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(54) Title: WIND ESTIMATION USING REMOTELY-DROPPED DROPSONDE

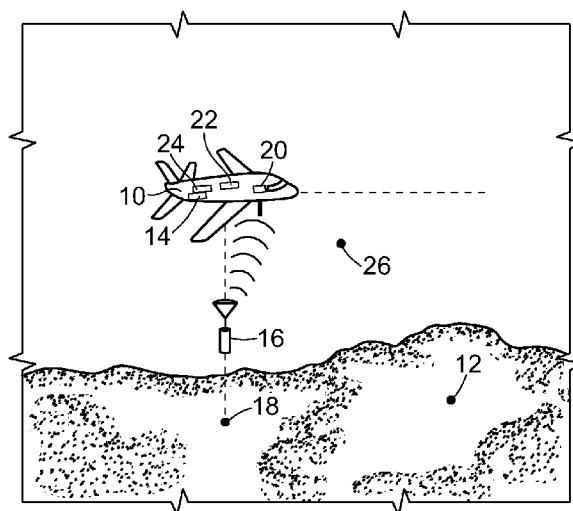


FIG. 1

(57) Abstract: Payload delivery to a drop zone includes selecting a remote location at which to measure a remote wind stick and doing so based at least in part on current weather conditions. This is followed by determining a release point, flying to it, and then dropping the payload from the release point. Determining the release point includes estimating a wind stick at the drop zone based at least in part on the measurement of the remote wind stick.



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Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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1 **WIND ESTIMATION USING REMOTELY-DROPPED DROPSONDE**

2

3 **RELATED APPLICATIONS**

4 This application claims the benefit of the December
5 9, 2016 priority date of U.S. Provisional Application
6 62/432,187, the contents of which are incorporated herein
7 by reference.

8 **FIELD OF INVENTION**

9 The invention relates to air drops, and in
10 particular, to determining when to release a payload.

11 **BACKGROUND**

12 In many cases, it is desirable to deliver a payload
13 by dropping it from an airplane. A difficulty that arises
14 is making sure that the payload lands where it is
15 intended to. This requires consideration of when the
16 delivery airplane should release the payload.

17 One approach to determining when to release the
18 payload is to rely on ballistics. Given the airplane's
19 speed and altitude, the acceleration due to gravity, and
20 the target location, it is a relatively simple matter to
21 calculate the correct release point.

22 Unfortunately, the presence of wind tends to make
23 this calculation inaccurate.

24 Another approach is to use wind forecasts to predict
25 the wind in the vicinity of the drop zone. However, this
26 method assumes the forecast is accurate at the local
27 level. In many cases, the forecast has difficulty
28 predicting winds at a local level, particularly as one
29 approaches the ground.

30 A suitable way to overcome this difficulty is to use
31 the delivery airplane to drop a dropsonde. As the
32 dropsonde falls, it collects data concerning the

1 conditions that it encounters and sends that data back to
2 a processor on board the delivery airplane. The processor
3 then calculates the optimal release point based on this
4 data and proceeds to drop the payload from the release
5 point.

6 A disadvantage of the foregoing method is that the
7 airplane must now make two passes: a first one to drop
8 the dropsonde and a second one to drop the payload. Aside
9 from requiring more fuel, in some circumstances, this
10 exposes the airplane to hostile fire twice instead of
11 once, and pinpoints release location of a payload in
12 advance.

13 SUMMARY

14 In one aspect, the invention features a method that
15 includes delivering a payload to a drop zone. The process
16 of delivering the payload includes selecting a remote
17 location at which to measure a remote wind stick and
18 doing so based at least in part on current weather
19 conditions. This is followed by determining a release
20 point, flying to it, and then dropping the payload from
21 the release point. The process of determining the release
22 point includes estimating a wind stick at the drop zone
23 based at least in part on the measurement of the remote
24 wind stick.

25 Among the practices of this method are those that
26 also include selecting a remote location at which to
27 measure the remote wind stick, and to do so at least in
28 part on the basis of a confidence level of the estimate
29 of the wind stick at the drop zone. This confidence level
30 is determined at least in part on the basis of the
31 current weather conditions.

1 Also among the practices of the invention are those
2 that include estimating a confidence level of the
3 estimate of the wind stick at the drop zone based on the
4 current weather conditions.

5 Also among the practices of this method are those
6 that include releasing a dropsonde at the remote
7 location, collecting data from the dropsonde, and
8 determining the release point based at least in part on
9 the collected data.

10 In yet other practices, determining the release
11 point comprises providing the remote wind stick to an
12 operational model that has been configured to provide a
13 transformation based on historical weather data and
14 applying the transformation to the remote wind stick to
15 obtain an estimate of a drop-zone wind stick at the drop
16 zone.

17 Some practices further include obtaining the
18 operational model by providing a training model with
19 historical weather data and simulated wind sticks.

20 Other practices include obtaining the operational
21 model by providing a training model with training data,
22 and using boosted regression trees to identify
23 transformations to transform a measurement of a wind
24 stick at a first location into an estimate of a wind
25 stick at a second location.

26 In another aspect, the invention features a method
27 that includes obtaining a first value of a variable,
28 providing the first value to an operational model that
29 has been configured by a machine-learning algorithm to
30 provide a transformation to yield an estimate of a value
31 of the variable at a second location, and transforming

1 the first value of the variable to obtain a second value
2 of the variable. The second value of the variable is an
3 estimate of a value of the variable at a remote location.
4 This first value is one that is obtained by measuring at
5 a measurement location that differs from the remote
6 location.

7 In some embodiments, the remote location is below a
8 region that contains the measurement location. In other
9 embodiments, the remote location and the measurement
10 location are separated along a circumferential direction
11 that is perpendicular to a line extending to the center
12 of the Earth.

13 BRIEF DESCRIPTION OF THE FIGURES

14 FIG. 1 shows an aircraft dropping a dropsonde at a
15 remote site;

16 FIG. 2 shows the aircraft of FIG. 1 releasing a
17 payload based at least in part on data received from the
18 dropsonde; and

19 FIG. 3 summarizes the creation of an operational
20 model through machine learning based on historical data.

21 DETAILED DESCRIPTION

22 FIG. 1 shows an aircraft **10** flying towards a drop
23 zone **12** to deliver a payload **14** that is intended to land
24 at the drop zone **12**. The aircraft **10** has recently dropped
25 a dropsonde **16** toward a remote location **18** that is at
26 some distance from the drop zone **12**.

27 As the dropsonde **16** falls, it periodically measures
28 wind vectors. The result is a set of wind vectors along
29 the dropsonde's path. This set of wind vectors will be
30 referred to herein as a "wind stick." As shown in the
31 figure, the dropsonde **16** transmits a first wind stick

1 back to a receiver **20** on the aircraft **10**. This first wind
2 stick consists of wind vectors measured in the remote
3 location **18**.

4 Aboard the aircraft **10**, a processor **22** receives,
5 from the receiver **20**, data representative of the first
6 wind stick. The processor **22** then retrieves, from a
7 memory **24**, a suitable transformation. This transformation
8 is obtained during a training phase of a machine-learning
9 procedure to be discussed below. The processor **22** then
10 applies this transformation to the first wind stick to
11 obtain a second wind stick. This second wind stick
12 represents an estimate of the wind present at the drop
13 zone **12**. Based on this second wind stick, the processor
14 **22** determines an appropriate release point **26** at which
15 the aircraft **10** should release the payload **14**.

16 The aircraft **10** then continues until it reaches the
17 release point **26**, as shown in FIG. 2, at which point it
18 releases the payload **14**. The payload **14** then falls. As it
19 does so, the prevailing wind causes it to drift. However,
20 because of the transformation applied to the first
21 vector, the prevailing wind should cause the payload **14**
22 to drift in such a way as to land at or near the drop
23 zone **12**.

24 The distance between the remote location **18** and the
25 drop zone **12** is essentially a race between the aircraft
26 **10** and the processor. The shorter this distance is, the
27 greater will be the accuracy of the estimate. On the
28 other hand, sufficient time must be allotted for the
29 processor **22** to actually determine the release point **26**.
30 Otherwise, the aircraft **10** have to circle around possibly
31 hostile airspace while waiting for the processor **22** to
32 complete its work. In a typical operating environment, a

1 distance of approximately one-hundred kilometers has been
2 found to be practical.

3 The process of providing a selection of
4 transformations that can be applied to the first wind
5 stick to estimate the second wind stick is the product of
6 a training procedure in which a machine-learning
7 algorithm uses historical data to identify a pattern of
8 differences between a wind stick at a selected zone and a
9 wind stick at a remote location **18**.

10 Referring now to FIG. 3, the machine-learning method
11 includes training a training-model **28** to create an
12 operational model **30**. The training procedure includes
13 providing the training-model **28** with training data that
14 includes historical data on both input features and the
15 expected output **32**, **34**. In the particular embodiment
16 shown, the historical data **32** includes a forecast grid.
17 This includes deterministic forecast data for wind
18 vectors, temperature, and humidity, as well as wind stick
19 data away from the drop zone **12**.

20 In the same particular embodiment, the expected
21 output **34** is represented through analysis data that best
22 estimates the actual wind stick over the drop zone **12**.
23 This will make it possible to estimate the error between
24 the wind stick data from the historical data **32** and the
25 target wind stick at the drop zone **34**. This estimate in
26 the error provides a basis for estimating uncertainty in
27 the prediction at the drop zone. In general, this
28 uncertainty varies with the weather conditions that
29 prevailed at the time that the estimate was made.

30 The training proceeds with the application of any of
31 a variety of data-mining and machine-learning algorithms
32 **36**. However, a particularly useful machine-learning

1 algorithm **36** relies on boosted regression-trees. Such an
2 algorithm has been found to accurately assimilate data
3 obtained by a dropsonde from a remote location **18**.

4 Accordingly, unlike conventional assimilation
5 methods, which rely exclusively on static data, the
6 method described in FIG. 3 is capable of adapting to the
7 weather conditions on the day of the actual measurement,
8 and to provide an estimate of the extent to which the
9 predicted wind stick at the remote location **18** will match
10 the actual wind stick at the drop zone **12**.

11 The ability to estimate the extent of this match
12 also provides a way to choose an optimal remote location
13 **18** at which to measure a remote wind stick and to do so
14 as a function of the weather conditions at the time of
15 delivery of the payload to the drop zone **12**. This differs
16 from the conventional approach in which the optimal
17 remote locations **18** are given in advance without having
18 considered the actual weather conditions at the time of
19 the delivery.

20 This distinction arises in part because the use of
21 machine learning is able to avoid predictions based on
22 static data that do not consider current weather
23 conditions. As a result, the transformation that is
24 applied to the measured wind stick at the remote location
25 **18** need not be a static transformation that would be the
26 same regardless of current weather conditions. Instead,
27 it is a dynamic transformation that responds to current
28 weather conditions. This offers a distinct advantage in
29 environments in which local weather conditions exhibit
30 high variance.

31 The model is trained on a pressure-level basis, with
32 each pressure level generally corresponding to an

1 altitude at which data is collected. It has been found
2 that thirty pressure levels is adequate to for normal
3 operation.

4 The data relied upon is by no means restricted to
5 wind speed and direction. Any observable data is fair
6 game for use in the training procedure. These observables
7 include wind, temperature, and humidity forecasts in the
8 vicinity of the drop zone **12** and the remote location **18**,
9 as well as similar features extracted from dropsonde
10 data. A suitable and widely available source of data is
11 that provided by NOAA based on historical weather maps.
12 In addition, numerous other forms of data can be created
13 using principal component analysis or other feature
14 development methods. This uses data over an extended wind
15 field evaluated within an area surrounding the drop zone
16 **12**. The extent of this area varies with local factors and
17 desired performance. However, a suitable area is a
18 circular area having a diameter of approximately one
19 hundred kilometers.

20 Examples of data that have been found useful are
21 listed below. In the following list, the first and second
22 components of the wind vector are orthogonal and lie in a
23 plane parallel to the Earth. Any component of the wind
24 vector perpendicular to this plane is ignored, but in
25 principle, need not be. The wind stick, being a set of
26 wind vectors, is regarded as having a component that
27 depends on its constituent wind vectors. Since each wind
28 vector is a vector, it can be resolved into components
29 that point in orthogonal directions. For example, a wind
30 vector may have a component along a north-south direction
31 and an orthogonal component along an east-west direction.
32 As used herein, a "vector-component" is used to refer to

1 any one of the constituent orthogonal components of a
2 wind vector.

3 A humidity stick is a similar set of measurements
4 of humidity, which, being a scalar, makes the humidity
5 stick a scalar. The data that has been found useful for
6 training includes:

- 7 • dropsonde measurements of a first vector-component
8 of the wind vector at a current pressure level,
- 9 • the forecast error in the first vector-component of
10 the wind vector at the remote location **18** based on
11 the forecast for the same component of the wind
12 vector at the drop zone **12**,
- 13 • principal-component analysis carried out on the
14 first vector-component of the wind vector field at
15 the current pressure level,
- 16 • a similar principal-component analysis carried out
17 on the first vector-component of the wind vector
18 field one level below the current level,
- 19 • a similar principal-component analysis but instead
20 carried out on the first vector-component of the
21 wind vector field one level above the current level,
- 22 • the forecast mean of the second vector-component of
23 the wind-vector stick at the remote location **18**,
- 24 • the variance in temperature at the current pressure
25 level,
- 26 • the forecast error in the second vector-component of
27 the wind vector at the remote location **18**,

- 1 • the forecast variance in the first vector-component
2 of the wind-vector stick at the remote location **18**,
- 3 • the forecast variance in the second vector-component
4 of the wind-vector stick at the remote location **18**,
- 5 • the forecast variance in the first vector-component
6 of the wind-vector stick at the drop zone **12**,
- 7 • the forecast error in the first vector-component of
8 the wind at the remote location **18**,
- 9 • the forecast variance in the second vector-component
10 of the wind-vector stick at the drop zone **12**,
- 11 • dropsonde measurements of the second vector-
12 component of the wind vector at the current pressure
13 level,
- 14 • the mean relative humidity at the current pressure
15 level,
- 16 • the forecast of the mean of the first vector-
17 component of the wind-vector stick at the drop zone
18 **12**,
- 19 • the forecast for the second vector-component of the
20 wind at the remote location **18**,
- 21 • the variance in the first vector-component of the
22 wind vector at current pressure level,
- 23 • the variance in relative humidity of a humidity
24 stick at the remote location **18**, and
- 25 • the variance in relative humidity of a humidity
26 stick at the drop zone **12**.

1 The outcome of the training procedure is an
2 operational model **30** that can be carried with the
3 aircraft **10** and used for near-real time decision-making
4 **38** based on operational measurements **40** that would
5 include the dropsonde data referred to in connection with
6 FIGS. 1 and 2. Such operational measurements **40** include,
7 for example, selected deterministic forecast features
8 from the entire field, including the drop zone **12**, and
9 wind measurements away from the drop zone **12** as provided
10 by the dropsonde. The availability of these operational
11 measurements **40**, and in particular, the current weather
12 conditions contained therein, makes it possible to
13 dynamically assess the uncertainty of the wind prediction
14 at the target by taking into account the weather
15 conditions prevailing at the time of the estimate.

16 The preceding method thus amounts to spatial rather
17 than temporal weather forecasting. In temporal weather
18 forecasting, the question is usually, "Given the weather
19 today, what will the weather be tomorrow?" In the method
20 described herein, the question instead becomes, "Given
21 the weather over here, what is the weather over there?"

22 The preceding method can also be regarded as a form
23 of computational remote-sensing. In conventional remote-
24 sensing, one makes a physical measurement at a remote
25 location, typically by observing a disturbance to a wave
26 that has passed through that location. Examples include
27 the use of Doppler radar, for electromagnetic waves, and
28 the sensing of various subsurface structures of
29 geological interest, using acoustic waves.

30 Rather than attempt to make such measurements, the
31 method described herein achieves a similar result by
32 carrying out local sensing and using the results of such

1 local sensing, together with historical data, to
2 computationally infer or estimate conditions at a remote
3 location.

4 The methods described herein find particular
5 application in weather-related phenomena. However, the
6 techniques are general enough to be used in other
7 applications. For example, in principle machine learning
8 of the same type can be used to estimate ocean currents
9 at otherwise inaccessible locations, or to infer the
10 existence of subsurface structures based on measurements
11 closer to the surface.

12 In the application described in connection with
13 FIGS. 1 and 2, the payload was unguided and therefore at
14 the mercy of the winds. However, in principle, the
15 payload need not fall unguided. Instead, it can be hung
16 from a parafoil having control surfaces that can be
17 actuated to maneuver the parafoil towards the drop zone.
18 A procedure similar to that described herein can be used
19 to control the parafoil.

20 In particular, as the parafoil descends, the Earth's
21 atmosphere is continuously being divided into two parts:
22 an upper part through which the parafoil has already
23 descended, and a lower part through which the parafoil
24 has yet to descend. As the parafoil descends, it makes
25 measurements similar to those made by the dropsonde. In
26 effect, the parafoil is acting as its own dropsonde.

27 The measurements made by the parafoil thus provide a
28 growing body of measurements for the upper part. These
29 measurements can then be used to predict conditions
30 within the lower part. In anticipation of these
31 conditions, the parafoil's control surfaces can be
32 adjusted to adaptively guide it towards the drop zone

1 based at least in part on its observations of atmospheric
2 conditions in the upper part.

3 This embodiment thus carries out a procedure similar
4 to that discussed in connection with FIGS. 1 and 2,
5 namely the estimation of a phenomenon in a first zone
6 based on a measurement of a similar phenomenon in a
7 second zone remote from the first zone that has been
8 provided to a model created by a machine-learning
9 algorithm that has examined historical data and simulated
10 measurements in an effort to compile a table of
11 transforms that can be applied to the measurement of the
12 phenomenon in the first zone in order to estimate the
13 similar phenomenon in the second zone.

14 Additional details and experimental results are
15 provided in the attached Appendix, which is incorporated
16 herein by reference.

17

CLAIMS

- 1
2 **1.** A method comprising delivering a payload to a drop
3 zone, wherein delivering said payload comprises
4 based at least in part on current weather
5 conditions, selecting a remote location at which to
6 measure a remote wind stick, determining a release
7 point, flying to said release point, and dropping
8 said payload from said release point, wherein
9 determining said release point comprises estimating
10 a wind stick at said drop zone based at least in
11 part on said measurement of said remote wind stick.
- 12 **2.** The method of claim **1**, wherein selecting said remote
13 location at which to measure said remote wind stick
14 comprises selecting said remote location at least in
15 part on the basis of a confidence level of said
16 estimate of said wind stick at said drop zone.
- 17 **3.** The method of claim **2**, further comprising
18 determining said confidence level at least in part
19 on the basis of current weather conditions.
- 20 **4.** The method of claim **1**, further comprising releasing
21 a dropsonde at said remote location, collecting data
22 from said dropsonde, and determining said release
23 point based at least in part on said collected data.
- 24 **5.** The method of claim **1**, wherein determining said
25 release point comprises providing said remote wind
26 stick to an operational model that has been
27 configured to provide a transformation based on
28 historical weather data and applying said
29 transformation to said remote wind stick to obtain
30 an estimate of a drop-zone wind stick at said drop
31 zone.

- 1 **6.** The method of claim **5**, further comprising obtaining
2 said operation model by providing a training model
3 with historical weather data and simulated wind
4 sticks.
- 5 **7.** The method of claim **5**, further comprising obtaining
6 said operation model by providing a training model
7 with training data and using boosted regression
8 trees to identify transformations to transform a
9 measurement of a wind stick at a first location into
10 an estimate of a wind stick at a second location.
- 11 **8.** The method of claim **1**, further comprising estimating
12 a confidence level of said estimate of said wind
13 stick at said drop zone based at least in part on
14 said current weather conditions.
- 15 **9.** A method comprising obtaining a first value of a
16 variable, providing said first value to an
17 operational model that has been configured by a
18 machine-learning algorithm to provide a
19 transformation to yield an estimate of a value of
20 said variable at a second location, and transforming
21 said first value of said variable to obtain a second
22 value of said variable, wherein said second value of
23 said variable is an estimate of a value of said
24 variable at a remote location, and wherein obtaining
25 said first value comprises measuring said first
26 value at a measurement location that is remote from
27 said remote location.
- 28 **10.** The method of claim **9**, wherein said remote location
29 is below a region that contains said measurement
30 location.

- 1 **11.** The method of claim **9**, further comprising selecting
2 said variable to be a wind velocity, wherein said
3 first value is a measurement of said wind velocity
4 made at said measurement location, and wherein said
5 second value is an estimate of said wind velocity at
6 a region below said measurement location.
- 7 **12.** The method of claim **9**, wherein obtaining a first
8 value of a variable comprises causing a parafoil
9 that is carrying a payload to be delivered to a
10 target location to pass through said measurement
11 location and to collect data while passing through
12 said measurement location, said collected data being
13 indicative of said first value, wherein said second
14 value is an estimate of said wind velocity at a
15 region below said measurement location.
- 16 **13.** The method of claim **9**, further comprising delivering
17 a payload to a target, wherein delivering said
18 payload comprise releasing a parafoil carrying said
19 payload from a release point, wherein a force
20 exerted by a current that exists between said
21 release point and said target causes said parafoil
22 to drift as said parafoil falls toward said target,
23 wherein a value of said current that causes said
24 parafoil to drift is based on said variable, wherein
25 said measurement location is between said release
26 point and an intermediate point, and wherein said
27 remote location is between said intermediate point
28 and said target.
- 29 **14.** The method of claim **13**, further comprising, based on
30 said estimate, steering said parafoil to correct for
31 said drift.

1 **15.** The method of claim **12**, wherein obtaining said first
2 value comprises continuously obtaining said first
3 value, wherein transforming said first value to
4 obtain said second value comprises dynamically
5 updating said estimate based at least in part on
6 said continuously obtained first value.

7 **16.** The method of claim **15**, further comprising
8 dynamically guiding said parafoil toward said target
9 based on said dynamically updated estimate.

10 **17.** The method of claim **16**, wherein dynamically guiding
11 said parafoil comprises adjusting at least one
12 control surface of said parafoil, thereby
13 controlling force exerted by said current on said
14 parafoil.

15 **18.** The method of claim **12**, wherein said current is
16 caused by wind velocity.

17 **19.** The method of claim **9**, wherein said remote location
18 and said measurement location are separated along a
19 circumferential direction that is perpendicular to a
20 line extending to the center of the Earth.

21

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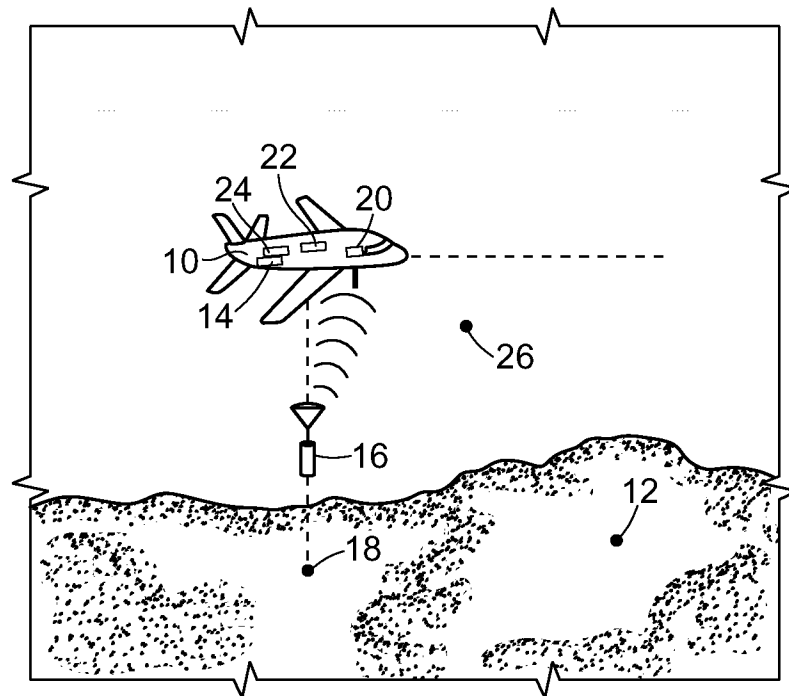


FIG. 1

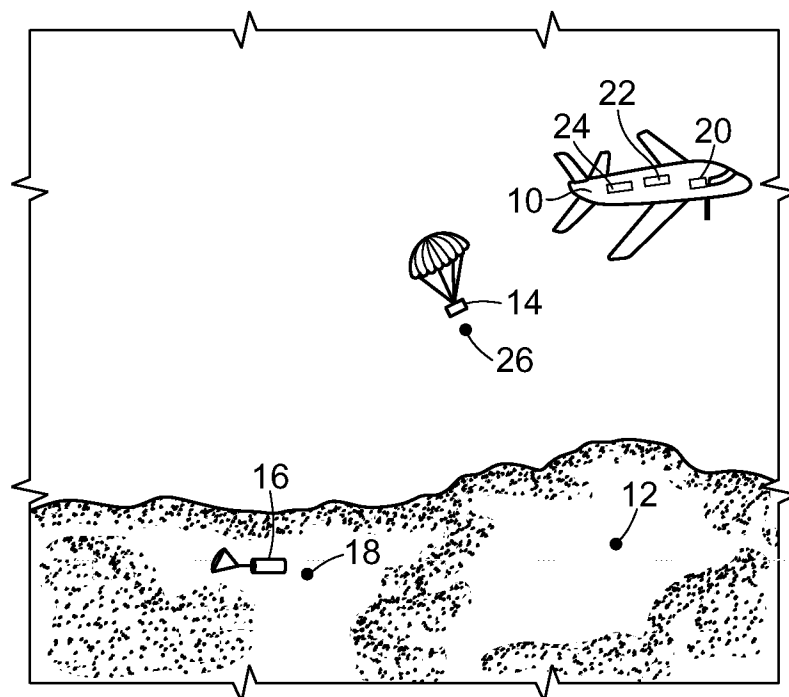
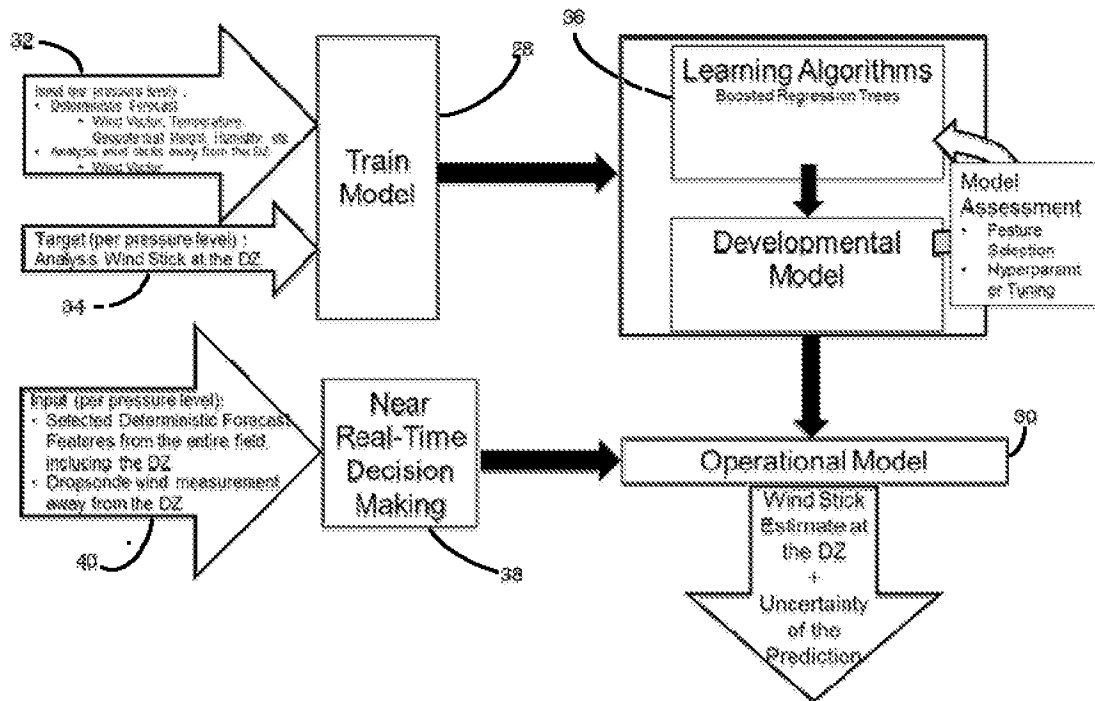


FIG. 2

**FIG. 3**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US17/53951

A. CLASSIFICATION OF SUBJECT MATTER
IPC - B64D 1/02; B64C 19/00; G01W 1/00, 1/10 (2017.01)
CPC - B64D 1/02; B64C 19/00; G01W 1/00, 1/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2014/0142788 A1 (UNITED STATES AIR FORCE) May 22, 2014; paragraphs [0021], [0026]-[0032]	1, 4, 5 --- 6
Y	US 2008/0169975 A1 (YEE YP) July 17, 2008; paragraph [0019]	6
A	US 8,939,056 B1 (NEAL DA III et al.) January 27, 2015; entire document	1-8
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A	US 7,782,664 B1 (CRAWFORD T et al.) September 7, 2010; entire document	1-8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
08 November 2017 (08.11.2017)

Date of mailing of the international search report

09 JAN 2018

Name and mailing address of the ISA/
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
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PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US17/53951

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-***-Please See Within the Next Supplemental Box-***-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
Claims 1-8

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US17/53951

-Continued from Box No. III Observations where unity of invention is lacking-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-8 are directed toward: a method comprising delivering a payload to a drop zone, wherein delivering said payload comprises based at least in part on current weather conditions.

Group II: Claims 9-19 are directed toward: a method comprising obtaining a first value of a variable, providing said first value to an operational model that has been configured by a machine-learning algorithm.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I include: a method comprising delivering a payload to a drop zone, wherein delivering said payload comprises based at least in part on current weather conditions, selecting a remote location at which to measure a remote wind stick, determining a release point, flying to said release point, and dropping said payload from said release point, wherein determining said release point comprises estimating a wind stick at said drop zone based at least in part on said measurement of said remote wind stick, which are not present in Group II.

The special technical features of Group II include: a method comprising obtaining a first value of a variable, providing said first value to an operational model that has been configured by a machine-learning algorithm to provide a transformation to yield an estimate of a value of said variable at a second location, and transforming said first value of said variable to obtain a second value of said variable, wherein said second value of said variable is an estimate of a value of said variable at a remote location, and wherein obtaining said first value comprises measuring said first value at a measurement location that is remote from said remote location, which are not present in Group I.

There are no common special technical features shared between Groups I and II.

Since there are no common special technical features shared between Groups I and II, unity is lacking.