Environmental Information for the Next Generation Air Transportation System

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Abstract

It is estimated that weather is responsible for approximately 70% of all air traffic delays and cancellations. Annually, this produces an overall economic loss of nearly $40B. These and other negative impacts on the U.S. National Airspace System will increase to the point of unsustainability unless the system is radically transformed. A Next Generation Air Transportation System (NextGen) was proposed to accommodate the increasing demand for capacity and the super-density operations that this transformation will entail. The heart of the environmental information component that is being developed for the new system will be a 4-dimensional data cube which will include a single authoritative source for NextGen Air Traffic Management (ATM) systems. Aviation weather constraints and safety hazards typically comprise meso-scale, storm-scale as well as microscale observables. These include convective weather, in-flight icing, turbulence, volcanic ash, space weather and the environmental impacts of aviation. Functional and performance requirements for the NextGen weather system are being established that will require significant improvements in current observations and forecasting capabilities. This will include satellite observations from geostationary and/or polar-orbiting sounders, imagers, lightning mappers, space weather monitors and other environmental observing systems. In 2003, a Joint Planning and Development Office (JPDO) was established by public law to design and implement NextGen. This paper provides the satellite meteorology community with useful insight on salient NextGen environmental information requirements that have been developed by the JPDO Weather Working Group. These efforts will help to shape current and future environmental satellite system capabilities, operations and applications.

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1. Introduction

Today's national airspace system is not performing adequately. Demand remains high in already congested markets. Weather is currently the greatest source of delays and cancellations. As the demand for capacity increases over the next two decades, if not addressed, aviation's environmental impact will present an even greater constraint on the system. That demand is expected to increase by as much as 2 to 3 times by 2025. For this reason, the Joint Planning and Development Office (JPDO) for the Next Generation Air Transportation System (NextGen) was formed in 2003. It comprises federal, industry and academic partners whose purpose is not merely to expand the airspace system, but to transform it. At airports and enroute, NextGen will increase both capacity and surface operations efficiency. It will allow planes to fly optimal flight paths while also improving their fuel consumption. It will also increase safety, greatly improve access to efficient transportation services and reduce aircraft emissions and noise.

The complete transformation of the current national (and global) airspace system is required. Today's airspace system is based upon twentieth century concepts such as ground-based navigation and surveillance and air traffic control communications by voice. It comprises disconnected information systems for air traffic control, fragmented weather forecasting, airport operations limited by visibility and forensic safety systems. NextGen is being developed to be a twenty-first century airspace system centered on satellite-based navigation and surveillance and with routine information to be sent digitally rather than by voice. Information will be network-enabled to be more readily accessible so that effective air traffic management will replace the current paradigm of sub-optimal air traffic control. Weather forecasts will be embedded into the decision making process which will allow operations to continue into lower visibility conditions. Safety systems will become evolve from current forensic capabilities to operate more prognostically. The transition to NextGen has already begun.

Because the current airspace system is contains such a highly structured and rigid network of routes it requires complex coordination and it can be easily crippled by significant weather anywhere in the system. Recognizing this, an ad hoc weather working group was incorporated into the JPDO early on to design a NextGen weather system to support the research and development of flexible airspace designs that can adapt to weather impacts. This system is built around four new approaches which are necessary to safely accommodate the increased airspace system capacity

1. Better weather information
2. Network enabled operations (NEO)
3. Increased use of automated decision tools
4. Better use of better weather information

2. NextGen Environmental Information

At the core of the NextGen weather concept of operations is a 4-dimensionsal, probabilistic weather cube that will contain a single authoritative source for routine air traffic management decisions. It will be populated with observations from satellites, radar, aircraft, surface systems and soundings. It will contain forecast information from numerical weather prediction models and expert nowcast systems which will be quality controlled by automated systems and NWS forecasters. All of this information will be integrated to support NextGen decision support systems and customized to generate both graphic and alpha-numeric information. The 4-D cube will contain information for the following primary aviation weather hazards and constraints

1. Convective weather and strong storms
2. Turbulence, wind shear and wake vortices
3. Icing (ground, in-flight and engine ice accretion)
4. Reduced visibility
5. Volcanic ash and gas
6. Space weather
7. Environmental impacts of aviation

a. Convective Weather.

Convective weather and string winter storms are the most significant source of delays and cancellation and high spatial and temporal resolution imagery and soundings will be required to optimize enroute efficiency and enable high density operations in the terminal area for arrivals and departures in convective weather and winter storm conditions. These data, however, are not sufficient. Satellite data will need to be integrated with all available high resolution data including:

1. Radar
2. Aircraft wind, temperature and water vapor profiles
3. Ground observations from ASOS and other sources
4. Lightning data
5. High resolution NWP model data

The development of convective applications that integrate satellite data with radar, aircraft and other data is an important first step that needs to be completed soon. In addition new research is needed to incorporate convective decay forecasts into these applications because current storm cell forecasts are too persistent. False alarm rates are also still too high. Echo top height analysis and forecasting requires significant improvement beyond trending. Vertical growth and decay estimates which are very difficult to produce need to be improved and incorporated into convective weather applications. Related forecasts such as lightning potential need to be incorporated into these applications that use more accurate satellite-derived microphysics including glaciation potential. Better information on the current and forecast rate and state of precipitation is needed. Finally, probabilistic fields derived from ensembles and statistics need to be developed that can meet the unique needs of aviation users for the very short (5-30 minute) and medium (30 min – 2 hour) tactical operations as well as the longer tern (2-6 hour) strategic forecasts required by aviation users operating in the convective environment.

b. Other Weather Hazards and Constraints for Aviation

While convection provides the greatest impact on aviation capacity and efficiency, turbulence is the primary safety hazard. It is responsible for most of the aviation-related injuries to air crews. Satellite data from improved imagers and sounders will be increasingly more useful to detect and forecast turbulence associates with convection (either in situ or remotely propagated turbulence), orographic effects or the jet stream. High resolution water vapor imagery and hyperspectral soundings hold particular promise in these areas. In-flight icing is a very serious safety hazard for aircraft which operate at lower flight levels and in lower dynamic ranges. This is especially true for low-end general aviation aircraft and small commuter aircraft. Since aircraft icing reports and radar microphysical observations are not as ubiquitous, satellite derived microphysics hold the key to improving icing nowcasts and forecasts sufficiently to use them in more than just an advisory capacity. More and better could property information is also needed to improve ceiling and visibility forecasts since unintended flight into IFR conditions continues to be a serious cause of weather mishaps for VFR pilots. Ceiling and visibility also routinely affects runway capacity at some airports such as San Francisco, Juneau, etc. Although rare, another aviation safety hazard that gets significant attention is volcanic ash since the results of an encounter with a volcanic ash cloud are potentially catastrophic. Multi-spectral processing of satellite data is critical for providing early warning of this hazard, to locate it both horizontally and vertically, and to differentiate it from ordinary clouds.

c. Space Weather

With the airlines' increasing dependence on trans-polar routes, the increasing exposure to atmospheric ionizing radiation associated with space weather is becoming more of a concern. Currently uninterrupted HF is the only requirement for trans-polar flight. Although the International Committee on Radiological Protections (ICRP) classifies air crews as radiation workers, the FAA cannot yet establish if standards for human exposure are required because an accurate atmospheric ionizing radiation model is still under development. The NASA Nowcasting of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) Model is under development to address the need for a model to correctly calculate human exposure/dosage. Using this new model, Mertens et al (2008) showed that ICRP total annual dose allowances for pregnant women were exceeded in any polar flight during the 2003 Halloween storm period, thus the increased concern.

d. Environmental Impacts of Aviation

As the airspace systems grows to meet increasing demand, the combined effects of aviation on climate, air quality, ground water and noise will collectively provide more constraints to that growth than those attributed to the weather. Aviation accounts for about 1 -3 per cent (+/- 300%) of global climate impact but may be substantially higher regionally. Much more research is needed to reduce the uncertainty in both carbon emissions and the impact of contrails on climate. The air quality impacts of aviation are even more poorly understood. Noise impacts are being addressed aggressively, however, through research efforts and roadmaps for improved engine and airframe designs by government and industry. It is expected that improved airframe designs that result in better icing resistance will significantly decrease groundwater contamination. In all of these areas however, increasing the quantity, quality and utility of satellite data for aviation will aid in the monitoring and forecasting needed to mitigate the environmental impacts of aviation.

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