Responses to questions from Senator Benjamin L. Cardin by Donald F. Boesch

1. *What do you think the essential elements of a science program for the Chesapeake Bay relative to climate change should be?*

   As summarized during the hearing by Dr. Christopher Pyke, the Scientific and Technical Advisory Committee of the Chesapeake Bay Program is near completion of a report *Climate Change Research and the Chesapeake Bay* that discusses the status of research in four research themes: physical drivers of change, environmental monitoring, impacts on restoration strategies, and adaptive strategies. The STAC report notes that, in particular, there is a low level of attention to the impacts on restoration strategies and to adaptive strategies. I would agree that a Chesapeake Bay science program relative to climate change should have an essential guiding focus on how climate change will affect our efforts to restore the Bay and on informing the policies and actions for adapting to the inevitable change we will experience in the 21st century. Given that, there are several questions that seem to me to be critically important at the start:

   a) How will likely changes in precipitation and evapotranspiration interact with projected land use changes to affect the flow of fresh water, nutrients and sediments into the Chesapeake estuary?

   b) How will likely sea-level rise and the resulting deepening of the Bay affect circulation, the distribution of salinity, groundwater intrusion, stratification, hypoxia, and sedimentation?

   c) How will tidal wetlands and shorelines respond to likely acceleration in sea-level rise and what are the most effective measures that can be taken to avoid or minimize negative impacts to natural environments and human infrastructure?

   d) How will likely increases in temperature and its seasonal timing affect ecologically and economically organisms, potential invasive species and key biogeochemical processes in the Bay?

   e) To what degree will increased CO_2 concentrations in the atmosphere result in acidification of Bay waters and what will be the ecological consequences of such changes?

2. *Can you take a moment to explain how you would see an 'adaptive management' program working the Chesapeake region as we deal with the evolving effects of global warming?*

   More effective application of adaptive management is required for Chesapeake Bay restoration in order to cross-compare model projections on which restoration measures are based with real-world, observed outcomes. This would allow more rigorous evaluation of the effectiveness of restoration efforts, appropriate redirection and redesign, and ultimately much greater efficiencies. This is essentially the point made in the Government Accountability Office's 2005 report *Chesapeake Bay Program: Improved Strategies are Needed to Better Access, Report, and Manage Restoration Progress*. (GAO 06-96). Adaptive management is also useful when changes in environmental and socioeconomic conditions occur and, thus, will be applicable in our efforts to adapt to climate change. For example, as we prepare for likely sea-level rise and river discharges over the planning horizon for Chesapeake Bay restoration, it is prudent to forecast how these changing conditions are likely to affect the attainment of restoration goals and either adjust the goals or measures (e.g. nutrient loading reductions) need to achieve them. Monitoring feeds into this iterative process not only realistic assessment of goal attainment but also information about the changing environment.

   What adaptive management cannot do is manage global warming. That is, we cannot monitor sea level, for example, until we observe a substantial acceleration in its rise and then decide to reduce greenhouse gas emissions. The residence times of greenhouse gases in the atmosphere are too long

and the responses in Earth's climate systems are too slow for that. Rather, our mitigation strategies must be anticipatory, precautionary and robust.

3. *In your experience around the nation, especially in Louisiana and other coastal areas, are they facing the same challenges? Are actions we are discussing important just to the Chesapeake, or are they equally applicable around the country?*

Coastal regions are among the most sensitive areas of the world to climate change as they are directly affected by sea-level rise but also are impacted by changes in the frequency and intensity of cyclones and other storms, temperature, and freshwater inflows. No coastal regions on Earth are immune to these effects and some effects, such as in coastal regions of the Arctic that are rapidly eroding due increased wave attack as sea-ice cover is reduced, are already quite dramatic. Coastal regions will vary to some degree in their susceptibility to climate change—compare steep, rocky shorelines to the low-relief coastal environments of Maryland's Eastern Shore of Louisiana, for example. And, coastal ecosystems may be more or less vulnerable to other climate related changes—river flow or temperature, for example. Actions taken to mitigate the increase in greenhouse gases in the atmosphere and thus reduce global warming are of consequence to all coastal regions of the country. However, the steps taken to adapt to inevitable changes will vary considerably depending on the important dynamics, drivers, and vulnerabilities of the region. One might think, for example, that a region like coastal Louisiana with its high rates of land subsidence, already degraded wetlands, and exposure to hurricanes may have few adaptation options. But, that region has the substantial capacity of Mississippi River sediments that could be managed to offset relative sea-level rise that other regions do not.

4. *Can you explain to the Committee the relationship you see between the global scientific efforts to understand and deal with global warming and the more regional understanding that is needed for areas like the Chesapeake? What is a reasonable scale, both geographically and in time, for us to understand and respond to climate change?*

Global climate change is being effected by processes in the atmosphere and the ocean that are global in scale, thus scientists have worked to develop global models of geophysical processes that help explain the changes that have been observed and project the changes that we are likely to experience based on current understanding. These models are the basis of the climate change projections made by the Intergovernmental Panel on Climate Change (IPCC) and conclusions about the reduction in emissions needed to stabilize greenhouse gas concentrations and thus the degree of climate change. These models are necessarily of global scope and thus, for practical reasons, do not resolve much detail at the scale of the Chesapeake Bay, its watershed, or the Mid-Atlantic region, for that matter, and consequently only fairly coarse regional projections are provided in the IPCC report. Furthermore, these models are unable to incorporate climatic dynamics that might operate on such region, as opposed to global scales. Furthermore, additional scientific efforts are required to interpret the consequences of the climate changes on regional ecosystems, resources and socioeconomic conditions.

As the National Research Council (NRC) recently pointed out in its report *Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results*, the U.S. Climate Change Science Program (CCSP) has done a very good job at keeping the U.S. at the leading edge of discovery science and understanding of the Earth's climate system at global, continental and ocean basin scales, but has been much less effective in predicting climate change at regional and local scales. Furthermore, the NRC found that the CCSP has lagged in advancing the use of that knowledge to support decision making and to manage risks and opportunities of climate change. This is beyond regretable because the congressionally mandated U.S. National Assessment completed in

2001 (*Climate Change Impacts in the United States: The Potential Consequences of Climate Variability and Change*) included very useful regional assessments that provide a solid basis for the science needed to improve regional understanding. In my opinion, the delay by the Federal government over the last six years in accepting the reality of global climate change resulted in avoiding the kinds of scientific investments needed to deal with the consequences of climate change in places where we live. I strongly support the NRC's recommendations that such investments are now urgently needed.

The space and time scales that must be addressed for understanding and response are in an important sense nested. Improving understanding at the regional scale, say on the scale of the Chesapeake Bay and its watershed, is a weak link at this time. However, this understanding will depend on continued development of our skill in making projections on a global scale. Furthermore, understanding and response will also be required on a very local scale, for example judging how sea-level rise and storm surges will affect vulnerability in downtown Baltimore. In the same vein, we need to develop the understanding to make more confident projections over this century, the principal time scale that the IPCC and U.S. National Assessment addressed, but we also need to understand the longer term changes that will occur as a result of actions during this period (e.g. sea level will continue to rise over hundreds of years as a result of the amount of 21st century warming that occurs). And, at the same time we will need to better understand whether anomalies that we see in one or a few years—this year's drought in the southeast or the 2005 hurricane season—are manifestations of climate change or just natural variability.