Ocean's Role in the Climate System

Progress and Opportunities

US CLIVAR
Climate Variability & Predictability

Celebrating over 15 years of research to advance understanding of the ocean's role in the climate system

What is US CLIVAR

> The mission of the US CLIVAR is to foster understanding and prediction of climate variability and change on intraseasonal-to-centennial timescales, through observations and modeling with emphasis on the role of the ocean and its interaction with other elements of the Earth system, and to serve the climate community and society through the coordination and facilitation of research on outstanding climate questions.

History

The US Climate Variability and Predictability (CLIVAR) Program was established in 1997 by four US funding agencies – National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), and Department of Energy (DOE) – to improve the understanding, modeling, and prediction of variations in global and regional climate. Since its inception, the program has served as the United States contribution to the international CLIVAR project of the World Climate Research Program (WCRP), sponsoring American scientist participation in coordinated international research projects.

Over the past 15 years, US CLIVAR has made substantial advances in our understanding of the climate system and its predictability from weeks to seasons, year-to-year, and decade-to-decade. This has been accomplished by enlisting the scientific community in planning and coordinating research projects, funded by sponsoring agencies, to establish the requirements for sustained climate observing systems, motivate field work, guide development of earth system models, and enable routine production of forecasts and information products having inherent value to decision makers. Building upon the progress achieved during the past decade and a half, a new Science Plan updates the scientific goals and identifies priority research challenges to guide US CLIVAR for the next 15 years.

Goals

To achieve its mission, US CLIVAR has the following goals:

- Understand the role of the oceans in observed climate variability on different timescales.
- Understand the processes that contribute to climate variability and change in the past, present, and future.
- Better quantify uncertainty in the observations, simulations, predictions, and projections of climate variability and change.
- Improve the development and evaluation of climate simulations and predictions.
- Collaborate with research and operational communities that develop and use climate information.

The ocean, covering roughly 70% of our planet, helps regulate weather and climate.

Water has a larger capacity for storing heat than air or land and plays a primary role in redistributing heat in the Earth system.

The ocean provides a primary source of moisture to the atmosphere and influences the distribution of clouds, rainfall, snow, and ice.

The ocean can store a tremendous amount of CO$_2$, but the rate of absorption may be leveling off.

Societal Impacts

Climate affects everyone. The change of seasons influences cultural traditions, agricultural practices, and even disease transmission. Year-to-year changes in climate, and the associated changes in weather characteristics, can either amplify or weaken the seasonally varying climate fluctuations leading to floods, droughts, cold spells, or heat waves, all of which have substantial human, environmental, and economic consequences.

Did you know…

- From 1980 through 2013, there were 170 weather-related disaster in the US with damages that exceeded one billion dollars (adjusted to 2013 dollars), with annual loss totals as high as $187 billion. (NOAA)
- US exports supply 30% of the wheat, corn, and rice on the global market and agriculture production heavily relies on accurate weather and climate forecasts. (EPA)
- 16.4 million people live in a coastal floodplain in the US and at risk from rising seas and storm surge. (NOAA)
- International trade in commercial fishing contributes $70 billion annually to our nation's economy, and changes in ocean temperatures, salinity, and pH can impact growth and distribution. (NOAA)

Drought

Droughts are one of the costliest weather-related disasters in the United States, causing over $199 billion in losses over the last three decades, according to the National Climatic Data Center. Improved information on whether droughts will occur and how long they will last enables society to better plan for and mitigate impacts and costs. US CLIVAR has coordinated research to advance understanding of the causes and the ability to monitor and predict drought, providing a scientific underpinning of the National Drought Information System.

Credit: USDA

Credit: NOAA

Hurricanes

Tropical storms and hurricanes have costly impact on society through damage to property and loss of life. Anticipating, from months to seasons in advance, the number and intensity of such events can improve readiness and mitigate impacts. Understanding how hurricane frequency and intensities may change in a warmer climate can inform longer-lead infrastructure decisions. US CLIVAR has coordinated modeling experiments to better understand the linkages between hurricane activity and variability in sea surface temperature on interannual timescales as well as changes in sea surface temperature in a warmer climate.

Sea Level Rise

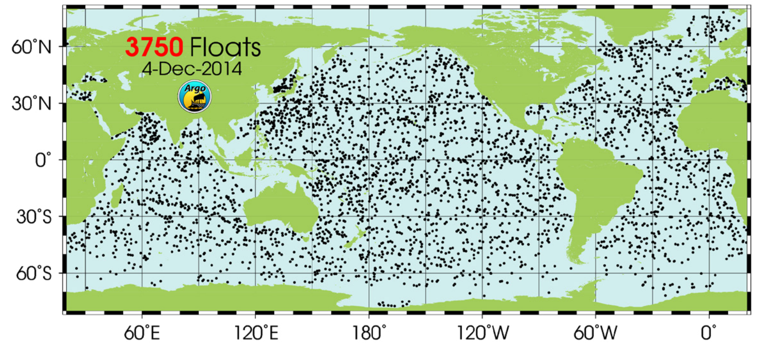
Two feet of sea level rise above the current level will put $1 trillion and 5,790 square miles of property at risk in the US (NCA 2014). One of the major contributing factors to current and future global sea level rise is the melting of ice sheets. The US CLIVAR community is trying to better understand the dynamics between ocean and atmosphere interactions with ice sheets and glaciers and how best to incorporate these into model projections. By studying ocean-driven melting of glaciers in Greenland and Antarctica, impacts on ocean circulation and sea level can be better understood and incorporated into climate prediction models.

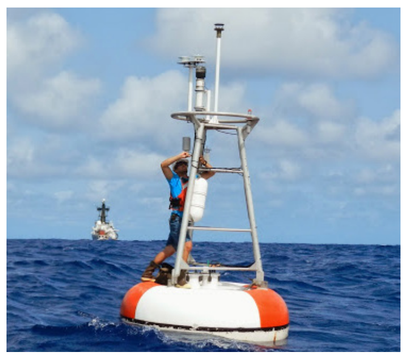
Credit: NOAA

Progress & Key Achievements

Expansion of a sustained ocean observing system

Argo: US CLIVAR helped establish the Argo global array of now over 3000 free-drifting floats that measure temperature, salinity, and velocity to 2000 meters below the ocean surface. The array has quickly grown to be a major component of the global ocean observing system. The data collected improves the monitoring, understanding, and modeling of variability of the upper ocean from months to decades.



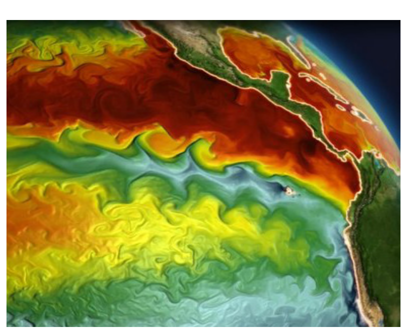

Credit: NOAA

Global Tropical Moored Buoy Array: US CLIVAR helped motivate and expand the array, now comprised of 110 fixed moorings spanning the tropics, to measure upper-ocean and surface meteorological variables important for climate monitoring and forecasting. The system components include the TAO/TRITON array in the Pacific, PIRATA in the Atlantic, and RAMA in the Indian Ocean. Data from this network of buoys contributes to our understanding of El Niño/La Niña events, hurricane activity, and monsoons.

US GO-SHIP: Recently completing a decade of ship-based full-depth surveys of the world's ocean basins, the US Repeat Hydrography Program (now known as US GO-SHIP) has advanced our understanding of the role of the ocean in climate change, carbon cycling, and biogeochemical responses. Analysis of observations collected over the period show that the deep ocean is warming and taking up to 30% of the excess heat in the entire Earth system, the global ocean has taken up a significant fraction of the anthropogenic carbon dioxide emissions, the surface oceans are acidifying, and oxygen minimum zones are expanding.

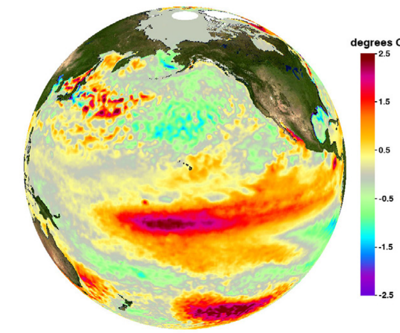

Credit: Katy Hill, WMO

Development of climate models with improved representation of physical processes


Credit: NOAA/GFDL

Climate Process Teams: US CLIVAR pioneered the concept of Climate Process Teams (CPTs) to accelerate the development of climate models by incorporating an improved understanding of important ocean and atmosphere processes gained through observational field campaigns. A series of CPT projects, funded by NSF and NOAA, has proven effective in advancing climate model development, and other Earth science communities are adopting the concept.

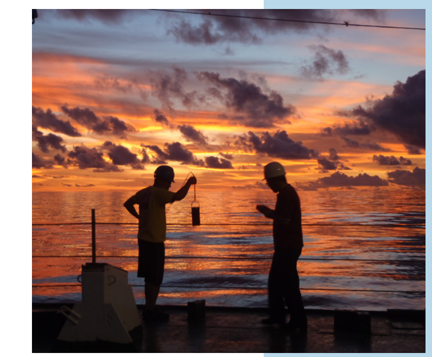
Increased understanding of the climate system and its predictability

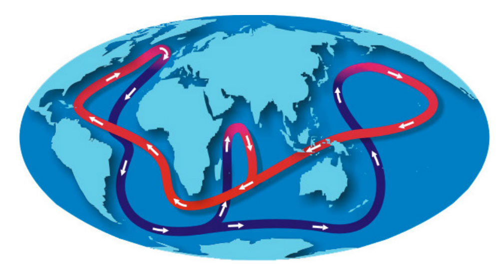


Credit: NASA/JPL

El Niño: El Niño-Southern Oscillation (ENSO), a naturally occurring phenomenon in the tropical Pacific, is a leading driver of seasonal-to-interannual climate variations and their forecasts. A US CLIVAR Working Group is pursuing further improvements in forecasting by understanding the diversity of ENSO events in terms of amplitude, location, evolution, triggering mechanisms, and global impacts.

Madden Julian Oscillation: The Madden Julian Oscillation (MJO) is the dominant component of subseasonal variability in the tropics and affects global weather and climate, including high-impact extreme events. A US CLIVAR Working Group developed diagnostics to assess and coordinate experiments to better understand and model the MJO. During 2011-2012, twelve countries joined US CLIVAR in the Dynamics of the MJO (DYNAMO) field campaign, gathering a rich dataset that is helping improve understanding and modeling of atmospheric and oceanic processes involved in the initiation of the MJO, with an aim to enable its prediction.


Credit: Hisayuki Kubota, JAMSTEC


Credit: NOAA/AOML

Atlantic Meridional Overturning Circulation: The unique basin-scale circulation of the Atlantic has northward flowing water at the surface, cooling and sinking in the subpolar Arctic, and southward deep return flow. This Atlantic Meridional Overturning Circulation (AMOC) drives climate variations from seasons to decades by changing sea surface temperatures and, in turn, the atmospheric circulation response. US CLIVAR's AMOC Science Team is deploying a trans-Atlantic observing system to document AMOC variability and change, is investigating its mechanisms and predictability, and is further exploring impacts.

20th Century Simulations and 21st Century Projections: US CLIVAR has coordinated analyses of model simulations of late 19th-20th century climate and 21st century climate projections of the Coupled Model Intercomparison Project (CMIP). Through agency-funded projects, scientists have examined oceanic and atmospheric modes of variability, trends in regional climate and monsoon variability, hydrological cycle behavior, extreme events, and feedbacks among the ocean, atmosphere, sea ice, and carbon cycle. Findings have informed the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports.


Credit: NASA

Current & Future Opportunities

From better predictability of El Niño events to understanding the causes of the slowdown in global warming, US CLIVAR is leading the way in helping scientists answer the cutting edge questions about the ocean's role in the climate system. This is accomplished through coordination of scientific community, continued investments in basic and applied research from US federal agencies, collaboration with national and international programs, training of the next generation of scientists, and dedication of individuals to keep driving the science forward.

Significant research challenges for the US CLIVAR community are outlined in the 15-year Science Plan and highlighted on the opposite page. These challenges are broad areas of climate science that are societally important, reflect the interests of the scientific community and funding agencies, and typically extend US CLIVAR beyond its traditional research agenda. Complex and cross-disciplinary in nature, these research challenges require involvement and collaboration of US CLIVAR observational, modeling, and prediction communities with research efforts of other Earth science communities.

US CLIVAR, through the community of scientists it engages, will continually adapt to both the needs of research and the challenges posed by advancements made in understanding the ocean's role in the climate system.

Enabling US CLIVAR to succeed

Coordination and partnership

US CLIVAR actively engages with other science communities both within the US and internationally – such as the weather, land, cryosphere, and carbon and biogeochemistry communities – to foster activities that address shared science questions.

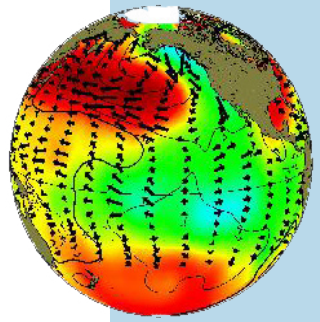
Sustained infrastructure

From ocean-based observing systems, ships, aircraft, and satellites to data and modeling centers, US CLIVAR research is enabled by critical infrastructure investments supported by federal funding agencies.

Credit: NASA

Decadal variability and predictability

Climate exhibits variability on decadal (10-20 year) timescales, with important societal consequences from impacts on rainfall patterns to altering fishery habitats. Decadal variability is described in terms of large-scale patterns found in the atmosphere and ocean, which oscillate on decadal timescales and are concentrated in specific regions (e.g., the Pacific Decadal Oscillation, Atlantic Multidecadal Oscillation, Arctic and Antarctic Oscillations). Understanding decadal variability and predictability has proven difficult, given the insufficient length of observations. US CLIVAR is using coupled climate models to extract as much information as possible from the scarce datasets to further understand the mechanisms leading to decadal variability and the degree to which such variability can be predicted.



Credit: Univ. Washington

Climate and extreme events

Extreme events – hurricanes, droughts, severe storms, floods, heat waves, cold snaps – can have costly and far-reaching impacts on society. The ocean impacts extremes primarily through its influence on cyclogenesis (developing low-pressure systems) and large-scale atmospheric circulation. US CLIVAR is identifying the small-scale, fast processes that underlie extremes and how they interact with the larger-scale, slower, and potentially predictable climate fluctuations linked to the ocean. These efforts aim to develop the capability of providing information on the past, current, and future evolution of extremes over seasons to years and how properties of extremes are changing in a warming climate.

Credit: FEMA

Polar climate

Climate change signals are amplified in polar regions and indicators, such as the collapse of ice shelves and melting of sea ice, have raised public awareness of the consequences of a warming world. Polar climate change can also have a profound influence at lower latitudes (e.g., sea level rise through ice sheet melting, changes in global ocean and atmospheric circulation). Despite their importance, polar regions are inadequately observed, due to logistical challenges of collecting data. This scarcity has hampered our ability to understand, model, and predict the influence of polar climate change on the overall Earth system. US CLIVAR is engaging the polar and cryosphere science communities to jointly develop strategies to better observe, understand, and improve model performance in simulating climate in the polar regions and its global impacts.

Credit: NASA

Climate and ocean carbon/biogeochemistry

The increase of atmospheric CO_2 and global warming are subject areas currently of great societal importance. The global ocean is a major sink of anthropogenic CO_2 and significantly slows the amount of CO_2 accumulating in the atmosphere. At the same time, increased warming from CO_2 affects the ocean's biogeochemistry and ecosystems in complex and uncertain ways. US CLIVAR is collaborating with the ocean carbon and biogeochemistry science community to increase observations and understanding of the coupled physical/biogeochemical processes that maintain the marine ecosystem and oceanic sources and sinks of carbon, and predict how they will evolve in response to climate variability and change.

Credit: NOAA

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