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AIR TRANSPORT IN GHANA: SOME CLIMATIC CONSTRAINTS

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Abstract. Understanding a definite geographic context is essential for effective air transport management. To date, the consequences of changing weather conditions and climate on the transportation sector in Ghana has been grievous to the economy of the country. Unfortunately, the impact of climate change on the aviation industry has received very little attention in Ghanaian literature. Meanwhile, it is widely known that transport systems on the whole perform poorly under adverse weather and climatic conditions. This paper seeks to reflect a growing orientation in research and philosophy in the field of air transport and severe weather and climatic constraints. Understanding underlying principles of climatic conditions and weather is essential to air navigation in Ghana. Clear air turbulence, ceiling and visibility, thunderstorms, electrical phenomenon, climate-induced seasonal variations, and vegetation are some of the threats to air transport across Ghana's airspace. Information is derived from literature surveys, workplace counts, and an aviation researcher. Overall, large information technology investments, consolidation, and re-structuring are all major issues that must be addressed by stakeholders ambitious to stay afloat and competitive in Ghana's airspace.

Keywords: climatic conditions, adverse weather, severe, extreme, origin, destination, Ghana, navigation.

1. Introduction

In the context of improving and expanding air travel in Ghana, the pertinent question that has remained unanswered over the years is, 'to what extent does the frequency of bad weather and climatic conditions hamper the growth and development of air travel'? A key question, according to the International Civil Aviation Organization, is 'whether the international aviation community fully understands what potential medium-term and long-term impacts there will be on commercial aviation safety', while stating that the physical impacts and the economic costs of climate change on transport systems are subjects 'for deeper study' (Economic… 2005). As the climate changes, extreme events are becoming more frequent on average. Predictions by EUROCONTROL see a doubling of two days air traffic by the year 2020 (Eurocontrol 2003). This predetermines the degree of safety measures required on the national airspace of Ghana. On 19 March 2012, for example, attempts by some domestic commercial airliners to land at the Tamale and Takoradi airports proved unsuccessful due to poor visibility, and those flights had to return to their origin. On 20 February 2012, Takoradi Airport was closed due to poor visibility. The same conditions repeated throughout all the busy airports in Ghana except Kotoka International Airport (KIA), where the situation could be managed with the aid of instrument landing systems (ILS). On 6 June 2000, an aircraft arriving at KIA from Tamale crashed due to poor visibility (vibe.

com). What is happening in Ghana seems to fit a larger pattern of frequent extreme weather and climatic events in other parts of the world. For example, the severe European heat wave that killed many thousands of people in 2003 and the powerful hurricanes that have struck China and the Americas in the past years are empirical evidence. In the wake of these global severe weather trends, Ghana needs to commence preventive preparations or measures in order to stand shoulder high to the occasion, should any unfortunate event arise as a result of changing weather conditions. Though the airspace of Ghana is ostensibly clear and gentle, the situation is gradually changing and might leap from a better yesterday to a good today and regrettably to a worse in the near future. 'In order to maintain the present level of development and to move steadily into the 21st century it is absolutely necessary for Ghana to update, improve and maintain facilities and equipment to ensure the comfort and safety of the flying public. This should be treated as a matter of urgency; otherwise the dangerous bacteria of obsolescence will infest and impair the good work done over the years' (Dwemoh 2007). The effects of adverse weather and climatic conditions on transport, particularly air transport in Ghana, have scarcely been documented. Rather, all efforts are harnessed at mitigating accident situations related to road traffic, which is the most patronised means of transport in Ghana. However, now is the time to place more premiums on the prevention of accidents on other means of transport, especially air transport, which is fast becoming the closest substitute or alternative option to road traffic. A study by M. A. Rossetti shows that for 66 out of 5,700 accidents in the USA between 1993 and 2002 the reported primary cause was weather (Rossetti 2002). Poor visibility delayed about 14 domestic and international flights serving Beijing (December 2011). Prominent causes of air flight delays range from extreme meteorological conditions and maintenance to severe weather and climate (Koetse, Piet 2007). J. Evans, S. Allan. and M. Robinson attempt to qualify the delay impact of convective weather noted that convective weather will reduce the capacity of an airport but rarely will thunderstorms close traffic to both arrivals and departures for more than 15 minutes (Evans *et al*. 2004). Weather is an integral component of climate. Hence, the climatic regions within which most active airports operate must be understood well by all stakeholders (airline operators, travellers, and air traffic management). This review consists of four major sections after the introduction in section 1. Section 2 covers an overview of the climate of Ghana. Section 3 analyses and synthesises severe weather and its potential impacts on air navigation in Ghana. Section 4 comprises conclusions and recommendations.

2. Overview of the climate of Ghana

2.1. Wet and dry seasons

The weather of a place refers to the day-to-day or hour-to-hour conditions of the atmosphere. It is the state of the atmosphere at any given time, whereas climate is the average spatial-temporal weather conditions (Minia, Z., Ghana Meteorological Service). The amount of rainfall varies in Ghana. Rainfall generally decreases northwards. This is explained by the movement of the low pressure belt known as the Inter-tropical Convergence Zone (ITCZ). The Inter-tropical Convergence Zone (ITCZ) is the meeting point of the tropical continental air mass (CT) and the tropical maritime air mass (MT). From May to August, the moisture laden air mass (MT) travels as far as to the Tropic of Cancer, thereby producing a lot of moisture, even in the northernmost part of Ghana. This subsequently produces condition suitable for both plant and animal life. From November to April, the tropical continental air mass (CT), which originates in the Sahara, takes over. The CT travels as far as 5 ° latitude. Thus, the air mass is known variously as the North-East trade winds or the Harmattan (dry season). It is generally dust laden, and severe cases for both air and road navigation are usually recorded between January and March.

2.2. Climatic regions of Ghana

Based on average spatial weather conditions with respect to time, Ghana is classified into four major climatic regions. The climate of a geographic region is indispensable to the extent that climate determines the type of vegetation of an area. The major climatic regions of Ghana are; tropical interior, wet semi-equatorial, dry equatorial, and wet equatorial.

2.2.1. Tropical interior

This climatic region covers all three regions of northern Ghana and parts of the region of Brong-Ahafo. Of particular interest is Tamale Airport. The region experiences short but heavy rainfall. Annual rainfall ranges between 1100 mm and 1250 mm. Cumulus and cumulonimbus are the cloud type peculiar to the region. Rains become more intensive between August and September as the ITCZ is on its way back to the equator. The rainfall types here are convectional, characterised by massive thunderstorms, lightning, and windstorms. This is a threat to air navigation. Lightning and thunderstorms have the potential of striking down flights at a certain flight level. For the aviation sector, wind speeds are important because of their impact on safety. Extreme wind speed implies that aircraft are not allowed to land at alternate aerodromes. This has drastic cost implications for both airlines and travellers.

Adversely, high winds imply that the departure of aircraft will be delayed. Wind speeds and directions also influence the use of runways and increase the probability of accidents. For example, one of the largest aviation accidents at Schipol Airport in the Netherlands in 1997, after the EL-AL Boeing catastrophe in 1992, was due to the landing of a Transylvania plane with very strong crosswinds. However, the tropical interior experiences single maxima rainfall, which usually starts in late April and lasts until early October. By late October, the rains abruptly give way to the harmattan, which is accompanied by wind shear stress. The dry season spans from November to March. Hazy conditions become the dominant factors influencing air travel at this period of the year. Relative humidity can fall as low as 20% in the dry season and rise to over 80% in the rainy season. Temperatures are quite steady in Tamale: 23°C minimum at night and 33°C on average during the day.

2.2.2. Wet semi-equatorial

The wet semi-equatorial climate type covers the southern fringes of Brong-Ahafo, the entire Ashanti and Eastern regions, and some parts of the Western Region (where Jasikan is located). Places of interest under this climatic region are Sunyani Airport and Kumasi airport, both serving domestic flights but can also serve as alternative aerodromes to international flights to Ghana or her neighbours. The wet semi-equatorial region experiences longer double maxima rainfall. The region sometimes experiences convectional precipitation and other times experiences conventional precipitation within any of the two major rainy seasons in a year. No single precipitation type is consistent. Convectional and conventional rains are generally associated with thunder and lightning. Such events contribute to the seasonal interruptions on navigational activities in this region. It is risky to fly through convective weather conditions with their maximum accident potential.

The first rains fall between April and July, whereas the second rains are often expected between September and November. The region experiences harmattan and its rippling effect between January and March. Hazy conditions set in instantaneously, thereby resulting in flight delays and cancellations. Mean annual rainfall can exceed 1600 mm. Relative humidity is about 78% with temperatures around 28°C. That notwithstanding, current conditions are subject to changes as a result of climate change.

2.2.3. Dry equatorial

The dry equatorial region is found along the coast of Ghana. Major cities harbouring this type of climate are Accra and Cape Coast, as well as the coastal fringes of the Volta Region. The characteristics of the dry equatorial climate region are similar to those of the tropical interior.

Less than 1000 mm, usually between 740 mm and 890 mm, of rainfall is annually recorded, however. The effect of the harmattan is minimal. The region also experiences double maxima rainfall. But second rains sometimes do occur in negligible amounts. This explains why Accra is more feasible and favourable than other regions in terms of navigation. Kotoka International Airport (KIA) is located in this region. Temperature varies all year round, between 25 and 28°C. Relative humidity ranges between 60 and 75%. Weather and climatic conditions in this region are moderate all year round, supporting navigational activities. Thus, KIA's location offers it an advantage over all other airports in the country to handle landing and takeoff, except in extremely severe cases. For example, average delays in Accra are 60 minutes for arrivals and 74 minutes for departures.

2.2.4. Wet equatorial/south-western equatorial

This climatic region records the highest annual rainfalls in Ghana. The region experiences showers throughout the year; of premium value in this discourse is Takoradi military/public Airport.

Annual rainfall ranges between 1900 mm and 2100 mm. But due to climate change, annual rainfall in some years reaches about 2500 mm, a typical example being the Axim area. Convectional rainfall occurs all over the world but especially within the tropics. It is usually heavy and accompanied by thunder and lightning. Air navigational activities in this region are expected to rise geometrically in the near future because of the discovery of oil and gas in commercial quantities in the region. Thus, conditions relating to weather and climate have come into the focus of organisations involved with aviation and the oil companies, as well as other symbiotic establishments. Precipitation characteristics in this region appear unfavourable to the much needed expansion of air transport, especially commercial aviation.

Temperatures in Takoradi area range between 21°C and 28°C, while relative humidity is approximately 80%. The skies above this region are generally areas where icing takes place. In January or late December, when the region experiences haze, visibility is impaired, making it difficult for landing or takeoff of flights. On 13 February 2012, visibility impaired by haze did not allow commercial flights to land at Takoradi Airport.

3. Severe weather

Severe weather is the predominant cause of aviation accidents (Mahapatra 1999). In addition to catastrophic crashes, atmospheric turbulence originating from severe weather creates discomfort and injury due to dislocation of cabin objects and passengers. Severe weather disturbance includes thunderstorms, turbulence, convection-induced ceiling and visibility, and in-flight icing (Kulesa 2002). The CPB has estimated that a 'wrongly' configured airport like Schipol – implying that the number of hours the airport has to close down is unnecessarily long–may lead to disadvantages for the aviation sector amounting to between 3 million and 1 billion euro (CPB 2002). Airlines have to compensate passengers for delays, providing meals or snacks or both. Flight delays at the airport of origin are less costly and safer for the flight operator than airborne delays. Severe weather is estimated to cause 70% of all delays while also being an important contributory factor in 23% of all aviation accidents in the USA. Poor visibility in the summer months and rain storms in the winter months lead to substantial delays and numerous cancellations (Eads *et al.* 2000). This alone explains that weather is an integral component of the climate in which flights navigate.

3.1. Potential impact of severe weather on air navigation

Adverse weather conditions lead among others to an increase in the average travel time, increase in spread of travel times, and an increased probability of accidents (Koetse, Piet 2007). Thus, generalized costs of transport are affected. Under severe weather conditions, people consider cancelling certain trips, depending on the purpose of the trip.

3.1.1. Thunderstorms/windstorms

A thunderstorm is a rain shower during which you hear thunder. Since thunder comes from lightning, all thunderstorms have lightning. A thunderstorm is classified as 'severe' when it contains one or more of the following: hail ¾ inch or greater, winds gusting in excess of 50 knots (57.5 mph), or a tornado. Worldwide, there are an estimated 16 million thunderstorms each year. At any given moment, there are roughly 2,000 thunderstorms in progress around the world (National Oceanic and Atmospheric Administration, NOAA). Windstorms make it difficult to control aircraft, especially during landing. Underestimating wind shear and direction may mean that wrong decisions are taken on the design of airports in terms of the capacity and orientation of runaways. For instance, within the tropical interior climate region of Ghana, rains are generally preceded by very strong windstorms that uproot very thick and large trees and damage buildings. Such winds can be catastrophic for aircraft.

Thunderstorms can close airports, degrade airport capacity for arriving and departing flights, and hinder or stop ground operations. Thunderstorms are a severe weather event of great concern to aviation. D. Rhoda, E. Kocab and M. Pawlak studies the deviations of pilots from nominal flight routes due to weather (Rhoda *et al.* 2002). The human analysts studied 43.5 hours of flight track data during six thunder-storms in 1999 over the Memphis, Tennessee Centre. They note that the main difficulty with this study is the identification of deviations since en route aircraft can generally avoid the storm edge by adjusting their course by as little as 10 to 20 degrees. Terminal area deviations require an aircraft to forfeit position in the landing queue and it is subsequently moved to the end of the queue at very busy airports like Heathrow in the UK.

Convection, the upward motion of warm air that causes thunderstorms, is most prominent between June and July in Accra, May and June near Takoradi and Kumasi, and July and September near Sunyani and Tamale in Ghana. Pilots are less likely to pass through line thunderstorms since they have fewer gaps in the system and are generally viewed as more hazardous (Jeffrey 2008). Though turbulence is the primary concern for pilots, several harmful atmospheric effects may be experienced near a thunderstorm (Mahapatra 1999). Lightning damage can remove an aircraft from operation and result in both loss of revenues and excess maintenance costs. It is generally benign for aircraft with electrically conducive skins such as aluminium skins. The cumulonimbus clouds that are common in Ghana contain ions that can lead to the crash of a flight.

3.1.2. Downburst

A downburst is a strong downdraft which causes damaging winds on or near the ground (National Weather Service Forecast Office, Columbia, SC). Cold air begins to descend from the middle and upper levels of a thunderstorm (falling at speeds of less than 20 miles an hour). A downburst is a localised area of damaging winds caused by air rapidly flowing down and out of a thunderstorm (National Severe Storm Laboratory, NSSL). Damage from downbursts can be so severe that it is mistaken for tornado damage. Downburst damage can cover hundreds of square miles or be limited to a single field. Downburst induces haze-like conditions, thereby posing a threat to flights during landing or takeoff.

3.1.3. Turbulence

In fluid dynamics, turbulence or turbulent flow is a flow regime characterised by chaotic and stochastic property changes. This includes low momentum diffusion, high momentum convection, and rapid variation of pressure and velocity in space and time. Nobel Laureate Richard Feynman described turbulence as 'the most important unsolved problem of classical physics'. Turbulence is air movement that normally cannot be seen. It may occur when the sky appears to be clear and can happen unexpectedly. It can be created by any number of different conditions, including atmospheric pressures, jet streams, mountain waves, cold or warm fronts, or thunderstorms. There are several notable problems with clear air turbulence. It cannot always be foreseen, so there is no warning. It is usually felt at its mildest on the flight deck and is generally more severe in the aft section. It can occur when no clouds are visible. Aircraft radar cannot detect it. It is common at high altitudes, where a cruising airliner can suddenly enter a turbulent area. Non-convective turbulence is a major aviation hazard. All aircraft are vulnerable to turbulent motions. Non-convective turbulence can be present at any altitude and in a wide range of weather conditions after occurring in relatively clear skies as clear air turbulence. The most hazardous clear air turbulence occurs in opposing motion to an aircraft. Any aircraft entering turbulent conditions is clearly vulnerable to damage; smaller aircraft are susceptible at lower levels of turbulent intensity than are large aircraft. Aircraft may experience jostling, which is a discomfort for passenger and crews, to sudden accelerations that can result in serious injury and temporary loss of aircraft control. It further causes reduced flight operation and delays. Turbulence is the leading cause of in-flight injuries. There are countless reports of occupants who were seriously injured while moving about the passenger cabin when clear air turbulence was encountered.

3.1.4. Jet streams

A jet stream is defined as a current of rapidly moving air that is usually several thousand miles long and wide, but is relatively thin (Department of Atmospheric Sciences, University of Illinois). They are found in the upper levels of Earth's atmosphere at the tropopause, the boundary between the troposphere and stratosphere. Jet streams are important because they contribute to worldwide weather patterns and as such they help meteorologists forecast weather based on their position. In addition, they are important to air travel because flying in or out of them can reduce flight time and fuel consumption (NOAA). Inversely, jet streams moving in the opposite direction to flight can lead to shortages of fuel and consequently flight may crash down. Thanks to research conducted by pilots and meteorologists, it is understood today that there are two main jet streams, which are located in the northern hemisphere. While jet streams do exist in the southern hemisphere, they are strongest between the latitudes of 30°N and 60°N. The weaker subtropical jet stream is located closer to 30°N. The location of these jet streams shifts throughout the year however, and they are said to 'follow the sun' since they move north with warm weather and south with cold weather. Jet streams are also stronger in the rainy season because there is a large contrast between colliding Arctic and tropical air masses. In the dry season, the temperature difference is less extreme between the air masses and the jet stream is weaker (NOAA).

3.1.5. Ceiling and visibility

Low ceiling and reduced visibility are safety hazards for all types of air navigation. Haze (dust-laden winds) during harmattan and liquid water in the atmosphere (rain) is the major causes of visibility ceiling. In the USA, statistics indicate that ceiling and visibility were cited as contributory factors in 24% of all general aviation accidents between 1989 and early 1997 (Gloria *et al.* 2003). Ghana had her own share in 2000, when an Air Force aircraft landed off the main runway at Kotoka International Airport (KIA). The situation was a result the impairment of visibility caused by a heavy downpour. In Ghana, not including KIA, at a certain visibility range only Air Force flights can manage to land at Takoradi, Kumasi, Sunyani, or Tamale airports. Air Force flights have a light system that aids visibility and enhances landing. Thus, commercial airlines may have to delay or cancel flights because of their visibility range policies. Depending on the size of aircraft, minimum visibility required before landing is 1800 meters. Low ceiling and poor visibility accidents occur when pilots who are not properly rated or are flying an aircraft not equipped with the necessary instrumentation encounter such conditions. This can result in loss of control or controlled flight into terrain. In 1991, the University of Illinois, USA, used simulated weather conditions to test twenty Visual Flight Rule (VFR) rated pilots. When deprived of visual contact, each pilot experienced loss of control. It on average took approximately 178 seconds, giving each pilot less than 3 minutes to live after entering a cloud (Kulesa 2002). Low ceiling and poor visibility are not just safety issues. They can also severely degrade the efficiency of commercial and military aviation, reduce the capacity of an airport, and lead to airborne or ground delays that result in diversion and cancellations, missed connections, and extra operational costs.

3.1.6. In-flight icing

This is the build up of ice on an aircraft during flight at altitudes above freezing. Hail (spherical or irregular pellets of ice) is also a nuisance to air navigation. Sunshine determines the weight of wind and humidity. When it is sunny, the wind is light and support for aircraft lift is minimal. When the temperature is low, humidity increases, and the wind is heavy, aiding lift. But when temperatures become cold, cloud or ice formation becomes possible. In icing situations, aircraft movement is affected. At altitudes where such icing occurs, ice may build up on control surfaces, instrument orifices, propellers, and airspeed instrument. This alone can potentially reduce airplane lift by 25%, increase drag, and lead to loss of control. In-flight icing causes approximately 11% of all weather-related accidents among general aviation aircraft (Gloria *et al.* 2003).

3.1.7. Vegetation and birds

Climate affects the vegetation of an area. The alternating effects of wet and dry seasons determine the life processes of a region. During the rainy season, most grasses and trees develop new flowers and leaves; insects gather around the new flowers and leaves, in turn serving as prey to migrating birds such as sparrows, egrets and vultures. Thus, vegetation and forests, which are dependent on climate, encourage bird habitation around an airport. The biggest enemy of an aircraft is the bird, and since aircraft cannot avoid birds during landing or takeoff, disaster is bound to occur. Aircraft that use jet propellers are especially vulnerable. If a bird flies into the propeller, the engine will stop abruptly, leading to fatalities. Many cases of accidents associated with birds have occurred in the USA and Canada.

Forecast data parameters are applied to critical aircraft thresholds such as icing, turbulence, convection, IFR conditions, winds, and crosswinds along a flight path. When critical weather thresholds are identified, the specific points are labeled to show favorable, marginal, and unfavorable (or adverse) hazardous flight weather, depending on the exceeded threshold. Thus, a tailored flight route weather effects field is created for each aircraft based on the aircraft's specific weather sensitivity thresholds (Knapp *et al.* 2006).

4. Conclusions

The goal of the study is to inform air transport policy and development planners and implementers in Ghana to create and protect safer and more efficient air transport services in the country and also to enable them at all times to keep abreast of weather conditions within the skies of the country at all lengths and heights of flight.

The study finds two major categories of climatic conditions that influence air travel: short term (instantaneous) and long term (seasonal). The study reveals that ceiling and visibility are instantaneous climatic conditions (weather) mostly affecting landing and takeoff at various origins and destinations. Ground and airborne delays can consequently occur, adding to the operational costs of airlines and providing immeasurable inconvenience to passengers.

The paper also finds that thunder, lightning and windstorms are seasonal convective weather phenomena that obstruct air navigation. These phenomena can lead to loss of control by a pilot or even outright strike by lighting.

The study finds that downbursts are dangerous to navigation. The rapid change in wind speed and/or direction poses a very real threat to airplanes during takeoff and landing. During landings the airplane begins its descent, flying into a strong headwind, a downdraft, and finally a strong tailwind, representing an extreme situation just prior to impact. During takeoff the pilot experiences a headwind and increased aircraft performance, followed by a short period of decreased headwind, a downdraft, and finally a strong tailwind.

Another finding of the study is that air turbulence can be immensely catastrophic and hostile to air navigation. The effects of air turbulence range from jostling, loss of control, flight route deviation, stalling movement to a crash.

Moreover, in-flight icing has also been found to be a severe weather condition that has the potential to decrease airspeed and even worse cause a flight to land prematurely as it adds more weight than the capacity of the flight.

In terms of commercial use, the jet stream is important for the airline industry. One of the most important impacts of the jet stream though is that as a strong current of rapidly moving air, it has the ability to push weather patterns around the world. As a result, most weather systems do not just sit over an area, but they are instead moved forward with the jet stream. This phenomenon hinders aircraft navigation.

Since weather conditions can seriously restrict operations and levels of service available to system users, the manner by which weather is observed and forecast and the way in which this information is disseminated and used in making air traffic management decisions must be addressed with optimal and innovative technology.

To estimate the impact of a convective weather system on en-route airspace, the distribution of the location and extent of the convective weather must be known (FAA). It is therefore imperative to deduce from the literature that existing convective weather can be forecast by comparing historical national convective weather for an hour. This can only be accomplished by using convective weather detection products, which are lacking at airports in Ghana, as a preventive measure against global severe weather trends hampering air transportation.

The magnitude of aircraft delays during thunderstorms and unclear weather conditions is large. Flights can be re-routed through longer paths further from their original flight plan instead of cancelling or delaying. There should be a more rigorous method to define the area of impact of the severe weather system and the flights that potentially could be affected. Unfortunately, you cannot look at a thunderstorm and see whether it is going to be severe. Doppler radar is able to look inside thunderstorms and 'see' the movement of air, giving meteorologists' indications of microburst and allowing them to issue warnings to pilots.

It is further learnt from the literature and reports of investigations that the use of integrated approaches to provide improved guidance of convective weather hazards for transoceanic flights could help mitigate potential hazards. The Ghana Civil Aviation Authority (GCAA), together with other stakeholders, should develop advanced concepts of using weather forecast models to create probabilistic weather-related impact predictions for today's consumption by air-traffic management planning in Ghana. This could necessarily be incorporated into largely automated decision-support tools in the near future.

Today, movement of the jet stream north has been detected, indicating possible changes in climate. Whatever the position of the jet stream though, it has a significant impact on the world's weather patterns and severe weather events like floods and droughts. It is therefore essential that meteorologists and other scientists understand as much as possible about the jet stream and continue to track its movement, to in turn monitor such weather around Ghana. A detailed assessment of the primary and supplementary sensor network for each of the major airports in Ghana should be conducted. KIA is the only airport in Ghana that has an instrument landing system (ILS), which permits landing even during severe weather.

Worth acknowledging is the idea acquired from the literature reviewed that Ghana Airspace Management needs to develop strategies and products for forecasting the potential for icing. Such a tool or mechanism will enable users to better anticipate where icing hazards are likely to occur. It will further allow air traffic controllers to make more informed decisions when assigning altitudes to aircrafts.

Furthermore, an algorithm that can help forecast turbulence is vital in Ghana's airspace navigation. The algorithm should be able to forecast turbulence models, jet streams, mountain-induced turbulence, and convective induced turbulence. Great attention should be placed on Aviation Digital Data Service. This is a tool available on the Internet. It allows pilots, airline dispatches, and other users' easy access to weather data. "Flight path Tool" is a component of ADDs, which displays vertical cross-sections of turbulence, icing, thunderstorms, and other aviation weather hazards for specific flight altitudes and flight paths selected by the user.

The hazy conditions that negatively influence air space navigation around Takoradi, Kumasi, Sunyani, and Tamale airports in Ghana during harmattan could be checked with forestation. But that is not to suggest that forests should be allowed to flourish around airports. Grasses and trees around runways, taxiways and aprons must be reduced to the barest minimum to avoid bird habitation and its consequences at the airport.

The latest technology that has proven crucial to the aviation industry is global navigation satellite systems (GNSS). GNSS comprises all forms of satellite-based navigation systems that provide global coverage and signals for navigation, positioning surveillance, and timing information for aviation and space applications. The GNSS comprises three categories: GNSS-1, GNSS-2 and GNSS-3. Ghana is under the GNSS-3 category, countries without the capacity or necessary infrastructure to deploy satellites but which have or seek to develop local systems to explore the full potential of the global systems. GNSS signals integrated with additional information layers enable air navigation and flight tracking. The system includes waypoints as well as precise navigation collision avoidance, cargo monitoring, and search and rescue operations. The European Global Navigational Operating System (EGNOS), which also is an aspect of GNSS-2, helps national, intercontinental, continental flights identify alternate aerodromes whiles in-flight. EGNOS directly provides flight height reduction in angle of approach (direct and curved), better lateral guidance, optimised routes and fewer diversions, increased airport capacity (for example, helicopters); allows operation in non–ILS equipped airports; avoids expensive land-based navigational aids and their maintenance; and above all increases safety. When extreme weather and climate conditions eventually lead to accidents and tragedies in Ghana's airspace, both passengers and freight transport will suffer. The negative economic repercussions that may arise as a result might be incalculable. People want to travel and need to travel; we should therefore make it possible for each and every one of us now and in the future.

References

CPB. 2002. Gevolgen van uitbreiding schipol [Consequences of extension of schipol airport]. USA, Illinois University: Den Haag. DAS.

Dwemoh, E. R. K. 2007. *History of civil aviation in Ghana.* Ghana Civil Aviation Authority.

Eads, G. C.; Kiefer, M.; Mendiratta, S., *et al.* 2000. *Reducing weather related delays and cancellations at San Francisco International Airport:* CRA Report No. D01868-00.

Eurocontrol. 2003. *User manual for the base of aircraft data (BADA):* Revision 3.5. Technical Report. European Organisation for the Safety of Air Navigation.

Evans, J.; Allan, S.; Robinson, M. 2004. Quantifying delay reduction benefits for aviation convective weather decision support systems, in *11thConference on Aviation Range and Aerospace Meteorology.* 4–8 October, 2004. Hyannis, MA.

Gloria, J. K.; Pace, D. J.; Fellner, W. L., *et al.* 2003. *The FAA Aviation Weather Research Program's Contribution to Air Transportation Safety and Efficiency*. Washington DC: Federal Aviation Administration,TRW Inc.

Review of Air Transport Developments in 2005. ICAO Annual Report, 2005.

Jeffrey, M. H. 2008. *Collaborative en route airspace management considering stochastic demand, capacity, and weather conditions:* Dissertation. Virginia, Blacksburg: Virginia Polytechnic Institute.

Knapp, D. I.; Raby, J.; Measure, E., *et al*. 2006. A weather decision aid for unmanned aerial vehicle missions, in *12th Conference on Aviation, Range, & Aerospace Meteorology*. 29 Jan–2 Feb. 2006. Atlanta, GA, Amer. Meteor. Soc., P 10.5.

Koetse, M. J.; Piet, R. 2007. *Climate Change, Adverse Weather Conditions, and Transport: A Literature Survey.* The Netherlands, Amsterdam: VU University Department of Spatial Economics.

Kulesa, G. 2002. Weather and aviation: How does weather affect the safety and operations of airports and aviation, and how does FAA work to manage weather – related effects?, in *The Potential Impacts of Climate Change on Transportation Workshop*. October 1–2, 2002, DOT Center for Climate Change and Environmental Forecasting.

Mahapatra, P. 1999. Aviation weather surveillance systems advanced radar and surface sensors for flight safety and air traffic management, volume 183. *Progress in Astronautics and Aeronautics.* The American Institute of Aeronautics and Astronautics and The Institution of Electrical Engineers. http://dx.doi.org/10.1049/PBRA008E

Rhoda, D.; Kocab, E.; Pawlak, M. 2002. Aircraft encounters with thunderstorms in en route vs. terminal airspace above Memphis, Tennessee, in *10th Conference on Aviation, Range, and Aerospace Meteorology.* 13–16 May, 2002. Portland, OR: American Meteorological Society.

Rossetti, M. A. 2002. Potential impacts of climate change on railroads, in *The Potential Impacts of Climate Change on Transportation Workshop Summary.* 1–2 October 2002 [online]. Available from Internet: http://climate.volpe.dot.gov/workshop1002