1 March 2017

Climate Change Science Institute 2017-2022 Strategic Plan

Advancing the Knowledge of Climate Change and Understanding its Consequences

Introduction. The Earth's climate has changed radically over its history. Roughly 10,000 years ago, it stabilized enough to support sustainable agriculture, and thus the development of civilization. Today, that stability is threatened by human activities that emit roughly 36 billion tons of carbon dioxide (CO_2) into the atmosphere annually, and that rate is increasing by roughly 1 billion tons per year. CO_2 is a powerful greenhouse gas that traps heat in the atmosphere and warms the planet. That is important because otherwise the planet would be too cold for life. However, CO_2 is building up in the atmosphere faster than nature can remove it, and it remains in the atmosphere for hundreds of years. That means the CO_2 being added to the atmosphere today will cause the climate to warm for many generations to come.

Recently, atmospheric CO_2 concentrations reached 400 parts per million for the first time in human history. According to the 2014 U.S. National Climate Assessment report, this is a 43 percent increase since the beginning of the Industrial Revolution. This rise has resulted in the Earth's surface warming 1.5 degrees Fahrenheit (°F) or 0.8 degrees Celsius, with most of this warming occurring over the past 50 years. That warming is evident in all climate change indicators, including melting sea ice and glaciers, dying ocean corals, plant and animal migrations, ocean and atmospheric temperature increases, and sea level rise. There is no way to explain these changes with only natural causes. In fact, human activities are the primary source of change over the past 100 years and at a rate 10 times faster than experienced in more than 800,000 years. These changes are not uniform around the globe. For example, the Arctic is warming at nearly double the globally averaged rate, and land surfaces have generally warmed more than the ocean surface even though oceans remain a key driver in current and future climate change because most of the added heat has been absorbed into deeper ocean levels. If global CO_2 emissions continue to increase at the current rates, the world will be 3–5°F warmer over the next few decades and 6–9°F warmer by the end of the century; that is warmer than the Earth has been in over 50 million years.

Given these current and future changes, it is important to deepen our understanding of the science and how society can mitigate and/or adapt to these changes. We must understand how ecosystems will respond to climate change in order to predict changes in natural resource availability and change in the carbon cycle that may either amplify or dampen the rate and extent of climate change. Public and private sector leaders will need information and tools to help their communities and customers have reliable and resilient access to food, water, housing, transportation, health, and energy services. Stakeholders in the financial, risk, relief, and other sectors will need information and tools to ensure these changes do not exceed response and

recovery capabilities and to evaluate future technologies and energy sources that can sustain a prosperous society, while also reducing the impact of climate change on society.

Climate Change Science Institute. *The Climate Change Science Institute (CCSI) is committed to this effort*. CCSI was formed in 2009 to help integrate climate science activities across Oak Ridge National Laboratory, including collocating 130 scientists in the areas of Earth system modeling; data integration, dissemination, and informatics; terrestrial ecosystems and carbon cycle science; and climate impacts, adaptation, and vulnerability science. While advancing fundamental science and a broad range of sponsor and policy priorities (see Appendix 1), CCSI must also develop information and tools to help users understand climate change and build climate resilience and economic strength for their communities.

There are many climate change centers and institutes. We believe CCSI is distinct based on the following unique features and high-level priorities that inform its values, mission, and goals**:**

CCSI Unique Features:

- **Collocation.** Multidisciplinary staff collocated within a diverse national science laboratory with world-class supercomputers, measurement and analysis tools, and scientific expertise.
- **Model–Data–Experiment Integration.** Improving multi-scale climate and biogeochemical models and their uncertainty characterization by integrating models, data, and long-term experiments.
- **Mission-Inspired Science.** Science driven by the need to better understand the impacts and consequences of climate change on human and natural land-energy-water systems.

CCSI High-Level Priorities—Creating the science, experiments, data, and community capacity needed to:

- Maintain excellence across the broad range of ongoing CCSI research programs.
- Strengthen the predictive capabilities and effectiveness of climate and biogeochemical models.
- Identify and understand how climate change impacts the resiliency of human and natural land-energy-water systems, including extreme events and tipping points.
- Participate in national and international climate assessments and response option analysis.
- Develop useful climate adaptation and mitigation tools and information in collaboration with land-energy-water system stakeholders.

CCSI's last strategic plan was developed more than five years ago. This new "actionable" strategic plan is designed to:

- focus on key scientific, societal, and organizational goals and better integrate CCSI activities;
- improve the connections and accountability between CCSI staff day-to-day activities and the high-level CCSI mission and goals; and
- serve as an effective management tool for guiding CCSI direction and investments.

CCSI Values, Vision, Mission, and Goals

Values. The CCSI values below are reflected in the mission and goals:

- **Transparency.** Open, fair, responsive, and honest in all that we say and do.
- **Work Environment.** Collaborative, respectful, adaptive, compassionate, and team-oriented work environment and colleagues.
- **Science.** Creative, innovative, objective, unbiased, rigorous, authoritative, high quality, multidisciplinary science and information that is well documented, relevant, reliable, reproducible, responsive, and accessible to sponsors, researchers, and society.
- **Integration.** Integrated, highly complex, technically advanced, and long-term research projects that demand diverse expertise—from molecular to global scales, from natural to human systems, and from experiments and observations to data and modeling.

Vision, Mission, and Goals. Below is the vision, mission, and goals that outline the CCSI direction and focus for the next 5-6 years.

- **Vision:** Advancing the Knowledge of Climate Change and Understanding its Consequences

- **Mission.** By 2022, CCSI will be a recognized research organization, partner, and source of knowledge for understanding climate change, evaluating its interactions with human and natural systems, and informing adaptation and mitigation policy and strategies.

CCSI will achieve this mission by supporting the following societal, scientific, and organization goals:

1. **Societal Goals**
   - 1.1. **Mission-Inspired Research.** Ensure that CCSI investments are both scientifically rigorous and useful by pursuing and advancing climate science that is responsive to human and natural land-energy-water stakeholder and sponsor needs, starting with local stakeholders and eventually expanding to the national level.
   - 1.2. **Policy Relevance.** Ensure that CCSI investments are policy relevant by pursuing and advancing climate science that is both scientifically rigorous and useful to national and international climate action plans and assessments.
   - 1.3. **Societal Outreach.** Support effective outreach by developing materials and CCSI staff opportunities to enhance societal awareness of climate change and its consequences.

2. **Scientific Goals**
   - 2.1. **Ecosystem Research, Experiments, and Model Development.** Explain how physical, biogeochemical, and human components of the Earth system interact across spatial and temporal scales and improve the prediction of climate-ecosystem states by applying an integrated system of hypothesis, observations, experiments, models, and uncertainty analysis, with special focus on the following areas:

2.1.1. Microbial and soil biogeochemical processes and their interactions with vegetation and soil physical properties.
2.1.2. Vegetation physiology and plant interactions with physical environment and heterotrophic communities.
2.1.3. Physical processes at the land surface, their interactions with vegetation, and soil biological processes.
2.1.4. The expression of human actions within terrestrial ecosystems.
2.1.5. Improve coupled representation of land surface processes in Earth System Models

2.2. **Global and Regional Earth System Model Development and Evaluation.** Improve understanding of the global Earth system; quantify and reduce uncertainties in predictions of Earth system models (ESMs); and deliver actionable climate change knowledge by developing and applying models and computational tools, integrating models and observational data, and providing usable model results with characterized uncertainties to the impacts research community.
2.2.1. Advance understanding of Earth system processes and improve predictions of climate variability and change by enhancing process representations in ESMs and conducting model experiments to quantify land–atmosphere and air–sea interactions and biogeochemical, cloud, aerosol, and radiation feedbacks with the climate system.
2.2.2. Enable application of Earth system models to questions requiring high resolution and high fidelity by improving the computational efficiency and numerical accuracy of ESMs through application and further development of modern numerical algorithms and libraries and by optimizing computational performance on leadership class computing resources.
2.2.3. Quantify and reduce uncertainties in predictions of ESMs by assessing model fidelity through comparisons with observational data, application of uncertainty quantification methods, and development and distribution of model benchmarking tools.
2.2.4. Provide usable model products to the impacts research community by delivering mission-relevant assessments of climate change and the influence of extreme events through modeling to refine and analyze multi-model projections at global, regional, and local scales.
2.2.5. Efficiently develop, analyze, and derive insight from very large Earth science data by applying information theoretic and data analytic methods and co-design of scalable software tools for management, workflow, synthesis, visual analytics.

2.3. **Data Tools and Archives.** Support Earth system modeling and analysis and an authoritative climate and terrestrial ecology data center by providing innovative data access, discovery, visualization, and storage tools and best practices; expanding access to relevant data and information; and highlighting the use of data products.
2.3.1. Support Earth system modeling efforts by developing next generation data infrastructures and working with relevant scientists to identify, curate, and archive

data products needed for regional and global change biogeochemical dynamics and impact, adaptation, and vulnerability studies.

2.3.2. Support CCSI modeling efforts by providing data storage, discovery, visualization, and access tools for high resolution modeling for Atmospheric Radiation Measurement Super Sites.

2.3.3. Improve the integration and use of CCSI Earth system science data by creating a virtual laboratory cyber-infrastructure strategic roadmap.

2.3.4. Explore new ways to archive and distribute data by using the Total Carbon Column Observing Network data as an ORNL Compute and Data Environment for Science pilot case study.

2.3.5. Expand the scientific utility of CCSI data products by developing guidelines for data product citations that follow recent international and scientific society practices.

2.3.6. Improve the registration and publication of CCSI data products by developing guidelines, best practices, and tutorials, including information for geospatial data and for visualizing complex data sets**.**

2.3.7. Improve the characterization of weather and climate related extreme events by developing new extreme event data resources and diagnostics and their application in impact, vulnerability, and adaptation studies.

2.4. **Impacts, Adaptation, and Vulnerability Research.** Understand and evaluate the risks and opportunities of extreme events and other climate change impacts on comprehensive human and natural land-energy-water systems by developing new integrated models, data analytics, and decision support capabilities, and contributing to national and international climate change assessment activities.

2.4.1. Improve understanding of the risks and opportunities associated with the impacts of climate variability and change on energy and interdependent infrastructure systems by analyzing energy system vulnerabilities to climate, water resources, and human dynamics and building connections between IAV, integrated assessment, and infrastructure dynamics models.

2.4.2. Improve understanding of the risks and opportunities associated with the impact of climate change on ecosystem services including agriculture, forestry, water resources, and carbon sequestration by developing new high performance modeling frameworks, sustainability indicators and metrics, and new techniques for geospatial data mining and fusion.

2.4.3. Improve understanding of the interactions between climate, land use patterns, and the evolution of human settlements by developing and applying next generation socioeconomic scenarios, new data analytics, and new dynamic models of coupled human and natural urban systems.

2.4.4. Improve understanding of climate adaptation and mitigation opportunities, constraints, and limits by supporting climate risk management and governance research; analyzing the costs and benefits of climate adaptation policies, practices, and options; and facilitating the incorporation of climate change into integrated resource planning.

2.5. **Near-term Stretch Goals**

2.5.1. Advance the science needed to create sustainable communities by supporting the development of models, data, and analytical tools needed to examine the interdependencies between energy, water, and related human and natural systems, and a robust data management and geovisual analytics platform to empower user-guided energy-water nexus data analysis and inquires.

2.5.2. Advance multi-scale water cycle science by supporting research on the terrestrial-aquatic interface, drought, and groundwater depletion.

2.5.3. Advance climate and environmental data systems by supporting the development of an earth systems science data archive, and foundational high-resolution climate modeling simulations needed for impacts, adaptations, and vulnerability studies.

2.5.4. Advance our knowledge of key nutrient cycles by better understanding the nitrogen economy and how it limits plant productivity, how to enhance global carbon sinks, and the development of an ecological forecasting system.

3. **Organizational Goals**

3.1. **Community Capacity**. Build community capacity by serving as a hub to train young researchers and others on CCSI research, experiments, modeling, and data best practices and organizing and hosting conferences on CSSI-relevant science.

3.2. **Outreach.** Broaden the exposure of CCSI capabilities, scientific information, and tools by better use of social media and websites, branded materials, news releases, webinars, and participation in important climate-related meetings.

3.3. **Leadership**. Extend CCSI leadership by participating in national and international research and meeting planning committees, editorial boards, and professional societies.

3.4. **Collaboration.** Optimize CCSI collaborations by establishing strategic and complementary partnerships with individuals and organizations.

3.5. **Scientific Rigor**. Maintain scientific rigor and leadership by producing a steady stream of high-impact publications and presentations at major scientific meetings.

3.6. **Integration.** Be a model organization for integrating mission-inspired climate science by optimizing and monitoring the integration of models, experiments, observations, and data; encouraging and rewarding multidisciplinary projects; and maintaining a collaborative work environment and business rules.

3.7. **Staff Development.** Support staff development by emphasizing strategic CCSI-wide staff and student workforce planning, including recruiting, mentoring, career development and training, succession planning, and professional awards.

3.8. **External Advice.** Maintain effective CCSI scientific and organizational direction and policies by regularly seeking advice from the CCSI Scientific Advisory Board and broadening the SAB membership to gain better insights from users of climate information and decision makers.

Conclusion

Approximately 80 percent of the core CCSI staff participated in developing this plan. It was also reviewed and endorsed by the CCSI Scientific Advisory Board (Appendix 2). It remains a living document and will change to reflect new opportunities and needs. Its revisions and derivatives are how CCSI communicates its values, purpose, and direction internally and to the public, sponsors, and partners. Developing this plan has already led to many CCSI cross-group discussions about the CCSI scientific focus, its contributions to society, and its aspiration as an organization. Comments on the plan are welcome, and we hope it spurs ideas for collaborations—a high-priority CCSI value.

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Appendix 1: External Priorities

There are over 50 CCSI-relevant national to local priorities in the documents listed below, including advancing science, informing decisions and outreach, helping with assessments, supporting workforce development, and being a valued community partner and leader.

President's 2013 Relevant Climate Action Plan Priorities

1. **Protecting our Economy and Natural Resources**
    a. Identifying Vulnerabilities of Key Sectors to Climate Change
    b. Promoting Resilience in the Health Sector
    c. Promoting Insurance Leadership for Climate Safety
    d. Conserving Land and Water Resources
    e. Maintaining Agricultural Sustainability
    f. Managing Drought
    g. Reducing Wildfire Risks
    h. Preparing for Future Floods
2. **Using Sound Science to Manage Climate Impacts**
    a. Developing Actionable Climate Science
    b. Assessing Climate-Change Impacts in the United States
    c. Launching a Climate Data Initiative
    d. Providing a Toolkit for Climate Resilience
3. **Other**
    a. Building Stronger and Safer Communities and Infrastructure
    b. Supporting Communities as they Prepare for Climate Impacts
    c. Preserving the Role of Forests in Mitigating Climate Change
    d. Strengthening Global Resilience to Climate Change

2012-2021 USGCRP Vision, Mission, and Goals

Vision: A Nation, globally engaged and guided by science, meeting the challenges of climate and global change.

Mission: To build a knowledge base that informs human responses to climate and global change through coordinated and integrated Federal programs of research, education, communication, and decision support. **Goals:**

1. **Advance Science:** Advance scientific knowledge of the integrated natural and human components of the Earth system. **Objectives:**
    a. Earth system Understanding: Advance fundamental understanding of the physical, chemical, biological, and human components of the Earth system, and the interactions among them, to improve knowledge of the causes and consequences of global change.

b. Science for Adaptation and Mitigation: Advance understanding of the vulnerability and resilience of integrated human-natural systems and enhance the usability of scientific knowledge in supporting responses to global change
c. Integrated Observations: Advance capabilities to observe the physical, chemical, biological, and human components of the Earth system over multiple space and time scales to gain fundamental scientific understanding and monitor important variations and trends.
d. Integrated Modeling: Improve and develop advanced models that integrate across the physical, chemical, biological, and human components of the Earth system, including the feedbacks among them, to represent more comprehensively and predict more realistically global change processes.
e. Information Management and Sharing: Advance the capability to collect, store, access, visualize, and share data and information about the integrated Earth system, the vulnerabilities of integrated human- natural systems to global change, and the responses to these vulnerabilities.

2. **Inform Decisions:** Provide the scientific basis to inform and enable timely decisions on adaptation and mitigation. **Objectives:**
   a. Inform Adaptation Decisions: Improve the deployment and accessibility of science to inform adaptation decisions
   b. Inform Mitigation Decisions: Improve the deployment and accessibility of science to inform decisions on mitigation and the mitigation-adaptation interface.
   c. Enhance Global Change Information: Develop the tools and scientific basis to enable an integrated system of global change information, informed by sustained, relevant, and timely data to support decision making.

3. **Conduct Sustained Assessments:** Build sustained assessment capacity that improves the Nation's ability to understand, anticipate, and respond to global change impacts and vulnerabilities. **Objectives:**
   a. Scientific Integration: Integrate emerging scientific understanding of the integrated Earth system into assessments and identify critical gaps and limitations in scientific understanding.
   b. Ongoing Capacity: Strengthen and evolve ongoing capacity to conduct assessments with accessible, transparent, and consistent processes and broad participation of stakeholders across regions and sectors.
   c. Inform Responses: Inform responses to global change with accurate, authoritative, and timely information that is accessible to multiple audiences in multiple formats.
   d. Evaluate Progress: Ensure ongoing evaluation of assessment processes and products, and incorporate the findings into an adaptive response for systemic improvement.

4. **Communicate and Educate:** Advance communications and education to broaden public understanding of global change and develop the scientific workforce of the future. **Objectives:**
   a. Strengthen Communication and Education Research: Strengthen the effectiveness of global change communication and education research to enhance practices.

b. Reach Diverse Audiences: Enhance existing and employ emerging tools and resources to inform and educate effectively, providing for information flow in multiple directions.
c. Increase Engagement: Establish effective and sustained engagement to enable a responsive and wholly integrated Program.
d. Cultivate Scientific Workforce: Cultivate a capable, diverse scientific workforce that is knowledgeable about global change.

DOE 2014-2018 Relevant Goals and Strategic Objectives

Science and Energy Strategic Objectives:

1. Advance the goals and objectives in the President's Climate Action Plan
2. Support a more resilient, efficient, and secure U.S. energy infrastructure
3. Deliver the scientific discoveries and major scientific tools

DOE Climate and Environmental Science Division Goals and Priorities

Mission Statement: To advance a robust predictive understanding of Earth's climate and environmental systems and to inform the development of sustainable solutions to the Nation's energy and environmental challenges. **Goals:**

1. Synthesize new process knowledge and innovative computational methods advancing next-generation, integrated models of the human-Earth system.
2. Develop, test, and simulate process-level understanding of atmospheric systems and terrestrial ecosystems, extending from bedrock to the top of the vegetative canopy.
3. Advance fundamental understanding of coupled biogeochemical processes in complex subsurface environments to enable systems-level environmental prediction and decision support.
4. Enhance the unique capabilities and impacts of the ARM and EMSL scientific user facilities and other BER community resources to advance the frontiers of climate and environmental science.
5. Identify and address science gaps that limit translation of CESD fundamental science into solutions for DOE's most pressing energy and environmental challenges.

Priorities include:

1. Developing Earth system models and strengthening the predictive understanding of climate
2. Advancing studies to enhance the understanding of atmospheric and terrestrial system processes
3. Understanding and predicting biogeochemical processes in subsurface environments
4. Utilizing CESD's user facilities for experimental studies designed to achieve unprecedented understanding of Earth's dynamic processes
5. Strengthening engagements with internal and external energy and environmental stakeholder communities.

ORNL 2014 Relevant Strategic Objectives

Excellence in Science and Technology

1. Scale computing, data infrastructure, and analytics for science
2. Advance understanding in biological, environmental systems, and climate change impacts science
3. Deliver science and technology to address complex global security challenges
4. Invigorate science through graduate and post-graduate research and education
5. Enhance technology transfer

Excellence in Laboratory Operations and Environment, Safety & Health

1. Develop workforce for competitive advantage
2. Increase value to the mission by driving process efficiencies and effectively managing risk

Excellence in Community Engagement

1. Sustain UT-Battelle's reputation as a valued community leader
2. Enhance ORNL's reputation for scientific excellence and societal Impact

Appendix 2: Climate Change Science Institute Scientific Advisory Board

The CCSI SAB members and their respective CCSI scientific Theme affiliation are below. These are busy and respected members of the scientific community. They have taken this strategic planning journey with us and we thank them for their commitment and critically important advice in this important planning process.

- Jeff Arnold, Corp of Engineers[4]
- Brian O'Neill, NCAR[4]
- Anthony Janetos, Boston University[4]
- David Hollinger, Forest Service[1]
- Anna Michalak, Stanford University[1]
- Sasha Reed, Chair, U.S. Geological Survey[1]
- Robert Chen, Center for International Earth Science Information Network at Columbia University[3]
- Mike Frame, U.S. Geological Survey[3]
- Curt Tilmes, NASA[3]
- Christiane Jablonowski, University of Michigan[2]
- Wayne Higgins, Climate Program Office, National Oceanic and Atmospheric Administration[2]
- Jean-Francois Lamarque, National Center for Atmospheric Research[2]

[1] Integrative Ecosystem Science Theme focus
[2] Earth system Modeling Theme focus
[3] Data Integration, Dissemination, and Informatics Theme focus
[4] Impacts, Adaptation, and Vulnerability Science Theme focus