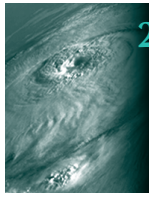

2.1 GLOBAL CLIMATE CHANGE

Rear Admiral David Titley

Today, I will drill down a little bit on some of the specifics regarding why the Navy cares about climate change. As you will see, it is more than humanitarian assistance and disaster relief (HA/DR). While that certainly can be a component of it, I think there are effects that can fundamentally impact both force structure and the ways in which we deploy and use our military forces.

To begin, I want to spend a few minutes on climate change. As I go around the country, I find that there are still a fair number of people who believe this is all some vast left-wing conspiracy, that climate change is a hoax. I am not going to ask for a show of hands or anything like that, but I hope to convince you that climate is in fact changing and that, at the global level, it is actually pretty simple to understand. When you start down-scaling to specific regions and ask what it is going to be like, say, in Fairfax County in 2038, then I am far less confident.

Rear Admiral David Titley is the Oceanographer and Navigator of the U.S. Navy. He received his B.S. in meteorology from Penn State and then went on to earn an M.S. in meteorology and physical oceanography as well as a Ph.D. in meteorology at the Naval Postgraduate School in Monterey, California. He was commissioned through the Naval Reserve Officers Training Corps and has held a number of shipboard, surface warfare, and meteorological and oceanography assignments, including service as the commander of the Fleet Meteorological and Oceanographic Center in Monterey. He also served as commander of the Navy Meteorology and Oceanography Command and was the first commanding officer of the Navy's recently established Naval Oceanography Operations Command. In addition to his duties as oceanographer and navigator, Rear Admiral Titley serves as director of the Navy's Task Force Climate Change.

But I can tell you that if the world continues to put greenhouse gases into the atmosphere, which we are doing, the climate will change, and it will probably change in some pretty significant ways. Figure 1a shows the Earth's global average temperature for the years from 1980 to 2010. [1] Those of you who are interested in more detail should refer to the references identified here. As you can see, climate, like the weather, has variations—some years are warmer than others. But if you look at the 25-year trend line, you see that the trend is clearly up.

Some people will take a 3-year or a 5-year portion of the curve and say, hey, guess what, it has not warmed in 5 or 10 years. For those of you took a time-series class back in graduate school, you will recall that you can get yourself in a lot of trouble with aliasing. It is really easy to do for temperature data like this, either intentionally or otherwise. But be careful of aliasing, especially when you talk about climate.

When thinking about climate, sometimes it is helpful to have an analogy. One that I frequently use, since I am in the Navy, is to ask people to recall a trip to the beach where you are playing with your kids and building sand castles and watching the waves come in and out. The individual waves are like the weather. On top of that is the tide, which can be going up or down, but over a much longer period of time. That is sort of the climate. The weather changes on a rapid time scale, the climate on a slower one.

I have had a lot of folks tell me that it is really just about the Sun. Some years you get a lot of sunspots, and some years you get fewer. So, let's look at sunspot data for the last 25 years (Figure 1b). [2] If you compare that curve with the one for temperature, you do not see the same trends, they just do not line up. So, it is probably something else. I want to emphasize again that these are actual observations. They are not predictions from a computer model.

Now let's look at the Arctic, where we have had some pretty dramatic changes. It was actually predicted by a lot of the models and by the theory that the effects of climate change would be amplified in the Arctic, and, indeed, we are seeing that. Figure 1c

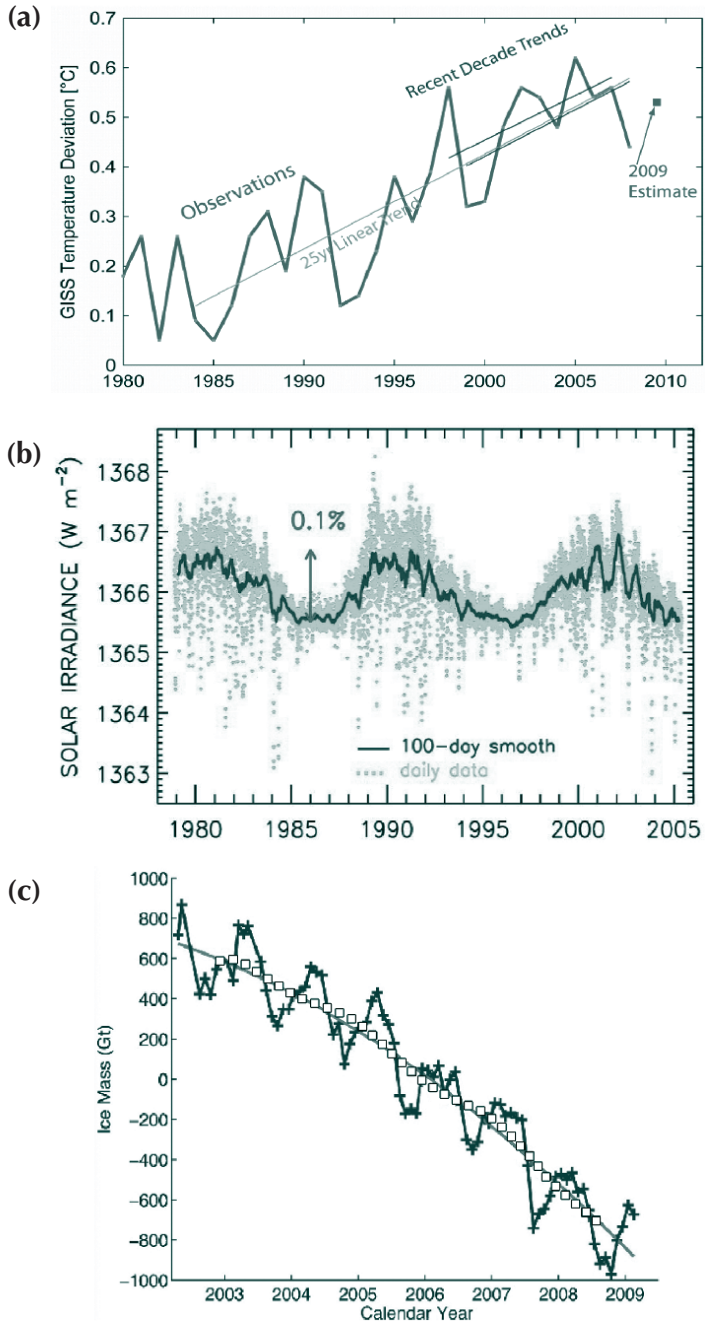

Figure 1. Historical Data Relating to Climate Change

shows the satellite data of the ice coming off of the Greenland ice sheet. [3] Ice on the Greenland ice sheet is ice on land. When the ice on the ocean melts, it does not impact sea-level rise because the sea level has already changed to accommodate the ice. However, when ice on land melts, it flows into the ocean, and sea level increases as a result. The graph in Figure 1c starts in about 2000 and goes to about 2010. It shows not only what is coming out, but also I think you can see that the rate at which it is coming down is, in fact, increasing.

The Intergovernmental Panel on Climate Change (IPCC), in their last report, stated, with a fair number of caveats, that sea-level rise in the 21st century was probably going to be around 7/10th of a meter, about 70 cm. I think a lot of the scientific community now projects that the most likely sea-level rise for the 21st century will be somewhere between 1 and 2 meters, or between 3 and 6.5–7 feet. To give you a basis for comparison, in the 20th century, global sea-level rise was about 20 cm. The expected rise for the 21st century is something between 100 and 200 cm, or 5 to 10 times as much. Based on the latest observations, sea level is currently rising at somewhere between 3 and 3.5 mm per year. That does not sound like much, and over 1 year, it is not.

But let's return to the data. For the 20th century, the rate was 20 cm divided by a 100 years, or 2 mm per year. Current measurements of sea-level rise are already 50% higher than those experienced in the 20th century.

As a bottom line, I can tell you that the Chief of Naval Operations (CNO) understands that the climate is changing and that I understand that the climate is changing. At the macro level, it is pretty simple to understand. There are certain gases that re-radiate at infrared wavelengths, the so-called long-wave radiation. They re-radiate heat back into the atmosphere. If we had no greenhouse gases, the average temperature at the Earth's surface would be –1°F. Fortunately for us, it is actually about 59° or 60°F, on average, thanks to greenhouse gases. So small amounts of greenhouse gases—a little methane, a little CO_2, some water vapor—make a lot of difference. However, when you start adding billions and

billions of tons of those gases to the atmosphere, which is what we are doing, you might expect things to change.

I expect that my friends in Task Force Energy will cringe when I talk about energy here, but we are in the process of digging up the dinosaurs and putting all that carbon back into the atmosphere. That has a big impact. One of the things I have learned from my time with Task Force Climate Change is just how sensitive climate is to really small changes. Again, for the engineers and scientists here, you can almost think of climate as kind of like a normal mode, but for any given mode, it does not take much to move it to another mode. That is kind of where we are.

So what are we going to do about it? For one thing, the White House has issued an Executive Order that addresses greenhouse gas emissions. [4] Secretary Mabus talked about how the Navy plans to move toward those goals. And, as we have heard, the recent *Quadrennial Defense Review* (QDR) addressed both climate change and energy security at some length. [5] Those of you who have read the entire Maritime Strategy that Admiral Roughead signed out in October 2007, more than 2 years before the latest QDR, will recall that that strategy talked about climate change. [6] I would argue that it has really stood the test of time quite well. These have been our guiding documents, if you will.

To address the concerns identified in Figure 2, the CNO established Task Force Climate Change in mid-2009. Its establishment was really driven by the CNO's desire to understand what is going on with the Arctic in the near term. If I had to frame CNO's overarching question, it was: When are the conditions in the Arctic going to change to the point where the United States Navy and the surface Navy need to be involved? At a somewhat more detailed level, he wanted to know (1) when will we need to have very robust communications, (2) when will we need to start thinking about infrastructure, and (3) when might the Navy be called on to support the Coast Guard on defense security operations for civil affairs, HA/DR, search and rescue, or potential assistance in oil spill? I think everybody knows the Navy has worked in the Arctic for many years. Our submarines have been in the Arctic when and

where needed for over half a century and have done exceptionally well there.

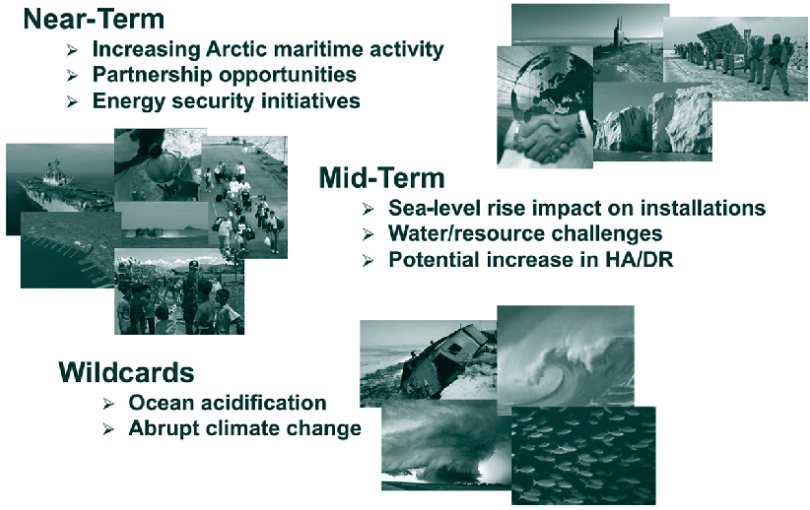

Figure 2. Navy Climate Change Concerns

If we look at our surface ships and ask how many U.S. Navy combatant surface ships are ice-strengthened, we find that the answer is zero! Now that is a pretty easy number to remember. Obviously, we need to ask whether that is the right number. In November 2009, the Vice Chief of Naval Operations, Admiral J. W. Greenert, signed out our new *Arctic Roadmap*, which calls for the Navy to conduct a capability-based assessment to understand whether it is better to devote a dollar to ice strengthening or to some other important need because, as I like to tell people, although the Arctic is opening up, nobody is flying over the Navy with C-17s and shoveling money out the back end for us to go do this. [7] So everything that we might consider doing in the Arctic will, rightfully, have to compete within all the other existing roles and missions that the Navy has. We do not see any of those going away.

Our Task Force on Climate Change started off from the word "go" arm in arm with the Coast Guard and with the National Oceanographic and Atmospheric Administration (NOAA), where

Dr. Jane Lubchenco has taken the lead in trying to establish, certainly within NOAA, a climate services agency. As I said, we are looking at climate change in general but really starting with the Arctic and working with a lot of folks. Within the Navy, we are working with Second Fleet, Third Fleet, and Pacific Fleet. We are also working with the combatant commanders and with the Office of the Secretary of Defense Policy, where Ms. Amanda Dory, the Deputy Assistant Secretary for Defense for Strategy, provides important leadership. We are also involved with the nations of the Arctic Council. Tremendous work is being done in this country today by many of our leading universities, including the University of Alaska at Fairbanks and the University of Washington Applied Physics Laboratory. Dr. Ralph Cicerone at the National Academy of Sciences has been a tremendous supporter.

Now, I am going to drill down on some of the specifics of climate change. While I do not profess to have all of the answers, I would like to offer some thoughts to help you think through the specifics of climate change and how they might affect force structure; or tactics, techniques, and procedures; or what DoD calls the full range of DOTMLPF issues (Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities). Since the Arctic was our first focus, I will just spend just a short time on that, and then I will move on to some of the others.

What are we trying to do in the Arctic? Our principal goal is to make sure that the U.S. Navy in the 21st century is ready to answer all bells. I can tell you three things about the Arctic, two that the Arctic *is*, and one that the Arctic *is not*. The first thing I would say is that, from a U.S. Navy perspective, the Arctic is a challenge and not a crisis. In recent years, especially in 2007 and 2008, not quite as much in 2009, a lot of media reports about the Arctic framed the issues in a way that made the Arctic sound like the Wild West. This was going to be the last great race for resources. When everybody converged at 90° North, we would all need to watch out. As you may recall, the Russians got there first and, by planting their flag on the North Pole, probably did us a big favor. They achieved what countless think tanks and Federally Funded Research and

Development Centers (FFRDCs) have been unable to do, and that was to get our leaders to focus on the Arctic.

There is a great article in *National Geographic* about that Russian expedition. It was kind of a tourist expedition. If you had had enough rubles, you too could have been on one of their submersibles. They sent two submersibles down, and then had a difficult time getting one of them back up through the ice. The expedition had huge political and strategic implications, but that is okay because it got people focused.

So what are we trying to do? In Navy parlance, we are getting ready to answer all bells. We want a ready and capable Navy to operate anywhere. What do we have to do? We have to understand what it is we are going to do before we start spending money or before we even study how we are going to spend money.

Our new Arctic strategy is now in final staffing and should soon be signed out. I will not go through the specifics, but I can tell you in broad terms what the U.S. Navy is looking for is a safe, stable, and secure Arctic. We need to make sure that we can train and operate there. In May 2009, I told the CNO that, by 2035–2040, the Arctic would probably have about 4 weeks of basically ice-free conditions in the late summer/early fall. I said on a confidence scale of 1 to 10, where 10 is perfect and 1 is nothing, I would consider that statement to be about a 2. Since then, I would keep that forecast, except I would probably change the confidence interval now to maybe a 3 or 4. There has been some recent research that says that a few weeks of ice-free conditions could exist by the 2030s. That is why we look at this as a challenge and not a crisis.

While cruise ships, fishing vessels, and exploration ships are moving around the edges of the Arctic, the big shipping industry probably will not be there for another 30 to 40 years. Those guys are looking for absolute, no-kidding, reliable, sea lines of communication. While it may save on distance traveled, it will not save you a whole lot of time if you have to travel at 3 knots for a considerable period behind an ice breaker. In addition to slowing you down, it will cost you $30,000 to $50,000 a day. That is not a great business model. There are also lots of secondary issues:

insurance, charting, navigation search and rescue, environmental concerns—what kind of fuel are you going to be allowed to burn. So for all those reasons, we do not really see the big shippers en mass coming up for quite a while.

When thinking about the Arctic, we need to consider that not only is it an ocean, but in some ways it is also the world's biggest estuary. The opening of the estuary is the Bering Strait between Russia and Alaska. At its closest point, it is only 4000 yards across. Think about the traffic that potentially is going to pass through that in 30 or 40 years. If the world is still hooked on hydrocarbons, you could get the Bering Strait to have attributes of the Strait of Hormuz and the Strait of Malacca simultaneously. So, this is a part of the world that we will need to really understand.

What stops the Arctic from being the Wild West? As it turns out, there is an internationally agreed governance regime for how we work on the oceans. It is called the United Nations Convention on the Law of the Sea. A hundred and sixty countries have ratified the treaty. A handful of countries have not; among those are North Korea, Iran, Syria, and the United States.

When the CNO provided his posture statement to the Congress just a couple of weeks ago, he again went on record in favor of the treaty. The last four of five CNOs have done so, as have the Secretary of State and the Secretary of Commerce. In fact, much of the entire executive branch has voiced support for the treaty. Even the White House is aware of this. It is now up to the political process to figure out how we are going to get this done. When people ask me why this is so important, I begin by telling them that, for one thing, our maritime lawyers essentially wrote the treaty. While we are currently abiding by it, we have not formally signed it. If somebody wants to change it and they have ratified it, they are at the table while we are not. That is one part. There is also something that the treaty, under Article 76, calls "extended continental shelves." For the United States, this amounts to an undersea area about the size of California where we would have sovereign access to minerals and resources. However, since we are not part of the treaty, there is significant doubt as to whether our claims would be taken seriously.

The Navy's currently partnering with NOAA to do hydrographic surveys in the Bering Strait. We are also pursuing partnership opportunities with the Air Force, the Department of Commerce, NOAA, and the Department of Energy to look at the next-generation forecasting system that goes from zero hours to 30 years—or what I call "0 to 30." Our goal would be to develop a new forecasting tool that would cover events of interest tactically all the way to the strategic time where you are thinking about the kind of 30-year ship-building plan that you need.

We also need to think about the kind of training program that we will need. If you believe the Arctic is going to be opening up in 25 or 30 years, the ladies and gentlemen who will lead the Navy at that time have already been accessed. They are today's junior lieutenants and lieutenant junior grades. How do we prepare those officers to lead in a seasonally ice-free and certainly ice-diminished Arctic? The answer is that we are doing a lot of things.

As I mentioned there are three things about the Arctic. One, it is a challenge, not a crisis, but we have the opportunity to get it right, and if we wait, it will become a crisis. Two, it is an ocean. We know how to govern an ocean. It is called the Law of the Sea. Three, the Arctic should not be viewed as if it existed in a vacuum. What happens in the Arctic will have repercussions in the mid-latitudes and the tropics, and vice versa. That is true on the science side as well as on the political side. Can we be certain that a conflict involving the major powers in the Arctic would remain there? I do not know. If there are heightened tensions in the Arctic, would that be confined to something north of 66° North latitude? We have done some wargames and I would say the answer is not entirely clear that such conflicts would stay isolated.

Now let's look at the link between climate and energy. One of the benefits of reducing our energy vulnerability and getting off carbon-based fuel is reduction in greenhouse gases. As you have heard, the Navy is participating in that effort. It is true, of course, that the Navy does not account for a very large share of greenhouse gas emissions. In fact, even if the U.S. Navy goes to zero on greenhouse gases, that only makes 5/100th of a degree difference in the global temperature. My counter to that is, while there are

a lot of nonlinear effects in climate science, especially as you get down to regional level, leadership is also nonlinear. A little bit of leadership—such as that being shown by the Secretary—can make a whole lot of difference.

Let's return to sea-level rise and consider why the Navy should care about that. An obvious answer is that our bases are invariably at sea level. So that will be a big impact. Think, too, about places like Diego Garcia, where the average elevation is a mere 4 feet. What does 1–2 meters sea-level rise do to that? How will sea-level rise affect, from a policy perspective, the disputed claims in the South China Sea where several of the Paracel and Spratly Islands currently stand just above sea level? Maritime lawyers will have a field day sorting out the competing claims. Can you build a caisson around that little outcropping and keep building it up? Is that still an island? Do you still have your exclusive economic zone? I do not know the answers, but my guess is there are going to be multiple views of how this goes, and it is probably something that we should start thinking about.

Water and resource challenges could also be important. Let's take a look at the Southwest Monsoon, the seasonal weather effect that delivers rain to places like Vietnam, China, and India. A significant shift in the prevailing pattern could have a huge impact on agriculture in that area. The tremendous population that lives in the area already imposes significant environmental stress. So how does that play out? What happens if northeast Russia—Siberia—becomes a better place to live? The demographics in Russia are not very good. They are depopulating for a variety of reasons. They also have a lot of people living to their south. How does that play out? Those are just some of the potential effects of climate change that the DoD, along with other agencies in our government, need to understand.

Another potential wildcard is ocean acidification. It is a silent cousin to global warming because almost half of the CO_2 that goes into the atmosphere does not stay there. It gets absorbed by the ocean, and in the process turns the ocean slightly more acidic. While it will not be like taking a bath in hydrochloric acid, it can have adverse effects. The ecosystem in the ocean has basically

been tuned for many hundreds of thousands of years to work at the pre-existing pH level (a measure of acidity). In the last 100 years, the amount of change has been greater than in the last several hundred thousand years. That change seems to be imposing significant stresses on the ecosystem. Frankly, it is a wildcard. It is unknown as to how the living ecosystem, all the way from the little tiny critters up to the big, big fish, is going to adapt to that. If they adapt, that is good. If they do not, we have to start asking ourselves, how do the 1 billion people who get their protein from the ocean today feed themselves in the future?

While we can predict some of the effects of climate change, we cannot predict all of them. Our climate forecasting models are not good enough at the regional scales. You may have heard about so-called down-scaling models. Basically, these involve running a really big climate model, which has pretty course resolution, and then putting in a finer-scale model at regional level. Be cautious when you see such results. Why do I say that? This is exactly how, in the 1970s and 1980s, the weather service and the Navy attempted to do hurricane and typhoon forecasting. It was not that good, honestly. We really got a whole lot better when the entire global model was able to resolve those specific features. That happened roughly 10 years ago. So just be careful when you see results that come from models with down-scaling. I do not necessarily mean that they are wrong, but I would treat them with less confidence.

One proposed mitigation that I have not put up here is something called geoengineering. It involves use of engineering processes as a technological "silver bullet" to either cool down the planet or take the CO_2 out of the atmosphere. Doing either could entail a lot of risk. In fact, the real risk is that it may be doable, but there is no international governance whatsoever. So my question is what would we do if we woke up one day and we turned on CNN and found out that another country had said that because the Earth's getting too warm, we have launched a dozen rockets with sulfates? We put them a hundred thousand feet up in the atmosphere, and we would like the United States to participate with us in 90 days when it is time to re-seed this. What would we do? Unfortunately, I do not know the answer. It is more than a DoD

question, it is a whole-of-government question. But it is something that we need to (1) understand the impacts of geoengineering to the point we can, and (2) start thinking about what would we do if somebody else unilaterally did that.

If you think about how the Navy is responding to climate change at large, CNO has chartered two task forces. I run Task Force Climate Change and Rear Admiral Philip Cullom runs Task Force Energy. We need to understand what is going on in time scales important to the Navy. One of those is the 5- or 6-year budget process by which the Department of Defense and the Department of the Navy make decisions. Another is the annual planning process used by those planning naval exercises. Another is the 30-year lifetime of our ships and the 30-year career length of our officers and sailors.

So those are the kinds of time frames for which we need to understand what is going on. We need to figure out how to adapt. We need to figure out how we are going to work in a changing world of rising sea level and potentially significant ocean chemistry changes, including ocean acidification, while watching for potential wildcards. Simultaneously, Task Force Energy is very concerned about energy efficiency and reducing our energy vulnerability, which, by the way, will reduce our carbon footprint.

That is one way in which the Department of Defense and the Navy can help provide leadership to our country to start working down the global greenhouse gases and the carbon footprint, because ultimately that is how we are going to do the best that we can to stabilize the climate over the long term.

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Q&A SESSION WITH REAR ADMIRAL TITLEY

Q: *Regarding the next-generation numerical prediction capability that you are planning, could you tell us a little bit more about the new capabilities that you have in mind?*

Rear Admiral Titley: I sometimes tell people that what I am trying to do is undo 60 years of collective bad behavior throughout the executive branch. It turns out that in the United States, each agency has, for various reasons, been allowed to develop its own set of weather models. And, like many things, these

numerical models get more and more complicated, and the budgets for associated with providing this capability continues to grow.

So, we have proposed that we put together the intellectual capital of the Navy labs, the National Center for Atmospheric Research, the NOAA labs, the Department of Energy labs, the National Aeronautics and Space Administration (NASA), and the National Science Foundation in order to build a first-rate forecasting system. If we pull these departments and agencies together using a single vision, I think there are ways that the infrastructure can develop a numerical forecasting system that is second to none. Moreover, our goal should be to create a unified approach that couples air, ocean, and ice forecasting in order to answer some of these basic questions.

What we need to do is to gather our efforts, and so far, we have a lot of support. Dr. Lubchenco at NOAA is on board with this as is Dr. Ralph Cicerone, President of the National Academy of Sciences. We also have the support of Dr. John Holdren, the President's Science Advisor.

This is not an efficiency initiative per se. This is really harnessing the intellectual capital of the United States, and I believe we have more than any other country if we put our mind to it. That model can support both military and civilian. On the military side, I would have the DoD run the model inside the their information-assured network so as to allow us to use observations from unmanned vehicles that may or may not be in the civilian network.

But as far as what that model is, the ones and zeroes of the computer code, I think you can have the same model there. So it is really trying to put all this together. I think it is pretty exciting. And this is one of the places—at least to me—where climate change has frankly provided the opportunity. Without that, we would not have the senior leadership attention that we have today.

Q: *Some of the climate effects you have talked about, such as sea-level rise, will impact modeling. Would it be advisable to set up an international effort to look? We could spread our effort and cover more of the world. Are there any steps to set up that sort of collaboration?*

Rear Admiral Titley: I think there are. I have discussed such issues with the U.K. Meteorological office. We have access to some of the European data. In fact, the intent of the IPCC is exactly that. It is the ability to take science that is being done around the world and review it on a level playing field and put the appropriate pieces together. So I believe that can be done. But I also think, at the end of the day, that if we are going to be making decisions for national security, I want the ability, at least within the U.S., to have the ability to come up with answers we need for our national defense.

Q: *Are seaports in the developing world, such as parts of Africa, much more vulnerable in terms of their infrastructure and the way in which they can adapt to climate change?*

Rear Admiral Titley: I think that is going to be looked at. Where you have large numbers of people living right on the coast, they are probably quite vulnerable. The potential for climate migrants has been mentioned as well; we heard a lot about that at Copenhagen, and it is noted in the QDR. At last week's Arctic conference in Miami, the Canadian Inuits gave a presentation in which they basically said, and I paraphrase here, "hell no, we're not going anywhere." They are not interested in moving in response to climate change. That is exactly the same reaction I heard from the citizens of New Orleans and the Mississippi Gulf Coast.

Now if you are on an island and the island is covered with water, you will have to leave. But I think we are probably going to see more pressure for people to stay and adapt than to just pick up and move. But we will see how that plays out.

Q: *As I recall, the plot of ice mass loss that you showed [Figure 1c] was based on data provided by NASA's GRACE mission, which will soon end and not be replaced in the near term. There is a lot of the climate monitoring data that is coming from science missions that are essentially one-of-a-kind-type missions. Do you see the United States*

going to an operational climate monitoring system, and what role will the Navy have in that?

Rear Admiral Titley: I think the Navy's role is to strongly support NOAA for that. I have spoken to the administrator at some length about the need for a national strategy for this. Many people here probably know NASA flies some incredible technologies, some tremendous space vehicles, but by and large NASA is an R&D organization. They will fly it once, then they are looking for a mission-funded agency to pick it up. The Navy is picking up almost a quarter of a billion dollars' worth of end posts that I now have to find the money to fund, just for altimetry, which has some climate uses for that, although the orbit I am looking at is more for day-to-day ocean forecasting.

Frankly, I think the country is going to have to come up with a strategy. I think this can be done in cooperation with the European space agency, the Japanese, perhaps some others. But there needs to be, at the very least, a national, if not international, strategy so we do not simply lurch from satellite to satellite and so that we can have climate records.