers for this forecast would include the general public through television, radio, and social media.

Figure 1: The Runway Configuration at SFO

Background

There has been much research done into the San Francisco International Airport stratus. However, much of the research has been on forecasting the stratus the morning of as well as using models which are not accessible to the general public or the media. Many of the research have been aimed at the Federal Aviation Administration (FAA), the National Weather Service (NWS), and many airlines so they can plan the ground delay programs at the airport. No research has been done for forecasting the actual delay or the burnoff the night before until this project.

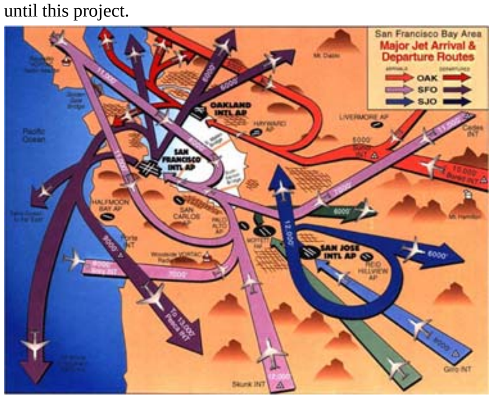

Figure 2 The Flight Paths of the Bay Area Airports including SFO. SFO's Bridge Approach which contains the stratus problem is in the light purple.

Methodology

In order to test whether it is possible to forecast the stratus the night before I tested a boundary layer cloud equation from Slingo [Slingo 1987]:

$$b = -6.67 * \left(\frac{d\theta}{dp}\right) - 0.667$$

Where b is the cloud cover and $\left(\frac{d\theta}{dp}\right)$ is the change in potential temperature. However, Slingo's equation was inadequate as it lacked humidity. Slingo later used humidity but the equation which included humidity was too difficult to use as it required base humidity, which is hard to determine. To compensate for this, Diao [Diao et al. 2014] recommend using equivalent potential temperature. Also, Slingo mentioned omega but it was in another separate equation to eliminate subsidence. A modified equation was developed to factor in all the problems aforementioned to create:

$$b = \left(-6.67 * \left(\frac{d\theta_e}{dp}\right) - 0.667\right)(-10 * \omega)$$

After developing the equation, it was put to the test by using the 12Z NAM 12 km model data on the equation around the airport to forecast the stratus from 12Z to 19Z. Once the forecast was made, it was compared to the actual hourly weather observations at the airport for the same time period.

While the equation was being developed, delay data was being collected using FlightStats, a website dedicated to flight statuses, which allowed to see if there was a correlation between the delays and the burnoff time of the stratus. To determine whether there would have a delay, a UNIX program was written so that if it could be determined if he FAA issued a ground delay so data would be manually collected that day but if there was no delay issued, no data due to the lack of stratus.

Results

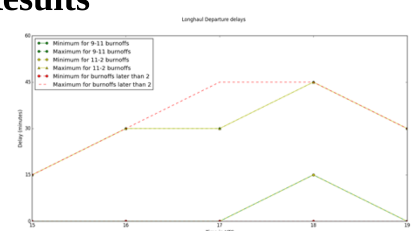

Figure 3-The Long Haul Departure Delays

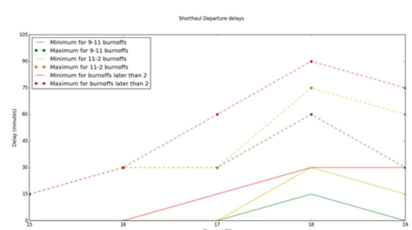

Figure 4-The Short Haul Departure Delays

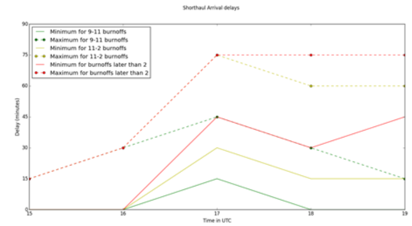

Figure 5-The Short Haul Arrival Delays

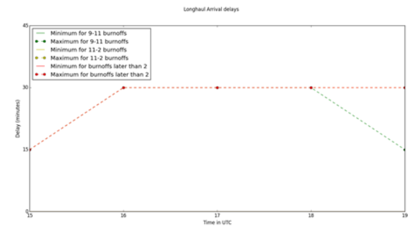

Figure 6-The Long Haul Arrival Delays

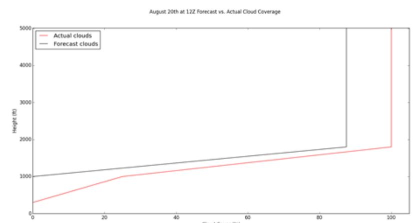

Figure 7-Comparison of a time where both the forecast predicted a ceiling correctly compared to the actual observation (August 20th at 12Z)

Conclusion

There is in fact a correlation between the burnoff times of the clouds and the delay times at the airport. Although the delay data was collected up to noon PDT (19Z) due to the fact that most of the burnoffs ended at 11 am PDT (18Z) and the most of the ground delay programs ended by then. This correlation is very much a success as that is what was one of the most important parts of the project.

The modified equation has in fact been succesful in predicting when there is a ceiling and where they is not. In the data collected. It had been found that the equation has been perfect when there was in fact a ceiling. However, when there was not a ceiling, the equation was about 85% correct of the time. This lapse without a ceiling can be considered okay due to a few possibilities including less moisture, subsidence where there was not and a higher Lifted Condensation Level.

Future Work

There can be much more research to be done on my equation such as factoring in thermal advection as well as resolving the matter of subsidence occurring when not forecasted. I can see my project as the cornerstone of a future research topic where the actual delay times can be forecasted at other airports around the United States the night before which can be very useful for common passengers.

References

Slingo, J., 1987: The Development and Verification of a Cloud Parameterization Scheme for the ECMWF Model. *Quart. J. Roy. Meteor. Soc.*, **113**, 900–927

Diao, M., M.A. Zondlo, A.J. Heymsfield, L.M. Avallone, M.E. Paige, S.P. Beaton, T. Campos and D.C. Rogers, 2014: Cloud-scale ice-supersaturated regions spatially correlate with water vapor heterogeneities. *Atmos. Chem. Phys.*, **14**, 2639-2656

[1]https://upload.wikimedia.org/wikipedia/commons/c/ce/SFO_map.png

[2]http://media.flysfo.com/media/sfo/media/west-plan.jpg

[3]https://www.rap.ucar.edu/asr2003/ceiling-visibility.html

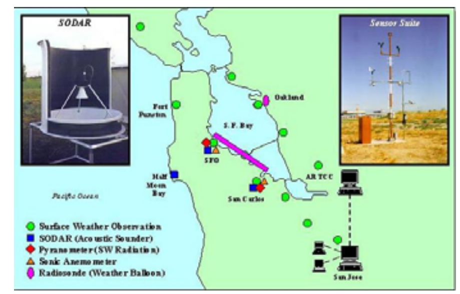

Figure 8-A map of the Weather Instruments being used to help forecast and measure the San Francisco Airport Stratus