Specifics of Aircraft Operation and Possibilities for Improvement in Forecasting Used for Meteorological Support of Flights in the Arctic

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***Abstract* – The paper considers climatic and weather specifics of the Arctic, identifying dangerous weather factors with the highest frequency. Specificity of flying in the Arctic and state-of-the-art in flight meteorology are considered. The authors define the tentative approaches to solving tasks in improving quality of flight meteorology in the Arctic using numerical hydrodynamic prognostic methods.**

Key words – weather and climate of the Arctic, aeronautical meteorology, flying in the Arctic, WRF models, hydrodynamic atmospheric models

I. INTRODUCTION

Currently, the Arctic is a promising region that undergoes active development and active works in prospecting and development of mineral deposits. The Arctic is also of interest in the context of development of the Northern Sea Route (NSR) as a national traffic artery connecting European and Asian markets, as well as from the point of view of tourism development, as the Arctic has unique flora, fauna, landscapes and specific climate. All these factors determine a necessity to develop air transport in the region.

Organization of air transport requires climate data. Additionally, short-time planning of meteorological support of aircraft operation requires valid current and prognostic meteorological information on several dozens of meteorological features and processes throughout the region of the flights. Speaking of information on natural phenomena characterizing meteorological conditions along the flight routes and in the vicinity of departure and landing airfields, first of all, data is needed on some dangerous and unfavorable phenomena and their complexes.

Currently, the Arctic has a widely spaced grid of polar meteorological stations, therefore, meteorological coverage of the region is very sparse. Thus, determining weather conditions and distribution of atmospheric parameters appears a very challenging task. Nevertheless, its solution is of a great interest for meteorological support of aviation.

II. RESULTS AND DISCUSSION

This study is relevant due to an important role of aviation in Arctic regions, as the air transport provides timely delivery of passengers and cargo to remote isolated locations in the Arctic, including urgent medical care to population of the regions, as well as emergency rescue works in the shortest possible time.

The aim of this research is to identify features of meteorological conditions, their frequency and spatial distribution, analyze existing methods for their prediction and determine some directions for improvement of those methods in the vicinity of departure and landing airports and along the routes of arctic flights with the aim of ensuring safety, regularity and economic efficiency of aircraft operation.

In order to reach the objectives of the research, the authors propose using available meteorological data, such as satellite photos in various spectra, data from the network of land-based meteorological station by using nephanalysis methods, physical-statistical and synoptic interpretations of the hydrodynamic prognosis results.

Use of hydrodynamic weather forecasts provides: a significant objectivity of the forecast, simplification of synoptician’s work; larger lead time, ability to improve forecasting methods on the basis of new theoretical knowledge of dynamics and physics of atmosphere using state-of-the-art information technologies.

Recent success in numerical forecast of fields of meteorological values allows implementing real-time short- and medium-term forecasting of pressure fields, geopotential heights, vertical movements and trajectories of air particles. To a large degree, prediction of weather elements related to synoptic-scale processes, as well as mesoscale ones (precipitations, convection, fog, local specifics of wind behavior, dangerous weather phenomena) shall be performed by means of statistical interpretation of the output data from hydrodynamic atmospheric models with their subsequent application is meteorological support of aircraft operation in the Arctic.

In this research, in order to study features of arctic meteorological conditions, their frequency and spatial distribution through the region, the authors analyzed data archive of meteorological observations at Dikson aeronautical meteorological station(AMS) (Dikson Island, Taymyrsky municipal district, Krasnoyarsk krai) from the actual weather journals AV-6 covering the period from 1983 through 2015 during the registered operation of the Dikson Airport, as well as observational data from a network of polar meteorological stations in the meteorological support region of the Dikson AMS and satellite photos in IR and television bands.

In order to ensure safety, profitability and efficiency of air transport operation, it is necessary to take into account features of meteorological support of air traffic as well as specifics of arctic air transportation [7].

The specifics of aircraft operations in the Arctic regions is determined by various factors, including polar day and polar night, low ambient temperature during winter, heavy snowfalls in mid-seasons, large frequency of weather phenomena that aggravate or distort visibility (whiteout and other), poor radio-wave propagation and extremely sparse network of meteorological stations. Another feature is lack of visual landmarks during the flights over northern seas.

Aircraft operations in the Arctic regions are usually performed without alternative airfields. Meteorological service in these regions takes a special responsibility for the quality of air traffic meteorological support.

Wind is one of the most important factors that influence aircraft flight. It is practical to use a strong wind if it is favorable, and take a detour of an adverse wind area in order to avoid extended flight duration and related increased fuel consumption.

The main factors that determine severity of the meteorological conditions are low clouds and limited visibility, which taken together form weather minima. The following minima are set for flights in the arctic conditions: visibility out at sea of at least 2000 m, cloud base height of at least 150 m; near the shores of continents, islands and archipelagos visibility shall be at least 5000 m without gravity winds, cloud base heights of at least 200 m.

At high latitudes, thunderstorms are very rare, but fogs and low cloud cover are common. High transparency of the atmosphere determines good visibility. However, near-ground inversions and collection of tiny ice crystals and droplets under them create conditions for visibility deterioration. Besides, at low temperature in no-wind environment a fog may form at the airstrip after an aircraft takes off (sometimes fog forms even behind a ground vehicle moving through the airstrip); evolution of this fog is almost impossible to predict.

Cloud veil which, is specific for arctic regions, is also very dangerous for flying. It consists of clouds with a thickness ranging from several meters to several dozens of meters. They are invisibles to ground-based observer and may be detected only instrumentally with the help of special instruments RVO-2M or RDV. The cloud veil usually locates at a height of 30–100 m. Flying through it leads to a significant visibility deterioration and moderate to heavy icing.

Information about low clouds (below 300 m) is of large importance for meteorological support of air traffic safety.

Summer maximum of low cloud frequency is typical for arctic regions. Melting of snow and ice during the summer, increased area of water-leads in the arctic seas lead to higher air humidity, resulting in increased frequencies of low clouds.

Spatial variability of cloud height significantly depends on synoptical situation, especially when air-mass clouds are substituted with frontal ones. High variability of the cloud ceiling creates significant issues in aircraft take-off and landing.

In winter, arctic air forms at high latitudes almost throughout the territory above the Polar circle, while during the summer it forms predominantly over the Arctic ice.

Low air temperature, its comparative dryness, snow and ice underlying surface determine high visibility in the arctic air. During a cloud-free weather, when the sky is bright blue, it is possible to see objects at extended range.

Visibility in sea arctic air is somewhat better than in the continental arctic air. The arctic air is very clean and transparent when there are neither precipitation, nor fog, nor haze. Sometimes, clouds cover may cause local areas of deteriorated visibility in the arctic air. Fogs form in locations where ice is cracking and open water appears. The water surface temperature is always higher than the ambient air temperature, leading to appearance of evaporation fog in such a locality. More extensive fogs appear during the polar day.

Days with precipitation and haze account for 36 % in the eastern sector of the Arctic. The lowest frequency values of snowfalls and rainfalls are in July (16 %) and September (15 %). 83 % of fogs last for 4–9 hours. Thick fogs (visibility less than 200 m) are quite rare. In 81 % of cases, visibility in fog conditions is from 400 to 1000 m.

Thus, due to its geographic location, Arctic is characterized with a specific yearly and seasonal movement of meteorological values, a very short summer and a long winter.

During the summer, the period of the most active navigation, aircraft operation is influenced by high frequency of such dangerous and unfavorable weather phenomena as:

- low cloud cover,
- fogs, haze,
- freezing precipitation.

The average background temperature in the Arctic during the summer is about 4–6 ºC, depending on passing of air masses with different characteristics. With such average temperature values, the height of the zero isotherm is low, thus, flights largely happen in a layer with the negative temperature; if there is precipitation in the form of rain or drizzle, there will be significant icing of aircraft in the subcloud layer.

During the winter, there is a high frequency of:

- strong winds,
- phenomena causing deterioration of visibility (snowfalls, snot storms),
- low temperatures (especially when the humidity is high).

The cold season is very long, from September to mid-June. Strong winds are formed with Siberian maximum over the

Central Siberia, at that, the air flows gravitate to the north, thus the wind direction changes to the southern and along the shores of arctic seas there is a strengthening of winds that causes deteriorated vision due to ground blizzards. Low temperatures at high humidity determine aircraft icing and influence equipment operation, that is, there are limitations for operation of aircraft and ground vehicles at temperatures of –30…–35 °C, while the temperature over the Taymyr Peninsula and some other territories may go as low as –45…–50 °C and even lower. Another source of significant influence over the local weather is the type of substrate (at sea it is cold water and ice, onshore it is tundra, mountains, permafrost) and specifics of atmospheric circulation in this region.

The influence of polar day/night over the radiation balance and correspondingly daily and yearly change of meteorological parameters is also large.

Large spaces over the northern seas and the Arctic Ocean precondition movement of baric fields with high speeds as there are no significant mountainous obstacles. This leads to a fast change of weather. Large magnetic variation in the Arctic is due to the magnetic north being located in the region of Greenland and northern part of the Canadian Archipelago, unlike the true geographic North Pole. Due to a large distance between these poles, magnetic variation in arctic regions may reach 30-40 degrees and sometimes even more.

During the warm period, dangerous fogs and low cloud cover pose the highest hazard for aircraft operation, as they are high-frequency events. As most flights are performed during the summer navigation, forecasting these meteorological parameters is of the greatest interest.

Specifics of observation network and weather monitoring network (hydrometeorological stations (HMSs, upper-air synoptic stations (UASS), AMSs, radar stations):

- extremely sparse HMS network,
- even sparser UASS network,
- sporadic isolated radar stations,
- rare AMSs, due to a small number of airfields in the Arctic, located at large distances from each other.

Taking into account specifics of observations and meteodata transmission, it shall be noted that the data arrives every 3 hours or less frequently, UASS data – only twice a day.

It is evident, that available meteorological data are insufficient for reliable forecasting of meteorological conditions.

In order to solve the task of improvement in weather forecasting methods and meteorological support of aircraft operation in the Arctic, the authors propose to develop an automated method aimed at determining hydrometeorological conditions and their influence over aircraft performance characteristics. The problem of determining the meteorological condition in areas with deficiency of meteorological data shall be solved largely by applying synoptic-statistic methods of forecasting.

The following tasks are assumed to be involved in attaining the set goal:

- to evaluate a possibility of obtaining forecast field of meteorological values by means of mesoscale WRF hydrodynamic model in the Arctic;
- to evaluate a possibility of applying methods of physical-statistical interpretation of the results from hydrodynamic forecasting,
- to develop diagnostic and forecasting methods for synoptic situation;
- to develop a method of probability forecasting for fog and low cloud cover during the summer;
- to develop a method to evaluate efficiency of the probability forecasting for fog and low cloud cover in the Arctic;

III. CONCLUSIONS

Statistical analysis of year-to-year variations and frequency of group atmospheric processes in the Arctic, as laid out in works of A.Ia. Korzhikov [8], where use of prognostic components of linear and polynomial trends allows obtaining development scenarios of arctic atmospheric processes for all seasons with lead time of of 1 to 3 years. Such data may increase the quality of meteorological support in planning flights, as from them it is possible to determine the prevailing type of baric field, and thus expected weather condition for a long-term forecast period. In order to solve the issues with the real-time weather forecasting to provide meteorological support to specific flights, it is necessary to supplement traditional methods with numerical predictive methods employing HDMA.

Such research will allow developing a procedure to take into account hydrometeorological condition onto operation of small and short-haul aviation in the Arctic on the basis of the developed method.

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