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(54) Benævnelse: **Metode og systemer til detektering af farer for luftfart på grund af konvektivt vejr**

(56) Fremdragne publikationer:
US-A1- 2009 177 343
US-B1- 7 486 220
GREENE ET AL: "Vertically Integrated Liquid Water A New Analysis Tool", MONTHLY WEATHER REVIEW, WASHINGTON, DC, US, vol. 100, no. 7, 1 July 1972 (1972-07-01), pages 548-552, XP007917709, ISSN: 0027-0644
ROCKWELL COLLINS: "Collins WXR-2100 Multiuscan Radar Fully Automatic Weather Radar", INTERNET CITATION, 1 January 2003 (2003-01-01), page 10PP, XP007917548, Retrieved from the Internet: URL:http://www.baron58.com/Downloads/weath er%20radar%20white%20paper.pdf [retrieved on 2003-01-01]

DESCRIPTION

BACKGROUND OF THE INVENTION

[0001] Airborne weather radars are used to identify convective weather that generates turbulence that can be hazardous to aviation. The detection is typically based only on radar reflectivity of the weather that exists at a selected part of a storm. The degree of hazard is assumed to be related to this reflectivity. However, this is not always a valid assumption to make.

[0002] US 2009/0177343 discloses a radar system capable of using algorithms to identify whether types and placing weather information in a three-dimensional buffer. GREENE ET AL: "Vertically Integrated Liquid Water A New Analysis Tool", MONTHLY WEATHER REVIEW, WASHINGTON, DC, US, vol.100, no. 7, 1 July 1972 (1972-07-01), pages 548-552, XP007917709 ISSN: 0027-0644, discloses an algorithm for determining vertically integrated liquid water in a storm using radar return information, the algorithm integrates the total weight of water in a notional column of volume within the storm. US 7,486,220 discloses weather radar analysis of a storm system in which ongoing development of the returns within notional cells of volume in a storm as monitored over time. ROCKWELL COLLINS: "Collins WXR-2100 Multiuscan Radar Fully Automatic Weather Radar", INTERNET CITATION, 1 January 2003 (2003-01-01), page 10PP,XP007917548, Retrieved from the Internet: URL: http://www.baron58.com/Downloads/weath discloses a proprietary weather radar system determining storm characteristics by radar scanning.

SUMMARY OF THE INVENTION

[0003] The present invention in its various aspects is as set out in the appended claims. An assessment of whether a convective weather cell is a hazard is more properly made by an evaluation of the amount of vertical development of the cell. The greater the vertical extent and amount of precipitation maintained aloft, the greater is the vertical air velocity, which then produces turbulence that is hazardous to aviation. Therefore, to improve the assessment of the degree of hazard resulting from convective weather, there is a need to include the amount of vertical development of convection.

[0004] The present invention provides systems and methods for improving output of weather information. A weather radar system receives weather reflectivity values. A processing device stores the received weather reflectivity values into a three-dimensional buffer, calculates a sum of the reflectivity value stored in a column of cells within the three-dimensional buffer, and assigns a first hazard indication to the cells of the column when the result of the calculation is above a first threshold. A display device generates a weather display based on data stored in the three-dimensional buffer. The weather display includes a display icon associated with the hazard indication when a cell from the three-dimensional buffer has been selected for the weather display.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Preferred and alternative embodiments of the present invention are described in detail below with reference to the following drawings:

FIGURE 1 is a schematic block diagram of a system formed in accordance with an embodiment of the present invention;

FIGURE 2 is a flowchart of an exemplary process performed by the system shown in FIGURE 1; and

FIGURE 3 is a conceptual perspective view of a portion of a three-dimensional buffer used by the system shown in FIGURE 1.

DETAILED DESCRIPTION OF THE INVENTION

[0006] FIGURE 1 illustrates an aircraft 20 that includes a weather display system 30 for providing an improved radar return. The exemplary weather display system 30 includes a weather radar system 40 and a display/interface front-end 38, and receives information from other aircraft systems 46. The display/interface front-end 38 includes a processor 42, memory 43, a display device 44, a user interface 48, and a database 32. An example of the radar system 40 includes a radar controller 50 (configured to receive control instructions from the user interface 48), a transmitter 52, a receiver 54, and an antenna 56. The radar controller 50 controls the transmitter 52 and the receiver 54 for performing the sending and receiving of signals through the antenna 56. The weather radar system 40 and the display/interface front-end 38 are electronically coupled to the aircraft systems 46.

[0007] Radar relies on a transmission of a pulse of electromagnetic energy, referred to herein as a signal. The antenna 56 narrowly focuses the transmission of the signal pulse. Like the light from a flashlight, this narrow signal illuminates any objects in its path and illuminated objects reflect the electromagnetic energy back to the antenna.

[0008] Reflectivity data corresponds to that portion of a radar's signal reflected back to the radar by liquids (e.g., rain) and/or frozen droplets (e.g., hail, sleet, and/or snow) residing in a weather object, such as a cloud or storm, or residing in areas proximate to the cloud or storm generating the liquids and/or frozen droplets.

[0009] The radar controller 50 calculates the distance of the weather object relative to the antenna based upon the length of time the transmitted signal pulse takes in the transition from the antenna to the object and back to the antenna 56. The relationship between distance and time is linear as the velocity of the signal is constant, approximately the speed of light in a vacuum.

[0010] The present invention uses the system 30 to obtain the three-dimensional distribution of radar reflectivity of weather using an airborne radar, perform integrations of the reflectivity in vertical columns, and evaluate the integrations. The result provides a degree of turbulence hazard information to the aircraft. Because of the nature of radar detection of weather, the present invention also identifies areas above and below the analyzed column that might present a turbulence risk. A top of the convective storm might actually be above the detected top because the reflectivity might drop below what can be detected by the radar at that range. Because of this, one embodiment allows for some margin above and below the column to account for the possibility that the hazard extends somewhat beyond the detected column because of radar limitations.

[0011] The present invention uses a radar system capable of measurement of the three-dimensional distribution of weather reflectivity from which vertical integrations of reflectivity can be performed. An example radar system capable of measurement of the three-dimensional distribution of weather reflectivity is the IntuVue™ made by Honeywell International, Inc.

[0012] FIGURE 2 is a flowchart of an exemplary process 80 performed by the system 30. First, at a block 84, radar reflectivity values are received and stored by the processor 42 into a three-dimensional buffer located in the memory 43. Next, at a block 86, the sum of reflectivity values stored in a column of cells in the three-dimensional buffer is calculated. In another embodiment, an integration of the values in the column is performed. The system 30 vertically integrates the product of reflectivity values and altitude, each raised to some power.

[0013] In the present invention, an approximation of that integral is performed by;

$$\sum_{i=1}^{N} Z_i^a h_i^b h_i \Delta h$$

[0014] where Z_i is the reflectivity of the i-th cell in the column, h_i is the altitude of the i-th cell in the column, N is the number of cells in the column in the 3D buffer, and Δh is the vertical size of the buffer cell. If a=1 and b=0 were used as the power values, then would be just a straight vertical integration of reflectivity (i.e., VIR). To compute vertically integrated liquid (VIL), which is a known quantity that has been generated in the past using ground-based radar data, b=0, a = 4/7 are used, and the result is multiplied by a factor of 3.44e-6. This factor and the 4/7 exponent are taken from a power law relationship between weather reflectivity and liquid water content (LWC), which has units of kg/m^3.

[0015] In the present invention, a=4/7, b=1 are used as the power values. This turns the result into something like a potential energy. Potential energy of a mass (m) lifted to a height (h) is given by PE=mgh, where g is the gravitational acceleration. So if the reflectivity is converted to LWC (which is a mass-like quantity), times an altitude, the result is proportional to the energy that the vertical motion has expended to lift the water up into the atmosphere. More energetic vertical motion is expected to generate more energetic turbulence.

[0016] At a decision block 88, the processor 42 determines whether the result of the action performed at the block 86 is above a first threshold. If the result is above the first threshold, a hazard icon in a first format is generated and displayed on the display device 44, see block 90. After block 90, the process 80 goes to a next column for analysis, see blocks 94, 86. If the result is not above the first threshold, the processor 42 determines whether the result is above a second threshold, see decision block 98. The actions after the decision block 98 are similar to those after the decision block 88, except a hazard icon in a second format is outputted if the second threshold is exceeded.

[0017] In one embodiment, the first and second formats indicate whether the hazard is a "moderate risk" (e.g., amber) or a "high risk" (e.g., magenta) hazard. Other hazard indications (color, geometric) may be used as well as more than two types of hazards.

[0018] FIGURE 3 is a conceptual perspective view of a portion of the three-dimensional buffer 120. The buffer 120 includes a column 126 of cells that have been analyzed, as described above, and determined to be greater than the first threshold. The cells in the column 126 are associated with a corresponding hazard indicator. When any of the cells of the column 126 are selected for display, a hazard icon associated with the hazard indicator is displayed based on the cell location on the display device 44.

[0019] In one embodiment, the three-dimensional buffer is replaced with a conventional buffer for storing values from various radar sweeps at a particular latitude/longitude location or just adding a value from a radar sweep at a particular latitude/longitude location to a previous summation of values at that location.

[0020] The reflectivity values can be obtained from off-aircraft sources (e.g., other aircraft, ground weather systems, etc.)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US20090177343A **[0002]**
- US7486220B **[0002]**

Non-patent literature cited in the description

- **GREENE et al.**Vertically Integrated Liquid Water A New Analysis ToolMONTHLY WEATHER REVIEW, 1972, vol. 100, 70027-0644548-552 **[0002]**
- **ROCKWELL COLLINS**Collins WXR-2100 Multiuscan Radar Fully Automatic Weather RadarINTERNET CITATION, 2003, 10PP- **[0002]**

Patentkrav

1. Metode (80) til frembringelse af information om vejrforhold, hvilken metode (80) omfatter: ved en behandlingsenhed (42)
a) modtagelse af værdier for vejrrefleksionsevne fra et vejrradarsystem (30)
b) lagring af de modtagne værdier for vejrrefleksionsevne i en tredimensional buffer (84, 120)
c) generering af en værdi på baggrund af modtagne værdier for refleksionsevne og en tilknyttet breddegrad/længdegradsposition ved
i) beregning (86) af en sum af værdien for refleksionsevne, der er lagret i en kolonne (126) af celler i den tredimensionale buffer (120)
ii) idet beregningen anvender ligningen:

$$\sum_{i=1}^{N} Z_i^{\frac{4}{7}} h_i \Delta h$$

hvor Z er reflektionsevnen for den i'te celle in kolonnen (126), h er højden af den i'te celle i kolonnen (126), N er antallet af celler i kolonnen i den tredimensionale buffer, og *Ah* er den vertikale størrelse af cellen i bufferen
d) tildeling af en fareindikation (88) til værdierne for refleksionsevne ved en længde/breddeposition, når den genererede værdi er over en første tærskel
e) ved en displayenhed (44) koblet til behandlingsenheden (42), generering af et vejrdisplay (90) på baggrund af data, der er lagret i den tredimensionale buffer, heriblandt et display-ikon forbundet med fareindikationen
og
f) gentagelse af trin b til d i en løkke (94) for alle kolonnerne i den tredimensionale buffer.

2. Metode ifølge krav 1, der i øvrigt omfatter tildeling (98) ved behandlingsenheden (42) af en anden fareindikation til cellerne i kolonnen, når resultatet af beregningen er over en anden tærskel, hvis den første tærskel ikke er blevet overholdt, hvori den anden tærskel er en tærskel for moderat risiko, hvori den første tærskel er en tærskel for høj risiko;

hvori generering af et vejrdisplay (90) på baggrund af data, der er lagret i den tredimensionale buffer, omfatter et display-ikon i et andet format forbundet med den anden fareindikation (100) (figur 2, pkt. 100).

3. System (30), der omfatter:
et vejrradarsystem (40), der er konfigureret til at modtage værdier for vejrrefleksionsevne, en behandlingsenhed (42), der er konfigureret til at udføre de funktioner, der er angivet i krav 1, og
en displayenhed (44), der er konfigureret til at udføre de funktioner, der er angivet i krav 1.

4. System ifølge krav 3, hvor behandlingsenheden (42) tildeler (98) en anden fareindikation til cellerne i kolonnen, når resultatet af beregningen er over en anden tærskel, hvis den første tærskel ikke er blevet overholdt, hvori den anden tærskel er en tærskel for moderat risiko, hvori den første tærskel er en tærskel for høj risiko.

DRAWINGS

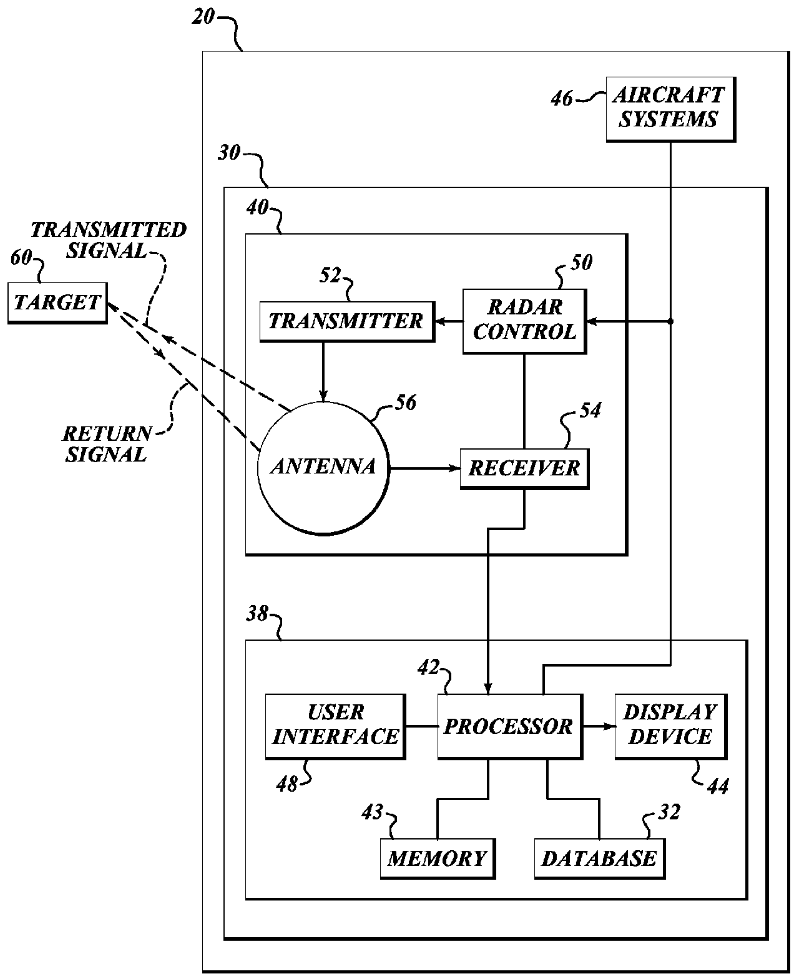

FIG.1

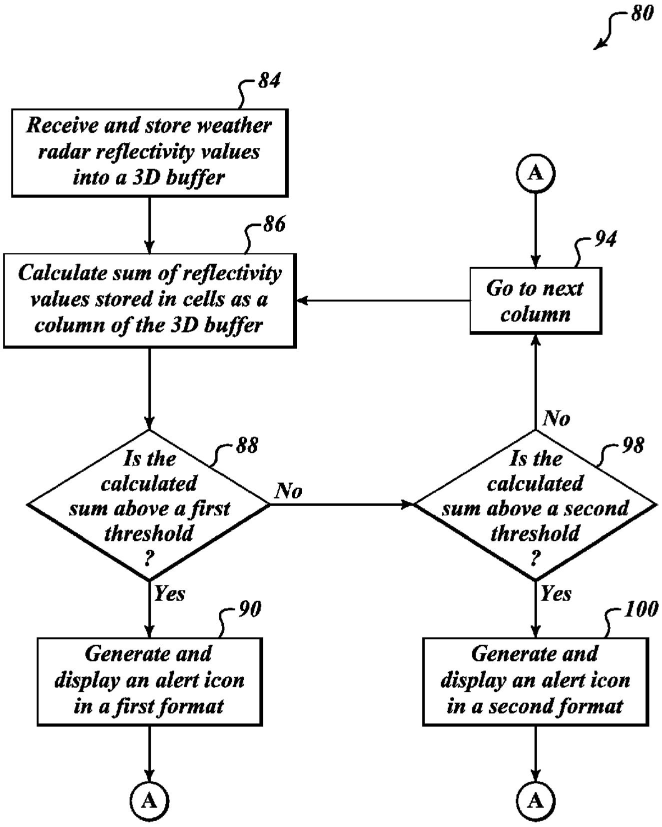
80
84
Receive and store weather radar reflectivity values into a 3D buffer
86
Calculate sum of reflectivity values stored in cells as a column of the 3D buffer
A
94
Go to next column
No
88
Is the calculated sum above a first threshold ?
No
98
Is the calculated sum above a second threshold ?
Yes
90
Generate and display an alert icon in a first format
Yes
100
Generate and display an alert icon in a second format
A
A

FIG.2

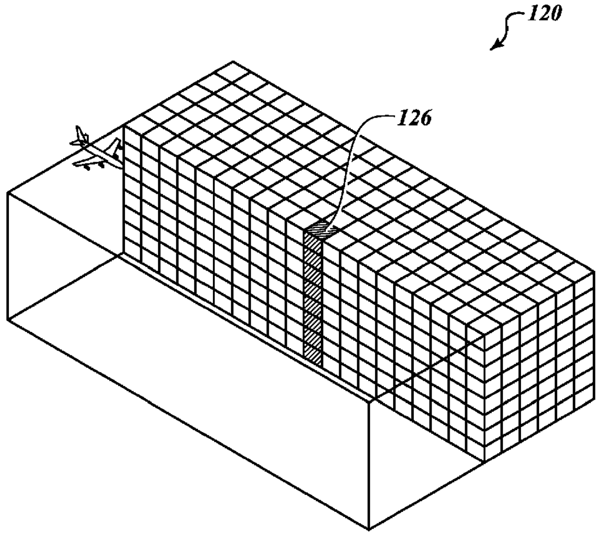

FIG.3