Planning for a new US climate-benchmark mission

Henry Revercomb, Fred Best, Robert Knuteson, David Tobin, Robert Holz, and Joe Taylor

NASA’s Climate Absolute Radiance and Refractivity Observatory will measure climate change from space with a new standard in high accuracy combined with techniques to improve climate-forecast models.

Given the rapid increase of carbon dioxide from fossil-fuel burning, new measurement systems are urgently needed to quantify the impact on the earth’s climate. To deal with climate change wisely, society needs the best possible knowledge of the changes that are occurring and predictions of what changes will ensue, depending on key societal choices. A new spaceborne mission, the Climate Absolute Radiance and Refractivity Observatory (CLARREO), is being planned in response to this need.

CLARREO was recommended for development by the 2007 Decadal Survey of the US National Research Council. It is being pursued by NASA, with the Langley Research Center as the implementing center. The mission’s societal objectives are to establish a climate benchmark and develop an operational climate forecast. An essential responsibility to current and future generations exists to put in place a benchmark global climate record that is accurate in perpetuity, tested against independent strategies that reveal systematic errors, and calibrated to international standards. There is also a critical need for climate forecasts that are tested, trusted, and systematically improved through a disciplined strategy using state-of-the-art observations on the basis of mathematically rigorous techniques.

Imperatives identified for CLARREO, in order of increasing specificity, are to initiate both an unprecedented, high-accuracy record of climate change—required to provide sound policy decisions—and a record of direct observables with the high accuracy and information content necessary to detect long-term climate-change trends (and to test and systematically improve climate predictions), and to observe the spectrally resolved radiance and atmospheric refractivity with the accuracy provided by international standards and sampling required to assess and predict the impact of changes in climate-forcing variables.

The CLARREO mission is based on new observational paradigms. First, radiation measurements for a climate benchmark should be chosen to maximize the information content about atmospheric and surface properties rather than to monitor the total radiative-energy budget. The latter has been the scheme followed for climate-benchmark missions ever since the first designed by Verner E. Suomi at the beginning of the space age (launched in 1959). The idea is to use spectrally resolved radiance to gain sensitivity because the spectrally integrated total energy budget can miss significant changes that cancel each other out. Observing regional averages and distributions of nadir-viewing spectra will reveal signatures of climate-forcing changes and responses to changes in temperature and water-vapor structure, atmospheric stability, cloudiness or aerosols, surface properties, and trace gases. The far-IR spectral regime will provide sensitivity to thick ice clouds and upper-level water vapor.

Second, to reduce the time to unequivocally resolve climate trends, a new standard in accuracy is needed. We will use internationally agreed calibration standards flown on the same spacecraft for on-orbit confirmation of the ultrahigh accuracy achieved by careful design and testing on the ground. For IR radiance spectra a brightness-temperature accuracy of 0.1K confirmed on orbit is practical (with 99% confidence that the limit is not exceeded). As illustrated in Figure 1, we are developing new techniques to use phase-change materials for direct on-orbit tests of this high accuracy. For refractivity measured using transmissions from the Global Positioning System, the accuracy depends on time measurements that can be made extremely accurately, corresponding to an accuracy for upper-level temperature better than 0.1K. Techniques to attain the corresponding accuracy for reflected solar-radiance spectra are being developed. Establishing highly accurate internationally calibrated traceable measurements in space alleviates the need to overlap subsequent generations of satellites to establish a climate record.

Third, CLARREO needs to achieve spatial and temporal sampling that will maintain this high measurement accuracy in cli-
matically significant regional and seasonal spectral products. Sampling biases are of equal importance to measurement errors. A new sampling approach for CLARREO would use three equally-spaced truly polar orbits (90° inclination) that do not precess in inertial space. These will cover all latitudes and longitudes and result in equal sampling for all times of day once every two months. Our simulations show that these orbits will also allow CLARREO to be used for highly accurate cross-calibration of operational and research instruments flying in sun-synchronous orbits.

In conclusion, a climate observatory is being designed around new paradigms to help chart a reasonable course through the challenges of climate change. We are providing new approaches for direct on-orbit tests of spaceborne measurements and hope to see these techniques employed on a wide range of platforms. We feel strongly that CLARREO or equivalent benchmark measurements need to be adopted as a key part of US operational plans and of the Global Earth Observation System of Systems in the next century.

Author Information

Henry Revercomb, Fred Best, Robert Knuteson, David Tobin, Robert Holz, and Joe Taylor
Space Science and Engineering Center
University of Wisconsin–Madison
Madison, WI
http://www.ssec.wisc.edu/

Henry E. Revercomb, director of the Space Science and Engineering Center, uses radiation measurements to study the atmospherics of the earth and other planets. His specialties include high-spectral-resolution instrumentation for atmospheric remote sensing and spectroscopy, operational temperature and water-vapor sounders, climate-observing systems, and net radiative-flux observations of Venus and Jupiter.

References