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(54) **SYSTEM AND METHOD FOR GENERATING AND DISPLAYING CLIMATE SYSTEM MODELS**

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(57) **ABSTRACT**

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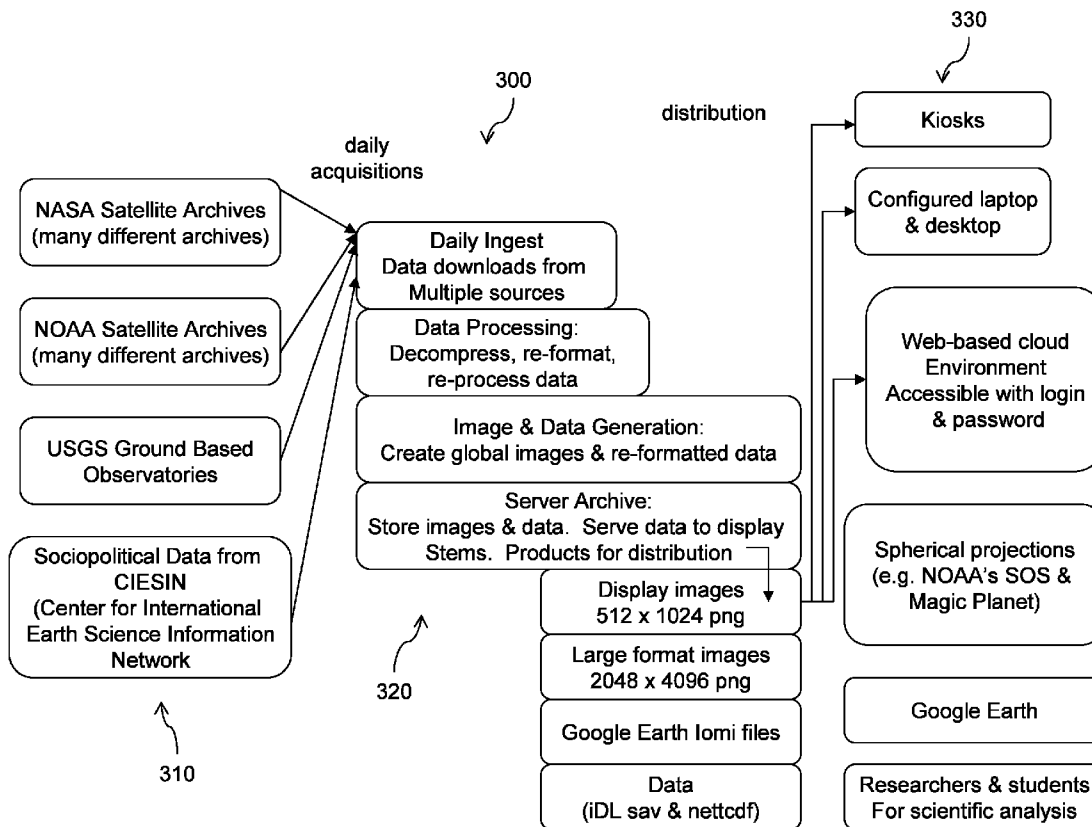
**Related U.S. Application Data**

(60) **Provisional application No. 61/448,498**, filed on Mar. 2, 2011.

**Publication Classification**

(51) **Int. Cl. G09G 5/00** (2006.01)

An embodiment of the invention provides a system and method for generating and displaying climate system models. A data collector automatically extracts global earth data from multiple data sources, wherein the global earth data includes atmospheric data, hydrospheric data, lithospheric data, cryospheric data, biospheric data, and/or anthropospheric data. A processor connected to the data collector generates global images based on the extracted global earth data, wherein the global images display the global earth data on a map. A display connected to the processor displays at least one second global image on a first global image. The first global image includes first global earth data for a select geographic area; and, the second global image includes second global earth data for the select geographic area.



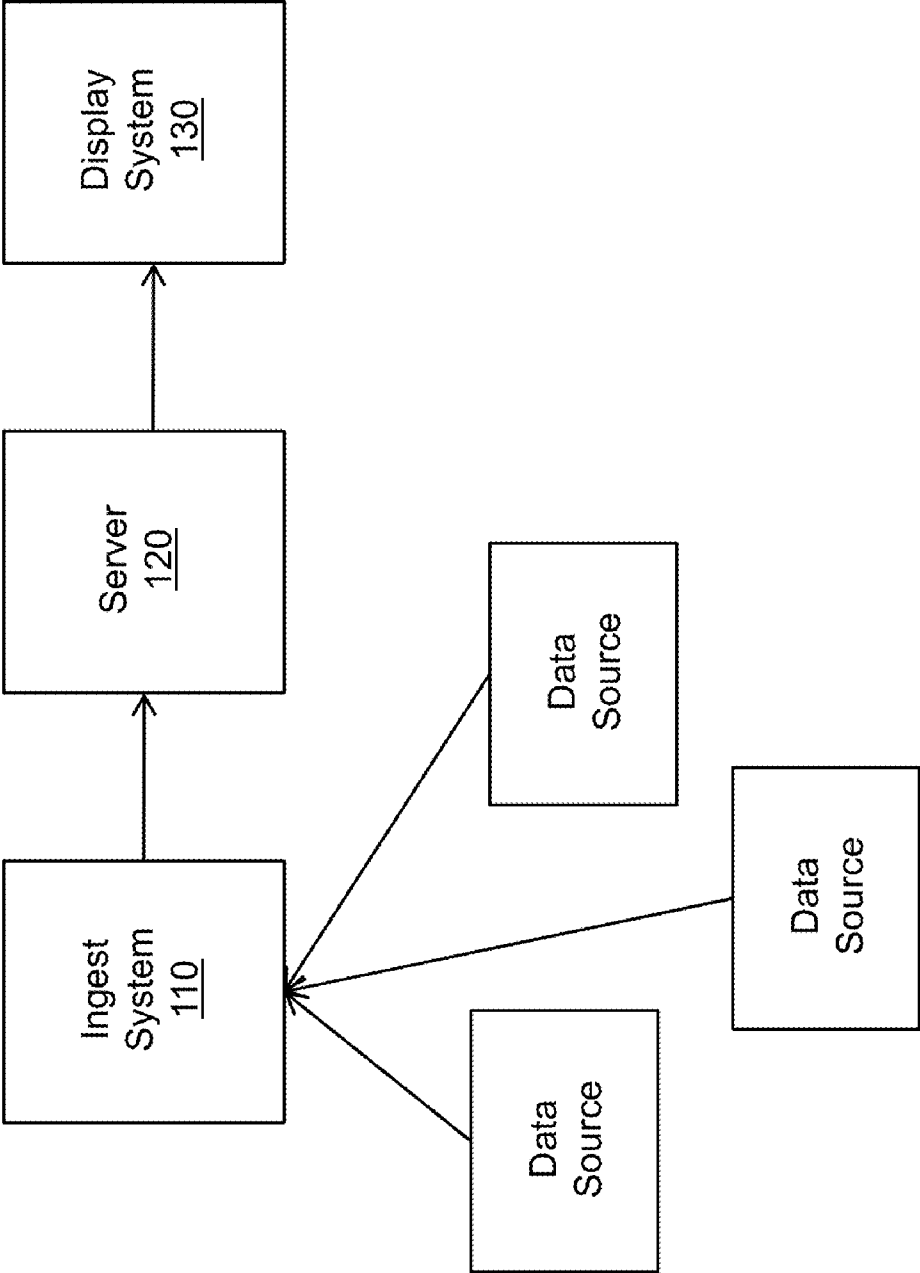


FIG. 1

Land Vegetation & solid earth	Air/Atmospheric	Greenhouse & trace gases	Water & Ice	Life	Static
land vegetation index (NDVI)	clouds	Carbon Dioxide CO2	rainfall	Ocean Chlorophyll Concentration	night lights
	water vapor				
	Carbon monoxide				
fires	Aerosol Index (UV)	water vapor methane Column Ozone Tropospheric Ozone	sea surface temperature	land vegetation index (NDVI)	country and state boundaries
	Aerosol (Optical Depth)				
soil moisture	Tropospheric Ozone Column Ozone	sulfur dioxide (SO2) surface or boundary layer	SSI anomaly	night lights	ocean circulation
Earthquakes	tropopause height	sulfur dioxide SO2 volcanic or mid-troposphere	soil moisture	population	plate tectonics
volcanoes	wind vectors (1,000, 850, 500, 300, 80 hPa)	nitrogen dioxide NO2	snow & ice cover	infant mortality	Hadley circulation
	wind intensity				
	lightning	Formaldehyde HCHO	sea ice	fires	animal migrations
	surface air temp.				

FIG. 2

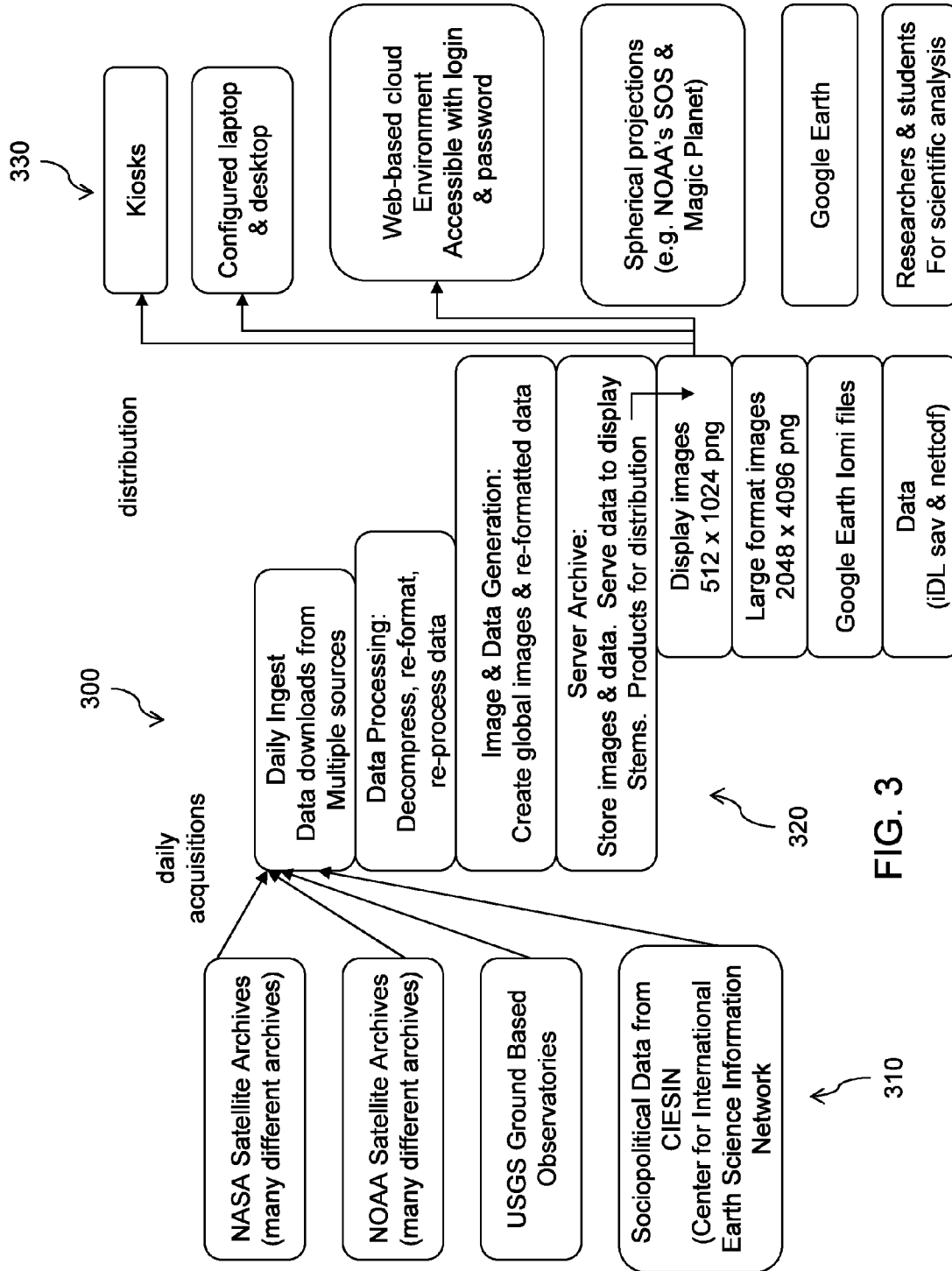


FIG. 3

310

320

300

330

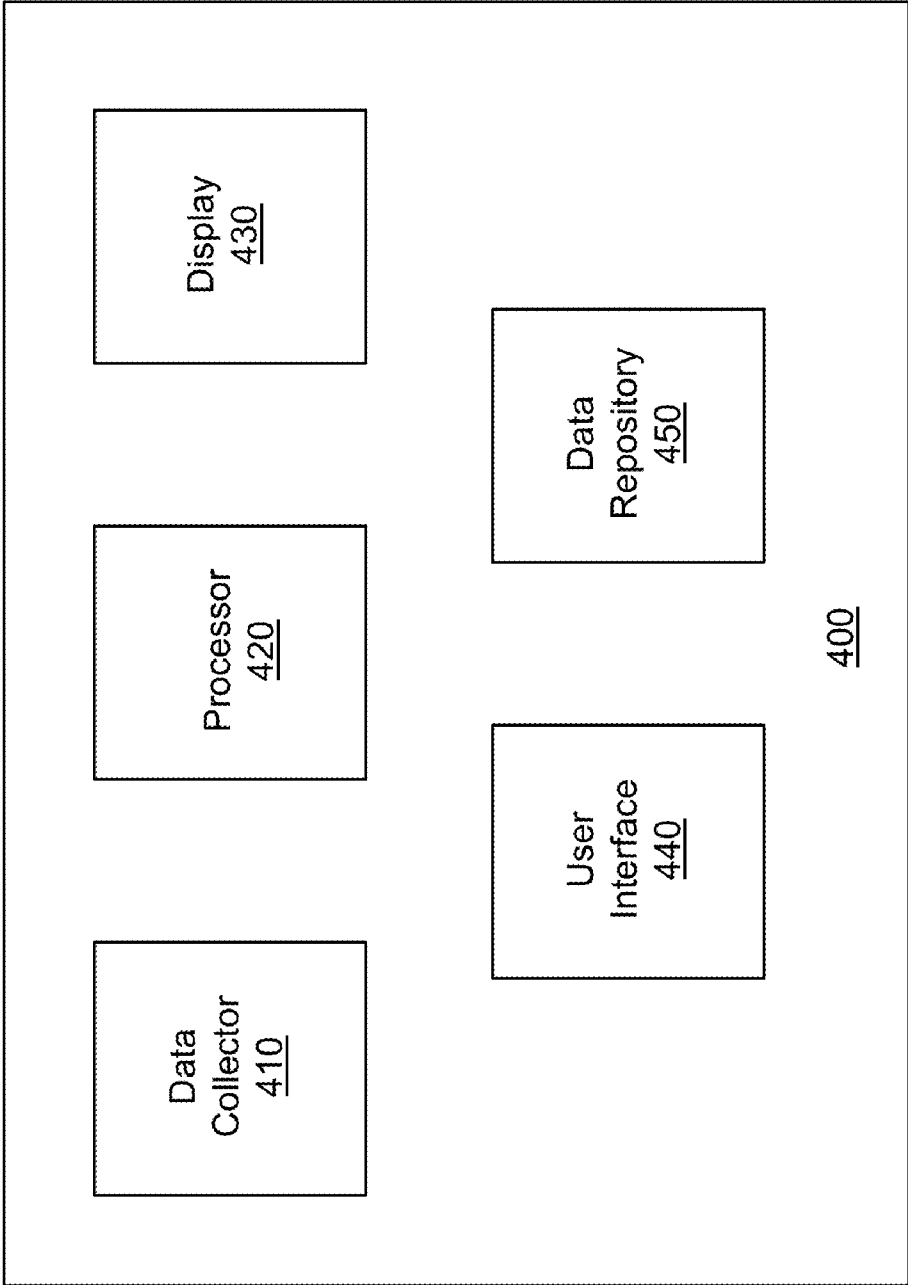


FIG. 4

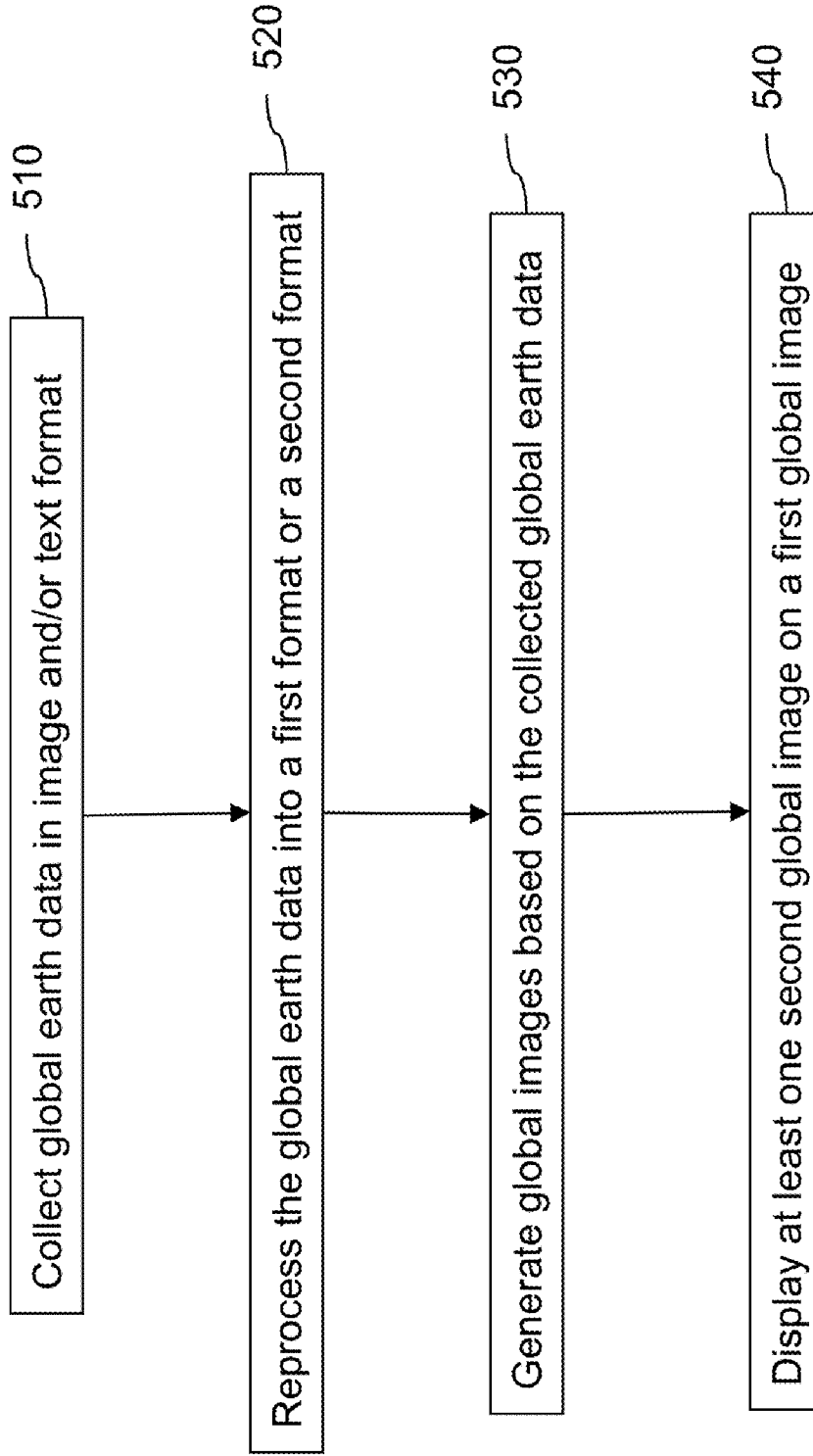


FIG. 5

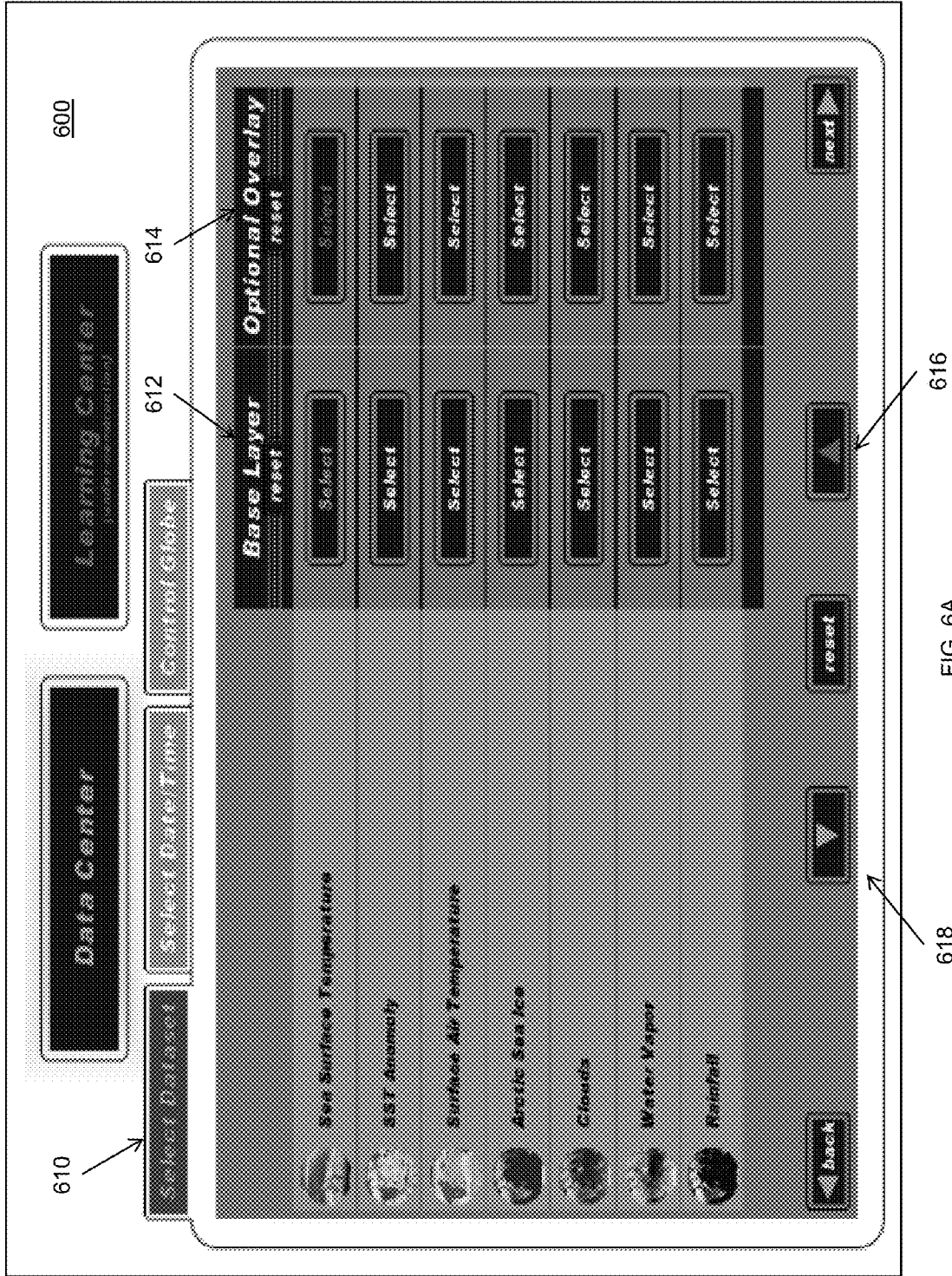


FIG. 6A

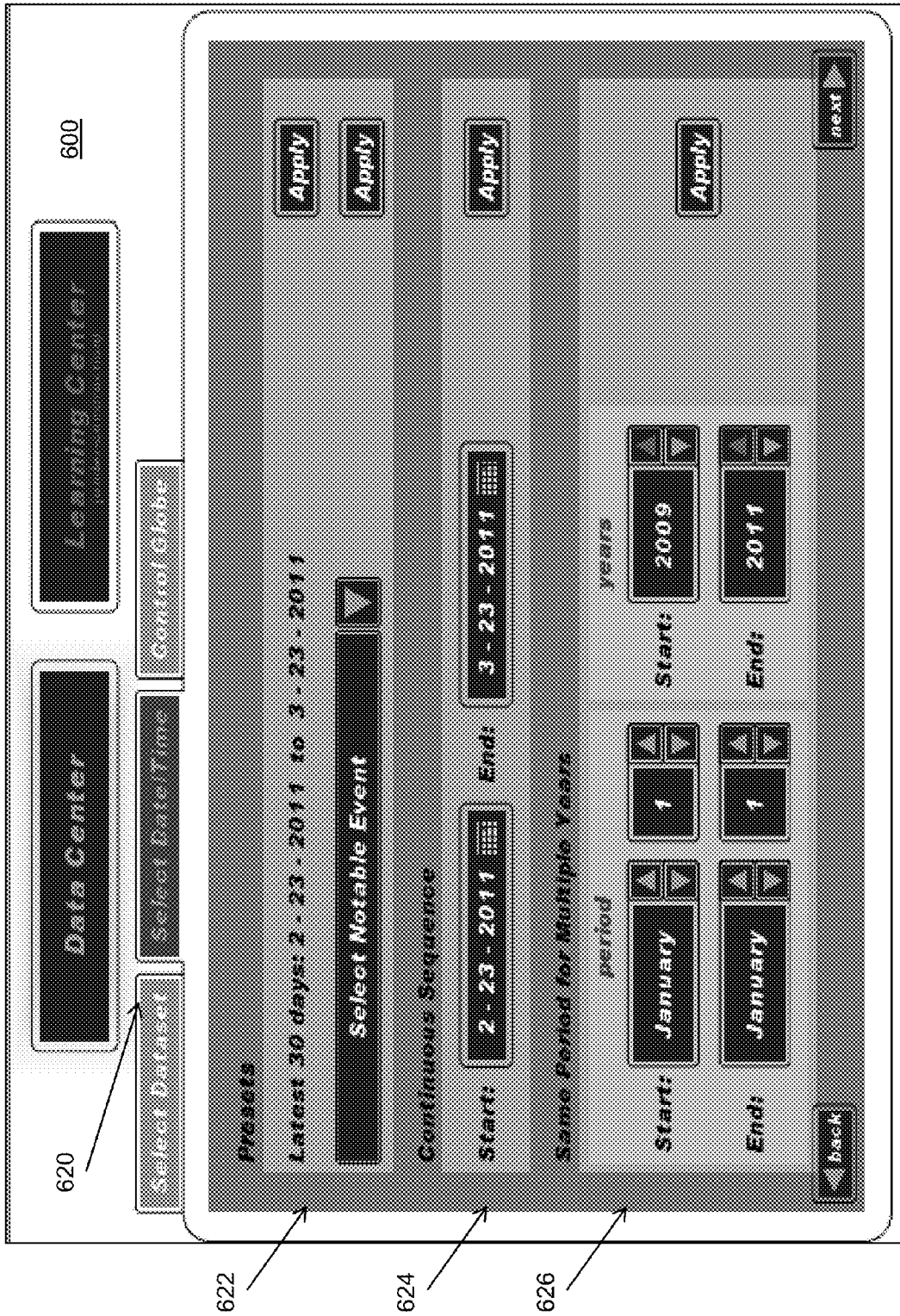


FIG. 6B



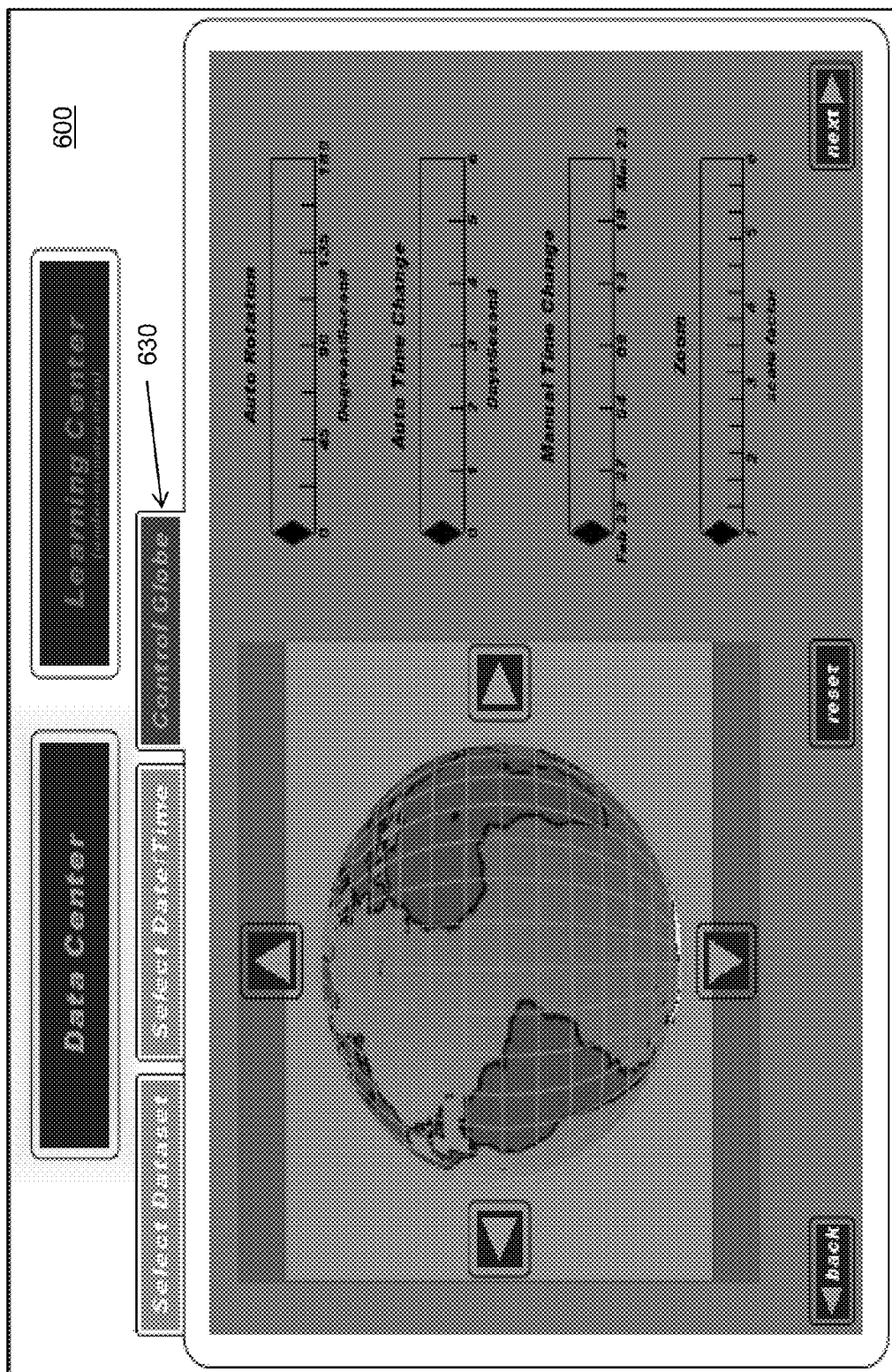


FIG. 6C

**SYSTEM AND METHOD FOR GENERATING AND DISPLAYING CLIMATE SYSTEM MODELS**

**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 61/448,498 filed Mar. 2, 2011, incorporated herein by reference.

**BACKGROUND**

[0002] The present invention is in the field of systems, methods, and computer program products for generating and displaying climate system models.

[0003] Much can be learned about the health of the earth by studying the dynamic interdependent relationships between the atmosphere (air), hydrosphere (water), geosphere or lithosphere (land), cryosphere (ice), and biosphere (life), collectively referred to as the five elemental spheres. Comparing and contrasting earth-observing satellite data from different sources deepens researchers' understanding of earth systems and the interdependency between different natural forces.

[0004] Until recently, the components comprising the five elemental spheres have been studied independently as their own respective disciplines. Now, the earth is being studied as a whole in order to understand the complex interrelationships and interdependencies of the different natural and anthropogenic forces.

**SUMMARY OF THE INVENTION**

[0005] An embodiment of the invention provides a system and method for generating and displaying climate system models. More specifically, a data collector automatically extracts global earth data from multiple data sources, wherein the global earth data includes data in at least three different formats. The global earth data includes image data and/or text data, and includes atmospheric data, hydrospheric data, lithospheric data, cryospheric data, biospheric data, and/or anthropospheric data.

[0006] A processor connected to the data collector reprocesses the global earth data into a first format or a second format. The processor generates global images based on the extracted global earth data, wherein the global images display the global earth data on a map. A display connected to the processor displays at least one second global image on a first global image. The first global image includes first global earth data for a select geographic area; and, the second global image includes second global earth data for the select geographic area.

[0007] It is an object of the invention to provide a system and method that automatically extracts near-real time global earth data from multiple independent data sources at predetermined time intervals without human interaction.

[0008] It is another object of the invention to provide a system and method that generates images based on the extracted global earth data, wherein the images display the global earth data on a map (e.g., precipitation over the state of Florida).

[0009] It is still another object of the invention to provide a system and method that displays two or more user-selected types of global earth data (e.g., rainfall and land elevation) on the same map in near-real time.

[0010] It is yet another object of the invention to provide a system and method that compares and contrasts global data representing all five elemental different sources to deepen understanding of earth systems and the interdependency between different natural forces.

[0011] It is still yet another object of the invention to provide a system and method that facilitates observation of relationships between divergent sets of earth-observing data from the five elemental spheres by collecting near-real time data that can be displayed on a rotating globe and animated by the end-user in real time.

[0012] It is another object of the invention to provide a tool that can be used in both formal and informal educational settings to improve the study of earth science.

**BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS**

[0013] The present invention is described with reference to the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements.

[0014] FIG. 1 illustrating a system according to an embodiment of the invention;

[0015] FIG. 2 is a table illustrating global earth-observing data sets from five elemental spheres and the anthroposphere according to an embodiment of the invention;

[0016] FIG. 3 illustrating a system according to another embodiment of the invention;

[0017] FIG. 4 illustrates a system generating and displaying climate system models according to an embodiment of the invention;

[0018] FIG. 5 is a flow diagram illustrating a method for generating and displaying climate system models according to an embodiment of the invention; and

[0019] FIG. 6A, 6B and 6C illustrate an interface according to an embodiment of the invention.

**DETAILED DESCRIPTION**

[0020] Exemplary, non-limiting, embodiments of the present invention are discussed in detail below. While specific configurations are discussed to provide a clear understanding, it should be understood that the disclosed configurations are provided for illustration purposes only. A person of ordinary skill in the art will recognize that other configurations may be used without departing from the spirit and scope of the invention.

[0021] An embodiment of the invention provides a system that displays near-real-time images (e.g., within 24 hours of measurement) of global earth observing data sets from five elemental spheres, namely, the atmosphere, hydrosphere, geosphere or lithosphere, cryosphere, and biosphere. When visually compared, an end-user can identify relationships between such data sets. End-users can also compare current data sets with historical data. Additionally, sociological data sets can be added which represent the anthroposphere, or structures and systems constructed or modified through human activity.

[0022] FIG. 1 illustrates a system 100 according to an embodiment of the invention. The system 100 includes an ingest system 110, an earth today server 120, and a display system 130. The ingest system 110 automatically ingests/retrieves data from various sources and unpacks the data from its native format. The second part, the earth today server 120, processes the ingested and unpacked data into image files,

re-processes the data files into common easy to use formats, archives the images and data, and prepares the images and data for distribution to end-users. The third part, the display system **130**, is an update and display software package that resides on an end-user's computer. The display system **130** allows the end-user to receive the most recent updates from the server, and provides an intuitive graphical user interface (GUI) that allows the end-user to view and manipulate the data sets, which reside on the end-user's computer.

**[0023]** The ingest system **110** can acquire global earth-observing satellite data sets from public archives where scientific data is posted daily—sometimes multiple times a day. Exemplary data sets representing the five elemental spheres include, but are not limited to, atmospheric data (air—meteorological, trace gas, aerosol, etc.), biospheric data (life—on land and in the sea), hydrospheric data (water—ocean temperatures, chlorophyll), lithospheric data (land—earthquakes and volcanoes, soil moisture, rainfall), cryospheric data (ice—snow and ice covering both land and sea) and anthroposphere (human—population, energy use, fires, birth/death rates). Much of the data may be acquired from governmental sources such as, for example, National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA) satellites and by United States Geological Survey (USGS) observatories. FIG. 2 is a table illustrating exemplary global earth observing data sets from the five elemental spheres and the anthroposphere.

**[0024]** In at least one embodiment of the invention, the ingest system **110** logs onto a series of File Transfer Protocol (FTP) or Hypertext Transfer Protocol (HTTP) sites and checks if new data has been posted. If there is new data, the data is transferred to the system ingest computer. Specifically, the ingest system **110** can include software having a series of standalone routines for each data product, wherein each code has the following generic structure: using system date-time we form the access file name and use WGET to access remote servers and locate the most updated file. This file is transferred to the local computer (e.g., via FTP). Files of interest are imbedded in various format files that are often difficult to access and interpret. Each data set is treated slightly differently based on the processes governing the data. The system also includes special codes to reprocess data or extend the data range. These formats include, but are not limited to, HDF5, HDFEOS, NetCDF, or GRIB. The codes extract the data from these files. For example, Google Earth files (in Keyhole Markup Language (KML)) are downloaded where data is extracted from these files.

**[0025]** Once the data of interest is extracted and unpacked, it is processed through a program to prepare each data set to be compatible in size, shape, and time sequencing so it can be compared with every other data set in the system. The data fields may be further processed to create more usable data. For example, very high resolution data may be re-gridded to lower resolution by averaging data within larger grid boxes. Data flags and data statistics can be used to reject bad data. If there is missing data due to incomplete coverage, data from the previous day may be used to fill in gaps as appropriate. Fourier filters and box car smoothing algorithms may be applied to noisy data to reduce noise.

**[0026]** Once the data processing is complete, an image generation module (also referred to herein as the “processor”) generates an image of the data. The image generation module automatically creates an image for the display system **130** (e.g., 512×1024 or a higher resolution 1024×2048 .png image

file) and/or a Google earth KML file, which includes a color bar and legend. In at least one embodiment, the image of the data is produced on a cylindrical map projection for creating a global map. The image generation module archives the data, image, and/or KML file, for example, as NetCDF or interface description language (IDL) .say files.

**[0027]** In at least one embodiment of the invention, each data set that is processed by the ingest system **110** has a unique data generation program (UDGP). That is, there is a separate and unique code for processing each data set. For instance, lightning data has its own separate code; chlorophyll has its own separate code, etc. Underlying these separate codes is the image generating software, date/time management software, etc. Some UDGP's produce multiple useful data sets. For example the sea surface temperature (SST) software produces SST's, SST anomalies, and coral reef stress. The ingest system **110** is configured so that it can run each UDGP at a different time of the day (e.g., using CRON jobs) to provide minimum stress on network bandwidth and processing resources. Some UDGP's can run multiple times a day to provide more frequent updates. One embodiment of the invention includes over 30 UDGP's written in IDL with over 50 specialized supporting routines.

**[0028]** In at least one embodiment, the server **120** manages the automatic logins and contains the archive folders for the data and images. The server **120** can bring updated images over from the ingest system **110** and from other sources as appropriate, and can provide the images to the display system **130**. In one embodiment, the server **120** software is UNIX-based C++ custom coded script. The server **120** can perform updates several times a day and can move images that it ingests into special folders. When the display system **130** updates the archive, it can log onto the server **120** and bring over the most recent data from the folders. In one embodiment of the invention, the server **120** only stores image data and has approximately half of the memory capacity at the ingest system **110**.

**[0029]** The display system **130** runs on a client computing device such as an appropriately configured laptop or desktop, a kiosk, or a cloud system or similar device. In at least one embodiment, the display system **130** includes update software, which, when it is run, logs onto the server **120**, compares the archive on the end-user's computer with the server **120** archive, and brings the end-user's archive up to date.

**[0030]** At least one embodiment of the invention uses touch screen controls, where the end-user selects the data sets of interest and the date ranges for those data sets. The appropriate images are located within the archive on the end-user's machine and a data movie is created “on the fly” by rapidly displaying the images in a sequence. The movie is shown on the image of a rotating earth globe that can be zoomed in or out and rotated to be viewed from any perspective and the speed of the movie can be varied. The touch screen controls allow image control and data selection. The system overlays two data sets, varying the transparency so that the two data sets can be seen at once—for example, clouds and precipitation.

**[0031]** The system is an effective tool in both formal and informal educational settings. It can be used by academic and research scientists in the course of their work to discuss science with their peers and investigate inter-relationships between data. Moreover, the system can be used as a browse tool to quickly scan through massive amounts of data, and to explain science to students and the public.

**[0032]** FIG. 3 illustrates a system 300 according to another embodiment of the invention, wherein the system 300 includes data archive sources 310, an ingest and processing module 320, and displays 330. The data archive sources 310 include data from NASA satellite archives, NOAA satellite archives, USGS ground based observatories, and sociopolitical data from the Center for International Earth Science Information Network. The ingest and processing module 320 is connected to data archive sources 310, and includes a daily ingest module, a data processing module, an image and data generation module, and a server archive module. As used herein, the term “connected” includes operationally connected, logically connected, in communication with, physically connected, engaged, coupled, contacts, linked, affixed, and attached. In at least one embodiment, each of the modules in the ingest and processing module 320 are on the same machine. The displays 330 include kiosks, laptop and desktop computers, a web-based cloud environment, spherical projections, Google™ Earth, and displays for researchers and students.

**[0033]** FIG. 4 illustrates a system 400 for generating and displaying climate system models according to an embodiment of the invention. The system includes a data collector 410, processor 420, display 430, user interface 440 and data repository 450. In at least one embodiment, the data collector 410, processor 420, display 430, user interface 440 and/or data repository 450 reside on the same machine. FIG. 5 is a flow diagram illustrating a method for generating and displaying climate system models according to an embodiment of the invention, for example, using the system 400.

**[0034]** The data collector 410 (also referred to herein as the “ingest system”) collects global earth data in image and/or text format 510. In at least one embodiment, the global earth data includes both image data and text data. The global earth data includes atmospheric data (e.g., meteorological data, trace gas data, and aerosol data), hydrospheric data (e.g., ocean temperature data, chlorophyll data, current data), lithospheric data (e.g., seismic data, volcano data, soil moisture data, rainfall data, plate boundary data), cryospheric data (e.g., snow data and ice data), and/or anthropogenic data (e.g., human population data, energy use data, fire data, birth data, death data).

**[0035]** In at least one embodiment of the invention, the data collector 410 automatically extracts global earth data from multiple data sources at predefined time intervals. For example, the data collector 410 can be programmed to extract global earth data from NOAA’s website every 60 minutes. In another example, the data collector 410 is programmed to extract global earth data from NASA’s website every Monday morning at 7:00 AM). Once the data collector 410 is programmed, it can automatically extract global earth data without human interaction.

**[0036]** The data collector 410 is connected to the processor 420 (also referred to herein as the “earth today server”). In at least one embodiment of the invention, the data collector 410 and the processor 420 reside on the same machine. In at least one embodiment, the global earth data includes data in at least three different formats, wherein the processor 420 reprocesses (i.e., converts) the global earth data into a first format or a second format 520. As described above, the ingest system extracts data stored in a variety of formats from separate and independent sources/archives. The data is unpacked and processed (i.e., cleaned up, decompressed, reformatted into common easy to use formats).

**[0037]** The processor 420 generates global images based on the collected global earth data 530, wherein the global images display the global earth data on a map. For example, a global image is generated that displays average air temperature over a map of the Washington, D.C. metropolitan area for a select time period (e.g., past 30 days). In another example, a global image is generated that displays precipitation over a map of the state of California for another select time period (e.g., past 24 hours).

**[0038]** The processor 420 is connected to the display 430, wherein the display 430 displays at least one second global image on a first global image 540. More specifically, the first global image includes first global earth data (e.g., wind speeds) for a select geographic area (e.g., the 22313 zip code); and, the second global image includes second global earth data different from the first global earth data (e.g., clouds) for the select geographic area. The second global image is superimposed on the first global image, wherein the transparency of the first global image and/or second global image can be adjusted via the user interface 440. In at least one embodiment of the invention, the first global image includes an animated sequence of global images of the first global earth data for the select geographic area; and, the second global image includes an animated sequence of global images of the second global earth data for the select geographic area. For example, the first global image includes an animated sequence of global images showing the movement of precipitation over a period of 2 hours.

**[0039]** The global earth data and/or global images are stored in the data repository 450 (also referred to herein as the “electronic historical archive”). In at least one embodiment, the displayed first and second global images are retrieved from the data repository 450.

**[0040]** FIGS. 6A, 6B and 6C illustrate a graphical user interface 600 according to an embodiment of the invention, having a first panel 610, a second panel 620 and a third panel 630. The first panel 610 (the “Select Dataset” panel) allows the end-user to select a data set for the base layer 612 and the option of selecting a second overlay layer 614. The overlay has a sliding bar for adjusting the transparency of that layer. The up/down arrows 616 and 618 at the bottom of the page allow end-users to scroll up or down the growing list of data sets.

**[0041]** The second panel 620 (the “Select Date/Time” panel) allows the end-user to select the desired time-range. In the top section 622, called “Presets”, the default option is the “Latest 30 days”. The next option, “Select Notable Event”, has a drop down menu of events the end-user is likely to be familiar with, such as, for example, Hurricane Katrina or the Japanese earthquake. The middle section 624 allows the end-user to custom-select a specific data range by using a drop-down calendar that allows them to select month, day, and year for the starting point and ending point of their selection. The bottom section 626 allows the end-user to select a time range over multiple years to compare the differences from one year to the next. This is useful when comparing, for example, the ozone hole from one year to the next, or the decline of arctic sea ice, or the El Niño/La Niña ENSO cycle in the Pacific.

**[0042]** The third panel 630 (the “Control Globe” panel) allows the end-user to control whether or not the earth rotates, or how fast it rotates. The orientation of the globe can also be altered. The end-user can also determine if and how rapidly the data advances, and can zoom closer in on a region-of-interest.

**[0043]** In at least one embodiment of the invention, source files containing global earth observing satellite data and ground-based observations are acquired in their native and diverse data formats on a regular basis from numerous public archive sources. These divergent data types are decompressed and reprocessed to generate images that can be compared visually and through time. The data may be imaged in 512×1024 .png images and 2048×4096 .png and saved as KML files. The data can be preserved in at least two common formats, e.g., netCDF and idl raw. Global earth observing satellite and ground-based images representing the five elemental spheres, (hydrosphere/water, lithosphere/land, atmosphere/air, cryosphere/ice, and biosphere/life) with added data from the anthrosphere/human are then displayed on client computing devices such as kiosks, configured laptop and desktop computers, hand held devices and through a cloud computing network system.

**[0044]** The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the root terms “include” and/or “have”, when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of at least one other feature, integer, step, operation, element, component, and/or groups thereof.

**[0045]** The corresponding structures, materials, acts, and equivalents of all means plus function elements in the claims below are intended to include any structure, or material, for performing the function in combination with other claimed elements as specifically claimed. The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the invention. The embodiment was chosen and described in order to best explain the principles of the invention and the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated. What is claimed is:

**1.** A method comprising:

collecting global earth data, the global earth data including at least one of image data and text data, the global earth data including at least one of atmospheric data, hydrospheric data, lithospheric data, cryospheric data, biospheric data, and anthrospheric data;

generating global images with a processor, the global images being generated based on the collected global earth data, the global images displaying the global earth data on a map; and

displaying at least one second global image on a first global image, the first global image including first global earth data for a select geographic area, and the second global image including second global earth data for the select geographic area.

**2.** The method according to claim 1, further comprising adjusting a transparency of at least one of the first global image and the second global image.

**3.** The method according to claim 1, wherein said collecting of the global earth data comprises collecting real-time global earth data.

**4.** The method according to claim 1, further comprising storing the global earth data and the global images in an electronic historical archive, wherein said displaying of the first and second global images comprising retrieving the first and second global images from the electronic historical archive.

**5.** The method according to claim 1, wherein the first global image includes an animated sequence of global images of the first global earth data for the select geographic area, and wherein the second global image includes an animated sequence of global images of the second global earth data for the select geographic area.

**6.** The method according to claim 1, wherein said collecting of the global earth data includes automatically extracting the global earth data from multiple data sources without human interaction.

**7.** The method according to claim 6, wherein said automatically extracting of the global earth data is performed at predefined time intervals.

**8.** The method according to claim 1, wherein the global earth data includes data in at least three different formats, and wherein said method further comprises reprocessing the global earth data into one of a first format and a second format.

**9.** The method according to claim 1, wherein:

the atmospheric data includes at least one of meteorological data, trace gas data, and aerosol data;

the hydrospheric data includes at least one of ocean temperature data, chlorophyll data, current data;

the lithospheric data includes at least one of seismic data, volcano data, soil moisture data, rainfall data, and plate boundary data,

the cryospheric data includes at least one of snow data and ice data; and

the anthrospheric data includes at least one of human population data, energy use data, fire data, birth data, and death data.

**10.** A method comprising:

automatically extracting global earth data from multiple data sources with a data collector, the global earth data including data in at least three different formats, the global earth data including at least one of image data and text data, and the global earth data including at least one of atmospheric data, hydrospheric data, lithospheric data, cryospheric data, biospheric data, and anthrospheric data;

reprocessing the global earth data into one of a first format and a second format with a processor;

generating global images with the processor, the global images being generated based on the extracted global earth data, the global images displaying the global earth data on a map; and

displaying at least one second global image on a first global image on a display, the first global image including first global earth data for a select geographic area, and the second global image including second global earth data for the select geographic area.

**11.** The method according to claim 10, further comprising adjusting a transparency of at least one of the first global image and the second global image.

**12.** The method according to claim 10, further comprising storing the global earth data and the global images in an

electronic historical archive, wherein said displaying of the first and second global images comprising retrieving the first and second global images from the electronic historical archive.

**13.** The method according to claim **10**, wherein the first global image includes an animated sequence of global images of the first global earth data for the select geographic area, and wherein the second global image includes an animated sequence of global images of the second global earth data for the select geographic area.

**14.** The method according to claim **10**, wherein said automatically extracting of the global earth data is performed at predefined time intervals.

**15.** The method according to claim **10**, wherein:

the atmospheric data includes at least one of meteorological data, trace gas data, and aerosol data;

the hydrospheric data includes at least one of ocean temperature data, chlorophyll data, current data;

the lithospheric data includes at least one of seismic data, volcano data, soil moisture data, rainfall data, and plate boundary data,

the cryospheric data includes at least one of snow data and ice data; and

the anthropospheric data includes at least one of human population data, energy use data, fire data, birth data, and death data.

**16.** A system comprising:

a data collector for collecting global earth data, the global earth data including at least one of image data and text data, the global earth data including at least one of atmospheric data, hydrospheric data, lithospheric data, cryospheric data, biospheric data, and anthropospheric data;

a processor connected to said data collector, said processor generates global images based on the collected global earth data, the global images displaying the global earth data on a map; and

a display connected to said processor, said display displays at least one second global image on a first global image, the first global image including first global earth data for a select geographic area, and the second global image including second global earth data for the select geographic area.

**17.** The system according to claim **1**, further comprising an interface for adjusting a transparency of at least one of the first global image and the second global image.

**18.** The system according to claim **1**, further comprising a data repository for storing the global earth data and the global images.

**19.** The system according to claim **1**, wherein the global earth data includes data in at least three different formats, and wherein said processor reprocesses the global earth data into one of a first format and a second format.

**20.** The system according to claim **1**, wherein:

the atmospheric data includes at least one of meteorological data, trace gas data, and aerosol data;

the hydrospheric data includes at least one of ocean temperature data, chlorophyll data, current data;

the lithospheric data includes at least one of seismic data, volcano data, soil moisture data, rainfall data, and plate boundary data,

the cryospheric data includes at least one of snow data and ice data; and

the anthropospheric data includes at least one of human population data, energy use data, fire data, birth data, and death data.

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