**2.1** EVOLUTION OF THE SFO MARINE STRATUS FORECAST SYSTEM DECISION SUPPORT TOOL BASED ON CUSTOMER FEEDBACK .

Austin Cross[1] and Christine Riley
National Weather Service

# 1 Introduction

San Francisco International Airport (SFO) is the second busiest airport on the West Coast, with 45 million passengers in 2013 (San Francisco International Airport, 2013). The airport is among the top 30 worldwide and serves as an import gateway for international traffic. The National Weather Service Weather Forecast Office (WFO) Monterey is responsible for the terminal forecast, and Center Weather Service Unit (CWSU) Oakland is responsible for the approach forecast, for the airport.

In 2012, the San Francisco International Airport was the second most weather related delayed airport in the United States (Federal Aviation Administration, 2014). The main culprit of these weather related delays are low clouds, known as stratus, during the summer season over the terminal and approach zone. The low ceilings cut the possible arrival rate to the airport in half, as closely spaced parallel runways generally require visual separation for simultaneous approaches. The resultant lowered capacity can have a ripple effect across the national airspace, requiring ground delays at airports across the country. Delays have steadily climbed at the airport year after year as traffic has increased (Federal Aviation Administration, 2014), and improving weather forecasts remains the only way to mitigate the issue at this time.

To meet this specific forecast challenge, the Marine Stratus Forecast System (MSFS), an FAA NextGen prototype was developed. MSFS is an impact-based decision support services tool that aids the prediction of stratus clearing in the approach area. The system uses a network of sensors, combined with statistical and dynamic forecast models, and has forecaster-over-the-loop input. It has been shown the system has seen a steady increase in performance, leading to a demonstrable reduction in delays, particularly after a change in guidelines for traffic managers that resulted in more aggressive increases in arrival rates upon forecast stratus dissipation (Reynolds et al., 2012).

# 2 Customer Outreach

The system has long been focused on the needs of NWS forecasters and the FAA decision makers. However, as a decision support tool, with multiple entities involved in the Collaborative Decision Making (CDM) process, it was important to reach out to the users. During the 2012 season, an effort was undertaken to further understand customer needs. The two authors, forecasters at the Weather Forecast Office in Monterey, and one forecaster from the Center Weather Service Unit in Fremont, traveled to the largest customer of SFO, United Airlines, and the FAA Command Center. The hope of this visit was to gain a better understanding SFO customer needs and increase collaboration with weather partners. Discussing the issues they deal with helped us gain insight into how we can improve our services to fit their needs.

The first part of the effort was to visit United Airlines headquarters in Chicago, IL. United has the largest airline presence at SFO and they account for almost half of all traffic at the airport. A briefing was given to the air traffic manager giving background on the NWS and explaining the difference in terminal and approach forecasts. The authors then shadowed the airlines meteorologists, learning about how they forecast for the West Coast and use the MSFS. In addition to seeing how they use the system, it was useful to get a sense of how we are forecasting the same thing in many similar ways despite somewhat different motivations.

The second major part of the effort was to visit the Federal Aviation Administration (FAA) Command Center (ATCSCC) in Warrenton, VA. The Command Center is responsible for the overall management of the National Airspace System (NAS) including the issuance of ground delay programs (GDP) due to restrictions at SFO. The authors were able to spend two days shadowing the air traffic specialists and meeting with managers at the facility.

These face-to-face meetings gave the forecasters something that could have never been achieved with phone conversations alone: a sense of teamwork. Collaborative phone conversations with regards to the forecast are now focused on sending out a consistent message, which have saved the airlines both time and money.

# 3 Increased Collaboration

We have since increased collaboration with National Weather Service partners. Through staff training, the WFO and CWSU are now in better contact to provide a consistent message to customers. Forecasters at both offices are better aware of the demands of their counterparts, and take advantage of frequent phone calls and online chat conversations to coordinate. WFO Monterey and CWSU Oakland hope that this relationship can be used as a model in the future for a close working relationship and

[1]Corresponding author address: Austin Cross, National Weather Service, austin.cross@noaa.gov, 21 Grace Hopper Ave., Stop 5, Monterey, CA 93940-5505

Figure 1: At the FAA Command Center from left to right: WFO Monterey Forecaster Christine Riley, National Aviation Meteorologist Michael Ekert, WFO Monterey Forecaster Austin Cross, CWSU Oakland Meteorologist Ashley Helmetag

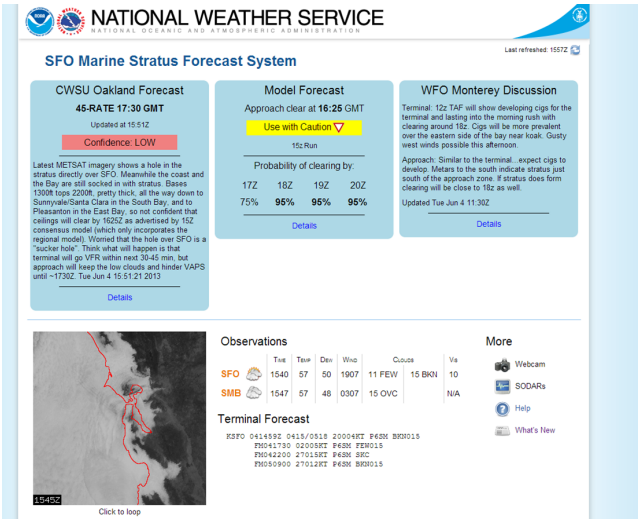


Figure 2: SFO Marine Stratus Forecast System current public web site interface

open communication lines between all WFOs and their nearest CWSU.

Contact was also made with newly stationed NWS National Aviation Meteorologists (NAM) at the FAA Command Center (figure 1). The NAMs are able to directly relay weather information to traffic specialists. By learning firsthand how they work with the air traffic coordination staff, we are better able to communicate a consistent message within that facility.

# 4 Technology Upgrades

## 4.1 Web Site

For the 2013 season, a new web presence was developed to allow an open, modern interface to the project data and forecasts for decision makers (figure 2). Feedback from users at the FAA and airlines was used in the development of this new interface. The site was designed to match the modern look of the National Weather Service's main weather.gov portal and adds dynamic interactivity to allow more information to be reached more quickly. By employing modern web technologies including asynchronous Javascript (AJAX), the display is continuously updated, while never taking control of the page away from the user.

Additional information not previously available was added to the site, to help make it a one stop shop for weather related to clearing of the airport approach. Two products from the WFO, the latest SFO terminal aerodrome forecast (TAF) and forecast discussion, are displayed. Having these forecasts available in the same place, and with clear distinction what area they are forecasting, has helped to reduce confusion over the different forecasts.

Key pieces of information, including the forecast confidence level, are highlighted and effort was made to make the data presented clear and concise. Forecast confidence is a keep part of the forecaster-over-the-loop concept, allowing forecasters to impart their expertise from working with the system to perform quality control and provide value added guidance. New terminology was developed for model reliability, and it is now clearly highlighted with colors and symbology.

The display interface and the underlying data have been separated creating more flexibility. Foremost, it allows the data to continue to be generated on the computer system running the models and yet presented via the National Weather Service public web servers. This move has created greater security and flexibility by not having end users directly access the machine running the models. Information that was previously only made available to the major stakeholders by password access is now available to all users of the airport, due to the elimination of hacking and bandwidth concerns. The data separation has also created more options in displaying the data, as exercised through the creation of a separate mobile page.

## 4.2 Web Cams

Web cams also play an important role in this new site. The information they provide is invaluable for the human forecaster to make a determination of the cloud behavior and position over the approach. With CWSU around 25 miles from the airport and WFO more than 100 miles away, forecasters do not have direct eyes on the approach. The two surface observation sites, the ASOS at the airport and the AWOS at San Mateo Bridge, give some idea of what is going on, but cameras are able to provide a complete visual of what is happening on the ground.

To increase the capabilities of the web cam system, we began archiving imagery every fifteen minutes. The most immediate use is the ability to animate loops of imagery.


Figure 3: Web cam side-by-side comparison page

During the morning hours, stratus forecasting becomes a minute-by-minute short term forecasting, or nowcasting, challenge with the subtle variations in stratus dissipation trends very important.

Stratus often forms in stagnant weather patterns so the ability to see the subtle day to day variation is important as well. To better visualize this we have created a side by side comparison view (figure 3). This view allow looping through today's imagery with the imagery from the previous day at the same time of day next to it. And finally, all the imagery is stored in an archive that can be used for case study review.

# 5 Summary and Discussion

Meeting with the users of MSFS helped us to better understand their needs. Increased collaboration has allowed us to present a clear, consistent message. The overhauled web site allows the communication of the message to be more effective. Less traditional observation technologies like web cams provide great benefits that can continue to be expanded upon.

Future work on the project includes continued collaboration. We look forward to working with more users and partners, including other airlines that serve the airport. Additional improvements may be possible to the model suite, including the utilization of satellite low cloud detection prior to sunrise and boundary layer winds determined from a wind profiler. Improvements in local WRF modeling are forthcoming, in order to have better three dimensional dynamic model output, which is useful in forecasting stratus development in addition to stratus burn off.

# References

Federal Aviation Administration, 2014: Operations Network (OPSNET). `https://aspm.faa.gov/opsnet/sys/`.

National Weather Service, 2014: SFO Marine Stratus Forecast System. `http://weather.gov/sfo`.

Reynolds, D. W., D. A. Clark, F. Wilson and L. Cook, 2012: Forecast-Based Decision Support for San Francisco International Airport. *Bulletin of the American Meteorological Society*, **93**(10).

San Francisco International Airport, 2013: Analysis of Scheduled Airline Traffic.