

THE NRC DECADAL SURVEY CLIMATE ABSOLUTE RADIANCE AND REFRACTIVITY OBSERVATORY: NASA IMPLEMENTATION

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ABSTRACT

The Climate Absolute Radiance and Refractivity Observatory (CLARREO) Mission has been recommended in the National Research Council Earth Science Decadal Survey as a key component of the future climate observing system [1]. NASA and NOAA share responsibility for CLARREO. The NOAA component involves the continuity of measurements of incident solar irradiance and Earth energy budget by flying the Total Solar Irradiance Sensor (TSIS) and Clouds and the Earth's Radiant Energy System (CERES) sensors that were removed from the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The NASA portion involves the measurement of spectrally resolved thermal IR and reflected solar radiation at high absolute accuracy. Coupled with measurements from on-board Global Positioning System (GPS) radio occultation (RO) receivers, these measurements will provide a long-term benchmarking data record for the detection, projection, and attribution of changes in the climate system. In addition, the SI traceable radiances will provide a source of absolute calibration for a wide range of visible and infrared (IR) Earth observing sensors, greatly increasing their value for climate monitoring.

CLARREO is identified as one of the four highest priority missions in the Decadal Survey. There is tremendous value in starting these key new climate measurements as soon as possible. NASA is implementing a systematic approach to resolving the remaining scientific and technological challenges for CLARREO. In particular, clear mission requirements that maximize the benefit for using these data to improve climate prediction are needed to ensure that NASA's performance objectives are met, future costs are contained, and delays are minimized.

This presentation will focus on on-going activities involved with the planning and implementation of the NASA portion of CLARREO. We will review the scientific objectives of CLARREO, possible mission configurations, and the potential impacts on climate science that the CLARREO data will provide.

Keywords— CLARREO, climate, calibration, remote sensing

1. INTRODUCTION

The 2007 NRC report, *Earth Science and Applications From Space: National Imperatives for the Next Decade and Beyond*, provides the basis for the future direction of NASA's space-based Earth observation system [1]. The missions were ranked based on considerations of the scientific merit, contributions to the long-term observational record, societal benefits, affordability, and technological readiness. The four missions recommended for earliest implementation are classified as the "Tier 1" missions, and NASA's initial focus is on these. The Soil Moisture Active-Passive (SMAP) and the Ice, Cloud, and land Elevation Satellite (ICESat-II) missions will be implemented first and have launch readiness dates (LRD) of 2012 and 2015, respectively. CLARREO and the Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI) are the remaining Tier 1 missions with a possible LRD of 2017.

CLARREO is a climate-focused mission that will become a key element of the climate observing system. The foundation for CLARREO is the ability to produce irrefutable climate records through the use of exacting on-board traceability of the instrument accuracy. Spectral visible and IR radiances and GPSRO refractivities measured by CLARREO will be used to detect climate trends and to test, validate, and improve climate prediction models. Stated succinctly, the CLARREO imperative is to:

- Initiate an unprecedented, high accuracy record of climate change that is tested, trusted and necessary to provide sound policy decisions.
- Initiate 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.
- Observe the SI traceable spectrally resolved radiance and atmospheric refractivity with the accuracy and sampling required to assess and predict the impact of changes in climate forcing variables on climate change.

As noted above, CLARREO is recommended as a joint NASA/NOAA mission. The NOAA portion is the continuation of the total and spectral solar irradiance and the Earth energy budget climate data records. NOAA is actively

pursuing this goal. CERES is now planned to fly on the NPOESS Preparatory Project (NPP) and both CERES and TSIS are planned to be flown on the first NPOESS satellite in 2013. The focus of this paper will be the new observations involved with the NASA portion of CLARREO.

2. CLARREO SCIENCE AND SOCIETAL BENEFITS

The Decadal Survey recommendations were strongly based upon the societal benefits of the missions. The primary benefit from CLARREO will be in strengthened decision support from improved climate predictions. The creation of a benchmark climate record that is global, accurate in perpetuity, pinned to international standards and that can be used to develop trusted, tested climate forecasts is necessary for the decision support structure for responding to climate change. CLARREO will provide this by measuring solar reflected and infrared emitted high spectral resolution benchmark radiance climate data records that can be used to test climate model predictions, improve climate change fingerprinting, and attribution. These climate records will be augmented and complemented by the GPSRO refractivity data record.

CLARREO will also provide climate-accuracy calibration for operational sensors, making CLARREO a cornerstone of the Earth observing system. CLARREO data will be used to calibrate other solar and infrared space-borne sensors and thereby improve climate accuracy of a wide range of sensor measurements across the Earth observing system. This is in alignment with the recommendations of the Achieving Satellite Instrument Calibration for Climate Change (ASIC³) and the Global Spacebased Inter-Calibration System (GSICS), both of which call for benchmark instruments in space with appropriate accuracy, spectral coverage and resolution to act as a standard for inter-calibration [2] [3].

CLARREO will also help to address a major issue of our current observing system. Climate data records that are not tied to the accuracy standards of CLARREO cannot produce long-term climate data records without substantial overlap between successive instruments. Without overlap, long-term data records such as the Earth radiation budget will be irretrievably broken if a new instrument cannot be launched prior to the failure of the current instrument. The requirement for redundant and overlapped missions has a great impact on the cost of the entire observing system. The absolute accuracy of CLARREO, when used to calibrate other sensors in orbit can dramatically reduce the impact of data gaps on decadal change data records across many climate variables

CLARREO will also potentially provide the first space-based measurements of the Earth's far infrared spectrum. This opens a new window to 50% of Earth's IR spectrum with key information on water vapor feedback, cirrus radiative forcing, and the natural greenhouse effect

3. NASA IMPLEMENTATION

NASA will be implementing all of the Decadal Survey missions as directed missions, prioritized roughly by their order in the launch queue defined by the NRC. Langley Research Center (LaRC) has been identified as the lead for CLARREO. Working with the Program Scientist and Program Executive at NASA HQ and the Earth Systematic Missions Program Office at Goddard Space Flight Center (GSFC), the LaRC team has defined an integrated Pre-Phase A mission study plan leading to a mission implementation decision by the end of FY09. The goal is to refine the mission definition sufficiently by the end of FY09 so that CLARREO will be ready to be the next mission start following SMAP and ICESat II.

The Decadal Survey recommendations represent the integration of community input on the future direction of Space-based Earth science. NASA will continue to engage the community to refine the mission requirements during the planning for CLARREO and the other recommended missions. This process began with the first CLARREO workshop held in July 2007 and will continue with the next two CLARREO workshops scheduled in Fall 2008 and Summer 2009.

Technology risk reduction for CLARREO is being addressed through NASA's Instrument Incubator Program (IIP). In April 2008, the NASA Earth Science Technology Office (ESTO) announced the selection for funding of three IIP proposals related to technology development for CLARREO. These are:

- A New Class of Advanced Accuracy Satellite Instrumentation for the CLARREO Mission (University of Wisconsin – Madison)
- Calibrated Observations of Radiance Spectra from the Atmosphere in the far-IR (LaRC)
- A Hyperspectral Imager to Meet CLARREO Goals of High Absolute Accuracy and On-Orbit SI Traceability (University of Colorado Boulder)

Each of these address key aspects of the technology required to meet the accuracy goals of CLARREO.

4. MISSION TRADE STUDIES

The Pre-Phase A Study team includes participants from NASA LaRC, Goddard Space Flight Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory along with key participants from the first CLARREO Workshop, IIP team members, and members of the global climate modeling community. Using the mission defined in the Decadal Survey as a baseline and incorporating the input from the first CLARREO Workshop, this team has identified trade studies that will be used to address outstanding questions concerning the CLARREO science requirements. The results of these studies will be used to ultimately flow down to the mission and instrument design.

Initial studies are focused on high-level science questions concerning the use of the benchmark radiances for testing and improving climate models. A key component of the studies will be the use of climate Observing System Simulation Experiments (OSSE). Simulated CLARREO IR and solar reflected radiances will be generated from three leading climate models analyzed in the fourth assessment report of the Intergovernmental Panel on Climate Change to determine the utility of these data for evaluating climate models [4]. Other studies will focus on using simulated CLARREO data from existing IR and visible hyperspectral data for testing intercalibration of operational sensors. Preliminary results from these studies will be presented at the Fall 2008 workshop.

Once the highest-level science questions are defined, the next step will be to apply the results of these studies to define the mission and observational requirements. Spatial and temporal sampling, spectral range and resolution, and other key mission elements will be considered in trade studies during FY09. These studies are planned to culminate with a potential Mission Concept Review by Fall 2009.

5. CONCLUSION

The CLARREO represents a new paradigm in climate observation. Initiating an observational system with measurements tied directly on-orbit to international standards will provide the irrefutable climate record required for informed public climate policy. CLARREO also represents the opportunity for integrating the climate modeling and observation communities. By engaging the climate modeling community during the planning phase of CLARREO, we are ensuring that the goal of improved climate prediction will be realized.

11. REFERENCES

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