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Micro weather risk mapping for very low-level aerial vehicles

Abstract

Micro-weather risk mapping for very low-level aerial vehicles includes receiving data indicating a first geographic area and obtaining meteorologic data for a second geographic area. The first geographic area is smaller than and entirely bounded by the second geographic area. Mapping includes determining topographic parameters associated with the first geographic area. Mapping includes performing a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. Mapping includes selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. Mapping includes determining, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area.

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Background/Summary

FIELD OF THE DISCLOSURE

(1) The subject disclosure is generally related to micro weather risk mapping for very low-level aerial vehicles.

BACKGROUND

(2) Atmospheric conditions affect all kinds of aerial vehicles. In urban air environments, small aerial vehicles operating below approximately 150 meters are subject to local and micro-scale wind effects of an urban canopy layer, which features complex atmospheric conditions due to direct interaction with local topology and other ground-based structures that effect formation of air flow and vorticity, as well as distribution of heat and humidity. The lower the operating altitude, the greater the impact of the urban canopy layer on the wind effects.

(3) Urban boundaries and urban canopy layers include characteristics of highly diverse wind fields and turbulences that can severely affect the safety and efficiency of airborne vehicles. For example, it is estimated that commercial and military drone operators unnecessarily cancel or delay about 30% of all drone flights based on operator interpretations of urban boundaries and urban canopy layers.

(4) Traditional microscale weather forecast models, including real-time or near real-time models, can require substantial computing resources, rendering them too inefficient for use by smaller aerial vehicle flights. Typical weather forecasts and reports are facilitated using a combination of local observation and computational calculation of wide-range physical models. The classic numerical calculations to generate weather forecasts and reports are time intensive and computing power intensive, and usually repeated in a given period. A high level of detail and additional environmental complexity—such as buildings in the urban canopy layer, low scale topology, or micro-climatic effects—can lead to an exponential increase of computing cost. Additionally, resource constraints are incompatible with the short lead times required for reliable forecasts of atmospheric conditions. Further, it is currently unclear if established modelling procedures can be transformed and efficiently applied to a microscale environment.

(5) Some approaches to downscaling existing regional weather reports, such as “model output statistics,” are not applicable in the context of very low-level flight planning. The model output statistics approaches rely on local observation stations to train a regression model that adjusts regional model outputs. Such observation stations can only be installed close to structures instead of flyable, open space. The idea of creating model output statistics with unmanned aerial vehicles as nodes is also not feasible because drones usually fly when the conditions are safe, and weather forecasts are most effective for operational purposes when the weather is non-ideal. In consequence, data points for the most critical situations are missing.

SUMMARY

(6) In a particular implementation, a method includes receiving data indicating a first geographic area. The method includes obtaining meteorologic data for a second geographic area. The first geographic area is smaller than and entirely bounded by the second geographic area. The method includes determining topographic parameters associated with the first geographic area. The method includes performing a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. The method includes selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. The method also includes determining, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area.

(7) In another particular embodiment, a non-transient, computer-readable medium stores instructions that, when executed by one or more processors, cause the one or more processors to initiate, perform, or control operations including receiving data indicating a first geographic area. The operations include obtaining meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area. The operations include determining topographic parameters associated with the first geographic area. The operations include performing a comparison of the topographic parameters associated with the

first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. The operations include selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. The operations also include determining, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area.

(8) In another particular embodiment, a device includes means for receiving data indicating a first geographic area. The device includes means for obtaining meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area. The device includes means for determining topographic parameters associated with the first geographic area. The device includes means for performing a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. The device includes means for selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. The device also includes means for determining, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area.

(9) In another particular implementation, a system includes a memory configured to store instructions and one or more processors configured to receive data indicating a first geographic area. The one or more processors are configured to obtain meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area. The one or more processors are configured to determine topographic parameters associated with the first geographic area. The one or more processors are configured to perform a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. The one or more processors are configured to select a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. The one or more processors are configured to determine, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area.

(10) The features, functions, and advantages described herein can be achieved independently in various implementations or can be combined in yet other implementations, further details of which can be found with reference to the following description and drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** depicts an example system for micro-weather risk mapping for very low-level aerial vehicles, in accordance with at least one implementation of the subject disclosure.

(2) FIG. **2** depicts an example architecture illustrating a particular implementation of an automated environment for micro-weather risk mapping for very low-level aerial vehicles, in accordance with at least one implementation of the subject disclosure.

(3) FIG. **3** is an example of a categorization of a micro-weather simulation, in accordance with at least one implementation of the subject disclosure.

(4) FIG. **4** is an exemplary illustration of a set of predetermined micro-weather simulations for divergent areas with characteristic properties estimating a micro-weather pattern for a different micro-weather area, in accordance with at least one implementation of the subject disclosure.

(5) FIG. **5** is a flow chart of an example method for providing micro-weather risk mapping for very low-level aerial vehicles, in accordance with at least one implementation of the subject disclosure.

(6) FIG. **6** is a block diagram of a computing environment including a computing device configured to support aspects of computer-implemented methods and computer-executable program instructions (or code), in accordance with at least one implementation of the subject disclosure.

DETAILED DESCRIPTION

(7) In order to appropriately account and prepare for atmospheric conditions in very low-level airspace operations, aerial vehicle operators can attempt to downscale typical mesoscale wind information available to operators of larger aircraft. The systems and methods described herein apply hyperlocal wind information for regionally common windspeeds and directions to identify similar patterns in forecast or real-time environments. By analyzing the identified patterns, the systems and methods disclosed herein can generate a local mapping of differently weighted risk zones. The local mapping can be used to determine whether to launch an aerial vehicle, can enable an automated path planning process to reduce atmospheric impact on flights of the aerial vehicle, can determine where to land the aerial vehicle, can enable flight path management that can optimize usage of different layers of the airspace, or combinations thereof. This can include, in a particular aspect, accounting for the individual constraints of the aerial vehicle.

(8) The figures and the following description illustrate specific exemplary embodiments. It will be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles described herein and are included within the scope of the claims that follow this description. Furthermore, any examples described herein are intended to aid in understanding the principles of the disclosure and are to be construed as being without limitation. As a result, this disclosure is not limited to the specific embodiments or examples described below, but by the claims and their equivalents.

(9) Particular implementations are described herein with reference to the drawings. In the description, common features are designated by common reference numbers throughout the drawings. As used herein, various terminology is used for the purpose of describing particular implementations only and is not intended to be limiting. For example, the singular forms “a.” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. Further, some features described herein are singular in some implementations and plural in other implementations. To illustrate, FIG. **1** depicts a system **100** including one or more processors (“processor(s)” **106** in FIG. **1**), which indicates that in some implementations the system **100** includes a single processor **106** and in other implementations the system **100** includes multiple processors **106**. For ease of reference herein, such features are generally introduced as “one or more” features and are subsequently referred to in the singular unless aspects related to multiple of the features are being described.

(10) The terms “comprise.” “comprises,” and “comprising” are used interchangeably with “include,” “includes,” or “including.” Additionally, the term “wherein” is used interchangeably with the term “where.” As used herein, “exemplary” indicates an example, an implementation, and/or an aspect, and should not be construed as limiting or as indicating a preference or a preferred implementation. As used herein, an ordinal term (e.g., “first.” “second.” “third,” etc.) used to modify an element, such as a structure, a component, an operation, etc., does not by itself indicate any priority or order of the element with respect to another element, but rather merely distinguishes the element from another element having a same name (but for use of the ordinal term). As used herein, the term “set” refers to a grouping of one or more elements, and the term “plurality” refers to multiple elements.

(11) As used herein, “generating.” “calculating.” “using.” “selecting.” “accessing,” and “determining” are interchangeable unless context indicates otherwise. For example, “generating,” “calculating.” or “determining” a parameter (or a signal) can refer to actively generating, calculating, or determining the parameter (or the signal) or can refer to using, selecting, or accessing the parameter (or signal) that is already generated, such as by another component or

device. As used herein, “coupled” can include “communicatively coupled,” “electrically coupled.” or “physically coupled,” and can also (or alternatively) include any combinations thereof. Two devices (or components) can be coupled (e.g., communicatively coupled, electrically coupled, or physically coupled) directly or indirectly via one or more other devices, components, wires, buses, networks (e.g., a wired network, a wireless network, or a combination thereof), etc. Two devices (or components) that are electrically coupled can be included in the same device or in different devices and can be connected via electronics, one or more connectors, or inductive coupling, as illustrative, non-limiting examples. In some implementations, two devices (or components) that are communicatively coupled, such as in electrical communication, can send and receive electrical signals (digital signals or analog signals) directly or indirectly, such as via one or more wires, buses, networks, etc. As used herein, “directly coupled” is used to describe two devices that are coupled (e.g., communicatively coupled, electrically coupled, or physically coupled) without intervening components.

(12) As used herein, the term “machine learning” should be understood to have any of its usual and customary meanings within the fields of computers science and data science, such meanings including, for example, processes or techniques by which one or more computers can learn to perform some operation or function without being explicitly programmed to do so. As a typical example, machine learning can be used to enable one or more computers to analyze data to identify patterns in data and generate a result based on the analysis. For certain types of machine learning, the results that are generated include a data model (also referred to as a “machine-learning model” or simply a “model”). Typically, a model is generated using a first data set to facilitate analysis of a second data set. For example, a first portion of a large body of data may be used to generate a model that can be used to analyze the remaining portion of the large body of data. As another example, a set of historical data can be used to generate a model that can be used to analyze future data. Examples of machine-learning models include, without limitation, perceptrons, neural networks, support vector machines, regression models, decision trees, Bayesian models, Boltzmann machines, adaptive neuro-fuzzy inference systems, as well as combinations, ensembles and variants of these and other types of models. Variants of neural networks include, for example and without limitation, prototypical networks, autoencoders, transformers, self-attention networks, convolutional neural networks, deep neural networks, deep belief networks, etc. Variants of decision trees include, for example and without limitation, random forests, boosted decision trees, etc.

(13) Since machine-learning models are generated by computer(s) based on input data, machine-learning models can be discussed in terms of at least two distinct time windows—a creation/training phase and a runtime phase. During the creation/training phase, a model is created, trained, adapted, validated, or otherwise configured by the computer based on the input data (which in the creation/training phase, is generally referred to as “training data”). Note that the trained model corresponds to software that has been generated and/or refined during the creation/training phase to perform particular operations, such as classification, prediction, encoding, or other data analysis or data synthesis operations. During the runtime phase (or “inference” phase), the model is used to analyze input data to generate model output. The content of the model output depends on the type of model. For example, a model can be trained to perform classification tasks or regression tasks, as non-limiting examples. In some implementations, a model may be continuously, periodically, or occasionally updated, in which case training time and runtime may be interleaved or one version of the model can be used for inference while a copy is updated, after which the updated copy may be deployed for inference.

(14) FIG. **1** depicts an example system **100** for micro-weather risk mapping for very low-level aerial vehicles, in accordance with at least one implementation of the subject disclosure. In some implementations, the system **100** includes a computing device **102** configured to communicate with one or more geographic area data providers **104**, one or more meteorological data providers **116**, or

some combination thereof.
(15) In some implementations, the geographic area data provider(s) **104** can include a memory **112**. The memory **112** can have stored thereon a variety of data and data types including, for example, geographic area data **132**. In some aspects, the geographic area data **132** can include one or more data values associated with one or more geographic areas. The data values can include, for example, data values indicating the location and size of a particular geographic area (e.g., through a plurality of latitude and longitude coordinates), topographical features of the particular geographic area (e.g., elevation, natural features, buildings, etc.), etc. In a particular aspect, the geographic area data **132** can include a superset of information from which is gathered, calculated, analyzed, and/or otherwise derived topographic parameters **114** associated with a particular geographic area, a first geographic area data **126**, or some combination thereof, as described in more detail below.
(16) In some implementations, the meteorological data provider(s) **116** can include a memory **110**. The memory **110** can have stored thereon a variety of data and data types including, for example, meteorological area data **134**. In some aspects, the meteorological area data **134** can include one or more data values associated with one or more geographic areas. The data values can include, for example, data values indicating wind speed, wind direction, temperature, barometric pressure, etc. for the one or more geographic areas. In a particular aspect, the meteorological area data **134** is mesoscale meteorological data applicable to a relatively large geographic area. The mesoscale data can, in some configurations, be identified as applicable to one or more smaller geographic areas within the relatively large geographic area. In the same or alternative particular aspects, the meteorological area data **134** can include a superset of information from which is gathered, calculated, analyzed, and/or otherwise derived meteorological data for a particular geographic area (e.g., second geographic area meteorological data **128**, as described in more detail below).
(17) The computing device **102** can include one or more processors **106** coupled to a memory **108**. The processor(s) **106** are configured to receive data from the geographic area data provider(s) **104**, the meteorological data provider(s) **116**, or some combination thereof. In some aspects, data indicating a first geographic area can be received from the geographic area data provider(s) **104** and stored as the first geographic area data **126** at the memory **108**. As noted above, the data indicating the first geographic area can include data indicating the location and size of the first geographic area (e.g., through a plurality of latitude and longitude coordinates), topographical features of the first geographic area (e.g., elevation, natural features, buildings, etc.), a name associated with the first geographic area, etc.
(18) In some aspects, the processor(s) **106** are configured to obtain meteorologic data for a second geographic area from the meteorological data provider(s) **116** and stored as the second geographic area meteorologic data **128** at the memory **108**. As noted above, the meteorologic data can include data indicating wind speed, wind direction, temperature, barometric pressure, etc. for the second geographic area. In some implementations, the first geographic area indicated by the first geographic area data **126** is smaller than and entirely bounded by the second geographic area associated with the second geographic area meteorologic data **128**. For example, the first geographic area data **126** can indicate a first geographic area corresponding to one city block or less, and the second geographic area associated with the second geographic area meteorologic data **128** can correspond to at least a neighborhood or city that contains the first geographic area.
(19) In some implementations, the processor(s) **106** are configured to determine topographic parameters **114** associated with one or more geographic areas. In some aspects, the processor(s) **106** are configured to determine topographic parameters **114** associated with the first geographic area (i.e., the geographic area indicated by the first geographic area data **126**). The topographic parameters **114** can include, for example, descriptions of buildings, descriptions of streets, descriptions of land usage, descriptions of land surface topology, or any combination thereof. In a particular aspect, the topographic parameters **114** can be gathered, calculated, analyzed, and/or otherwise derived from all or a portion of the first geographic area data **126**, the geographic area

data **132**, or some combination thereof.
(20) In some implementations, the processor(s) **106** are configured to perform a comparison of the topographic parameters **114** associated with the first geographic area to topographic parameters **114** associated with a plurality of predetermined micro-weather models **120**. Each of the plurality of predetermined micro-weather models **120** can include data associated with a mathematical model of a particular weather pattern associated with a particular geographic area. In some aspects, each of the plurality of predetermined micro-weather models **120** can generate output including estimates of a plurality of local wind fields **130** within the first geographic area. In a particular aspect, the estimates of a plurality of local wind fields **130** can be stored at the memory **108**. In the same or alternative aspects, each of the plurality of predetermined micro-weather models **120** can be associated with a particular set of meteorologic conditions associated with the second geographic area.
(21) In some aspects, one or more of the plurality of predetermined micro-weather models **120** includes parameters for calculating, based on the second geographic area meteorologic data **128**, estimates of a plurality of local wind fields **130** within the first geographic area. In the same or alternative aspects, one or more of the plurality of predetermined micro-weather models **120** can include a machine-learning model configured to receive input based on the second geographic area meteorologic data **128** and to generate output including estimates of a plurality of local wind fields **130** within the first geographic area. In further the same or alternative aspects, one or more of the plurality of predetermined micro-weather models **120** indicates predetermined estimates of a plurality of local wind fields **130** within a third geographic area. In such aspects, the topographic parameters **114** of the third geographic area are a closest match, based on the comparison of the topographic parameters **114** associated with the first geographic area to topographic parameters **114** associated with a plurality of predetermined micro-weather models **120**, to the topographic parameters **114** of the first geographic areas.
(22) In some aspects, at least a subset of the plurality of predetermined micro-weather models **120** are generated using a computational fluid dynamics analysis of one or more third geographic areas based on topographic parameters **114** associated with the one or more third geographic area and meteorologic data associated with one or more fourth geographic areas, where each of the one or more third geographic areas is smaller than and entirely bounded by a respective one of the one or more fourth geographic areas, and where the first geographic area is distinct from each of the one or more third geographic areas. In a particular aspect, the second geographic area is distinct from each of the one or more fourth geographic areas.
(23) In some implementations, the processor(s) **106** are configured to select a particular micro-weather model from among the plurality of predetermined micro-weather models **120** based on the comparison of the topographic parameters **114** associated with the first geographic area to topographic parameters **114** associated with the plurality of predetermined micro-weather models **120**. In some aspects, a micro-weather model selector **118** of the processor(s) **106** can be configured to select the particular micro-weather model from among the plurality of predetermined micro-weather models **120**.
(24) In some aspects, selecting the particular micro-weather model from among the plurality of predetermined micro-weather models **120** includes selecting a third geographic area that is similar to the first geographic area based on the topographic parameters **114** of the first geographic area and corresponding topographic parameters **114** of the third geographic area. For example, the micro-weather model selector **118** can select a third geographic area with substantially similar building descriptions and land surface topology to the building descriptions and land surface topology of the first geographic area. In such aspects, the processor(s) **106** can be configured to estimate, based on the selected micro-weather model and the second geographic area meteorologic data **128**, local wind fields for the third geographic area. The processor(s) **106** can also be configured to perform one or more data transformation operations to map the local wind fields for

the third geographic area to the first geographic area. The data transformation operations can include, for example, rotating positions of the local wind fields based on a wind direction of the second geographic area meteorologic data **128** and relative orientations of the first and third geographic areas.

(25) In some implementations, the processor(s) **106** can be configured to determine, based on the second geographic area meteorologic data **128** and the selected micro-weather model, risk data **122** indicative of probability of particular meteorological conditions in the first geographic area. In a particular aspect, the risk data **122** can indicate probability of occurrence of local winds that exceed one or more specified thresholds. For example, a first risk level can be associated with a probability of occurrence of winds below five miles per hour, a second risk level can be associated with a probability of occurrence of winds between five and ten miles per hour, a third risk level can be associated with a probability of occurrence of winds between ten and fifteen miles per hour, etc.

(26) In some aspects, the risk data **122** includes a plurality of risk values for the first geographic area. In such aspects, the risk data **122** can include, for example, a representative risk value for each grid section of a plurality of grid sections of the first geographic area, wherein the plurality of grid sections represent laterally offset subregions of the first geographic area. As an additional example, the risk data **122** can include a respective risk value for each layer of a plurality of layers of the first geographic area, wherein the plurality of layers represents vertically offset air volumes associated with the first geographic area.

(27) In the same or alternative aspects, the processor(s) **106** can be configured to obtain a descriptor of an aircraft type. The descriptor can include, for example, data associated with a particular aircraft, a particular type of aircraft, etc. In such configurations, the risk data **122** can be further based on the aircraft type. For example, an aircraft type with a large airframe may be at less risk of high winds than an aircraft type with a smaller airframe.

(28) In some implementations, the processor(s) **106** can be configured to generate a graphic user interface **124** representing at least the first geographic area and visually distinguishing, via the graphical user interface **124**, a first portion of the first geographic area that is indicated in the risk data **122** to be associated with a first risk level from a second portion of the first geographic area that is indicated in the risk data **122** to be associated with a second risk level.

(29) FIG. **1** provides an example illustration **136** of the operation of the systems and methods disclosed herein. In operation, the system **100** receives data indicating a first geographic area (e.g., the first geographic area data **126**). The system **100** also obtains meteorologic data for a second geographic area (e.g., the second geographic area meteorologic data **128**), wherein the first geographic area is smaller than and entirely bounded by the second geographic area. The data indicating the first geographic area can identify a first geographic area **140**. The first geographic area **140** is smaller than and entirely bounded by a second geographic area **138**. The second geographic area **138** can have meteorologic data associated therewith, indicating, for example, wind conditions, temperature, barometric pressure, etc.

(30) In the example illustration **136**, the system **100** can determine topographic parameters **114** associated with the first geographic area **140**. For example, the system **100** can determine descriptions of buildings within the first geographic area **140**. The system **100** can also perform a comparison of the topographic parameters **114** associated with the first geographic area **140** to topographic parameters **114** associated with a plurality of predetermined micro-weather models **120**. For example, the system **100** can compare the descriptions of buildings within the first geographic area **140** to descriptions of buildings within the geographic areas associated with each of the plurality of micro-weather models **120**.

(31) In the example illustration **136**, the system **100** can select a micro-weather model **142** from among the plurality of predetermined micro-weather models **120** based on the comparison of the topographic parameters **114** associated with the first geographic area **140** to topographic parameters **114** associated with a plurality of predetermined micro-weather models **120**. The selected micro-

weather model **142** has associated therewith particular topographic parameters **114** (e.g., descriptions of the buildings illustrated within the selected micro-weather model **142**), as well as output that indicates estimates of a plurality of local wind fields **130** within the first geographic area **140**. In the example illustration **136**, the estimates of local wind fields within the first geographic area **140** are illustrated by the various arrows within the selected micro-weather model **142**.

(32) In the example illustration **136**, the system **100** can also determine, based on the meteorologic data for the second geographic area **138** (e.g., the second geographic area meteorologic data **128**), risk data **122** indicative of risk of particular meteorological conditions in the first geographic area **140**. For example, each of the plurality of micro-weather models **120** can have an associated mathematical model that must be solved for a particular set of mesoscale meteorologic conditions associated with the second geographic area **138**. Based on the particular set of mesoscale meteorologic conditions, the selected micro-weather model **142** can estimate a plurality of local wind fields within the first geographic area. The system **100** can then associate risk data **122** with various portions of the first geographic area **140** based on the estimates of the plurality of local wind fields. In the example illustration **136**, the risk data **122** includes a respective risk value for each grid section of a plurality of grid sections **144** of the first geographic area **140**, wherein the plurality of grid sections represent laterally offset subregions of the first geographic area **140**. The risk values associated with the plurality of grid sections **144** can, for example, be illustrated with a graphic user interface **124** as differently shaded sections, with different shades associated with different risk levels.

(33) The illustration **136** is provided to aid in understanding and is not intended to limit the scope of the subject disclosure. For example, the second geographic area **138** is illustrated as a square grid. However, the data indicating the second geographic area **138** could describe the second geographic area **138** in any other appropriate manner without departing from the scope of the subject disclosure.

(34) The system **100** can also include components not illustrated in FIG. **1**. For example, to receive some or all of the geographic area data **132** and/or the meteorologic area data **134**, the system **100** can also include one or more input/output interfaces, one or more network interfaces, etc. Further, although FIG. **1** illustrates the memory **108** of the system **100** as storing certain data described below, more, fewer, and/or different data can be present within the memory **108** without departing from the scope of the subject disclosure.

(35) Additionally, although FIG. **1** illustrates certain operations occurring within the computing device **102**, these operations can be performed by other components of the system **100** without departing from the scope of the subject disclosure. For example, one or more of the meteorologic data providers **116** can be configured to host or otherwise incorporate one or more of the predetermined micro-weather models **120**.

(36) Further, although FIG. **1** illustrates the computing device **102**, the geographic area data provider(s) **104**, and/or the meteorologic data provider(s) **116** as separate, other configurations are possible without departing from the scope of the subject disclosure. For example, the computing device **102** and the meteorologic data provider(s) **116** can be integrated into the same electronic device. As an additional example, some or all components of the computing device **102** can be integrated into the same electronic device as some or all components of the geographic area data provider(s) **104** and/or the meteorologic data provider(s) **116**. As a further example, one or more components of the computing device **102** and/or one or more components of the geographic area data provider(s) **104** and/or one or more components of the meteorologic data provider(s) **116** can be distributed across a plurality of computing devices (e.g., a group of servers). As a still further example, one or more components of the geographic area data provider(s) **104** can be combined with one or more components of the meteorologic data provider(s) **116** into one or more computing devices.

(37) FIG. **2** depicts an example task diagram **200** illustrating a particular implementation of an automated environment for micro-weather risk mapping for very low-level aerial vehicles, in accordance with at least one implementation of the subject disclosure. Each of the components of the task diagram **200** can be performed by, for example, the processor(s) **106** of FIG. **1**. The example task diagram **200** includes a micro-weather data creation region **202**, a canopy layer modeling region **204**, and a pattern recognition region **206**.
(38) In some implementations, the task diagram **200** includes the micro-weather data creation region **202**. The operations described in the micro-weather data creation region **202** illustrate an exemplary structure for generating the predetermined micro-weather models of FIG. **1**. In some aspects, the micro-weather data creation region **202** includes, at block **208**, identification of critical conditions for vehicles. This can include, for example, identifying a particular type of vehicle, a particular class of vehicles, etc., as well as the types of meteorologic conditions for which the identified vehicles may need to be especially aware for the purposes of flight planning. For example, a particular class of unmanned aerial vehicle may be particularly susceptible to strong winds, winds from a particular direction with respect to the vehicle's flight path, a particular rotational wind effect, etc.
(39) In some aspects, the micro-weather data creation region **202** also includes, at block **210**, wind model generation and observation. This can include, for example, collecting real-world meteorologic data associated with one or more geographic areas. The collected data can be used to establish or refine parameters associated with one or more of the predetermined micro-weather models **120** of FIG. **1**. As another example, the wind model generation can include creation of a number of surrogate computational fluid dynamics simulations in lieu of, or in addition to, collecting real-world meteorologic data. In some aspects, the wind model generation and observation can also receive as input data from the canopy layer modeling region **204**, as described in more detail below. This data can include, for example, topographic parameters such as building height, vegetation, etc. used to create an environmental infrastructure model.
(40) In some aspects, the micro-weather data creation region **202** also includes, at block **212**, solving of the model for predefined mesoscale conditions. As described in more detail above with reference to FIG. **1**, micro-weather risk mapping for very low-level aerial vehicles can include solving a selected one of the plurality of predetermined micro-weather models **120** for a particular set of mesoscale meteorological conditions. In a particular aspect, a particular micro-weather model can be solved for a predetermined set of mesoscale meteorological conditions. By associating a particular micro-weather model with a predetermined set of mesoscale meteorological conditions, some of all of the predetermined micro-weather models **120** can be precomputed for use in micro-weather risk mapping.
(41) In some implementations, the task diagram **200** can include the canopy layer modeling region **204**. The operations described in the canopy layer modeling region **204** illustrate an exemplary structure for enabling the comparison of the topographic parameters **114** associated with the first geographic area to the topographic parameters **114** associated with a plurality of predetermined micro-weather models **120** of FIG. **1**. In some aspects, the canopy layer modeling region **204** includes one or more operations for categorization of model components by key indicators that impact the atmospheric conditions on a hyperlocal scale. For example, the canopy layer modeling region **204** can include, at block **214**, standardization of canopy layers. This can include, for example, setting standard elevations at which canopy layers are set across the plurality of predetermined micro-weather models **120** of FIG. **1**.
(42) The canopy layer modeling region **204** can also include, at block **216**, environmental infrastructure modeling. Environmental infrastructure modeling can include identifying a plurality of key factors across which the topographical features of various models should be categorized. Those key factors can include, for example building height **218**, vegetation characteristics **220**, surface indices **222**, and other information **224**. By establishing a standardized category of features

for the micro-weather models and the geographic areas under consideration, automated comparison of topographic features (e.g., the topographic parameters **114** of FIG. **1**) across areas and models can be facilitated. Although three key features (e.g., the building height **218**, the vegetation characteristics **220**, and the surface indices **222**) are illustrated in the example task diagram **200**, more, fewer, and/or different key features can be used without departing from the scope of the subject disclosure.
(43) In some implementations, the task diagram **200** can include the pattern recognition region **206**. In some aspects, the pattern recognition region **206** includes, at block **226**, translation of the solved model (e.g., the output from block **212**) into risk zones. As described in more detail above with reference to FIG. **1**, the processor(s) **106** can be configured to determine, based on the meteorologic data for the second geographic area and the micro-weather model, risk data (e.g., the risk data **122**) indicative of risk of particular meteorological conditions in the first geographic area.
(44) In some aspects, the pattern recognition region **206** can also include, at block **228**, pattern recognition. Pattern recognition can include, for example, identifying a best match in an existing data set for a different micro-weather area, as described in more detail below with reference to FIG. **5**. In a particular aspect, the recognized pattern can be used to create one or more micro-weather models for a different geographic area. For example, by comparing the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models, and selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison, the selected micro-weather model can be transferred to a new data set with different, but substantially similar, topographic features.
(45) In some aspects, the pattern recognition region **206** can also include, at block **230**, model creation. Model creation can include, for example, creating a new micro-weather model based on the results of the application of the pattern recognition algorithm. In some aspects, the transfer of a model to a new data set (e.g., at block **234**) can also include, at block **232**, generalization of similar areas. For example, the pattern recognition algorithm can identify a plurality of geographic areas with substantially the same topographic features. By generalizing the predicted micro-weather associated with each of the plurality of geographic areas, a model that is more readily adapted to a similar area can be created. Once a particular model is ready for use (e.g., as described in more detail above with reference to FIG. **1**), the model can, at block **236**, be deployed.
(46) Although FIG. **2** illustrates certain operations occurring within various portions of the task diagram **200**, these operations can be performed by other components and/or at different points of the task diagram **200** without departing from the scope of the subject disclosure. For example, the operations of the micro-weather data creation region **202** can be performed by the processor(s) **106** of FIG. **1**, while the operations of the canopy layer modeling region **204** can be performed by the processor(s) **106** and/or another electronic device. As another example, although three key features (e.g., the building height **218**, the vegetation characteristics **220**, and the surface indices **222**) are illustrated in the example task diagram **200**, more, fewer, and/or different key features can be used without departing from the scope of the subject disclosure.
(47) FIG. **3** is an example of a categorization **300** of a micro-weather simulation, in accordance with at least one implementation of the subject disclosure. In the example of FIG. **3**, data associated with a mesoscale model **302** of a geographic area is used to solve a micro-weather model **304** of a particular subregion of the geographic area. Data associated with a risk value categorization **308** can be used to translate the output of the micro-weather model **304** into a plurality of risk factors associated with the particular subregion. In some implementations, the categorization **300** can be performed by one or more components of the processor(s) **106** of FIG. **1**.
(48) In some implementations, the mesoscale model **302** of a particular geographic area **311** has associated therewith certain meteorological conditions. For example, the mesoscale model **302** can have windspeed values and wind direction values (e.g., “X m/s, West”) associated the particular

geographic area **311**. The geographic area **311** is illustrated in FIG. **3** as a plurality of grid sections representing laterally offset subregions **312**, **314**, **316**, **318**, **320**, **322**, **324**, **326**, **328** of the geographic area **311**. Each subregion that is entirely bounded by the geographic area **311** can have an associated plurality of predetermined micro-weather models (e.g., the plurality of micro-weather models **120** of FIG. **1**). In the illustration of FIG. **3**, the subregion **320** is entirely bounded by the geographic area **311** and has an associated micro-weather model **304**.

(49) The micro-weather model **304** has associated therewith particular topographic parameters (e.g., descriptions of the buildings illustrated within the micro-weather model **304**), as well as output **305** that indicates estimates of a plurality of local wind fields within the subregion **320**. In the example categorization **300**, the estimates of local wind fields within the subregion **320** are illustrated by the various arrows within the micro-weather model **304**.

(50) In addition to the micro-weather model **304**, the categorization **300** can also make use of the risk value categorization **308** to translate the output **305** of the micro-weather model **304** into a plurality of risk factors associated with the particular subregion. The risk value categorization **308** illustrates a graph with an x-axis **359** indicating wind speed and a y-axis **356** indicating a cost index. The cost index indicated by the y-axis **356** can include, for example, an operational cost associated with operating an unmanned aerial vehicle within a particular subregion (e.g., the subregion **320**) of the geographic area **311**. The risk value categorization **308** includes an exemplary line **354** that shows how the cost index rises as a function of wind speed. In a particular aspect, for a particular type of aircraft (e.g., “Airframe Type ‘A’,” as illustrated in FIG. **3**), the risk value categorization **308** can have assigned a plurality of risk categories **348**, **350**, **352** based on predetermined cost thresholds. The risk category **352** can illustrate, for example, a first level of risk associated with operating a vehicle with airframe type A below a first threshold point **358** associated with a first particular wind speed and a first particular cost index value. The risk category **350** can illustrate, for example, a second level of risk associated with operating the vehicle with airframe type A above the first threshold point **358** and a below a second threshold point **360** associated with a second particular wind speed and a second particular cost index value. The risk category **348** can illustrate, for example, a third level of risk associated with operating the vehicle with airframe type A above the second threshold point **360**.

(51) By incorporating data associated with the vehicle type (e.g., the “Airframe Type ‘A’”), the risk value categorization **308** can adapt the risk categories **348**, **350**, **352** depending on a cost associated with operating that particular vehicle type in a particular set of meteorological conditions. For example, if airframe type A is lighter than airframe type B, it may be more expensive to attempt to operate the airframe type A in higher wind speeds, but less expensive to attempt to operate the airframe type A in lower wind speeds. Thus, the line **354** illustrating how the cost index changes as a function of wind speed can differ from the airframe type A to the airframe type B. Accordingly, the threshold points **360**, **358** can be at different points on the risk value categorization **308** depending on the airframe type.

(52) In the example of FIG. **3**, the risk categories **348**, **350**, **352** are each associated with a different shading. The three exemplary risk categories **348**, **350**, **352** and the associated shading is illustrated by a risk category key **362** associated with a graphical representation **306**. The shading associated with the risk categories **348**, **350**, **352** are mapped to each grid section of a plurality of grid sections **310** of the subregion **320**, where the plurality of grid sections **310** represents laterally offset subregions of the subregion **320**. In other configurations, the risk categories **348**, **350**, **352** can be mapped to each layer of a plurality of layers of the subregion **320**, where the plurality of layers represents vertically offset air volumes associated with the subregion **320**.

(53) In some aspects, the graphical representation **306** includes the plurality of grid sections **310** in the context of the particular geographic area associated with the mesoscale model **302** described above. The particular geographic area associated with the mesoscale model **302** can be represented graphically by a plurality of geographic regions **330** (e.g., a square grid including the subregions

332, **334**, **336**, **338**, **340**, **342**, **344**, **346**). As illustrated, a first portion of the plurality of grid sections **310** (e.g., the portion associated with the first risk category **352**) is depicted in a manner that is visually distinguishable from a second portion of the plurality of grid sections **310** (e.g., the portion associated with the second risk category **350**).

(54) Although FIG. **3** illustrates the categorization **300** as including particular components, more, fewer, and/or different components can be present within the exemplary categorization **300** without departing from the scope of the subject disclosure. For example, the geographic area **311** can include more, fewer, and/or different subregions, can be indicated, depicted, and/or analyzed in a manner other than as a grid, or some combination thereof. As an additional example, the risk value categorization **308** can include more, fewer, and/or different risk categories than the risk categories **348**, **350**, **352**.

(55) FIG. **4** is an exemplary illustration **400** of a set **402** of predetermined micro-weather simulations **406** for subregions **408**, **410**, **412**, **414**, **416**, **418**, **420**, **422**, **424** with characteristic properties estimating a micro-weather pattern for a different micro-weather area **426**, in accordance with at least one implementation of the subject disclosure.

(56) Each of the predetermined micro-weather simulations **406** of the set **402** is associated with a particular geographic area, as described in more detail above with reference to FIGS. **1-3**. In the illustration of FIG. **4**, the micro-weather simulation **406** is associated with a particular geographic area that can be subdivided into a plurality of subregions **408**, **410**, **412**, **414**, **416**, **418**, **420**, **422**, **424**. Each of those subregions is associated with one or more topographic parameters or properties (e.g., the topographic parameters **114** of FIG. **1**). For example, the topographic parameter of interest for a particular micro-weather simulation **406** can include a description of land surface topology. In the illustration **400**, each of the plurality of subregions **408**, **410**, **412**, **414**, **416**, **418**, **420**, **422**, **424** have an associated topographic parameter denoted by a combination of the letters X, Y, and Z. For example, the subregion **410** has a particular land surface topology described by the letters “XYZ.”

(57) Additionally, the subregion **408** has a particular set of topographic parameters that can include a particular layout of buildings, illustrated by the different rectangles within the subregion **408** in the illustration **400**. In some implementations, a pattern recognition algorithm can identify a best match among the set **402** of predetermined micro-weather simulations **406** for a new, different micro-weather area **444** of a larger geographic area **426**. As with each of the predetermined micro-weather simulations **406**, the geographic area **426** can be subdivided into a plurality of subregions **428**, **430**, **432**, **434**, **436**, **438**, **440**, **442**, **444**.

(58) As described in more detail above with reference to FIG. **2**, each of the plurality of predetermined micro-weather simulations **406** and the data associated with the new geographic area **426** can be standardized according to one or more topographic parameters of interest. For example, as each of the subregions of the predetermined micro-weather simulation **406** can have an associated topographic parameter describing the land surface topology of each of the subregions, so too will each of the subregions **428**, **430**, **432**, **434**, **436**, **438**, **440**, **442**, **444** have an associated topographic parameter describing the land surface topology of each of the subregions **428**, **430**, **432**, **434**, **436**, **438**, **440**, **442**, **444** (e.g., as denoted by a combination of the letters X, Y, and Z in the illustration **400**). For example, the subregion **428** has a particular land surface topology described by the letters “XZZ.”

(59) In some aspects, the pattern matching algorithm can identify a best match among the set **402** of predetermined micro-weather simulations **406** for the new, different micro-weather area **444** of the larger geographic area **426** by comparing the topographic parameters associated with each of the subregions **408**, **410**, **412**, **414**, **416**, **418**, **420**, **422**, **424** of the micro-weather simulation **406** with the topographic parameters associated with each of the subregions **428**, **430**, **432**, **434**, **436**, **438**, **440**, **442**, **444** of the geographic area **426**. For example, the pattern matching algorithm can compare the topographic parameter “XYZ” of the subregion **410** with the topographic parameter “XZZ” of the subregion **428**. In the illustration **400**, the greater the number of letters in common

between the topographic parameters of a plurality of subregions, the more similar the topographic parameter will be. For example, the topographic parameter "XYZ" of the subregion **410** and the topographic parameter "XZZ" of the subregion **428** only differ by one letter, indicating an approximately 67% similarity between the two topographic parameters. In the illustration **400**, each pair of compared subregions between the predetermined micro-weather simulation **406** and the geographic area **426** shows at least an approximately 67% similarity. Some pairs (e.g., the subregion **422** and the subregion **440**) show an approximately 100% similarity.

(60) With such a high degree of similarity between the topographic parameter(s) of the predetermined micro-weather simulation **406** and the topographic parameter(s) of the geographic area **426**, the predetermined micro-weather simulation **406** can be used to estimate micro-weather behavior at the geographic area **426**. For example, the subregion **408** of the predetermined micro-weather simulation **406** has a different arrangement of buildings (illustrated by the rectangles within the subregion **408**) than the subregion **444** of the geographic area **426** (illustrated by the rectangles within the subregion **444**). However, if the arrangement is sufficiently similar and the topographic parameters of the respective surrounding subregions are also sufficiently similar for a particular set of mesoscale meteorological conditions, the outputs of the predetermined micro-weather simulation **406** can be used to predict meteorological conditions associated with the subregion **444** of the geographic area **426**. For example, as described in more detail above with reference to FIG. **1**, the outputs of a micro-weather simulation can include estimates of a plurality of local wind fields. Those estimates, associated with the subregion **408**, can be used to predict a plurality of local wind fields associated with the subregion **444**. Since the set **402** of predetermined micro-weather simulations **406** are predetermined and the pattern recognition algorithm is less intensive with regard to computing resources than a full mathematical simulation based on meteorologic data, an estimate of micro-weather meteorological conditions at a subregion can be provided (e.g., by the processor(s) **106** of FIG. **1**) faster and with fewer computing resources.

(61) In the illustration **400**, the letters X, Y, and Z are used to illustrate various potential values for a particular topographic parameter. The letters X, Y, and Z are provided as illustrative only to aid in understanding. The particular use of these letters should not be understood to limit the scope of the subject disclosure. For example, in a particular configuration of the system **100** of FIG. **1**, the topographic parameter associated with each of the subregions **408**, **410**, **412**, **414**, **416**, **418**, **420**, **422**, **424**, **428**, **430**, **432**, **434**, **436**, **438**, **440**, **442**, **444** can be numerical data values. In such a configuration, the similarity between two topographic parameters can be established by comparing two numerical data values with reference to a predetermined difference threshold (e.g., 5%). In the same or alternative configurations, the topographic parameters can include a plurality of numerical data values describing one or more particular topographic parameters. In such configurations, the similarity between any two topographic parameters can be established by comparing two numerical data values with reference to a predetermined difference threshold (e.g., 5%), comparing the respective similarities of sets of numerical data values with respect to a predetermined similarity threshold (e.g., at least ⅔ of the sets of numerical data values must be within 5% of one another), or some combination thereof.

(62) FIG. **5** is a flow chart of an example method **500** for providing micro-weather risk mapping for very low-level aerial vehicles, in accordance with at least one implementation of the subject disclosure. The method **500** can be initiated, performed, or controlled by one or more processors executing instructions, such as by the processor(s) **106** of FIG. **1** executing instructions from the memory **108**.

(63) In some implementations, the method **500** optionally includes, at block **502**, receiving data indicating a first geographic area. For example, the processor(s) **106** of FIG. **1** can receive the first geographic area data **126** from the geographic area data provider(s) **104**.

(64) In some implementations, the method **500** optionally includes, at block **504**, obtaining meteorological data for a second geographic area, wherein the first geographic area is smaller than

and entirely bounded by the second geographic area. For example, the processor(s) **106** of FIG. **1** can obtain the second geographic area meteorologic data **128** from the meteorologic data provider(s) **116**.

(65) In some implementations, the method **500** optionally includes, at block **506**, determining topographic parameters associated with the first geographic area. For example, the processor(s) **106** of FIG. **1** can determine the topographic parameters **114** associated with the first geographic area indicated by the first geographic area data **126**.

(66) In some implementations, the method **500** optionally includes, at block **508**, performing a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. For example, the processor(s) **106** of FIG. **1** can compare the topographic parameters **114** associated with the first geographic area indicated by the first geographic area data **126** to the topographic parameters **114** associated with a plurality of predetermined micro-weather models **120**.

(67) In some implementations, the method **500** optionally includes, at block **510**, selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. For example, the micro-weather model selector **118** of FIG. **1** can select a micro-weather model from among the plurality of predetermined micro-weather models **120** based on the comparison of the topographic parameters **114** associated with the first geographic area indicated by the first geographic area data **126** to the topographic parameters **114** associated with a plurality of predetermined micro-weather models **120**.

(68) In some implementations, the method **500** optionally includes, at block **512**, determining, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area. For example, the processor(s) **106** of FIG. **1** can determine, based on the second geographic area meteorologic data **128** and the micro-weather model selected from among the plurality of micro-weather models **120**, the risk data **122** indicative of risk of particular meteorological conditions in the first geographic area indicated by the first geographic area data **126**.

(69) Although the method **500** is illustrated as including a certain number of steps, more, fewer, and/or different steps can be included in the method **500** without departing from the scope of the subject disclosure. For example, the method **500** can vary depending on the count and variety of data requirements available for processing, as described in more detail above with reference to FIGS. **1-4**. For example, the method **500** can also include generating a graphic user interface (e.g., the graphical user interface **124** of FIG. **1**) representing at least the first geographic area and visually distinguishing, in the graphical user interface, a first portion of the first geographic area that is indicated in the risk data to be associated with a first risk level from a second portion of the first geographic area that is indicated in the risk data to be associated with a second risk level.

(70) FIG. **6** is a block diagram of a computing environment **600** including a computing device **610** configured to support aspects of computer-implemented methods and computer-executable program instructions (or code), in accordance with at least one implementation of the subject disclosure. For example, the computing device **610**, or portions thereof, is configured to execute instructions to initiate, perform, or control one or more operations described in more detail above with reference to FIGS. **1-5**. In a particular aspect, the computing device **610** can include the computing device **102**, the geographic area data provider(s) **104**, and/or the meteorologic data provider(s) **116** of FIG. **1**; one or more servers; one or more virtual devices; or a combination thereof.

(71) The computing device **610** includes one or more processors **620**. In a particular aspect, the processor(s) **620** correspond to the processor(s) **106** of FIG. **1**. The processor(s) **620** are configured to communicate with system memory **630**, one or more storage devices **650**, one or more input/output interfaces **640**, one or more communications interfaces **660**, or any combination thereof. The system memory **630** includes volatile memory devices (e.g., random access memory

(RAM) devices), nonvolatile memory devices (e.g., read-only memory (ROM) devices, programmable read-only memory, and flash memory), or both. The system memory **630** stores an operating system **632**, which can include a basic input/output system for booting the computing device **610** as well as a full operating system to enable the computing device **610** to interact with users, other programs, and other devices. The system memory **630** stores system (program) data **638**, such as the instructions **636**, the topographic parameters **114**, the plurality of micro-weather models **120** of FIG. **1**, or a combination thereof.

(72) The system memory **630** includes one or more applications **634** (e.g., sets of instructions) executable by the processor(s) **620**. As an example, the one or more applications **634** include the instructions **636** executable by the processor(s) **620** to initiate, control, or perform one or more operations described with reference to FIGS. **1-5**. To illustrate, the one or more applications **634** include the instructions **636** executable by the processor(s) **620** to initiate, control, or perform one or more operations described with reference to receiving first geographic area data **126**, obtaining the second geographic area meteorologic data **128**, determining the topographic parameters **114** associated with the first geographic area, performing the comparison of the topographic parameters **114** associated with the first geographic areas to the topographic parameters **114** associated with the plurality of predetermined micro-weather models **120**, selecting the micro-weather model from among the plurality of predetermined micro-weather models **120** based on the comparison, determining, based on the second geographic area meteorologic data **128** and the selected micro-weather model, the risk data **122** indicative of risk of particular meteorological conditions in the first geographic area, or a combination thereof.

(73) In a particular implementation, the system memory **630** includes a non-transitory, computer readable medium (e.g., a computer-readable storage device) storing the instructions **636** that, when executed by the processor(s) **620**, cause the processor(s) **620** to initiate, perform, or control operations for providing micro-weather risk mapping for very low-level aerial vehicles. The operations include receiving data indicating a first geographic area. The operations also include obtaining meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area. The operations also include determining topographic parameters associated with the first geographic area. The operations also include performing a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. The operations also include selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. The operations also include determining, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area.

(74) The one or more storage devices **650** include nonvolatile storage devices, such as magnetic disks, optical disks, or flash memory devices. In a particular example, the storage devices **650** include both removable and non-removable memory devices. The storage devices **650** are configured to store an operating system, images of operating systems, applications (e.g., one or more of the applications **634**), and program data (e.g., the program data **638**). In a particular aspect, the system memory **630**, the storage devices **650**, or both, include tangible computer-readable media. In a particular aspect, one or more of the storage devices **650** are external to the computing device **610**.

(75) The one or more input/output interfaces **640** enable the computing device **610** to communicate with one or more input/output devices **670** to facilitate user interaction. For example, the one or more input/output interfaces **640** can include a display interface, an input interface, or both. For example, the input/output interface **640** is adapted to receive input from a user, to receive input from another computing device, or a combination thereof. In some implementations, the input/output interface **640** conforms to one or more standard interface protocols, including serial

interfaces (e.g., universal serial bus (USB) interfaces or Institute of Electrical and Electronics Engineers (IEEE) interface standards), parallel interfaces, display adapters, audio adapters, or custom interfaces ("IEEE" is a registered trademark of The Institute of Electrical and Electronics Engineers, Inc. of Piscataway, New Jersey). In some implementations, the input/output device(s) **670** include one or more user interface devices and displays, including some combination of buttons, keyboards, pointing devices, displays, speakers, microphones, touch screens, and other devices.

(76) The processor(s) **620** are configured to communicate with devices or controllers **680** via the one or more communications interfaces **660**. For example, the one or more communications interfaces **660** can include a network interface. The devices or controllers **680** can include, for example, the geographic area data provider(s) **104** and/or the meteorologic data provider(s) **116** of FIG. **1**.

(77) In some implementations, a non-transitory, computer readable medium (e.g., a computer-readable storage device) stores instructions that, when executed by one or more processors, cause the one or more processors to initiate, perform, or control operations to perform part of or all the functionality described above. For example, the instructions can be executable to implement one or more of the operations or methods of FIGS. **1-5**. In some implementations, part or all of one or more of the operations or methods of FIGS. **1-5** can be implemented by one or more processors (e.g., one or more central processing units (CPUs), one or more graphics processing units (GPUs), one or more digital signal processors (DSPs)) executing instructions, by dedicated hardware circuitry, or any combination thereof.

(78) The illustrations of the examples described herein are intended to provide a general understanding of the structure of the various implementations. The illustrations are not intended to serve as a complete description of all of the elements and features of apparatus and systems that utilize the structures or methods described herein. Many other implementations can be apparent to those of skill in the art upon reviewing the disclosure. Other implementations can be utilized and derived from the disclosure, such that structural and logical substitutions and changes can be made without departing from the scope of the disclosure. For example, method operations can be performed in a different order than shown in the figures or one or more method operations can be omitted. Accordingly, the disclosure and the figures are to be regarded as illustrative rather than restrictive.

(79) Moreover, although specific examples have been illustrated and described herein, it should be appreciated that any subsequent arrangement designed to achieve the same or similar results can be substituted for the specific implementations shown. This disclosure is intended to cover any and all subsequent adaptations or variations of various implementations. Combinations of the above implementations, and other implementations not specifically described herein, will be apparent to those of skill in the art upon reviewing the description.

(80) The Abstract of the Disclosure is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, various features can be grouped together or described in a single implementation for the purpose of streamlining the disclosure. Examples described above illustrate but do not limit the disclosure. It should also be understood that numerous modifications and variations are possible in accordance with the principles of the subject disclosure. As the following claims reflect, the claimed subject matter can be directed to less than all of the features of any of the disclosed examples. Accordingly, the scope of the disclosure is defined by the following claims and their equivalents.

(81) Further, the disclosure comprises embodiments according to the following clauses:

(82) According to Clause 1, a method includes receiving data indicating a first geographic area. The method also includes obtaining meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area. The

method also includes determining topographic parameters associated with the first geographic area. The method also includes performing a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. The method also includes selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. The method also includes determining, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area.

(83) Clause 2 includes the method of Clause 1, the method further including generating a graphical user interface representing at least the first geographic area and visually distinguishing, in the graphical user interface, a first portion of the first geographic area that is indicated in the risk data to be associated with a first risk level from a second portion of the first geographic area that is indicated in the risk data to be associated with a second risk level.

(84) Clause 3 includes the method of Clause 1 or Clause 2, the method further including obtaining a descriptor of an aircraft type, and where the risk data is further based on the aircraft type.

(85) Clause 4 includes the method of any of Clauses 1-3, wherein the micro-weather model includes a machine-learning model configured to receive input based on the meteorologic data and configured to generate output, and wherein the output includes estimates of a plurality of local wind fields within the first geographic area.

(86) Clause 5 includes the method of any of Clauses 1-4, wherein the micro-weather model includes parameters for calculating, based on the meteorologic data, estimates of a plurality of local wind fields within the first geographic area.

(87) Clause 6 includes the method of any of Clauses 1-5, wherein the micro-weather model indicates predetermined estimates of a plurality of local wind fields within a third geographic area, wherein the topographic parameters of the third geographic area are a closest match, based on the comparison, to the topographic parameters of the first geographic area.

(88) Clause 7 includes the method of any of Clauses 1-6, wherein the first geographic area represents an area corresponding to one city block or less, and the second geographic area represents an area corresponding to at least a neighborhood or city that contains the first geographic area.

(89) Clause 8 includes the method of any of Clauses 1-7, wherein the topographic parameters include descriptions of buildings, descriptions of streets, descriptions of land usage, descriptions of land surface topology, or any combination thereof.

(90) Clause 9 includes the method of any of Clauses 1-8, wherein selecting a micro-weather model includes selecting a third geographic area that is similar to the first geographic area based on the topographic parameters of the first geographic area and corresponding topographic parameters of the third geographic area.

(91) Clause 10 includes the method of Clause 9, the method further including estimating, based on the micro-weather model and the meteorologic data for the second geographic area, local wind fields for the third geographic area. The method also includes performing one or more data transformation operations to map the local wind fields for the third geographic area to the first geographic area.

(92) Clause 11 includes the method of any of Clauses 1-10, wherein the risk data includes a plurality of risk values for the first geographic area.

(93) Clause 12 includes the method of Clause 11, wherein the risk data includes a respective risk value for each grid section of a plurality of grid sections of the first geographic area, and wherein the plurality of grid sections represent laterally offset subregions of the first geographic area.

(94) Clause 13 includes the method of Clause 11 or Clause 12, wherein the risk data includes a respective risk value for each layer of a plurality of layers of the first geographic area, and wherein the plurality of layers represent vertically offset air volumes associated with the first geographic

area.
(95) Clause 14 includes the method of any of Clauses 1-13, wherein at least a subset of the plurality of predetermined micro-weather models are generated using computational fluid dynamics analysis of one or more third geographic areas based on topographic parameters associated with the one or more third geographic areas and meteorological data associated with one or more fourth geographic areas, wherein each of the one or more third geographic areas is smaller than and entirely bounded by a respective one of the one or more fourth geographic areas, and wherein the first geographic area is distinct from each of the one or more third geographic areas.
(96) Clause 15 includes the method of Clause 14, wherein the second geographic area is distinct from each of the one or more fourth geographic areas.
(97) According to Clause 16, a computer-readable storage device stores instructions that, when executed by one or more processors, cause the one or more processors to perform operations including receiving data indicating a first geographic area. The operations also include obtaining meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area. The operations also include determining topographic parameters associated with the first geographic area. The operations also include performing a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. The operations also include selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. The operations also include determining, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area.
(98) Clause 17 includes the computer-readable storage device of Clause 16, wherein at least a subset of the plurality of predetermined micro-weather models are generated using computational fluid dynamics analysis of one or more third geographic areas based on topographic parameters associated with the one or more third geographic areas and meteorological data associated with one or more fourth geographic areas, wherein each of the one or more third geographic areas is smaller than and entirely bounded by a respective one of the one or more fourth geographic areas, and wherein the first geographic area is distinct from each of the one or more third geographic areas.
(99) Clause 18 includes the computer-readable storage device of Clause 16 or Clause 17, wherein the operations further include obtaining a descriptor of an aircraft type, and where the risk data is further based on the aircraft type.
(100) According to Clause 19, a computing device includes one or more processors configured to receive data indicating a first geographic area. The one or more processors are also configured to obtain meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area. The one or more processors are also configured to determine topographic parameters associated with the first geographic area. The one or more processors are also configured to perform a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models. The one or more processors are also configured to select a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison. The one or more processors are also configured to determine, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area.
(101) Clause 20 includes the computing device of Clause 19, wherein the one or more processors are further configured to generate a graphical user interface representing at least the first geographic area and visually distinguishing, in the graphical user interface, a first portion of the first geographic area that is indicated in the risk data to be associated with a first risk level from a second portion of the first geographic area that is indicated in the risk data to be associated with a second risk level.

Claims

1. A computer-implemented method comprising: receiving, by a processor, a request for a risk value categorization for an operation of an aerial vehicle; receiving, by the processor, data indicating a first geographic area; obtaining, by the processor, meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area; determining, by the processor, topographic parameters associated with the first geographic area; performing, by the processor, a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models; selecting, by the processor, a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison; determining, by the processor and based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area; generating the risk value categorization based at least on the risk data; and transmitting the risk value categorization in response to the request.
2. The method of claim 1, further comprising generating, by the processor, a graphical user interface representing at least the first geographic area and visually distinguishing, in the graphical user interface, a first portion of the first geographic area that is indicated in the risk data to be associated with a first risk level from a second portion of the first geographic area that is indicated in the risk data to be associated with a second risk level.
3. The method of claim 1, further comprising obtaining, by the processor, a descriptor of an aircraft type, and where the risk data is further based on the aircraft type.
4. The method of claim 1, wherein the micro-weather model includes a machine-learning model configured to receive input based on the meteorologic data and configured to generate output, and wherein the output includes estimates of a plurality of local wind fields within the first geographic area.
5. The method of claim 1, wherein the micro-weather model includes parameters for calculating, based on the meteorologic data, estimates of a plurality of local wind fields within the first geographic area.
6. The method of claim 1, wherein the micro-weather model indicates predetermined estimates of a plurality of local wind fields within a third geographic area, wherein the topographic parameters of the third geographic area are a closest match, based on the comparison, to the topographic parameters of the first geographic area.
7. The method of claim 1, wherein the first geographic area represents an area corresponding to one city block or less, and the second geographic area represents an area corresponding to at least a neighborhood or city that contains the first geographic area.
8. The method of claim 1, wherein the topographic parameters include descriptions of buildings, descriptions of streets, descriptions of land usage, descriptions of land surface topology, or any combination thereof.
9. The method of claim 1, wherein selecting a micro-weather model includes selecting a third geographic area that is similar to the first geographic area based on the topographic parameters of the first geographic area and corresponding topographic parameters of the third geographic area.
10. The method of claim 9, further comprising: estimating, by the processor, based on the micro-weather model and the meteorologic data for the second geographic area, local wind fields for the third geographic area; and performing, by the processor, one or more data transformation operations to map the local wind fields for the third geographic area to the first geographic area.
11. The method of claim 1, wherein the risk data includes a plurality of risk values for the first geographic area.
12. The method of claim 11, wherein the risk data includes a respective risk value for each grid

section of a plurality of grid sections of the first geographic area, and wherein the plurality of grid sections represent a respective plurality of subregions of the first geographic area laterally offset from one another.

13. The method of claim 11, wherein the risk data includes a respective risk value for each layer of a plurality of layers of the first geographic area, and wherein the plurality of layers represent vertically offset air volumes associated with the first geographic area.

14. The method of claim 1, wherein at least a subset of the plurality of predetermined micro-weather models are generated using computational fluid dynamics analysis of one or more third geographic areas based on topographic parameters associated with the one or more third geographic areas and meteorological data associated with one or more fourth geographic areas, wherein each of the one or more third geographic areas is smaller than and entirely bounded by a respective one of the one or more fourth geographic areas, and wherein the first geographic area is distinct from each of the one or more third geographic areas.

15. The method of claim 14, wherein the second geographic area is distinct from each of the one or more fourth geographic areas.

16. A computer-readable storage device storing instructions that when executed by one or more processors cause the one or more processors to perform operations comprising: receiving a request for a risk value categorization for an operation of an aerial vehicle; receiving data indicating a first geographic area; obtaining meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area; determining topographic parameters associated with the first geographic area; performing a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models; selecting a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison; determining, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area; generating the risk value categorization based at least on the risk data; and transmitting the risk value categorization to the user in response to the request.

17. The computer-readable storage device of claim 16, wherein at least a subset of the plurality of predetermined micro-weather models are generated using computational fluid dynamics analysis of one or more third geographic areas based on topographic parameters associated with the one or more third geographic areas and meteorological data associated with one or more fourth geographic areas, wherein each of the one or more third geographic areas is smaller than and entirely bounded by a respective one of the one or more fourth geographic areas, and wherein the first geographic area is distinct from each of the one or more third geographic areas.

18. The computer-readable storage device of claim 16, wherein the operations further comprise obtaining a descriptor of an aircraft type, and where the risk data is further based on the aircraft type.

19. A computing device comprising: one or more processors configured to: receive a request for a risk value categorization for an operation of an aerial vehicle; receive data indicating a first geographic area; obtain meteorologic data for a second geographic area, wherein the first geographic area is smaller than and entirely bounded by the second geographic area; determine topographic parameters associated with the first geographic area; perform a comparison of the topographic parameters associated with the first geographic area to topographic parameters associated with a plurality of predetermined micro-weather models; select a micro-weather model from among the plurality of predetermined micro-weather models based on the comparison; determine, based on the meteorologic data for the second geographic area and the micro-weather model, risk data indicative of risk of particular meteorological conditions in the first geographic area; generate the risk value categorization based at least on the risk data; and transmit the risk value categorization in response to the request.

20. The computing device of claim 19, wherein the one or more processors are further configured to generate a graphical user interface representing at least the first geographic area and visually distinguishing, in the graphical user interface, a first portion of the first geographic area that is indicated in the risk data to be associated with a first risk level from a second portion of the first geographic area that is indicated in the risk data to be associated with a second risk level.