1.1 Weather support to aviation: thoughts for the future with emphasis on operational needs

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1. Introduction

Many advances have occurred in aviation weather over the past twenty or so years, including:

- Developing near mastery over microburst wind shear
- Developing high resolution mesoscale and regional-scale models
- An increasing dependence on atmospheric measurements from profilers, *in-situ* aircraft, and satellite-borne means
- A transition (unfortunately still in progress) from text-based products to color graphical products in three spatial dimensions

Development of a rich variety of weather hazard products derived from research and technology transfer:

- Convective storms
- Icing
- Turbulence
- Winter storms
- De-icing weather aids
- Ceiling and visibility
- Weather in remote regions (e.g., oceanic)
- High altitude (space) weather impacts
- Continued development of volcanic ash advisories
- Continuing development of wake vortex advisories

These advances have been made because managers, visionaries, and scientists and engineers from government (i.e., FAA, NOAA, NASA, DOD), the national labs conducting aviation weather research (i.e., MIT Lincoln Laboratory, and NCAR), have created an aviation weather brain trust of lasting and I believe profound proportions.

I would like to focus my thoughts and little presentation time on a few basic concepts that will be addressed in many papers in this conference, that have come under attention by a six-agency effort attempting to design a Next Generation Air Transportation System (NGATS) for the U.S., transitioning from today's system to one that would be fully operational near the year 2025. This work is housed in an office called the Joint Program & Development Office (JPDO).[3] It is not my intent to cover NGATS/JPDO, as it is the topic of a paper at this conference, which I co-authored. But I do want to address a few critical items that reflect on where

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[3] The best briefing with notes on NGATS is available from http://jpdo.digiplaces.com/tech_hangar/

aviation weather must go to be fully viable in the future.
There is little doubt from statistics that weather is a major factor in aviation, certainly in capacity impacts due to weather, accidents in general aviation, and in earlier days, wind shear. At least in the U.S., the safety factor has decreased substantially, as the civil (FAR Part 121) accident rate domestically as fallen to a point that accidents may not occur for a few years. So the NGATS issue will be to reduce capacity impact greatly while maintaining safety, vectors that tend to work in opposite directions (capacity goes down as safety increases).

Principal foci of NGATS are:

- Net-Enabled Information Access
- Performance-Based Services
- Weather-Assimilated Decision Making
- Layered, Adaptive Security
- Broad-Area Precision Navigation with automated and agile Air Traffic Management System
- Trajectory-Based Aircraft Operations
- "Equivalent Visual" Operations
- "Super Density" Operations

A fundamental driver for NGATS is an authoritative estimate that there will be an approximate three-fold increase in air traffic operations between 2005 and 2025. Many new aircraft will include thousands of UAVs, microjets, many more regional jets, and a migration of U.S. carriers to smaller, more efficient aircraft.

If we were to consider the current air transportation system, there is a widely held view that it would be impossible to evolve it to meet the needs of a three-fold expanded system. Consequently, the driving force is to develop an airport "curb-to-curb" concept of a revolutionary new system that is transformational over perhaps three steps to the year 2025.

2. A Brief Primer on Wx IPT in NGATS

The Wx IPT is addressing the following primary efforts:

- Integration of weather information increasingly derived by automated means, into air traffic management decision support systems. It is my view that the greatest failure of aviation-related weather capabilities has been the failure of the transportation system to adequately use weather information in determining improved air traffic flow outcomes. By 2025, a very high degree of air traffic control and management will be automated. Additionally, many ATC functions will occur in the cockpit, first by pilots, then increasingly by cockpit automation, and yes, by 2050, there may be no pilots in civil airliners!

- Dissemination of weather information by Net-Centric-Operations (NCO) to produce a broad National Weather
- Information Network. There are and will be many more weather observations, models, and forecasts on a variety of spatial, temporal and probabilistic scales that will need to be integrated

into a push-pull source that provides a shared situational awareness picture of the weather in the context of the air transportation system.

- Improved aviation weather forecasts will evolve in a variety of ways. Convective forecasts will extend to six hours, the maximum flight length over the CONUS. Forecasts will be come probabilistic, match the conversion of air traffic systems now wholly using deterministic concepts. Finally, the role of the forecaster will change, from today's forecaster-in-the-loop, to an intermediate forecaster-over-the-loop, to fully automated weather products.

- Improved weather observations will come from very advanced hyper-spectral and Doppler space-borne platforms, a vastly expanded use of aircraft, including UAVs for in-flight measurement of weather parameters, and from the next generation weather radar, a fully phased array electronically scanning radar to replace NEXRAD.

- Improved weather training for pilots and controllers, and for aviation forecasters will be required to gain the best possible utilization of new capabilities. Much of this training will use web-based and other computer-based techniques, often as an icon on the actual displays used by pilots, controllers, and traffic controllers and managers.

- Aircraft mitigation techniques are being addressed to harden aircraft for turbulence encounters, reducing wake vortex production and reaction, and decreased impact of icing.

- Policy issues must be fully addressed in the Wx IPT, including understanding what the government pays for versus the private sector, international regulation regarding weather product policy.

- System engineering considerations are critical to the success of the Wx IPT, in developing a roadmap of activities that fit together with a complex and diverse set of needs emanating from the other IPTs and core activities of the JPDO. A common systems architecture is needed for success.

- Metrics that can well measure success of new approaches to weather capabilities are critical and difficult, and the Wx IPT is addressing improving them, and making such evaluations more useful and believable.

3. Aviation Weather Driven by User Needs

Meteorologists have long been associated with addressing meteorological hazards to aviation, in the strongest of beliefs that weather plays a critical role to safety and capacity issues. Statistics can support these views, but in other ways, some realities do not. For example, air traffic controllers in the U.S. view weather, including wind shear, as an advisory function, as opposed to their primary function, to separate aircraft from other aircraft and from terrain. Air traffic management has a significantly closer connection to weather, and a few of the advanced weather products do make it into the FAA Systems Command Center and Air Route Traffic Control Center decision-making process regarding rearranging traffic flow due to weather considerations; this is particularly true for convective weather.

Many advanced weather capabilities have become available through the FAA's Aviation Weather Research Program, whereby weather products are available on the Aviation Digital Data Service (ADDS), a web-based aviation weather product service. The MIT Lincoln Laboratory efforts in the Integrated Terminal Weather System (ITWS), and the Corridor Integrated Weather System (CIWS) are examples of excellent weather brain trust demonstrations that can be fit into NGATS. A number of private companies have likewise produced a stream of weather products that serve a variety of customers both within and outside of government.

The successes of aviation weather basic and applied research has been most obvious when it has been closely tied to operational user needs, a reality that sometimes runs counter to the conventional wisdom of the science process. The value of science outcome is closely related to operational need, and this thought must be kept in the forefront.

4. Concerns for the Future of Aviation Weather

Cutting to the chase, I have a number of major concerns about the future of aviation weather, outlined below:

The first one is based on a lifetime of working the weather system in aviation, and its relationship with users. "IT'S NOT ABOUT THE WEATHER!" It is about what the system does with weather information if it is (a) accurate; (b) dependable; (c) easily available to the various users; (d) weather information for the users comes to them in a common operational picture (COP); and (e) the product, decision support system, or other capability specially addresses a real need of the user, not the need of a meteorologist.

Let me give an example of these concerns. If there is a well-forecast squall line, and forecasts hit the windows from a forecast perspective, are the observations and forecasts provided in such a way as they are will disseminated and integrated into the ATM/ATC/flight deck system, or is the squall line well depicted in the forecast office or the CWSU, but not where operational decisions are made? I believe that often the answer is the proper connects are not made. To further the example, and concerning dependability, how did the forecast do yesterday, or tomorrow; if today was a hit, what is the overall reliability of hits versus misses?

The ATC system is currently a deterministic one, whereby an aircraft is given positive control information based on the perceptions of a controller (there are many computer assists in use, however). In a future NGATS, the complexity of operating a threefold increase in capacity will require a probability approach to ATC. Likewise, the infusion of weather into the system must use probability methodology, a sort of risk assessment field of likelihood of a weather event. In such a view there would be a complex field of probability functions for which the ATC system would design the lowest risk routing in terms of weather.

The distribution of weather information has traditionally been stovepiped, in that there have been developed a multitude of individual systems to provide information. Oftentimes, the information between systems is not consistent nor shared between these many perspectives, including spatial and temporal accuracy and quality of product. Because of this, and many other reasons, users can become confused by the inconsistencies in products, and hence become inured regarding how to make reliable use of weather products. Because net-centric concepts have been so well evolving in DOD and in the FAA, developing a robust National Aviation Weather System data grid will be a critical goal in the coming years. This grid must be updatable very frequently (e.g., microburst, and on the larger scale, oceanic weather hazards for long track flights. It is my belief that this weather information network should be government-developed, but could be operated by the private sector, and certainly used by the private sector.

Regarding the mix of public, academic and private sector elements of aviation weather, I believe that the federal government, particularly NOAA/NWS has the principal responsibility to develop capability for a future system. That being said, the FAA, DOD, and NASA must play a vital role in these developments. I also believe the private sector represents part of this brain trust of development. As an aside, during the development of mitigation of microburst wind shear dangers, the private sector joined the government and academia in these development, and on any given element of the work, I could not fully discern any difference between sectors. So for aviation weather, I believe that the greatest success in NGATS be realized by a close coordination between these public, academic, and private sectors. Indeed, NGATS has established a private sector institute to address these issues.

5. Conclusions

Weather will forever be an issue for aviation. There will always be weather hazards so serious that the aviation system must address them with safety and capacity considerations. That being said, it is likely over time that weather factors will become increasingly invisible to the flying public users, as weather is more effectively addressed by integration, automation, and dissemination. There have always been those who have stated that weather is "not my problem" or "not a problem" in aviation. Yet any pilot knows that it always will be a critical issue. The trick is to make the case, successfully, that scientists and engineers can provide the means of using weather for aviation.

6. Acknowledgements

As a courtesy to the development of the Wx IPT at NGATS/JPDO, the NCAR Research Applications Laboratory has supported my time, under contract No. S03-41778 from the University Corporation for Atmospheric Research.