THE ROLE OF SPACE-BASED OCEAN OBSERVATIONS IN SUPPORT OF CLIMATE UNDERSTANDING AND PREDICTION

Statement of

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Good afternoon. Chairman Mollohan and members of the committee, thank you for this opportunity to testify. I am Dr. Tony Busalacchi, Director of the Earth System Science Interdisciplinary Center and Professor of Atmospheric and Oceanic Science at the University of Maryland. I also serve as the Chair of the Joint Scientific Committee for the World Climate Research Programme. I will use my time this afternoon to summarize the key role of oceanographic satellite observations in advancing climate understanding and prediction.

Satellite measurements have revolutionized our understanding of ocean circulation, marine biology, and interactions with the atmosphere. I am often asked the question, "If we can't predict our weather more than a week in advance, why should one believe we can predict future climate?" The answer to that question rests within the ocean. For the case of day to day weather prediction, comprehensive observations of the atmosphere are fed into complex numerical models. This initial state of the atmosphere is then integrated forward in time based on the governing equations of motion for the atmosphere alone. After several days, errors in these initial conditions and nonlinearities in the system begin to take over and the prediction skill falls off dramatically after one week. However when this same type of numerical weather prediction model is coupled to an interactive ocean, only then can the forecast lead time be extended. For it is the thermal inertia of the ocean, i.e., the longer time scale at which heat moves within the ocean relative to the atmosphere, that enables climate forecasts from seasons out to a year in advance with the realistic prospect of extension to years and decades. On longer decadal to centennial time scales, it is climate change that brings new risks to marine life due to ocean warming, changes in circulation, sea level rise, and acidification from increased atmospheric carbon. Yet, many of the measurements needed to monitor and predict such changes are now at risk because of budget constraints and the lack of a national strategy to sustain them.

The ocean climate community has three basic observational needs: (1) sustained, continuous, and often overlapping, measurements of certain key oceanographic parameters critical to monitor long-term climate trends and to validate coupled ocean-atmosphere climate models, (2) observations to initialize and force coupled climate prediction models, and (3) new or improved measurements of additional key parameters to advance ocean climate science and reduce uncertainty in our understanding of climate processes and interactions within the coupled ocean-atmosphere system. Due to the remoteness of the vast oceans, satellites have provided the foundation for the first truly global ocean observing system. Prior to the satellite era, ocean observing platforms included ships, fixed moorings, drifting buoys, and island stations, none of which, even when taken together, could provide basin-scale coverage at the spatial and temporal scales required to resolve the dynamic nature of the ocean. Satellite data from infrared radiometers, scatterometers, altimeters, and ocean color sensors have opened up a new field of satellite oceanography and, as a result, yielded new understanding of how mass is transported within the ocean, how energy is exchanged with the atmosphere, and the role of the ocean in the global carbon cycle.

Of all the ocean climate variables, sea surface temperature is the most important as it is the one variable that couples the ocean to the atmosphere. Observations of sea surface temperature have the longest heritage in ocean remote sensing. Going back to the late 1970's, sea surface temperature has been provided by orbiting infrared radiometers and complemented more recently by all-weather passive microwave radiometers. Ocean surface temperature is one of the most important indicators of global climate change and is used in a broad range of ocean climate studies such as changes to the Gulf Stream circulation and the El Nino/Southern Oscillation. The climate data record provided by the order 30 years of sea surface temperature observations has been calibrated, validated, and reprocessed with surface observations from ships, buoys, and drifters. In contrast to the meteorological observations used to initialize a weather forecast, the construction of such climate data records has unique requirements for instrument characterization, calibration, stability, continuity, and data systems to support climate applications. Space-based climate observations are not a mere extension of those used to monitor and forecast the weather.

Understanding increases in sea surface temperature and anthropogenic heat input to the surface ocean have important ramifications for quantifying and predicting sea-level rise. Since 1992 high-precision radar altimeters, beginning with the joint U.S./France TOPEX/Poseidon mission, have been monitoring changes in the ocean surface topography. Sea level is not only a proxy for the amount of heat stored in the ocean, but much akin to the highs and lows on a weather map, fluctuations in the sea surface topography provide valuable information regarding the global ocean circulation. Monitoring the heat stored in ocean eddies is also providing new insights as to how upper-ocean heat content can lead to hurricane intensification as was the case with Hurricane Katrina. Even after 17 years of observations, I find the radar altimeter to be a marvelous feat of technology. Similar to the radar gun in a police car, a satellite altimeter sends down radar pulses from 1300 km in orbit and senses changes in sea level to within 2 centimeters. That is like standing here in Washington and monitoring changes in the elevation of the St. Johns River in Jacksonville, Florida to within one inch. Unfortunately, at the present time the US has not yet secured the next in the series of follow-on radar altimeters, known as Jason 3, required to continue this valuable record.

A different sort of radar instrument, the scatterometer, provides crucial information regarding the ocean surface wind speed and direction that forces world-wide surface currents. By measuring how a radar signal is backscattered off ever increasing wind-driven ripples on the sea surface, a synoptic view is provided of the surface wind velocity. These data have yielded new insights into the exchange of heat and momentum between the atmosphere and ocean. Weather forecasting has also been significantly improved by incorporating scatterometer-derived winds into forecasts. For example, scatterometer data are particularly useful for determining the location, strength, and movement of cyclones over the ocean.

Most of the space-based ocean observations I have described to this point are specific to the physics of the ocean. Important information on ocean biology is obtained from the color of the ocean. The ability to derive global maps of chlorophyll concentration in the upper ocean from ocean color sensors was a remarkable achievement for the oceanographic community. This estimate of marine biomass can be related to how and where the marine ecosystem takes up and sequesters carbon. The first ocean color sensor was the Coastal Zone Color Scanner (CZCS), an experimental proof of concept mission operating on the Nimbus 7 satellite between 1978 and 1986. The CZCS demonstrated that it is possible to detect subtle changes in the color of the ocean and relate these to the concentration of chlorophyll from marine phytoplankton in the upper ocean. The first truly world-wide continuous monitoring of ocean color did not begin until 1997 with the launch of the SeaWiFS mission. This class of global ocean color observations has continued to the present day with the MODIS sensor on the NASA Terra and Aqua satellites. Such satellite observations provide the only means of estimating and monitoring the role of ocean biomass as a sink for carbon. Yet, once again, unfortunately, the continuation of the quality of such a data record is in serious jeopardy due to degraded performance specifications with the VIIRS sensor scheduled for the forthcoming NPOESS Preparatory Project.

While great strides have been made in satellite oceanographic research, we face some fundamental challenges in making the transition from research to sustained operations. Last year I chaired The National Academies' "Panel on Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft." This study was in response to a NASA and NOAA request to the National Research Council for a follow-on report to the Decadal Survey in Earth Science that focused on recovery of lost measurement capabilities, especially those related to climate research, which occurred as a result of changes to the NPOESS and GOES-R satellite programs. In the Decadal Survey it was noted there is a lack of clear agency responsibility for sustained research programs and the transitioning of proof-of-concept measurements into sustained measurement systems. Sustained climate observations require a long-term strategy. Much of the climate science as I have outlined here today depends on long-term, sustained measurement records. Yet, as has been noted in many previous NRC and agency reports, the nation lacks a clear policy to address these known national and international needs. Institutions have responsibilities that are in many cases mismatched with their authorities and resources: institutional mandates are inconsistent with agency charters, budgets are not well matched to emerging needs, and shared responsibilities are supported inconsistently by mechanisms for cooperation. While my comments today have been based on satellite oceanography, in our NPOESS study we recommended that, in a broader context, our nation needs a deliberate, forward looking, and cost-effective strategy for satellite-based environmental monitoring. The nation requires a coherent strategy for Earth observations which provides for operational climate monitoring and prediction, scientific advances, *and* the continuation of long-term measurements. The nation *deserves* such a strategy. Thank you for the opportunity to appear before you today on this important topic. I am prepared to answer any questions you may have.