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FINAL REPORT OF SHA AIRPORT
Sub-title (if any)

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Summary

According to the scope of AvRDP, SHA has made some efforts on the MET capacity promotion and weather impact quantifying on ATM operation, some practices are proved effective to help ATM reduce the impact of adverse weather, such as rapid refresh NWP system building, convective initialization mask, ATM users oriented products design, impact translation, etc.

To meet ATM requirements on more longer leading time and finer prediction under convective weather, cases review between MET and ATM, evaluation on service effectiveness are conducted synchronously.

The gaps such as the accuracy of over 2hours nowcasting, translation probabilistic forecast into ATM impact, TBO meteorological information integration are identified. Appropriate verification method for the 'operational impact forecast' should be set up.

I. Introduction

(1) Airport information

Shanghai Hongqiao International Airport (SHA) is located about 13 km (8 miles) west of downtown Shanghai, and 60 km (37 miles) from Shanghai Pudong International Airport (PVG). As one of the biggest international aviation hubs in China, SHA is a 4E-class airport with 2 closely spaced parallel runways (365m) and 2 passenger terminals, handles 40 million passengers annually.

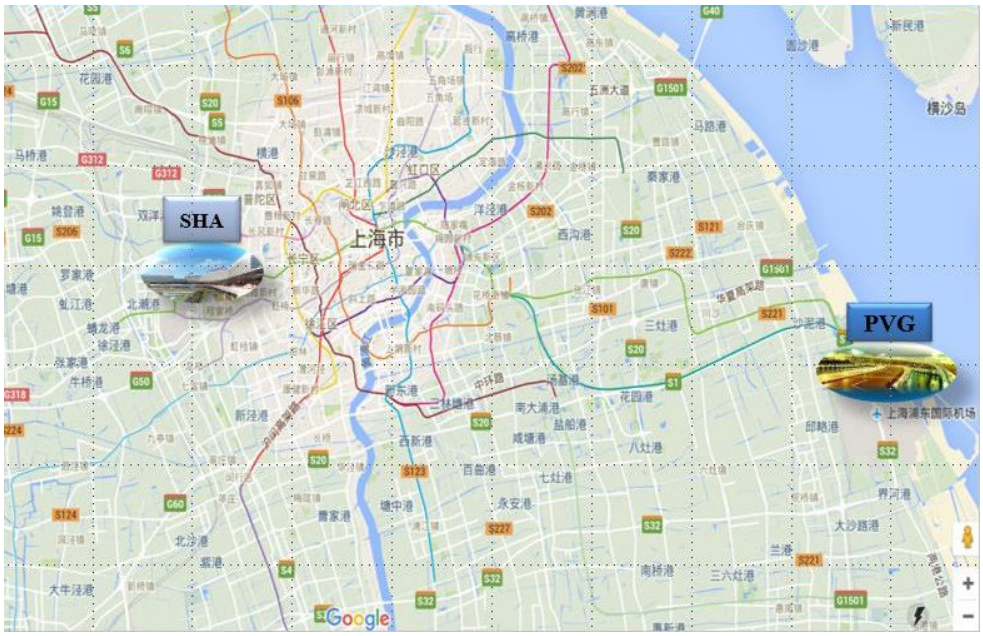

Figure 1 Location of SHA

(2) Impacting weather

Located in the west coast of the Pacific Ocean, Shanghai is affected by subtropical monsoon climate with four distinct seasons, full sunshine and abundant rainfall.

According to the climatic statistics of SHA, thunderstorm /low visibility /low ceiling and gale are the most significant weather which affect flight safety and normality in SHA, and thunderstorm is the most serious one. Actually, along with the rapid increase of flights in Shanghai, summer season convective weather has been one of the most critical influences on the flight normality. So, how to predict the convective weather with more leading time and more accuracy, it's our primary task, meanwhile, how to integrate the MET information into ATM system, in other word, how to convert MET information into airspace capacity block is as important as the prediction ability.

SHA selected convective weather as the study object of the project.

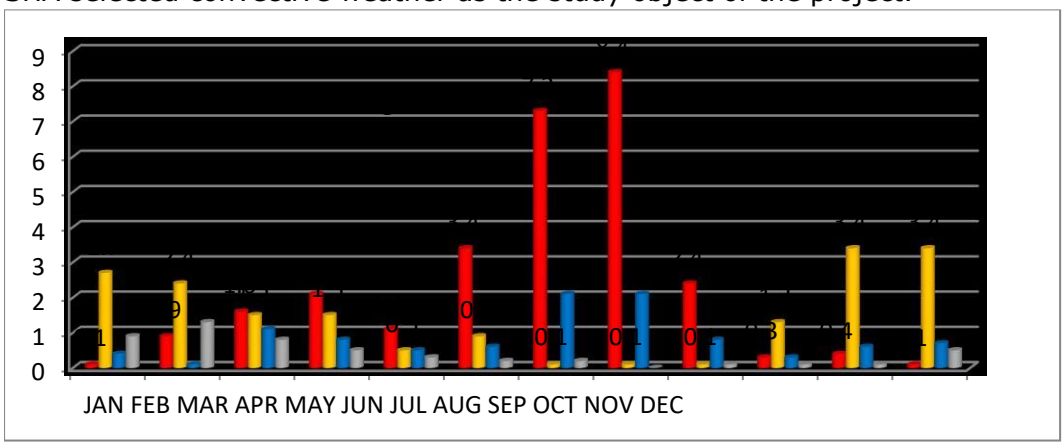

Figure 2 Adverse weather in SHA, 2000-2014

(3) ATM/Airline/Pilot/Aviation Community Needs

In SHA, aviation meteorological center set up service units separately in the hall of ATC and airport AOC, experienced forecasters in the units offer on-site

weather briefing and make CDM (Collaborative Decision Making) with ATFM/ATC supervisors, airline dispatchers and chief operator of airport AOC. Actually, the needs for weather service from ATM, airlines and airport AOC are different. In brief, in face of adverse weather and airspace block, ATM is in desperate need of precise convective weather prediction, they need to assess the impact on relevant air routes, key waypoints, specific terminal sections and airports. According to MDRS (Massive Delay Response System based on air traffic capacity), ATFM usually consult with MET one day in advance to prepare for their air traffic management solution, they often focus on large hub airports, main air routes and key sections of terminal approach, and they need at least 6 hour leading time. Terminal approach control department is in charge of tactically command and guide flights in approach phase prepare for landing, they need to know the weather changes of specific terminal sections, key waypoints of SHA airport in advance, and they hope the leading time is more than 2 hours, but at least half hour.

The needs for weather services from airlines and airport AOC are different from ATFM and ATC. Under adverse weather conditions, ATFM department manages regional airspace capacity uniformly, adjust and control regional flight flow, strive best to keep the balance of air traffic flow amount and actual airspace capacity, sometimes, ATFM will consult with airlines to cut some flights in advance. As for airlines, they strongly hope that their flights would be carried out entirely even if some flights would be obviously delayed. Meanwhile, airport authority hopes for a minimum backlog of flights and smooth flow of passengers at any time.

(4) Study approach / techniques

In 2010, SHA has built a set of regional short range ensemble forecast system (12 members) with 3 domains (China, east China and SHA terminal area) in 36/12/4km resolution. This set of forecast system is in higher prediction skills than the past systems, and it can output probability for forecasters reference, however, it run only twice a day because of insufficient computing power, low update frequency cannot meet the increasing needs of MET service.

According to the scope of the AvRDP, the project should be composed of research and demonstration on nowcasting technique, impact identification and prediction, verification and technology transfer etc., and it should be conducted in 2 Phases: Phase I (2015-2017) and Phase II (2016-2018).

SHA selected convection as the study object of the AvRDP, and we have been striving to upgrade the prediction technique and improve the aviation weather service. For the sake of rolling update forecasts, we decided to develop a set of rapid refresh system to meet the different needs from ATC/ATFM users, it's named as The Enterprise Integrated Aviation Weather System (eIAWS).

New system is aimed to make rapid refresh for regional airspace, main air routes and SHA TRACON, make nowcasting for Shanghai FIR, SHA TRACON or even SHA aerodrome. It is equipped with the following features:

- Multiple modules
  - Regional rapid refresh NWP module
  - Regional nowcasting module
  - TRACON nowcasting module
- Customized outputs designed for different users, including air route/TRACON/aerodrome weather prediction.

- Impact prediction. Weather forecasts should be translated into the impact on aviation operations.
- ……

• Nowcasting
  - SHA TCWPS
    SHA TCWPS (Terminal Convective Weather Prewarning System) was developed before 2015. It is a web-based platform overlaying radar mosaic animation with SHA terminal sections, can show the radar echo changes in different terminal sections in the past hour. Although it is only a primary product that integrates MET information and ATM geographic information, it can help ATC controllers to know the weather changes in the terminal area.

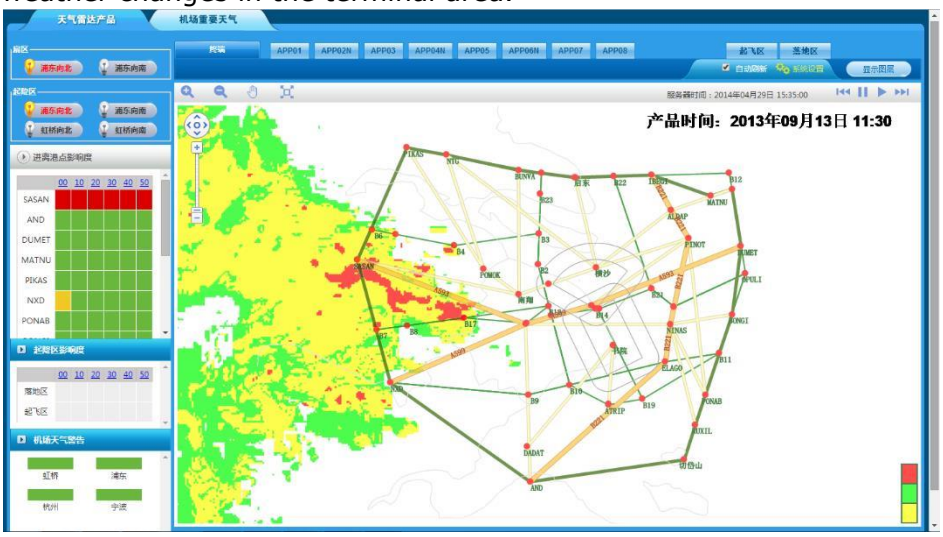

Figure 3 SHA Terminal Convective Weather Prewarning System
(green <35dBZ, yellow35-45dBZ, red≥45dBZ)

  - East China Rapid Refresh NWP System.
    As a module of eIAWS, the NMMB-cored rapid refresh NWP system was built in 2016-2017, with 3km resolution, 10min time step, 1 hour update frequency and 9 hours forecasts, see figure 4.
  - East China Convective Weather Nowcasting
    We developed east China convective weather nowcasting module to realize the function of convective initialization mask, radar mosaic extrapolation and outlook, etc., with adaptive blending of satellite, radar and NWP forecast, using the technique of big data self-learning. It can make 3 hours convective weather nowcasting for Shanghai FIR (5km res/10min step/update per 10min), see figure 5.
  - SHA TRACON Convective Weather Nowcasting
    90 minutes convective weather nowcasting with radar mosaic extrapolation and outlook (1km res/5min step/update per 5min).

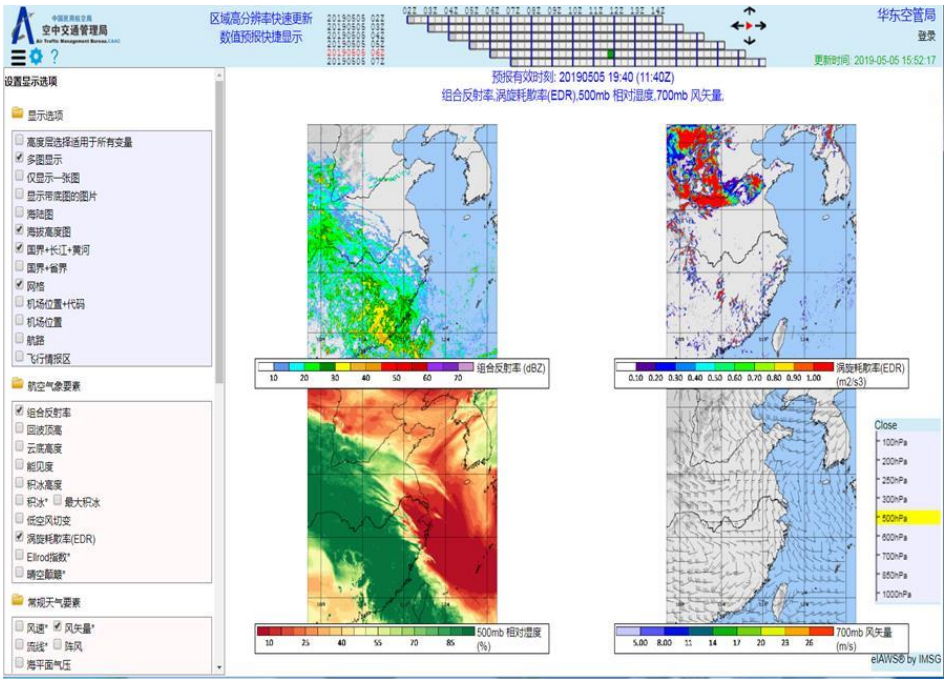

Figure 4 East China Rapid Refresh NWP System

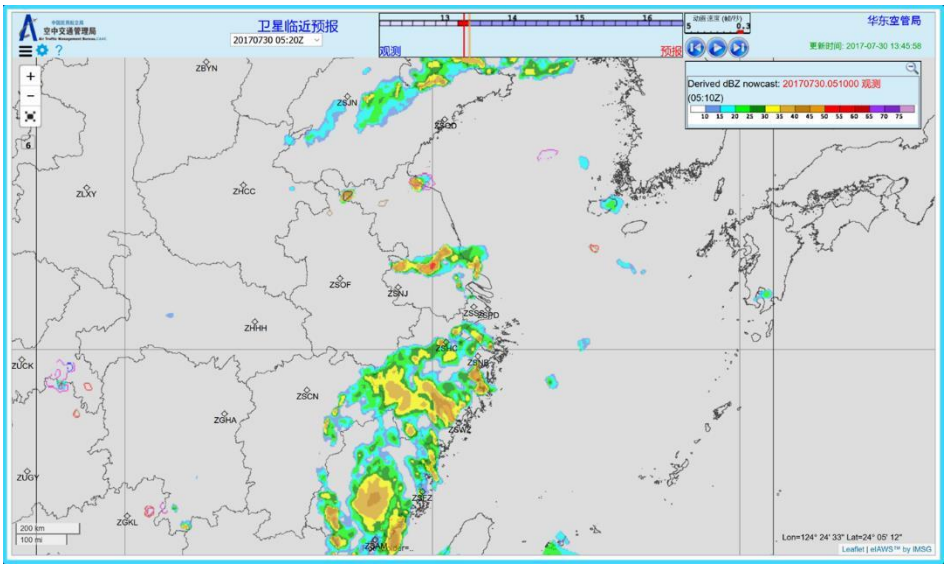

Figure 5 East China Convective Weather Nowcasting

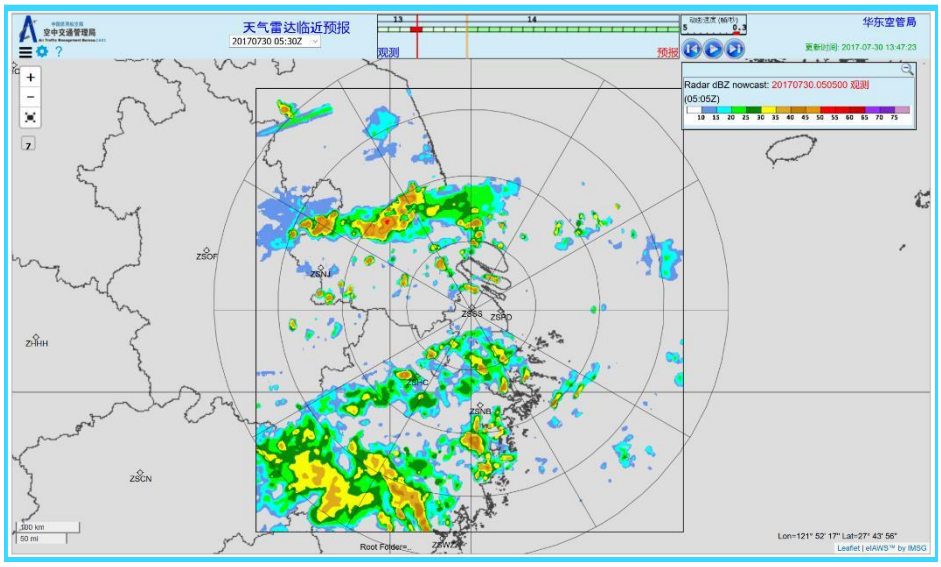

Figure 6 SHA TRACON convective weather nowcasting

- Impact translation

  Weather changes in the airspace, and it's a part of the airspace. The current and foreseen weather should be converted into the occupation of airspace. So, how to translate MET information into the ratio of blockage in some space should be a key point of AvRDP. It is the important method of MET-ATM integration.

  - Airspace capacity prediction. The forecast system outputs fine prediction, then the weather prediction is translated into airspace capacity prediction. Under the collaboration among MET ATM and airlines operators, they can make decision how to adjust flights plan in pre-tactical stage, or control flight flow tactically. There are still many difficulties in airspace capacity prediction in CAAC. For example, the decision tools such as TRACON section block, airway point impact, and air route availability are in used routinely. See figure 7 and 8.

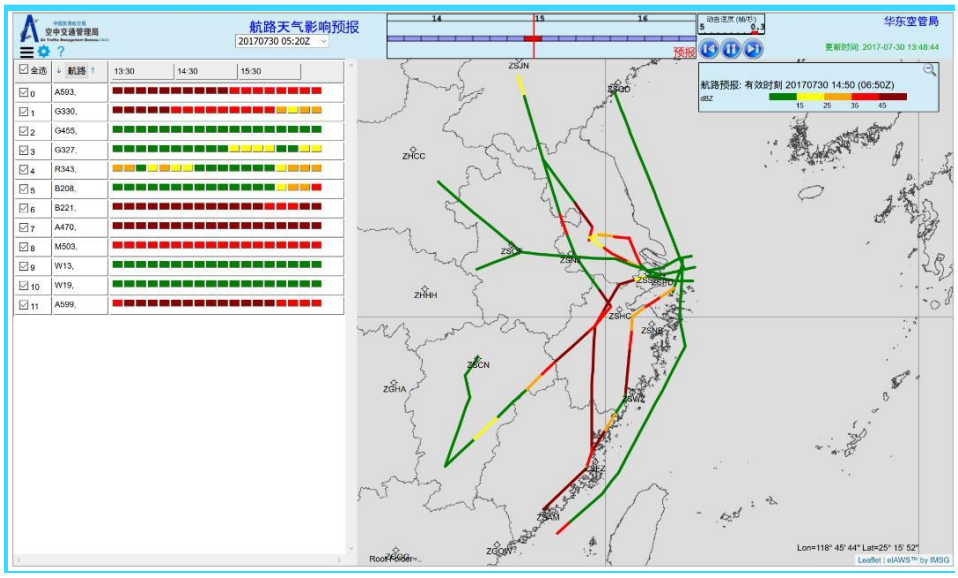

Figure 7 Air Route Availability (green <15dBZ, yellow15-25dBZ, orange 25-35dBZ, red 35-45dBZ, brown≥45dBZ)

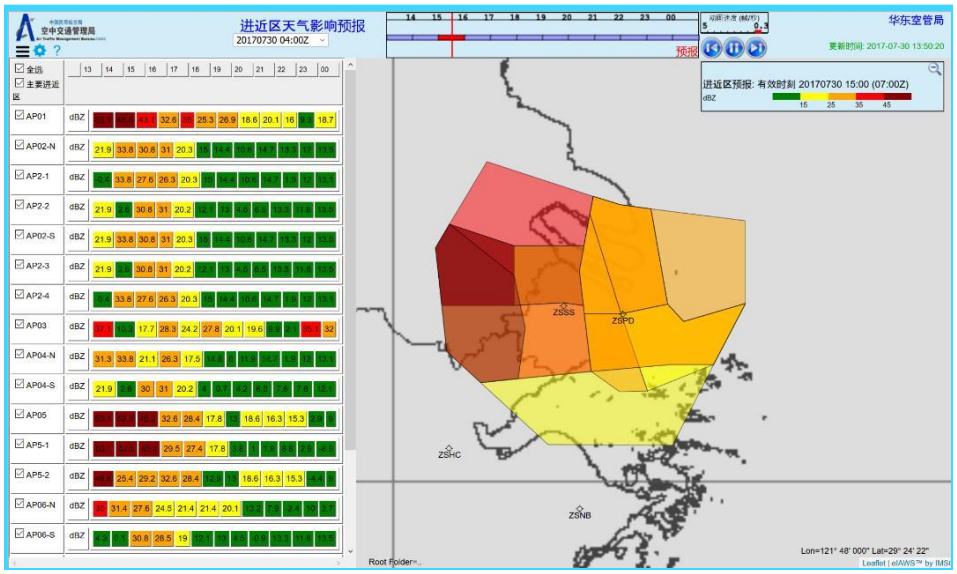

Figure 8 TRACON Weather Impact (green <15dBZ, yellow15-25dBZ, orange 25-35dBZ, red 35-45dBZ, brown≥45dBZ)

- Cases review through co-joint analysis among MET, ATM and airlines. As we have mentioned before, CDM mechanism plays an important role in daily operation management. Cases review can not only help CDM participators see value of cooperation, but also help them find out the gaps and deficiencies to improve. Co-joint analysis has become a routine job.

• Verification
  - Prediction accuracy assessment
  - Validation on MET-ATM impact translation
    Apart from CSI/RMSE/BIAS scores are used to assess the skills of NWP, MODE (Method of Object-Based Diagnostic Evaluation) is used to evaluate the similarity between forecast and observation. In addition,

the accuracy of airspace capacity prediction is judged by MET, ATM operators subjectively through cases review.
We still have to improve the skills of verification.

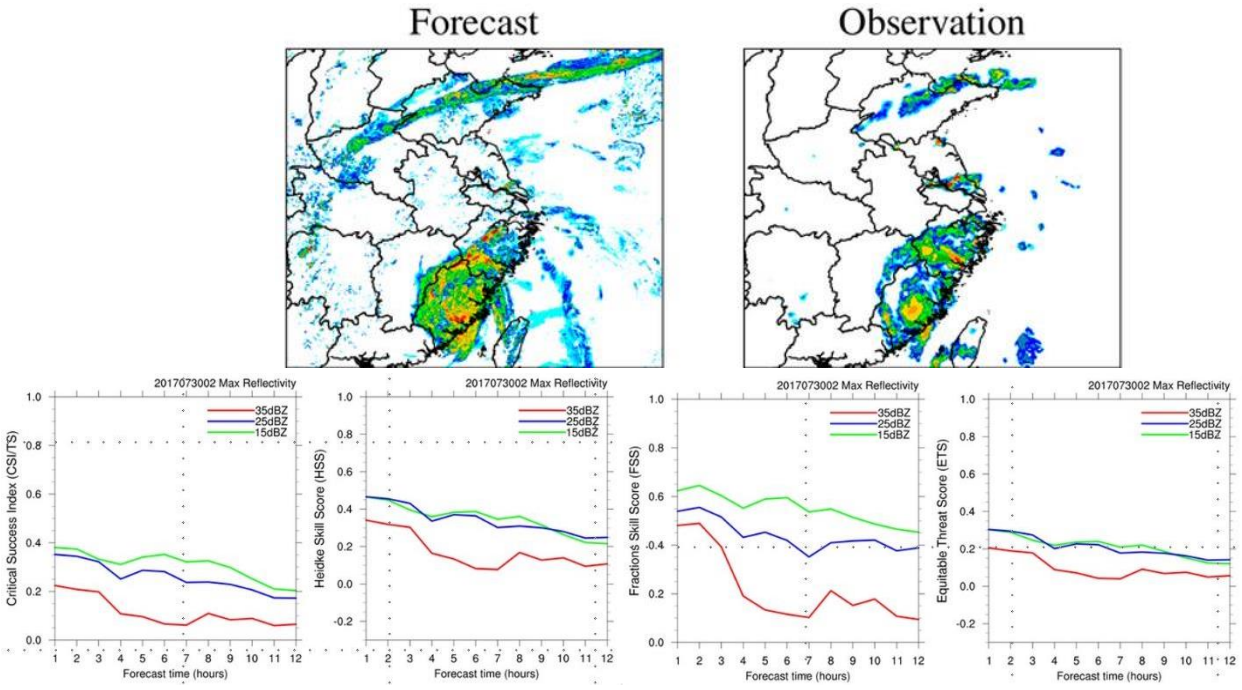

Figure 9 Verification Examples

(5) Timeline …

Phase I MET capacity May 2015 – Jul 2017	• Data collection May2015 – Oct 2016	• User needs analysis • MET/ATM data collection • Cases selection
	• NWP and Nowcasting research Oct 2015 - Jul 2017	• Technique update - Rapid Refresh - Radar mosaic extrapolation - Convective initiation mask • Verification • Cases study
Phase II MET-ATM integration Jul 2016 – Jul 2019	• Impact translation May 2016 - Jul 2018	• Airspace capacity prediction • MET-ATM impact assessment • Co-joint analysis

II. Outcomes

(1) Phase I achievements (MET Capability)

During Phase I (2015-2017), we have conducted the user needs analysis, evaluated the MET support tools for ATM, found the short board of MET capacity. To improve the aviation weather service, besides convection cases collection, we always focused on the NWP and nowcasting technique research. With the cooperation of partners, we set about to build the Enterprise Integrated Aviation Weather System. It is a set of multi-module rapid refresh system, can distinguish convective initialization utilizing big data self-learning algorithm, blended with radar mosaic extrapolation and rapid refresh NWP, can catch and predict convection more skillful than previous system.

(2) Phase II achievements (MET-ATM Integration)

With the promotion of MET capacity, we made efforts on MET-ATM integration and designed a series of support tools for impact translation, such as air route availability, TRACON weather impact, and etcetera. We have conducted some research on quantifying the impact of weather on airspace capacity to improve MET service.

(3) Verification (if any)

Co-joint analysis and verification are conducted synchronously.

III. Summary

(1) Benefits to local ATM

In the progress of AvRDP, SHA has made some efforts to promote MET capacity and to help ATM reduce the impact of adverse weather. Some practices are proved effective, such as: thorough assessment of the MET capabilities, finding gaps between the MET capabilities and aviation users' needs, optimizing aviation nowcasting methodologies, translating MET information into ATM impact, etc.

- CDM and MDRS. Meteorologists are involved in CDM mechanism, make on-site service delivery under MDRS, MET ATM and other aviation community managers can form an enhanced situational awareness, ATM will understand the uncertainty of weather prediction better, and it is helpful for ATM formulate the air traffic flow management scheme.
- User needs analysis. It is very important to collect and analyze the needs from different users, and analysis results should contribute to the development of nowcasting system and the improvement of weather service.
- High resolution rapid refresh technique can restrain the rapid growth of prediction errors and improve nowcasting markedly, it is very crucial for the development of nowcasting system, and would be beneficial to make more reliable, fine nowcasting.
- The technique of convective initialization mask, big data self-learning, adaptive blending etc., are proved very effective in the promotion of convection identification and pre-warning, 5-20 minutes leading time is beneficial to keep flights flow smooth in TRACON.

(2) Contributions to ASBU

According to the thread AMET of ASBU, MET service should meet the requirements of ATM, MET-ATM integration should be conducted to support ATM operation decision making.

SHA is aimed at MET-ATM integration during AvRDP Phase II. We have made efforts on quantifying the impact of weather on airspace capacity, tried to provide 'operational impact forecast' under the research on MET impact translation, designed a series of support tools such as air route availability, TRACON weather impact, weather avoidance area (WAF) etc..
The first initial 4D TBO demonstration flight in China and Asia-Pacific region has been carried out successfully in Mar 2019. As we know, TBO need seamlessly high-resolution, rapidly-updated nowcast and forecast along the whole flight trajectory from take-off, ascending, en-route, descending to landing phases be integrated into ATM system, and we will keep on promote MET capabilities to meet the needs of TBO operations.

(3) Gap identified

- How to improve performance of over 2hours nowcasting?
- Deterministic prediction cannot solve the problem of uncertainty, ensemble forecast can describe the uncertainty and randomness of weather change and can output probabilistic forecast.
- How to translate probabilistic forecast into ATM impact?
- How to set up appropriate verification method for the 'operational impact forecast'?

(4) Resources for sharing (website, software, document, data, ..., if any)

IV. Recommendation

(1) Future Studies

- Instant performance evaluation of multisource nowcasting (confidence index)
- Translation ensemble forecast into operational impact
- Expanding nowcasting length

(2) Plans (if any)

V. References

Appendix (including the details of the following but not limited to)

Instruments employed

In SHA, aviation meteorological center has deployed many kinds of detecting /monitoring system, including AWOS, C-band dual-polarized Doppler weather radar, FY serials satellite receiving and processing system, wind profilers, lightning detecting system, etc.

MET and ATM Data used

In SHA, aviation meteorological center can get synoptic data from GTS, collect AMDAR and PIREP data routinely, get ATM operational information from ATC and ATFM.
Furthermore, aviation meteorological center has developed high resolution regional aviation NWP system and rapid refresh nowcasting system through which forecasters

and MET users can get guidance and assess the adverse weather impact on air traffic flow.

Algorithms

Nowcast and/or NWP models
The Enterprise Integrated Aviation Weather System (eIAWS)

ATM KPI (if any)
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