The Possibility of Satellite Projects:

Deepening Scientific Understanding of Global Climate Change and Other Matters

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Abstract

Satellites provide a plethora of information for the realm of science. In the current time of global climate change, several satellite projects could prove useful in terms of understanding exactly what is happening in the global environment of earth. Several National Aeronautics and Space Administration's (NASA) current and future projects are highlighted: Orbiting Carbon Observatory (OCO); Active Sensing of CO_2 Emissions Over Nights, Days, And Seasons (ASCENDS); Gravity Recovery and Climate Experiment (GRACE); GRACE-II; Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynl); and Climate Absolute Radiance and Refractivity Observatory (CLARREO).

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In studying science, perspective makes a huge difference. This fact is illustrated with the variety of scales that can be obtained, for example, in just maps alone. A map of the library is not very useful when planning a trip cross-country and a map of the country would not be useful when trying to find the restrooms that are located in the library; though both maps are useful, their usefulness is limited to their relative scales or basic features, such as which side is north. Similarly, when studying the science of global climate change a scientist on the ground can provide lots of useful information, but a global perspective can be enlarged obtained by satellites. Global climate change and other scientific topics can be explored and more thoroughly understood by the employment of satellite projects.

Carbon dioxide (CO_2), as pertaining to its role in understanding the carbon cycle, is an important aspect of the global climate change issue that could benefit from a more thorough study by the aid of satellites. The National Aeronautics and Space Administration (NASA) has tried to enlarge upon the understanding of CO_2 with global perspective though the Orbiting Carbon Observatory (OCO) by using reflected sunlight (*Earth Science*, 2007, p. 85). The first OCO mission was launched February 24, 2009, but due to a “launch vehicle failure” the satellite never made orbit and it and the launch vehicle were incinerated during reentry to Earth (Netting, 2013e; “OCO”, 2009). In spite of this setback, NASA still plans to go forward with the OCO mission through the means of OCO-2 as OCO-2 is based on the original OCO mission (Netting, 2013f). After the scheduled launch in July 2014, OCO-2 will run for two years (Netting, 2013f). There is an extra OCO satellite, even after the loss of OCO and designation of OCO-2, and this has led to the plan of OCO-3. OCO-3 will use the “spare…instrument, with additional elements added" (Netting, 2013g). After its launch in December 2016, OCO-3 will go to the International Space Station and be installed on the ISS Japanese Experiment Module-Exposed Facility (JEM-EF) and live out its three year operational life (Netting, 2013g). NASA has plans to study CO_2 atmosphere concentrations through the various OCO missions.

The OCO missions will study the distribution of CO_2 through chemical properties as analyzed by its on-board instruments. The OCO missions are each equipped with three spectrometers, and it is through the spectrometers that the atmospheric CO_2 is measured ("Instrument Design", n.d.). A spectrometer can measure the amount of CO_2 by looking at the incoming electromagnetic radiation reflected from the earth ("Instrument Design", n.d.). The electromagnetic radiation, which comes from the sun, covers the full color spectrum of light. Once the light hits the earth's atmosphere, some of the energy is absorbed by different molecules and atoms in the earth's atmosphere, removing a specific "color" or frequency from the electromagnetic spectrum ("Instrument Design", n.d.). Because every different molecule or atom absorbs a different "color" of the electromagnetic spectrum (of which light is a part), depending on what the radiation passes through the radiation has a unique dark spot where the energy was absorbed—and in this case, the "color" that is absorbed is near-infrared ("Instrument Design", n.d.). Also, the OCO missions are equipped with three spectrometers so that CO_2 measurements can be taken by each satellite at three different points at one time ("Instrument Design", n.d.; "Measurement Approach", n.d.). Each spectrometer has a different mode associated with it: Nadir, Glint, and Target Modes ("Measurement Approach", n.d.). Nadir Mode is used to look at the ground directly below the satellite ("Measurement Approach", n.d.).Glint Mode is used to look where the sunlight is directly reflected off of the surface of the earth and it is used specifically for oceans ("Measurement Approach", n.d.).Target Mode is used to look at a "a specific surface location, and will retain that view while flying overhead" ("Measurement Approach", n.d.). Target Mode is especially useful to calibrate, or check, the accuracy of satellite's instruments ("Measurement Approach", n.d.). With all of this information, the OCO missions can map the world's distribution of atmospheric CO_2.

As of yet, measurements of CO_2 are currently very resource-intensive and face seasonal and/or latitudinal bias, including the OCO system (*Earth Science*, 2007, p. 85). Unfortunately, the spectrometer is a passive system, meaning it just observes the outcome of a process without stimulating the absorption process itself. Therefore, the spectrometer has a few problems because of its limitations. For instance, "at high latitudes, passive systems which rely on reflected sunlight [such as spectrometers] are limited by…an inability to observe high-latitude targets [such as polar regions] during the local winter" and oceans are generally limited to glint mode and "dark oceans are virtually inaccessible" (*Active Sensing*, 2008, p. 18). Also, because a spectrometer relies on light from the sun, the passive system does not work in night because there is nothing for the spectrometer to pick up. The usage of spectrometers on OCO to measure CO_2 is not perfectly comprehensive.

Many of the possible statistical errors and inaccessibility issues can be overcome through Active Sensing of CO_2 Emissions Over Nights, Days, And Seasons (ASCENDS) (*Earth Science*, 2007, p. 85; *Active Sensing*, 2008, p. 18). ASCENDS has been called the "logical next step in a global carbon cycle observing strategy" because of the problems associated with OCO in terms of observing CO_2 (*Active Sensing*, 2008, p. 18). ASCENDS would use a multi-frequency laser (lidar system) to observe CO_2 in an active fashion (*Satellite Observations*, 2008, p. 11; "ASCENDS", n.d.). This means that ASCENDS would use its own light (from the laser) instead of using the light reflected from the sun and the multi-frequency laser would allow ASCENDS to make measurements "day and night, over ocean and land surfaces, and at all times of the year" (*Active Sensing*, 2008, p. 18). Because ASCENDS would work in day and night, unlike OCO, ASCENDS would be able to measure the differences of atmospheric CO_2 levels not only when photosynthesis is working, which is during the day, but also when photosynthesis is not working and the process of respiration is on-going at night (*Satellite Observations*, 2008, p. 11). Also, some benefits include that ASCENDS would be "less susceptible to errors from atmospheric scattering" and would have "simpler observational geometry" (*Active Sensing*, 2008, p. 18). By having ASCENDS measure several aspects of the column of air beneath the satellite, including the "ambient air pressure and temperature", "length… [through] using a laser altimeter", and "number density of Carbon Dioxide (CO_2)", ASCENDS will improve the models of long-term climate changes by deepening the understanding of the carbon cycle, including the role of atmospheric CO_2 ("ASCENDS", n.d.). There is also a hope for not only a CO_2 sensor to be on ASCENDS but also a carbon monoxide (CO) sensor to be installed, because this would allow the reasons of CO2 release to be pinpointed to whether the cause is plant related in terms of respiration or whether the cause was due to combustion of fossil fuels or fires (*Satellite Observations*, 2008, p. 11). Even though the estimated cost of ASCENDS is $400 million, ASCENDS is planned to be launched between 2013 and 2016 (*Satellite Observations*, 2008, p. 11). This is so that ASCENDS would overlap the OCO missions, as part of verification of the data gathered and a baseline to be established (*Satellite Observations*, 2008, p. 11). By obtaining a greater understanding of atmospheric CO_2 as it pertains to the carbon cycle will result of how CO_2 influences global climate change and more accurate forecasting models can be made—all thanks to the study of ASCENDS.

The Gravity Recovery and Climate Experiment (GRACE) has deepened the understanding of earth by providing a clear picture of the distribution of the various strengths of gravity. GRACE was launched in March 17, 2002 with a planned five year lifetime, but nevertheless, GRACE is still in use today (Netting, 2013c). GRACE was launched with the purpose of making “detailed measurements of Earth’s gravity field” and since then connections between gravity changes and Earth’s natural systems have been drawn (*Satellite Observations*, 2008, p. 17). Before there was GRACE, the picture of the global distribution of the various strengths of gravity was made by stitching together the data from “several dozen satellites”, but the dedicated study by GRACE created a much clearer and cohesive picture (“The Science”, 2012). GRACE studies gravity through the implementation of several instruments, including a “microwave K-band ranging instrument”, “accelerometers”, and “Global Positioning System [GPS] receivers” (“Gravity Recovery”, c2011). Because of the combination of GRACE’s instruments, GRACE was able to map out the earth’s gravity differentiation distribution.

GRACE’s instruments have proven their worth because their measurements of gravity have multiple applications. Because gravity is directly related to mass, then the variability of gravity is due to the variability in mass—and it is the changes in mass, especially water movement, which show the connection between gravity and earth’s natural systems (*Satellite Observations*, 2008, p. 17). The changes that result from movement of mass, such as the “changes in volume of ice sheets”, can be tracked over time which is especially important as to the evidencing and predicting the consequences due to global climate change (*Satellite Observations*, 2008, p. 17). For example, because of GRACE, studies “using Grace and other data indicate that between 2000 and 2008 the Greenland ice sheet lost as much as 1,500 gigatons of mass” and GRACE also points out the exact areas of loss versus the areas of gain (“Greenland

Gains Some", 2010). Gravity, especially as it pertains to mass, is also a study of global environmental concern that is further clarified by the GRACE.

The information gained from GRACE is valuable, but as GRACE is past its planned lifetime by a considerable amount and therefore a replacement is in order: GRACE-II. Though a lot can be said about GRACE, "GRACE-II would extend and improve on…GRACE" (*Satellite Observations*, 2008, p. 17). GRACE-II's estimated cost is $450 million and its expected launch is between 2016 and 2020, which is between 14 and 18 years since the initial launch date of GRACE (*Satellite Observations*, 2008, p. 17). GRACE-II would accomplish the work of GRACE and increase its quality by using either a "microwave or [a] laser ranging system", which would improve upon the resolution of the earth's gravity differential by increasing the resolution "to around 100 kilometers" (*Satellite Observations*, 2008, p. 17; "GRACE-II", n.d.). As the changes in mass on certain spots of the earth, such as the presence then absence of ice sheets, is very important as to climate change, GRACE-II will be a mission of monumental importance. The valuable information gained by GRACE could be continued through the mission of GRACE-II.

Because changes elevation of land is often a sign of several geological process, including the effects of global climate change, monitoring the deformation of the earth is an important study which can be accomplished through satellites. Land deformation can be a sign of "earthquakes, volcanic eruptions, and landslides" similarly to how a balloon, when it is over-inflated, can be a warning sign that it is about to pop ("DESDynl", n.d.). Deformation is also visible "when fluids are injected underground to stimulate production from oil and gas reserves", which is known as fracking; when extracting hydrocarbons; and in the extraction of water from the aquifers (*Satellite Observations*, 2008, p. 13; "DESDynl", n.d.). The concept of deformation can also be key to other factors of global climate change: how “ice sheets deform in response to changes in temperature and precipitation, providing clues to large-scale melt that can raise global sea levels”; as part of the management of CO_2 through carbon sequestration (such as when carbon is pumped into the ground); or by monitoring the amount of carbon a forest approximately holds by analyzing the “changing height of a forest canopy” (*Satellite Observations*, 2008, p. 13; “DESDynl”, n.d.). The Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynl) satellite project would monitor all of these systems by using “an inter-ferometric synthetic aperture radar (InSAR)” and a “multibeam laser altimeter, [that would be] operating in the infrared range” (*Satellite Observations*, 2008, p. 13). Just in the study of the changing ice alone, DESDynl would be a complement to GRACE and GRACE-II as DESDynl would provide further confirmation to the previous findings and deepen the understanding of what was already uncovered. As of yet, all of these benefits to the realm of science are theoretical until DESDynl is actually launched, according to plan, in 2021 and then is put into operation (Netting, 2013b; Netting, 2013d). The DESDynl would, in short, be a priceless instrument to the realm of science and mankind as it would help to forecast the occurrence of drastic events, whether as a result of humankind or nature itself.

One of the most valuable missions in terms of global climate change is the Climate Absolute Radiance and Refractivity Observatory (CLARREO). The key about global climate change is the increase in trapped energy from the sun (due to insolation) and that because of an increase in greenhouse gases, such as CO_2, less energy is being reradiated out into space. This study of what is known as the energy budget. CLARREO will be equipped with “absolute, spectrally resolved interferometers” to measure the incoming radiated energy from the sun and is then bounced off of the earth as compared to what radiation from the sun was absorbed and then reradiated out into space (*Satellite Observations*, 2008, p. 12). These measurements “will be used to detect climate trends and to test, validate, and improve climate prediction models” (“CLARREO”, n.d.). Climate prediction models will also be improved upon by predicting “[c]hanges in sea level, storm patterns, and rainfall associated with temperature pattern changes” and provide “[o]zone and surface radiation forecasts and public advisories” (“CLARREO”, n.d.). The problem with CLARREO is the question of when CLARREO will be launched. Previously, in 2008, it was hoped that CLARREO would be launched between 2010 and 2013, but now the launch date is currently unknown (*Satellite Observations*, 2008, p. 12; Netting, 2013d). Though there is no specified launch date, CLARREO is on the table as it is classified as “under study”, but unfortunately, chances are that CLARREO will not be launched for a while (Netting, 2013a; Netting, 2013d). Once CLARREO is up and running, CLARREO is supposed to validate and clarify the inner-workings and effects of global climate change.

Satellites have a lot to offer in terms of understanding global climate change and science in general. CLARREO would go to the root of the matter by analyzing the underlying problem of global climate change—a destabilization of the energy budget by an increase in the store of energy. This extra energy trapping, as found in an increase of CO_2 is to be studied more thoroughly in the ASCENDS project in conjunction with the OCO project. GRACE-II would follow up scientific advancements of GRACE by looking to one of the most notable effects of global climate change—melting of the world’s permanent ice—by analyzing the change in mass distribution through mapping the gravity of earth. DESDnyl would also looks at the permanent ice, but in a different approach than GRACE or GRACE-II. DESDnyl would analyze the whole global climate change issue, from fossil fuel extraction to ice, by measuring the deformation of earth itself. In this time of massive change, especially climatically, can be a very useful tool to studying out the matter thoroughly. Because of satellites unique perspective—they can see the whole picture—and are therefore invaluable to science and to society.

References

"ASCENDS: Active Sensing of CO2 Emissions over Nights, Days, and Seasons." (n.d.). *NASA Earth Science Decadal Survey Studies.* Retrieved October 29, 2013, from http://decadal.gsfc.nasa.gov/ASCENDS.html

Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) mission NASA science definition and planning workshop report. (2008). Ann Arbor: University of Michigan. Retrieved October 29, 2013, from http://decadal.gsfc.nasa.gov/documents/12-30-08-ASCENDS_Workshop.pdf

"CLARREO: Climate Absolute Radiance and Refractivity Observatory." (n.d.). *NASA Earth Science Decadal Survey Studies.* Retrieved October 29, 2013, from http://decadal.gsfc.nasa.gov/CLARREO.html

"DESDynl: Deformation, Ecosystem Structure and Dynamics of Ice." (n.d.). *NASA Earth Science Decadal Survey Studies.* Retrieved October 29, 2013, from http://decadal.gsfc.nasa.gov/DESDynI.html

Earth science and applications from space [electronic resource]: national imperatives for the next decade and beyond/Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future, Space Studies Board, Division on Engineering and Physical Sciences, National Research Council of the National Academies. (2007). Washington, D.C.: National Academies Press, c2007.

"GRACE II: Gravity Recovery and Climate Experiment." (n.d.). *NASA Earth Science Decadal Survey Studies*. Retrieved October 29, 2013, from http://decadal.gsfc.nasa.gov/GRACE2.html

"Gravity Recovery and Climate Experiment." (c2011). *Mission Control*. Retrieved November 13, 2013, from http://www.jpl.nasa.gov/missions/details.php?id=5882

"Greenland Gains Some, Loses More." (2010). *Space Images*. Retrieved November 13, 2013, from http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA12845

"Instrument Design." (n.d.). *Observatory*. Retrieved from November 13, 2013, from http://oco.jpl.nasa.gov/observatory/InstrumentDesign/

"Measurement Approach." (n.d.). *Science*. Retrieved from November 13, 2013, from http://oco.jpl.nasa.gov/science/MeasurementApproach/

Netting, R. "CLARREO." (2013a). *NASA Science | Missions*. Retrieved November 13, 2013, from http://science.nasa.gov/missions/clarreo/

Netting, R. "DESDynl." (2013b). *NASA Science | Missions*. Retrieved November 13, 2013, from http://science.nasa.gov/missions/desdyni/

Netting, R. "GRACE." (2013c). *NASA Science | Missions*. Retrieved November 13, 2013, from http://science.nasa.gov/missions/grace/

Netting, R. "Missions." (2013d). *NASA Science | Missions*. Retrieved November 13, 2013, from http://science.nasa.gov/missions/

Netting, R. "OCO." (2013e). *NASA Science | Missions*. Retrieved November 13, 2013, from http://science.nasa.gov/missions/oco/

Netting, R. "OCO-2." (2013f). *NASA Science | Missions*. Retrieved November 13, 2013, from http://science.nasa.gov/missions/oco-2/

Netting, R. "OCO-3." (2013g). *NASA Science | Missions*. Retrieved November 13, 2013, from http://science.nasa.gov/missions/oco-3/

"OCO." (2009). *NASA*. Retrieved November 13, 2013, from http://www.nasa.gov/mission_pages/oco/launch/index.html

Satellite observations to benefit science and society [electronic resource]: recommended missions for the next decade/National Research Council of the National Academies. (2008). Washington, D.C.: National Academies Press, c2008.

"The Science Behind the GRACE Mission." (2012). *GRACE*. Retrieved November 13, 2013, from http://www.csr.utexas.edu/grace/science