Impact of an Ice-Diminishing Arctic on Naval and Maritime Operations

July 10-12, 2007
Washington DC

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National Ice Center and
United States Arctic Research Commission

SUMMARY REPORT

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U.S. Arctic Research Commission (USARC)

The USARC recommends Arctic research policy to the President and the Congress and works with the National Science Foundation to support cooperation and collaboration throughout the Federal Government. The USARC guides development of national Arctic research projects as well as interacts with Arctic residents, international Arctic research programs, organizations and local institutions in order to obtain the broadest possible view of Arctic research needs.

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BACKGROUND INFORMATION

The 100-year historical record from ships and settlements going back to 1900 shows a decline in Arctic ice extent starting about 1950 and falling below pre-1950 minima after about 1975 [Naval Operations in an Ice Free Arctic, 2001]. According to satellite records available since late 1978, an overall downward trend in the extent of Arctic sea ice is present. This trend seems to have been accelerating during the last decade. In addition to the Arctic Climate Impact Assessment document published by the Arctic Council in 2004, numerous other reports and articles published since have documented significant recent sea ice extent reductions, both during summer and winter seasons. The percentage of multiyear ice in the winter has also been shown to be decreasing significantly.

This symposium addressed the immediate and future impacts of these rapid changes. It was a follow-up to the symposium, Naval Operations in an Ice-Free Arctic, sponsored by the Office of Naval Research, NIC, the Oceanographer of the Navy, and the USARC in April 2001. While the 2001 symposium focused mainly on naval operations and national strategic issues, the 2007 symposium expanded the discussion to impacts on other maritime operations such as commercial transportation, oil and gas exploration and exploitation, fisheries, and oceanographic research. This symposium served to update results from the Arctic Marine Transportation Workshop, sponsored by the Institute of the North, the USARC, and the International Arctic Science Committee in 2004. It also provided a forum for the review of the dramatic changes in Arctic sea ice conditions observed over the last several years and of recent adjustments to sea ice forecast model predictions.

Observations of the change of the Arctic perennial sea ice extent were recently made using imagery from the SeaWinds scatterometer aboard the QuikSCAT satellite during the months of March 2005 and March 2007. A comparison of imagery from the 2 periods demonstrated a drastic reduction in the amount of sea ice equivalent to about 671,080 square miles, roughly half the area of Greenland. This represents a 23% loss of the perennial sea ice extent over the two year period. Perennial sea ice is ice that has remained frozen for more than one year and is thicker than seasonal ice. The loss of perennial sea ice extent represents a significant loss of total sea ice mass.

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SUMMARY REPORT INDEX

IV. Day 3 Technical Presentations Summary Points *and Discussions*

[Electronic access to this document and related symposium presentations is available at: http://www.star.nesdis.noaa.gov/star/IceSymposiumProgram.php]

EXECUTIVE SUMMARY

This report provides a compilation of summary key points made during symposium briefings, panels, and interactive discussions with the audience. The symposium had over 100 people in attendance. The discussion about an accessible Arctic has matured significantly since the symposium in 2001. No one is debating the fact of a diminishing Arctic sea ice pack. Almost every speaker noted the importance of partnerships agencies within the U.S., other countries and agencies in other countries, commercial interests, Non-Government Organizations (NGOs), academia, etc. The U.S. and other countries are working in the Arctic now – northern peoples are being impacted now. This is not a discussion that can wait for the future – the future is upon us. The United Nations Convention on the Law of the Sea (UNCLOS) ratification / accession / signing must be a priority for the U.S. that will enhance its credibility in international partnerships and provide a seat at the table in international negotiations on the governance of the global commons. The rule of law on the sea is in the best national interest of the nation.

While an ice-diminished Arctic will increase the scope of naval and maritime operations, the U.S. has little capacity to expand and little ability to operate in the Arctic environment. For example, U.S. Coast Guard (USCG) polar icebreakers are aging and need replacement. Of course, an ice-diminished Arctic will have significant impacts beyond maritime operations to issues relating marine and land mammals, fisheries, coastal erosion, economic activity, and Arctic inhabitants. There is a recognized need for increased Arctic research of 1) physical processes in the ocean and ice in order to better understand observed changes and accurately predict future changes; 2) biological processes and their response to environmental changes; 3) economic issues positive and negative impacts; and 4) social impacts on the people of the north, their cultures, lifestyles and health.

There are many stakeholders with diverse interests in the Arctic - many countries – many different types of uses – many cultures – many views. Negotiation is key particularly as rules of engagement with northern peoples may change. Commercial maritime activity in the Arctic will be driven by economics much more than diminishing ice. Ship traffic will be overwhelmingly destinational and dominated by the development of natural resources and tourism. On the other hand, routine ocean to ocean transit shipping is not expected to develop significantly for quite some time. Governance regimes are desperately needed to overcome many expected challenges and barriers. Particularly, rules for Arctic navigation, pollution prevention, interaction with communities and indigenous peoples, and resource exploitation must be developed or updated. As polar sea ice gets thinner, the difference between Arctic residents' view of change and the shipping industry's view of opportunity may become more pronounced.

I. Keynote and Opening Presentations Summary Points and Discussions

A - Opening Remarks: Oceanographic Implications of an Ice-Free Arctic - RDML Timothy McGee, USN Commander, Naval Meteorology and Oceanography Command

Summary

- Naval implications of "ice-free" Arctic must be addressed.
- Arctic ice conditions addressed in the context of general climate changes.
- Polar route = 40% decrease in Europe-Asia sailing distance – there is a need for aids to navigation.
- Oil companies will go to Arctic for resources – U.S. must take the lead to protect the pristine environment there and ensure responsible commerce.
- Changing global weather patterns will affect food production and water distribution; displace persons; hungry, thirsty populations fuel terrorism
- Polar issue with global consequences / impacts.
- Opportunities for new alliances exist – countries, NGOs, commercial partners.
- There are capacity issues for the military.

Discussion

- Does the U.S. have capability to build a ship that can operate in Arctic now, as does Finland and Russia?
- Russia is taking advantage of their link with the Lomonosov Ridge to lay claim to a large area of the Arctic Ocean, as would most countries in the same situation – countries need to negotiate on responsibility in the Arctic – it must not be a land rush.

B - Opening Keynote Speech, Lisa Murkowski, U.S. Senator for Alaska

Summary

- Referred to an "accessible" Arctic Oceans vice "ice-free".
- At Symposium in 2001, group was largely focused on strategic considerations for naval operation; in 2007 we are more broadly focused on maritime operations that include commercial transportation.
- As change sweeps through the Arctic, we must remember that there is a diverse group of Arctic residents.

    - Residents are seeing many changes in the Arctic environment that validate the scientific findings; change is happening very fast in the Arctic.
- The International Polar Year (IPY) – U.S. leads in 52 of 225 projects and participates in 85% of projects.
- The Arctic Climate Impact Assessment (ACIA) report; Intergovernmental Panel on Climate Change (IPCC) report; National Center for Atmospheric Research (NCAR) studies – more recent studies bring the prospect of commercial shipping in the Arctic decades closer.
- An Arctic Marine Shipping Assessment (AMSA) report is due in 2009.
- U.S. Arctic policy is currently under review – opportunity for U.S. to be a leader in Arctic but needs to increase priorities for Arctic research, polar icebreakers, and the integrated Arctic Observing Network (AON).
- U.S. must focus its cooperation within Arctic Council – must fully engage in discussions about Arctic governance.
- Arctic Council has been successful because of the collaboration between indigenous peoples, scientists and governments.
- U.S. must make it a priority to ratify the UNCLOS in order to enhance its credibility in international relations.
    - This will allow U.S. to lawfully claim to 45,000 Sq Miles of continental shelf and would give U.S. a voice in challenging claims by Russia and other countries.
- Arctic is unquestionably unique – adapting to changes is the challenge and opportunity.

Discussion

- Currently there is support within the Bush Administration to ratify UNCLOS and there is lots of discussion going on – it is a matter of finding the right time and vehicle to make it happen.
- Alaska Fisheries Council has frozen fishing north of Bering Sea until more research is done – essentially frozen the fishing areas even as stocks move northward.
- Congress should fund a study to initially determine requirements for new icebreakers.
- Canada and Norway have active programs going in the AON and U.S. needs to participate – funding must be allocated.

C - USCG Strategy and the Arctic - ADM Thad Allen, Commandant USCG

Summary

- The oceans are the last global commons and we need a governance regime for them.
- U.S. capability to operate in Arctic has not changed since needs were articulated in 1985.
- USCG priorities are safety, security, stewardship safe, reliable navigation including multinational cooperation on ship routing; e.g., impacts of increased shipping through Bering Strait where the sea lanes are only 20 miles wide; the key to moving ships safely in narrow waterways is international cooperation.
- Major issues in the Arctic relate to time, distance and environment; different response strategies and platforms are needed; need an in-depth assessment of risks and response capabilities for Search & Rescue and for environmental emergencies (e.g. oil spill).
- It is essential that the U.S. ratify UNCLOS in order to give the U.S. a place at the table to undertake negotiations.
- Thoughtful risk assessment is absolutely essential.
- Value of the USCG is its multi-mission capability but there is a limit to how much the capability can be stretched across added missions.

Discussion

- U.S. needs an international risk assessment before adopting mandatory standards such as proposed by International Maritime Organization for polar navigation.
- Limits to USCG capability to operate in Arctic are primarily the lack of a forward operating base and crew limitations on the length of time away from home port.
- Cost of developing port infrastructure makes basing the *Healy* in Alaska cost-prohibitive; multi-crewing the *Healy* to keep her at sea longer would be more advantageous.
- USCG can likely keep one Polar class icebreaker operating until a replacement is available – but not both.
- More icebreakers will be needed even in the face of diminishing ice because there will be greater access for commercial shipping near ice; note that summer ice-free does not mean no winter ice; USCG will need to gain access to vessels stranded in ice for Search & Rescue purposes and to prevent and clean up oil spills in ice.
- Concerning an possible increase in airborne operations to make up for a lack of surface ship capability:

    - IIP may increase airborne operations to track more icebergs calving from Greenland and moving to the North Atlantic sea lanes.
    - Airborne operations may assist with increased vessel traffic monitoring especially in Bering Strait.
    - Airborne operations will help increase Maritime Domain Awareness, which together with IIP, improves the Common Operating Picture.
- Sea-basing is an increasing concept in the U.S. Navy (USN) and is possible anywhere, including the Arctic; however, there will be a need to operate with partners.
- To secure funding for the next icebreaker, it is necessary to obtain a national consensus on the need; the discussion to vet the policy requirements is just commencing in USCG and is one of the major issues for USCG; then, a mission analysis is needed to determine the number of icebreakers needed; there is no likelihood of the U.S. using nuclear icebreakers.
- USCG will expand in Anchorage to support westward expansion of Bering Sea fisheries but otherwise there are no plans to increase shore-side operations in Alaska.

D - Rethinking America's Maritime Strategy - VADM John G. Morgan, USN, Deputy Chief of Naval Operations

Summary

- Basis of U.S. existence is sea power; a major strategy initiative was undertaken to understand its importance to the U.S. and to develop a new Maritime strategy; included academic pursuit, economic discussion and public conversation.
- Report will not be published for some months but initial findings are:
    - There is a new global system with new players; it is a fluid system - not bi-polar, with nation states and non-state actors coming and going.
    - There is no existential enemy.
    - There is new competition and an accelerating need for resources.
    - There are new rules of game but little experience.
    - There are new challenges and dangers but also new opportunities.
    - There are new organizing principles e.g. the thousand ship navy – and a more holistic look at how sea power affects everybody – not just the U.S.
    - There are new social and environmental factors to consider.
- The goal is stability and prosperity of global system.
- U.S. must go beyond just joint operations to interagency and combined efforts.

- New objective is to prevent war - not win it; and if that is not possible, then limit and localize war.
- Global interests must be considered.
- How will climate change affect American sea power?

Discussion

- Maritime strategy will be compatible with other government initiatives.
- Quality and depth of thinking and the substance of the work will convince policy makers of the need to adopt a new maritime strategy.
- Condition of the merchant fleet is deteriorating – Navy is concerned but there is no easy solution – one major conclusion is that sea power is at the heart of the U.S. - if the nation has to re-think its policies to maintain that sea power, then the discussion must be held.
- Mechanisms for joint operations in the Arctic do not currently exist; they need to be developed.
- USN funding for Arctic research has declined as priorities shifted – the new maritime strategy will guide new budgets which will determine what investments must be made, e.g. should less risk be taken in the Arctic in relation to other areas?
- Cooperative security must arise from each circumpolar state understanding how their own self-interest is enhanced through cooperation.
- Major impact of climate change in the short term relates to the urbanization of the world – a trend that is not going to reverse and which makes populations more vulnerable to changes in climate; climate change led to the conflict in Darfur and will likely lead to other conflicts; there will be winners and losers which sets the stage for conflict.
- In the past, the Arctic has always been set aside or considered secondarily; the fact that senior naval decision makers are engaged in this discussion now, improves the likelihood that future strategic decisions will consider the Arctic.
- Everyone in military is in agreement that it is essential that the U.S. sign UNCLOS; the rule of law in the seas is in the best national interest.

E - NOAA Arctic Challenges – Mr. Scott Rayder, Chief of Staff, NOAA

Summary

- Partnerships are important particularly for long term climate monitoring to climate change research.
- Bering Sea fishery contributes half of total U.S. fishery – what will happen to it as the Sea warms? – science will be the guide.
- NOAA is contributing $30M to IPY – including $308K for unmanned aircraft systems to collect data over the North Pole.
- Integrated earth observations through GEO – an EKG system for the earth which includes the Arctic.
- The concept of inclusive leadership should be adopted.

F - U.S. Policy Statement on Arctic Sea Ice Change and its Impacts – Dr. Susan Hayes, WHOSTP

Summary

- Canada's recent talk of exercising sovereignty over NW Passage is a very important strategic consideration for both the U.S. and Canada.
- The White House is very comfortable that IPCC AR4 conclusions reflect the best science - warming of the climate system is unequivocal and most of the warming in the last 50 years is *very likely* (>90%) due to human caused greenhouse gas emissions.
- It was noted that estimates for sea level rise in AR4 are under-estimates because models used are out of date and ice is melting faster than predicted.
- Impacts are happening now – there are lots of examples of impacts evident in ecosystems.
- Impacts increase with increasing temperature.
- Not all impacts will be bad – there may be some benefits; but only for lower amounts of temperature increases; at high temperature increase, impacts are all negative.
- Negative impacts will be greater in some regions than others.
- There is a clear need for more research to understand why sea ice is breaking up faster than expected – what are the processes involved?
- U.S. is very expert at physical impacts of climate change but not so good at the social or economic impacts.

G - U.S. Arctic Research Goals with an Accessible Arctic Ocean - Hon. Mead Treadwell, Chair, USARC

Summary

- Concerns of Alaska natives
  - Unregulated and unmonitored ship traffic will negatively impact animal species.
  - Neither the USCG nor the USN have the capability to currently undertake Search & Rescue operations off the coast of Alaska.
  - Climate change will eradicate animal species and no one is taking action to mitigate the effects of climate change.
- Five key research goals in USARC recommendations
  - Environmental change of the Arctic and Bering Seas
  - Arctic human health
  - Civil infrastructure
  - Natural resource assessment & earth science
  - Indigenous language, identity and culture
- The AON is a prime legacy of IPY.
- The USARC has the role to keep Arctic issues in front of policy makers.
- Institute of the North – shuttle study for Adak-Iceland findings
  - Improved technology and globalization are contributing to Arctic navigation increase as well as reducing ice.
  - Adak-Iceland shuttle could be competitive with Suez for a 750 TEU ship and 3-5 times cheaper for a 5,000 TEU ship.
- U.S. should lead the way in ensuring that Arctic seas are safe for all Infrastructure needs must be met, including ice and weather forecasting.
- The Bering Strait and NW Passage must remain international waters for security reasons.

II. Day 1 Technical Presentations Summary Points and Discussions

A - U.S. National/Naval Ice Center (NIC) Support to Naval and Maritime Operations - CDR Raymond E. Chartier, Director and Commanding Officer, NIC

Summary

- U.S. is working in the Arctic now – it is not just a future consideration.
- The National Ice Center (NIC) is partnership of USCG, Navy and NOAA.
- NIC international partnerships include the North American Ice Service (NAIS), the International Arctic Buoy Programme (IABP), and the International Ice Charting Working Group (IICWG).
- 600,000 images input – 13,000 products distributed – 117,000 hits on web page last year – products have multiple uses.
- An experimental sea ice thickness proxy chart is being produced.
- March 2004 – March 2005 area of MY ice the size of Texas melted out; what is next?

Discussion

- 2006 and 2007 March minimums continued the same trend to decreasing multi-year ice with an even larger change; change 2004-2005 was 12.5%; change 2005-2006 was 23%.

B - Ice in the Canadian Arctic - Canadian Ice Service (CIS) Perspective on the Future, or, What's Really Happening to Arctic Sea Ice – Mr. Douglas Bancroft, Director, CIS

Summary

- About 100 ships per year operate in the Canadian Arctic – but they go in and out, not through; there are only about 6 transits a year - almost all of which are Canadian Coast Guard (CCG) icebreakers.
- Ice moving into Canadian Arctic Archipelago from the Arctic Ocean will continue to affect shipping in the Archipelago and the Northwest Passage (NWP).
- There are general decreases in the amount of ice but there is also extreme inter-annual variability.
- Expectation is that the Northern Sea Route (NSR) will be accessible to commercial shipping first, the transpolar route next and the NWP last.

- The real drivers for increased shipping in Canada's Arctic will be economic – not environmental.
- There has been a significant, continuing decrease in the extent of sea ice in the North and the Canadian Arctic.
- "Shipping season" in the Canadian Arctic will lengthen by 3-4 months by the end of the century.
- There will continue to be extreme inter-annual variability in ice conditions.
- Still considerable uncertainty when ice conditions in the NWP will permit regular passages.
- The Russian NSR will be the first to open.
- There will be unanticipated impacts.
- As today, most of future shipping in Canada's Arctic will be destination not transit trips.
- Ice regime in Hudson Bay could approximate current Gulf of St Lawrence conditions by mid-century – Port of Churchill could benefit.
- Shipping will increase in Canada's Arctic in support of development of non-renewable resources.
- Multi-year ice and inter-annual variability will continue to challenge shipping in Canada's Arctic.

C - From 2001 to 2007: What we Learned and What We've Done - Dr. Richard W. Spinrad, NOAA Assistant Administrator for Oceanic and Atmospheric Research

Summary

- Results of 2001 symposium were overtaken by events – higher priorities became paramount – however early trends were detected.
- Key policy issues from 2001
  - USN and USCG will need alliances.
  - There is a need to deal with passage disputes and internal waters issue with Canada.
- Science needs – satellite observations; monitoring and modeling; high resolution bathymetry; land and ocean-ice weather platforms and stations; improved environmental sensors; reliable Arctic climate change predictions.
- Since 2001, we now have :
  - More observations of the changing state of sea ice
  - New knowledge of the fate of sea ice and its age structure
  - New insight on the role of the Arctic Oscillation (AO) on the Arctic
  - Information on changes in ice mass balance

  - Observed warming of the Arctic Ocean
  - Comparisons of model projections and observed sea ice decline
  - Improved representation of sea ice in global GCMs – higher resolution, more realistic dynamics
- Knowledge of spatial differentiation in reduction of sea ice is important.
- Sea ice is decreasing faster than predictions – why?
- Fish stocks have been seen further north than ever before in the Chukchi Sea – are there other changes that are happening that we have not yet observed?
- Mission drivers for 2007:
  - Increased economic activity
  - Increased law enforcement / security
  - Improving documentation of native perspectives on sea ice – increased credence given to native knowledge
- International science partnerships are critical – there must be government involvement and there must be regional associations – Arctic Global Ocean Observing System (GOOS).

Discussion

- To overcome U.S. regulatory roadblocks, the potential use of unmanned aerial vehicles need proper planning - early, high level engagement with authorities.
- Ratification of UNCLOS is critical to the Bush Administration – for resource management, security and enforcement reasons; responsibility of the Senate to do it.
- U.S. satellite network is important to the AON and to climate observations at high latitude; NPOES is under budgetary review – it is important to look at alternatives as well such as UAVs, underwater vehicles, etc.; climate monitoring must be continuous and cannot suffer interruptions.
- Trend for funding of observational capabilities has not increased dramatically – perhaps it has declined slightly (but difficult to determine what all is included).

D - National Security and the Threat of Climate Change - CDR Sean C. Maybee, Federal Executive Fellow, Center for Naval Analysis

Summary

- Climate change is a threat to national security with impacts related to:
  - Water – flood and drought
  - Food
  - Disease

- Weather
- Climate change will pose threats even in stable reasons – mass migration of people.
- There is a Climate, Security and Energy overlap.
- There are different regional impacts:
  - Greatest impact is in Africa – weakened governance, economic collapse – need for U.S. to intervene for humanitarian reasons.
  - In Middle East, the greatest threat is shortage of water.
  - In Asia, the greatest threat is inundation – 40% of Asia's 4 billion people live near coast.
  - In the Western Hemisphere, coastal areas are vulnerable to sea level rise coupled with more hurricanes; water shortage in South America due decreased glacier runoff.
  - An Arctic with less sea ice could lead to greater competition for resources, increase human presence , and associated impacts.
- Ice free arctic increases scope of naval operations but navy has little capacity to operate there,
- The recently published Center for Naval Analysis (CAN) report on National Security and the Threat of Climate Change has been widely covered in the media and has received significant attention in Congress.
- A significant statement was made in the report by General Anthony C. "Tony" Zinni (Ret.) - "We will pay for this one way or another. We will pay to reduce greenhouse gas emissions today and we'll take an economic hit of some kind. Or, we will pay the price later in military terms and that will involve human lives. There will be a human toll."

E - A NASA Look from Space at Changes in the Arctic - Dr. Seelye Martin

Summary

- ICESat operates two months a year since 2003 to get ice thickness – the Geoscience Laser Altimeter System (GLAS) is the main instrument.
- The National Snow and Ice Data Center (NSIDC) and University of Washington Applied Physics Laboratory Polar Science Center (APL/PSC) have used Lagrangian drift tracking techniques to show that thickest ice is pushed toward Canadian Arctic Archipelago.
- Between 1983 to 2006 NSIDC found 41% loss of multiyear ice (MYI) in spring.
- Oldest thickest ice is confined to a much smaller portion of the Arctic Ocean – decrease in volume is greater than the apparent decrease in extent because of shift from MYI to first-year ice (FYI).

F - Research to Support Naval Operations in Arctic – CDR Douglas Marble, Office of Naval Research

Summary

- The Office of Naval Research (ONR) still has an interest in high latitudes that is aligned under the physical oceanography program – even though it is lower than previously.
- Research questions remain relating acoustics, navigation, global ocean circulation, climate, biology, natural resources.
- Foreign policy changes are also important factors for future consideration.

Discussion

- Not aware of North Atlantic Treaty Organization (NATO) engagement on potential changes to Global Thermohaline Circulation – ONR is primarily focused on the Western Pacific.
- Consideration of underwater navigation network and unmanned vehicles under ice would likely be a hard sell in the current environment.

G - UNCLOS and the Need and Opportunity for Mapping of the U.S. Arctic Bathymetry – Mr. George Newton, Advisor, USARC

Summary

- There is unequivocal support to U.S. accession to UNCLOS – one of the most important things the U.S. could do for the future.
- We are witnessing a tremendous opportunity that can only be exploited through the great concern and respect we have for the environment; this is a big challenge – it is not easy to build a military that is capable in the Arctic and that takes care of the environment at the same time.
- Less than 10% of the world ocean's bottom have ever been directly measured (for public release).
- Arctic bathymetry is primarily based on submarine data – 300,000 track miles; some multi-beam.
- Less quantity and quality of data in the Arctic Ocean than in temperate waters.
- The General Bathymetric Chart of the Oceans (GEBCO) for the Arctic is pretty and convincing although less than 10% has been directly measured.
- Claims for the extension of the continental shelf are made under UNCLOS Article 76.

- There has been a concern that UNCLOS may inhibit international ocean research – bottom and sub-bottom research cannot be conducted without the agreement of the coastal state.
- Ratification of UNCLOS also brings some other considerations:
    - More maritime hazards – research moorings, other unknowns (oil drilling, autonomous underwater vehicles (AUVs), seamounts)
    - Notices to mariners (currently have an unofficial system; proposal to create new Arctic NAVAREAs)
    - Ice forecasting is critical – needs will grow with activity; near real-time information will be critical)
    - Safety and Casualty response (emergency liaison centralized – manned and funded internationally); if there is a major incident in the Arctic, everyone loses
    - National rules for (mainly) ice covered areas (Article 234)
- A lot to do – there must be infrastructure to support activity in the Arctic.

Discussion

- Article 234 states that nations may develop rules to protect their mainly ice-covered seas – these can be rules for ice-class, ice-navigation etc. that will be national – not international.
- There is an International Maritime Organization (IMO) guide for polar navigation but is not mandatory.
- To solve the access to oceans for research, the most likely approach is diplomacy and cooperation between countries – there is a need to develop a common code for research activities (at least).

III. Day 2 Technical Presentations Summary Points and Discussions

A - NOAA Arctic Research, or, NOAA Plans for Arctic Sea Ice Studies – Dr. John Calder, NOAA Climate Program Office

Summary

- NOAA contributes to AON with:
  - Ice mass balance and IABP buoy programs – to provide long term ice thickness trends and improve understanding of factors controlling ice thickness.
  - Atmospheric Observations at 6 circumpolar locations under development.
  - Remote sensing by unmanned aerial vehicles (UAVs) can provide detail greater than satellites and cover larger areas than in situ – NOAA and partners are evaluating their use.
  - Support for NIC U.S. Interagency Buoy Program (USIABP)
- It also supports research on physical variability and ecological response to a reduced sea ice in Bering, Chukchi, and Beaufort marine ecosystems and coastal areas.
- Other key areas of involvement include improving sea ice dynamics in GCMs, data analysis and data dissemination.

Discussion

- There is no cost estimate for UAV operation but it is expected to be expensive – will try to partner with DOD to share costs.
- There is an on-going research program at the seasonal time scale to fill the gap between the weather scale and the global climate scale – seasonal scale predictions are of great advantage to people.

B - The State of the Arctic Report – Dr. Jacqueline Richter-Menge, CRREL

Summary

- A consensus review by team of 26 international scientists – highlighting Arctic data from 2000 to 2005 – updates some of the records from the ACIA provides a few selected observations with relatively high confidence and repeatability.
- There is convincing evidence of sustained period of warming temperature.
-

- There are shifts in spatial patterns of land temperatures and ocean salinity and temp – moving towards climate norms – increased spatial extent of variability.
- A new Arctic report card provides an annual update and expansion of content.
- 2005 was record minimum ice extent – 2006 almost as low – the appearance of a Beaufort Sea polynya was unusual.
- Maximum ice extent in winter 2006 was a record minimum – 2007 not quite as small but still small.
- NSIDC reported a decline in maximum ice extent is 2.5% per decade; decline in minimum ice extent is 8.9% per decade.
- Sea ice cover is the great integrator of solar radiation and ocean heat flux, of wind and ocean stresses – reflects impacts of atmospheric and oceanic forcing.
- When AO is negative – colder winter temps, strong Beaufort Gyre increases resident time for ice – "ice wins".
- When AO is positive – warmer winter temps; Transpolar Drift Stream sweeps ice out of Arctic Ocean – "ice loses".
- AO positive in 1990's – neutral since then which is neither good nor bad for ice – why has there been continued decrease in extent?
    - Sea ice age is very dependent on circulation pattern – older ice thicker and more robust – from 1987 to 2006 there has been a loss of old ice – precipitous drop in amount of old ice 1989-1990 – there was a great flushing of ice through Fram Strait – the Arctic Ocean has since had more young ice that cannot survive the summer melt as easily.
- Ice albedo feedback enhances the ice edge retreat.
- Confluence of events – rising global temp + strong and persistent positive AO + ice albedo feedback.
- Is this a persistent trend or is it a temporary variation? IPY is coming at a good time to help answer this question.

Discussion

- Cloud cover affects increasing albedo a lot – clouds basically act like a blanket to warm the ice.
- Audience for this report goes beyond the scientific community – policy makers as well.

C - IPCC Arctic Climate and Sea Ice Projections – Dr. James Overland, NMFS

Summary

- A key change in IPCC Fourth Assessment Report (4AR) is that 22 GCMs results were made widely available – over 400 groups examined the raw output data.
- GCMs have been improving steadily over the IPCC lifetime.
- Still, we do not have to have perfect reproduction of observations to accept that models can provide reasonable representations of the climate.
- Differing anthropogenic forcing scenarios were used – important to note that at 2050 there is little difference in models because of the lag - but by this time most uncertainty comes from the models themselves, not the forcing scenarios.
- Cloud feedbacks are the primary source of differences between models.
- Ensemble of models run with CO2 very closely simulate 20th century global temperature – impossible to do so without CO2 in the models; convincing evidence for the human causes for warming.
- Temperature changes are likely on the order of 30 years – drought and sea ice loss; sea level rise is more like a 100 year issue.
- Regional sea ice forecasts show some surprises – there is little ice loss predicted in Baffin-Labrador but there is a large interannual variability; small ice loss East Greenland.
- Model to model variability – fractional ice area in 2050 relative to 1990
    - Beaufort Sea 7 of 11 lose more than 40% of ice – summer
    - Bering Sea 5 of 7 models lose more than 40% in winter
    - Holland model is on extreme of losing ice compared to other models
- We will still have very large natural variability – AO more volatile now than all through the 20th century –we are not familiar with this new regime.
- Greater than 40% ice loss in summer Arctic seas and winter marginal seas is expected by 2050 – except Baffin Bay.
- A 3º C temperature increase by 2050 in Arctic is also shown by the GMCs.
- We must consider large natural variability in near term climate projections - <20 years.

Discussion

- Anomalous result in Baffin Bay may be due to deep ocean mixing or change in storm tracks.

- Not a large change in temperature patterns in fall vs. spring – models want to warm things up in fall while real world temperatures increase in spring.
- Models do consider changes in solar radiation - it is pretty well accepted that these changes are an order of magnitude smaller than the CO2 effect.
- Models are good at simulating thermodynamic processes but do not do so well at complex dynamic effects; this is one reason why the first 20-year period is relatively unpredictable – after that heat storage effects outweigh dynamic effects so longer term predictions are more valid.

D - Arctic Marine Shipping Assessment (AMSA) Responding to Changing Marine Access - Dr. Lawson Brigham, USARC and Chair, AMSA

Summary

- The Arctic Council initiated AMSA to be conducted under guidance of U.S., Canada and Finland as lead countries; Completion targeted for spring 2009.
- Two documents precede and guide AMSA
  - ACIA - is most widely distributed and read report on the Arctic
  - Arctic Marine Strategic Plan
- AMSA interest is circumpolar and has regional and local focus.
- Draft chapter outline
  - Introduction & Geography
  - History of Arctic Marine Transport & Governance
  - Current (2004) Levels of Arctic Marine Use *(Data Survey)*
  - Indigenous Arctic Ocean Use *(Town Hall Meetings)*
  - Scenarios of Future Arctic Marine Activity ~ 2020/2050 *(Scenario Workshops ~ San Francisco and Helsinki)*
  - Environmental Impacts ~ Current /Future Marine Activity
  - Social & Economic Impacts ~ Current/Future Marine Activity
  - Arctic Marine Infrastructure & Anticipated Needs
  - Findings of the Assessment (to the Arctic States & International Maritime Community)
  - Appendices, Research Agenda
- Shipping is arguably the largest commercial activity in world; we don't really know how many ships are in the Arctic Ocean – AMSA is the first comprehensive survey to determine this – will make a snapshot of Arctic shipping in 2004.
- Tourism in Arctic raises concerns for Search & Rescue of large numbers of people in accessible areas.

- Norilsk Nickel's *Arctic Express* represents the future of arctic shipping – ice capable ships not requiring icebreaker escort.
- Bering Strait is a natural choke point – all trans-Arctic voyages must go through abutting Exclusive Economic Zones (EEZs) of the U.S. and Russia.
- Plenty of winter ice will remain in the future.
- High interannual variability drives insurance and ship costs up – big reason that NWP will not be the best option for ocean to ocean transportation.
- The NSR was kept open during Soviet era by a fleet of nuclear icebreakers in order to preserve economic independence of country.
- Ships have reached all areas of the Arctic Ocean in summer – only one has reached North Pole in winter.
- Scenarios for future 2050
  - Governance and resources/trade are major drivers; climate change is a filter; must consider commodity prices
  - Wild cards – multiple use (whaling and shipping); ship emissions impact on low level ozone
- Potential AMSA findings
  - Primary Driver - Regional & Global Natural Resource Development
  - Lack of Integrated Governance-Regulatory Framework
  - Continued Sea Ice Retreat ~ Increased Access
  - Winter Arctic Sea Ice Cover Remains
  - New Ship Technologies ~ Allow Greater Access & Independent Operations (No Convoys)
  - Global Maritime Industry ~ Key Stakeholders
  - Minimal Arctic Infrastructure to Support Expanded Marine Activity
  - Sectors: Oil & Gas, Hard Minerals, Tourism & Fishing, Timber & Water (Future?)
  - Greatly Enhanced Monitoring Required
  - Intense Development ~ NW Russia & Norwegian-Barents-Kara Seas
  - Balance Freedom of Navigation with Coastal State Marine Safety & Environmental Protection Interests
  - Lack of Experienced Mariners

E - Arctic Change and the Future of the U.S. Icebreaking Fleet – CDR Tom Wojahn, Manager USCG Ice Operations Program

Summary

- *Polar Sea*, *Polar Star* and *Healy* are the only U.S. surface assets capable of supporting U.S. missions in the polar seas.

- Long history of USCG polar icebreaker operations through changing priorities.
- From 1885 to present: discovery – enforcement – security – research future trend – safety/security/stewardship.
- Polar Class – 1971 appropriations – *SS Manhattan* voyage as proof of concept to transport crude oil through NWP – 1970's oil shortage in U.S.
- Polar icebreaker needs
  - Strategic national security – primary mission
  - Direct mission tasking – polar research, logistics re-supply
  - Contingency tasking – readiness missions – homeland security, enforce laws and treaties, etc.
- Cooperation with CCG for Thule re-supply since 1993 – USCG responsibility delivered through cooperative agreement.
- Changes in U.S. (in 10-15 year horizon)
  - Arctic sea ice changes
  - UNCLOS
  - Increased resource exploration and exploitation
  - 9/11 attacks & focus on homeland security
  - Hurricanes Katrina and Rita – prevention and response focus
- Why is a maritime presence needed in the Arctic?
  - Projecting power – large areas could be in dispute in Arctic.
  - Even with less ice, icebreakers are still needed – Arctic sea ice will be more dynamic; operations may be necessary in winter sea ice.
  - Changing maritime shipping patterns have a focus on the Arctic; Capacity to move cargo between Asia and west coast of U.S. is at maximum – companies looking at ways to get to the U.S. east coast – Arctic routes become more important.
- Future U.S. Arctic Mission needs:
  - Energy security
  - U.S. Sovereignty (security) – maritime presence to reinforce U.S. jurisdictional claims
  - Defense and homeland security readiness
  - Global mobility
  - Safeguarding our oceans and resources
  - Polar research support
- Why is the USCG in the Arctic?
  - U.S. is an Arctic nation and Arctic is primarily a maritime domain – needs a maritime national surface presence.
  - USCG has broad responsibilities and with its multi-mission capabilities can enforce all aspects of U.S. sovereignty.

Discussion

- USCG has provided commercial escort in Arctic in the past for the *SS Manhattan* voyage but has not done so since - supporting commerce outside of the Great Lakes is not in the statutory mission of the USCG.
- Maritime issues in the Arctic are broader than USCG can handle alone and a discussion has commenced with USN to become closer aligned.

F - The Impact of Arctic Climate Change on Canadian Icebreaking and Marine Transportation – Mr. David Jackson, Manager, CG Icebreaking Division

Summary

- Support to commercial transportation is in the CCG mandate.
- Oceans Act, Canada Shipping Act, Arctic Waters Pollution Prevention Act provide the legislative basis.
- CCG supports many Arctic programs but has no formal security role – does provide platforms for others with security responsibilities.
- CCG has 1 heavy, 4 medium and 1 light icebreaker plus 1 icebreaker dedicated to science and several smaller vessels.
- Shipping Safety Control Zones are still in effect although slightly out of date; Arctic Ice Regime Shipping System is a replacement.
- In 2004, there were 107 voyages by 61 different vessels in the Canadian Arctic.
- Resource extraction is increasing; tourism is increasing; northern activity requiring increased import of materials is increasing.
- Lengthening of the navigation season is already presenting a capacity problem for CCG; impacts support to southern ice escort operations in Eastern Canada.
- Drivers for CCG activities
    - Need to replace aging icebreaker fleet
    - Need for improved Arctic marine charts and aids to navigation
    - Improved Arctic port infrastructure – fuel, water, supplies, repair
    - Improved monitoring of marine traffic
    - Increased traffic = increased risks
    - Resolution of disputed boundary areas
    - UNCLOS ratification – have until 2013 to delineate claim
    - Research and Development (R&D) – improved ice information systems, improved detection if hazardous ice by marine radar
    - Heavy participation in IPY over next 2 years
- Outlook for the Future:

- Arctic shipping is currently at a steady state – future increase will be gradual yet continuous.
- Most shipping will be north-south for resource extraction and re-supply.
- There will be a steady increase in cruise traffic.
- Interannual variability will persist - CCG has seen very heavy ice years in the NWP and Canadian Archipelago.
- NWP transits are not common – although adventurers are increasing.
- Shipping will continue to be driven y local supply demands as well as global resource markets.
- Commercial economic activity is encouraged.
- Inclusion of local populations and organization is encouraged and provides an indispensable resource.

Discussion

- *Louis S. St. Laurent* was built in 1969 and refitted in ; has 30,000 HP; due for replacement between 2015 and 2025.
- CCG icebreakers do not operate in Arctic past mid November.
- Recent announcement of Arctic/Offshore Patrol Ships by the Canadian Navy – some icebreaking capability (1.2 meters of first year ice with some multiyear ice inclusions) but conventional hull form to provide good open ocean sea-keeping.
- Canada does not collect user fees in the Arctic as a conscious political decision; however, icebreaking fees in southern Canada are collected whenever a commercial ship is in a control zone; fees are designed to reflect the cost of the CCG program – not just icebreaker escort.
- Canada encourages carriage of ice pilots in the Arctic but it is not mandatory – most ships do so for insurance reasons.
- There are no charges for Search & Rescue operation in the high Arctic and no plan to do so.
- There will certainly be an increase in marine traffic if the Mackenzie Valley pipeline project goes ahead.

G - A New Generation Polar Research Vessel – Mr. Richard Voelker, Maritime Administration, DOT (retired)

Summary

- There is no unified approach to Arctic research vessels – mix of government commercial, academia; multi-missions including science.
- The vessel is a dedicated research platform with polar icebreaking capability.

- *Nathaniel B. Palmer* is a current vessel commissioned in 1992; can break 0.9 m of ice, has 60 day endurance and a full complement of science labs – very successful operating mainly in the Antarctic region.
- Requirements for the next generation research vessel:
  - Enhanced icebreaking capability – intended to operate in 90% of the sea ice environment found around Antarctica; break 1.4 metres of ice at 3 kts
  - Endurance 80 days
  - Accommodations for 50
  - Moon pool
  - Ability to tow nets
  - Acoustically quiet to improve scientific sampling
  - Capability to operate AUV/ROV (Remotely Operated Vehicle)
  - Jumbo piston coring (50m)
  - Compliance with IMO Arctic guidelines
  - Reduced air emission
  - Etc.
- Designed for 40 year life to allow for refit without tearing ship apart.
- Desired operating profile – 265 days away from port; 65 days for maintenance per year.
- Goal to reduce greenhouse emissions by 90% - new generation of diesel. engines is coming that will provide very significant reductions in emissions
- Of all the requirements, the need to enhance icebreaking capability is by far the most expensive to meet; other requirements are almost insignificant above base ship cost.
- Eight year project life including 4 years for ship construction, 2 years for pre-RFP development and one year for bidding evaluation and contract.
- Icebreaking research ship build duration – ARRV (Alaska Region Research Vessel) duration is 17 years (2011-2013); 15 years to replace polar class (2022-2024); Antarctic ship (commercial lease back to NSF) 11 years (2015-2017).
- *Healy* probably cannot operate north of Bering Strait in winter; Polar Class icebreakers will not be available for Arctic in winter.
- These vessels require a high skill level of personnel for ice piloting and ice navigation.

IV. Day 3 Technical Presentations Summary Points and Discussions

A - Sea ice Changes Affecting Alaskan Coastal Communities, Marine Ecosystems and Offshore Transportation, Dr. John Walsh, UAF Alaska Center for Climate Assessment & Policy

Summary

- Coastal ice in southern Beaufort Sea has been analyzed.
  - Polynyas and flaw leads are wind driven during winter; ice melts back from the coast in early summer.
  - No change in the concentration of ice along the coast over past several years
  - No change in ice thickness
  - A lot of year to year variability
- Largest warming in globe is over Alaska – onset of freeze-up delayed by 2-3 weeks, onset of melt delayed by 1-2 weeks, in past 50 years.
- Local observations and traditional knowledge indicate a less stable coastal ice cover which has impacts on travel over the ice and the harvest of marine mammals; mid-winter ice “breakouts” (fast ice floes breaking off) have increased in recent years.
- Barnett Sea Ice Severity Index shows less severe ice conditions since 2002 but not unprecedented (1958 and 1968 were easy); also notable is 1975 which was very severe.
- Storm frequencies are increasing in recent years in Alaska – coinciding with ice retreat.
- Largest projected changes in sea level are in Beaufort Sea due to thermal expansion.
- Severe coastal erosion, coastal floods – Alaska and Siberia are especially vulnerable because of low flat terrain.
- Mean sea ice edge has shifted northward; sea surface temperatures rising in Bering Strait; fish species shifting northward.
- IPCC Models predict little winter ice retreat in Bering/Chukchi but summer ice edge retreats to 80° N.
- Projected changes - thinner winter sea ice – more dynamically active sea ice during winter.

Discussion

- There is no scientific work going on to measure bottom scour – which one would expect based on the observations above.
- Upwelling in this region could cause large releases of methane – wild card in climate change projections.

- If there is thinner ice offshore, there could be different effects on ice thickness near the coast due to increased rafting and ridging.
- "Gut" feeling is that the IPCC models are much too conservative in clearing ice – Walsh.
- Main implication of this on the oil industry is the much longer access window for re-supply; greater access could also increase infrastructure needs along the coast because of tourists.
- Some recent anomalous seismic events offshore of Alaska that could have been methane "explosions".
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B - NSF Role in Support of Science in a Changing Arctic – Simon Stephenson, Division of Arctic Sciences, NSF

Summary

- Must look at Arctic climate system in a global context – must strengthen Arctic modeling in the context of improved global modeling.
- Surface Heat Budget of the Arctic (SHEBA) – Energy balance of the Arctic
- Fresh Water Initiative – Fate and changes of fresh water in the Arctic Ocean
- Bering Sea Ecosystem Study (BEST) – Climate change effects on the marine ecosystems of the Bering Sea
- Coupled human & sea ice system – changes in ecosystems at scales relevant to coastal inhabitants
- 1988-1990 Surge – Purge of Thick Old Sea Ice out of Arctic – Pfirmann et al.
- If we seriously going to take on role of a maritime mission, NSF would like to play; can make the case that there is a naval, economic and commercial benefit to Arctic research – NSF would like to be a supporter of this – not likely a leader.
- We need a multi-agency approach to undertaking studies in the Arctic.

Discussion

- Navy seems to be opening the door for partners and other agencies to partner in science and operations; as partnerships start to develop, synergies will quickly develop.
- Rather than a single agency leading the process, need a inter-agency group to bring everyone together.
- Office of Polar Programs can help with logistics that follow science projects but have not built an infrastructure in the Arctic to host research

(except Summit, Greenland); work with USCG to fund projects with *Healy*; look for a better idea of where we are going next.

- To get policy makers on board, must show the right kind of information to the right people – information on effects on people gets policy makers' attention most often.

C - The Development of a U.S. Arctic Observing Network (AON) and its Integration with International Observing Systems – Dr. Martin O. Jeffries, AON Program Director, NSF

Summary

- AON is an important initiative of the IPY.
- Change is occurring throughout the Arctic system – glaciers, greenness, boreal forest, permafrost, Eurasian rivers discharge increased, heat flux of Pacific water increased, salinity of surface layer of Beaufort Gyre has decreased;
  - The Arctic is changing rapidly and we are not well prepared to monitor these changes.
  - The Arctic is affected by the rest of the globe and every indication is that it affects the rest of the globe.
  - Changes in the Arctic are affecting the people who live there; e.g. coastal villages are in danger from erosion due to decreased ice – estimate to re-locate the Nome village of Shishmaref is $200M.
- Consensus for an AON has been built using IPY as launching springboard.
- AON is one of the 3 main pillars of the Study of Environmental Arctic Change (SEARCH) – to observe and record the full suite of changes in the Arctic system.
- AON includes operational observing, research observing, community-based observing/traditional knowledge and data and information management.

Discussion

- There is a significant gap in observing systems on the Eurasian side of the Arctic Ocean – there are technical issues related to the lack of MYI (to locate instruments) - also there are geo-political issues that need to be resolved.

D - Oil and Gas Exploration, Production and Transportation in the Arctic – Peter Noble, ConocoPhillips

Summary

- Arctic activity for oil and gas development is expanding after a hiatus of 20 years.
- Beaufort and Chukchi, North Slope of Alaska, Canadian Beaufort, Canadian Arctic Archipelago, Norwegian and Russian Barents Seas, Timan-Pechora and Kara Seas; subarctic Sakhalin and Caspian Sea
- Arctic navigation is not all about ice – must also consider cold weather, total darkness, rough water, severe storms.
- Industry tries to balance the cost of a decision with the benefits; the Alaska pipeline turned out to be 2.5 times more costly than estimated – it may have been the wrong decision – tanker export as proven by the *SS Manhattan* may been less costly.
- Oil and gas industry designs total systems – not individual ships e.g. Varandey oil export system includes on-shore storage + conical offshore transfer structure + icebreaking shuttle tankers + open ocean storage + open ocean tankers.
- The industry needs reliable year-round simulation because it is very expensive to store product; use models to simulate the system.
- ConocoPhillips is building 3 icebreaking tankers to break 1.7 m of ice continuously – pod tractor drives but not double-acting - $150M each additional icebreaking support vessel - Korean Arctic tanker construction – keel-laying to launch is 9 weeks.
- Snohvit LNG off Hammerfest will come on stream before end of year – gas brought from offshore island by pipeline, liquefied and loaded to tankers – no ice but Arctic conditions.
- Shtokman is the world’s second largest gas field – fleet of 30 ships needed; not icebreakers but prepared for cold weather and extremely harsh environment.
- Arctic Naval Architecture Challenges:
    - Design the right ships before designing the ships right – total system design
    - Ships and offshore structures must have good performance in ice and open water - Make ice-worthy ships that are also sea-worthy
    - Must be efficient, reliable, cost-effective and environmentally sound
    - May not have much infrastructure support e.g. bunker ports, dry-dock) - must be self-sufficient
    - High deadweight ton (dwt) capacity but shallow draft
    - High powered but fuel efficient
    - Navigation and communications systems are challenged in Arctic.

- Crew habitability and working conditions in regions of total darkness, extreme cold, high noise, etc must be accommodated.

Discussion

- Tractor pods act in both directions – with props astern of pod – wash ice along the side to lubricate the hull; ahead of pod, props mill through thick ice.
- Biggest reason for cost over-runs is schedule slip – in the Arctic, few weeks delay can mean entire year delay – cost over-runs are usually huge.
- It may be possible to use the third Varandey tanker for a NW Passage demo voyage on way from Korea to Russia – although it would have to an economic venture.
- All of the Russian oil and gas production is going to the U.S. - mainly to west coast refineries of ConocoPhillips; there no markets in Asia (Editor's Note – I think Mr. Noble may have only been referring to his company and that it is ConocoPhillips that does not market to Asia).

E - Effects of Arctic Change on Energy Exploration and Exploitation – John Goll, Regional Director Alaska, U.S. Minerals Management Service

Summary

- U.S. Arctic oil & gas - 3500 wells active on North Slope – production offshore is mostly by Extended Reach Drilling; in last 10 years, only 1 exploration well has been drilled offshore – Shell is drilling another this fall.
- Oil production in Alaska peaked in 1988 at 2M barrels – now down to about 750,000 barrels.
- Operation of trans-Alaska pipeline is problematic if volume is too low – major reason for activity now; it takes 10-20 years to bring new oil online.
- Planning sale of leases in Beaufort and Chukchi Seas + Cook Inlet where there are ice issues; Chukchi Sea oil and gas estimates are very respectable compared to other countries.
- Areas within 25 miles of Alaska coast are not available for exploration due to whale and other marine mammal migration patterns,
- Seismic surveys cannot be done with ice around; exploration drilling done from ice or gravel islands (ice islands not likely used in future because of soft ice).

- The only production outside Barrier Island is Northstar which has a buried pipeline to shore; when pipelines reach shore they are carrying warm oil – must design infrastructure to ensure it does melt permafrost.
- At Snohvit, all production will be on the ocean bottom which will likely be the future for most installations; pipelines will connect the production well-head to shore or to floating offshore storage facilities serviced by shuttle tankers.
- Developments must consider:
  - People onshore – subsistence, cultural stress, economy, new tax base
  - Marine fauna – protected species, fisheries, noise in the ocean
  - R&D to understand new technologies, impacts on environment, environmental conditions changes, oil spill contingency plans, research in spill management, detecting oil under ice (to track spills under the ice)
- In an ice-diminished Arctic:
  - Arctic nations will pursue oil & gas.
  - Offshore current cold weather technology is well adapted to warming conditions.
  - Onshore operation will change.
  - Nearshore operations will be affected.
  - Will ice be "reliable? – Variability is difficult to deal with.

Discussion

- Vessels on Grand Banks tow icebergs regularly – a concern is where to take them.
- Most current ship traffic in Beaufort is involved in bringing things in (seismic, exploration equipment, etc) – in 15-20 years, ship traffic will depend on how the oil and gas comes out – pipeline vs. ship – long way from deciding that.
- It will take a big discovery in the Chukchi before anything serious happens – will cost $10B to develop.

F - Increased need for Arctic oil spill prevention and response preparedness – Amy Merten, NOAA Office of Response and Restoration, Coastal Response Research Center

Summary

- There is a need for inter-agency collaborations to understand the spill risks and what can be done about them.
- There is not a lot of research on oil spills in ice in small amounts and the risks to ecosystems; most work has concentrated on large spills.
- Oil in Ice Program – 9 projects $7M, 3-5 years

  - Small scale offshore oil spill experiment in Canada in 2008
  - Full scale offshore oil spill experiment in Svalbard in 2009
  - Generic oil spill mitigation and response plan
- Not many techniques to deal with oil in ice:
  - Mechanical recovery – not too successful
  - In-situ burning – works when the oil will actually burn (more than 50% water emulsification prevents this)
  - Oil spill dispersants – not used much in U.S. but more common elsewhere
  - Detection and tracking of oil under ice needed
- Active involvement in international R&D will provide opportunity for increased collaborations at the field-scale assessment level.
- There is a need for comprehensive, environmental sensitivity mapping and monitoring strategy for prioritizing efforts in the Arctic.
- There is need to focus on societal consequences of increased spill risks in the Arctic.

Discussion

- There is evidence that biological processes in the Arctic do not go slower than in temperate waters.
- Communication of research to Alaska communities that may be affected is not as effective as it should be.
- It is politically impossible to conduct field releases of oil in U.S. waters; however, spill tests in Canada and Norway will be quite comparable to U.S. conditions; main disadvantage is the cost of participation in foreign experiments – limits the involvement and what can be learned.

G - The Effect of a Retreating Ice Edge on Fisheries Activities – Philip Mundy, Alaska Fisheries Science Center, NOAA

Summary

- Bering Sea fishing includes large scale industrial activity, coastal community commercial activity and subsistence fishing.
- Time and space scales for animals are small – singular events (one cold year amidst many warm ones) can have dramatic effects on animal populations.
- Distributions of many fish stocks is changing; changes are dependent on factors particular to each species.
- Sea ice drives the physics, the chemistry and the biology.
  - Early ice retreat means a late bloom and more zooplankton – favors pelagic production.

    - Late ice retreat means an early bloom and less zooplankton – favors benthic production.
    - Water temperature and wind speeds are important in determining uptake into the food chain.
    - As ice retreats, will shift from a physics-driven system to a biologically-driven system that is less stable and less predictable.
- Ocean acidification has a dramatic effect on fisheries.
- Blue king crab fishery totally failed in 1985 and has not recovered despite a ban on fishing – don't know why but may be related to acidification.

Discussion

- There are no widespread monitoring programs for ocean alkalinity to the level of detail necessary – ocean color satellite data may help.

H - The State and Future of Mammal Populations in the Beaufort Sea and Arctic Ocean – Dan James, USGS

Summary

- Walrus
    - 90% of world walrus population lives in Bering and Chukchi Seas.
    - They spend 80% of their lives in water but need land to rest and breed.
    - Males go to land after breeding; females stay with ice so they drift with food and have reduced predation – in future, will they stay with the ice into deep water or go to land to maintain contact with shallow waters?
- Polar bears
    - Top predator in Arctic marine environment; changes in polar bear population indicate problems in Arctic ecosystem.
    - Female bears travel great distances.
    - Pelagic bears stay with sea ice even if forced into deep water regions but may not have access to preferred shallow water feeding grounds.
    - In recent years, appears that female bears are having more cubs – but the cubs have a lower survival rate.
    - Archipelago bears exploit sea ice in the Canadian Arctic Archipelago but also employ sea ice free strategies, as in Hudson Bay.
    - Average date of breakup in western Hudson bay is 3 weeks earlier than 30 years ago – bears come ashore earlier and are therefore thinner.
    - Hudson Bay bear population has been declining since 1988.

Discussion

- Data on population of polar bears is now being collected in preparation for listing them as an endangered species – data needs to be analyzed before that will happen.
- Very little data on walrus populations and risks to it.

I - On a Thinning Ice – Polar Residents Face Arctic Climate Change – Igor Krupnik, Smithsonian Institution

Summary

- At the Ice Free Arctic Symposium of 2001:
    - Social scientists were not part of the discussion and would have had little to contribute (the only study was in 1965); there was no communication between sea ice researchers and social scientists.
    - There was hardly any Native "track record" to rely upon; native knowledge was seen as "anecdotal evidence".
- Since then, social science has exploded – many research projects now include indigenous knowledge - but remains much further behind physical science.
- Indigenous knowledge:
    - Is completely oral and therefore outside of the normal channel of scientific communication
    - Integrates generations of observations of sea ice at specific locations
    - Is not unlike the use of Icelandic Chronicles and Skippers' log books
    - Comprises observation, sea ice terminology, interpretation, historical record, risk assessment
- Arctic residents are very astute observers; 24/7 watching weather, ice, sea.
- Any northern village can put more experienced people on ice watch than a good-sized university.
- Hunters go on the ice year after year – listen to the elders – pass on their knowledge.
- All local observations are shared daily – unusual signals or sightings are commonly checked with other hunters and elders.
- Hunters observe ice and weather that instruments do not – e.g. tides or shore currents.
- Carefully examine bodies if animals they harvest for health and condition.
- Local dialects have 60-120 different terms for sea ice.

- Local experts are used to drastic and rapid fluctuation of ice and weather conditions; preserve records of many unusual conditions beyond individual hunter's experience.
- Elders are cautious in their predictions and reserved in their interpretation of change.
- Historical records are difficult to tap; dating relies on extraordinary events - specific points of reference (teacher's arrival, bush pilots, coast Guard ships, whale hunts, personal life stories).
- What we already know from other sources:
  - Bering Sea ice regime shift is real; Bering Sea has lost its multi-year ice.
  - Most of the ice is locally formed first year ice ("winter that is born locally").
  - Timing and patterns of fall ice formation and spring ice disintegration have changed dramatically.
  - Ice is thinning.
  - A huge restructuring of marine mammal behavior and distribution is going on due to sea ice reduction and change (e.g. fall whaling is extending to December; February whaling now very successful; spring whaling risky and frustrating due to unstable weather and ice conditions).
- What we do not know from other sources:
  - More risky and dangerous to walk on and hunt on today's ice – unanimous opinion on this.
  - Diversity of sea ice types and ice habitats has increased – not just MYI and FYI but now there is a mixture of various kinds of FYI.
  - Several ice break-up episodes may occur each winter.
  - Ice is now very unstable – it is easily broken up by winds, storms, waves, currents – storms in mid-winter breaking up ice was unheard of previously.
  - Marine mammals are avoiding many forms of unstable first year ice.
- As polar ice gets thinner, the difference between arctic residents view of the change and the shipping industry's view becomes more pronounced.
- Travel routes on ice are changing because it is too dangerous; hunting along ice leads or on drifting ice is more risky and less predictable.
- Time-honored rules for interpreting ice conditions changed after 1975-76; it is much less predictable and elders are no longer listened to because they are often wrong now.
- Coast Guard ships used to have a close contact with communities and were welcomed; now bigger ships have less communication with locals.
- Northern residents are now well educated and politically astute; they will not be passive by-standers – they want a voice in decisions and have power to wield – the rules of engagement have changed.

Discussion

- Getting scientific information back to native people can be difficult.
- The people are interested, well educated and want to know - but they don't read papers.
- If people hear the information, it then gets spread among the community.

V. Arctic Shipping and Transportation Panel Discussions

Lead: Dr. Lawson Brigham, USARC and Chair, AMSA
Panelists: Doug Bancroft, Dave Dickins, Richard Voelker, Ben Ellis, Peter Noble

AMSA Panel Discussions

- In the decades ahead, will a majority of Arctic voyages be regional (destinational) or trans-Arctic?
    - In next 10-15 years, voyages will be overwhelmingly destinational; import of supplies and building materials and export of natural resources.
    - Fees for canals are based on market demand and the same will be true for fees on Arctic routes; this will reduce the economic attractiveness of Arctic routes; Panama is committed to expand and the canals will compete aggressively.
    - Ships currently being built for Arctic operation are purpose-built - bulk ore carriers, LNG tankers; there is a huge economic penalty to use heavy ice-capable ships for long open ocean voyages – trans-shipment from ice-capable to open water ships will likely increase.
    - Barriers to trans-Arctic voyages are immense – there is a complete lack of infrastructure, Search & Rescue capability and salvage capability; reliability of schedule is the biggest risk – if a vessel docks only a few hours late it could elicit serious financial penalties – a delay of 24 hours once in a season could eliminate all of the cost savings due to a shorter route.
- Trans-polar route may become viable for specialized voyages by mid-century, e.g., transporting one-off shipments.
    - Strategic naval re-deployments could use trans-polar routes.
    - Russia will adjust fees for the NSR to compete aggressively.
    - NSR will likely be the first trans-Arctic route to be used but there is currently a debate in Russia over the need for icebreakers – Russia is not sure that commercial ships should be allowed in the NSR without an icebreaker escort regardless of their capability.
- Issues of governance, reliability, shortness of distance all fit within a regional envelope; the lack of global governance for insurance, etc. will negatively affect Arctic transportation.
- Development of Arctic shipping will be sporadic as experience is gained and risk is reduced; some government-supported demonstration voyages to show the ease or relative risk would be useful; in the past, pipelines were built, even though they may be less beneficial, just because of a perceived high risk of Arctic navigation.
- There is little concern about large, responsible companies taking risks in the Arctic – the major concern is that a rogue, rust-bucket ship attempting

to take advantage of a shorter Arctic route and causing a risk of a major pollution event.

- Upcoming lease sales that are being fast-tracked in the Beaufort and Chukchi Seas give an indication of the level of marine activity to be expected in the area.
- The search for new resources takes place in continually changing physical, economic, social and political environments.
  - Arctic is attractive because of relatively stable governments although there is uncertainty in predicting Russian stability over 10-15 years.
- Marine activity is not based on diminishing ice – it is based on economics and technological capability; if the Arctic is too expensive, industry will go elsewhere.
- Tourism activity will be driven by reduced ice and also by security concerns in other parts of the world.
  - The largest single human presence in the polar regions is tourists – far exceed scientists and residents.
  - Economics of tourism will be the driver; tourism offers the greatest certainty for profit that has continuity and room for expansion.
  - The greatest risk for tourism is the lack of infrastructure for Search & Rescue and medical evacuation; in 2006, a vessel hit an uncharted pinnacle in the Antarctic and had to evacuate 300 people.
  - Tourists want to see wildlife, whales and glaciers and take voyages into narrow channels; tourists would love to follow Amundsen's transit of the NWP.
  - Last year there were 34 cruise ships in the Antarctic – the largest carried over 3000 passengers – all in an area where there was no capacity for Search & Rescue.
  - Influx of tourists to some Arctic communities is an issue - while dollars may be good for the community, not all communities are able to handle 2000 people suddenly coming in, buying up food, taking pictures and leaving their garbage behind.
  - As large cruise ship routes become established, the industry will want shore infrastructure built – roads, hotels, etc. – which impacts local communities.
- Indigenous peoples and regional groups may exercise authority that will affect Arctic shipping.
- Nunavut land claims include all of the internal waters and the Territorial government has jurisdiction setting acoustic requirements for ships so as to not affect marine mammals.
  - Shell has agreed to shut down in September so as not to disturb whaling north of Alaska.
  - Voisey's Bay Nickel must follow demanding required procedures when a ship enters the fast ice to leave the fast ice undisturbed.

- Scientific interest in the Arctic will drive a small amount of marine activity; in next few years there will be lots of activity related to research and delineation of continental shelves.
- What are the key infrastructure requirements to support increased marine use of the Arctic Ocean?
  - Environmental prediction – weather, waves, currents, ice to reduce risk
    - Better forecasts, particularly in the medium term (seasonal); METAREAs are just now being established in Arctic.
    - With increasing maritime activity, there is a need for ice information and forecasting is increased – better resolution, timeliness, accuracy.
    - Concern with capacity as areas and seasons of navigation expand; will require more resources to meet the demand.
    - IICWG offers opportunity to share best practices and standardize.
    - Even though there may be less sea ice, more variability and more mobility will make it more difficult to forecast; need more high resolution observations; more mobile ice also presents a greater difficulty to the navigator.
    - Ice navigation and ice pilotage are the most critical factors in ice operations – many incidents on the Polar Class icebreakers could have been avoided with better information, tools and experience on the ship.
  - Oil spill response
    - Most current spill response strategies involve ships operating fairly close to shore – within helicopter range – where shore-based facilities are key; this may not be the case in the Arctic.
    - National governance is incapable of dealing with deep ocean spills that would likely cross national boundaries – need international governance.
  - Ports and terminals will be an issue in some regions.
    - The Beaufort Sea is particularly vulnerable because of shallow water, low land subject to erosion and melting permafrost.
    - There may be a need for ships that can be self-sufficient for an entire season.
  - Search & Rescue
    - Capability to evacuate large numbers of people from a disabled cruise ship in a remote area; medical evacuation will be required.
    - Industrial ships will likely be more self-sufficient in Search & Rescue, e.g., having safe havens until later evacuation.
    - NAVAREAs are just now being established in Arctic.
    - In 1912, the Titanic disaster galvanized the world to take action; Titanic was in a major shipping lane and a similar incident in the

Arctic would be even more disastrous – getting action before such a major disaster happens is difficult.

- Ice navigation tools and technologies
  - Ice detection from ship - e.g., what is the largest bergy bit that a ship can impact without damage and can it detected at collision avoidance range? (LNG tankers want to go fast (20 kts) to get to port before they lose too much cargo – small amounts of ice and bergs are hazardous)
  - Ship operators need information about ice conditions as they will affect their ship; help for the person on the bridge to make the best operational decisions is welcome.
  - Oil and gas ships cost about $50-100K per day to operate – 1/10 the cost of drilling equipment; any invest in shipboard equipment that will maximize use of drilling equipment is easy to justify.
- Availability of fuel
  - The need to carry all of the fuel is a limiting factor in operational capability including a need for the right kind of fuel for low air emissions.
  - Nuclear powered commercial ships may make sense but will not be possible unless the public accepts that the risk of nuclear power is lower than the risk of oil pollution.
- Reliable communications
  - Voice and data communications are necessary for operational support of ships but are limited in the Arctic.
  - There are cost issues as well as technological issues for high data rates (e.g. satellite images to ships).
  - This is one area where all polar nations have a common interest and where international collaboration is likely.
- Salvage capability and ports of refuge for damaged ships
  - There is currently a complete lack of infrastructure to take a disabled vessel to a safe harbor and no heavy tugs that are ice capable.
  - There is a question about whether this is a government responsibility or commercial responsibility.
- Charting, Aids to Navigation and Ship Routing
  - This is a responsibility of governments but they have capacity issues; industry may have to pay for hydrographic surveys to get operating permits - not unusual in the resource industry.
  - Canadian model of NORDREG and shipping control zones, although imperfect, is the best that is available.
  - In Russia, zones of navigation are in effect although different than Canada's; the federal navigation system which is responsible needs a lot of investment.

    - U.S. plans to develop zone control for Alaskan waters but it is not clear that any agency has a priority to do that.
    - Need to educate insurance industry on what is available to reduce risk.
  - Icebreakers escorts for commercial ships
    - This is likely to become the realm of private sector because tax-payers will not want to help large oil and mining companies with free icebreaker escort.
  - Knowledgeable people experienced in Arctic navigation
    - Knowledgeable mariners are in short supply.
    - Training capacity is insufficient to meet demand.
  - Availability of routine things is a limiting factor
    - Building materials (e.g. gravel, timber)
    - Dredging equipment (U.S. has issues with the availability of dredgers and Jones Act restrictions to build new ones.)
    - Oil and gas industry likes to build on what is available already – whether a ship, pipeline or port, the first installation is very expensive – additional ones are much less expensive; implication is that, when possible, new development will tie into existing infrastructure e.g. Beaufort Sea and Alaskan North Slope.
  - Regulations for Arctic navigation
    - Canadian, Russian, Baltic and IMO International regulations are not complete and not compatible.
    - Classification societies are harmonizing codes but are behind ship-building practice; industry is building new ships for which there is no previous experience; it is valuable to instrument new ships to provide knowledge for the future but there is a cost; it is also valuable to instrument ships to improve operating efficiency allowing operators to be less conservative.
    - Russian Federation is working on a new navigation code for the NSR; it is uncertain if Russia will allow ships to independently navigate the NSR.
    - Establishment of a Marine Reserve and protected areas will restrict navigation - e.g., Herschel Basin is one of only two deep draft mooring areas in the Beaufort Sea and is now not available because it is a national park.
- Level of traffic will not justify the cost of some of this infrastructure in the early years.
  - Ships will have to be more self-reliant with redundant capabilities – multiple power plants, field replaceable parts, etc.
  - Best safety net for commercial ships will likely be sister ships in the same fleet.

- Will increased activity in the Arctic affect the rate or direction of climate change itself?
  - New ships are to be green so air emissions will certainly have less effect than aircraft flights over the Arctic.
- Artificial islands that were created in the Beaufort Sea held fast ice in longer and affected the marine regime – the possibility of similar effects exist elsewhere.

AMSA Panel Summary

- Arctic shipping will be overwhelmingly destinational or regional for at least the next 15-20 years.
  - The economic reward of ocean to ocean trans-Arctic voyages will not be sufficient; risk to schedule (delays) will be largest single impediment; lack of infrastructure in every aspect (navigation, safety, regulation, etc) reduces attraction.
- Arctic marine traffic will be concentrated in two areas:
  - Resource development (logistics material in and natural resources out)
  - Tourism (cruise ships with large numbers of people)
- Secondary traffic will be related to scientific research, military re-deployment, security and regulatory enforcement.
- The volume of Arctic shipping will be mainly dictated by economics – other considerations include stability of the governance regime and technology (not just related to ice).
- Indigenous and regional groups have a considerable amount of power in the Arctic and will certainly be a factor in the development of Arctic shipping.
- Primary infrastructure needs to support Arctic shipping are:
  - Environmental predictions (weather, ice, waves) to reduce risk
  - Search & Rescue capability – ability to evacuate large numbers of people from cruise ships
  - Pollution response capability to handle significant oil spill in cold water and ice
  - Charts and Aids to Navigation
  - Availability of reliable communications
  - Availability of fuel, water, supplies
  - Salvage capability in ice-laden waters and ports of refuge for disabled ships
  - Knowledgeable and experienced mariners to crew ships
  - Regulations for Arctic navigation

VI. Symposium Wrap-up Panel Discussions

Lead: Dr. Pablo Clemente-Colón, Chief Scientist, NIC
Panelists: Hon. Mead Treadwell, Doug Bancroft, CAPT Malcolm Williams, John Goll, Dr. John Calder

Closing Discussions

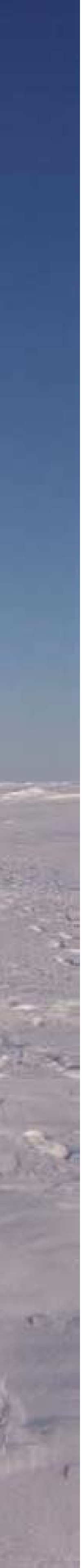
- What key issues were raised that you would like us to track?
  - Observations
    - satellites are great but we need higher resolution data that closer to the field – such as UAVs
    - essential that data from the Arctic Observation Network be available freely and openly as soon as possible after collection
    - important that data policies and standards be established and enforced to permit broad use
    - Inter-disciplinary cooperation and collaboration – need to develop observational programs that consider needs other agencies and disciplines
  - Lack of infrastructure will be an issue for the Navy; given other priorities for ships, Arctic is not a high priority.
  - Needed support for maritime operations – funding follows requirements – Navy needs feedback from its users.
  - Resource extraction as it is going to take place regardless of ice – global economics are the key driver.
  - Wild cards
    - models don't accurately capture export of ice
    - methyl hydrates
    - acidity in ocean
    - stratification of ocean
  - UNCLOS ratification is important for the U.S.
  - Arctic risk assessment & the Maritime strategic plan are internal Navy documents that need to be made public to let science community address some of the issues.
- Are there any cross-cutting (policy/science/operational) issues that merit special attention?
  - Ice thickness observations and on-going monitoring
  - SCICEX is dormant but could be revived
  - Is a UAV network feasible?
- Are there significant events that could put Arctic maritime before the public eye?
  - IPY will have a key legacy.
  - AMSA will have enough credibility that government leaders will not be able to ignore it.

  - Trans-Arctic voyages may happen much earlier than 30-40 years – something in next 5 years is not out of the question.
  - The polar bear issue will galvanize public opinion.
  - A shipwreck would be horrible but would likely spur some action.
- An Arctic operations centre that could develop a research agenda to reduce the risk of Arctic operations would be helpful.
- Search & Rescue protocols must be put in place as soon as possible because of the proliferation of Arctic cruise ships and commercial development; the absence of Search & Rescue capabilities is central to risk assessment.
- Search & Rescue military cooperation between countries is very good – need to move that kind of cooperation into public agencies.
- A $2B of investment in Arctic ships and infrastructure would compare very favorably with a similar investment in the Panama Canal – if the Arctic is going to be developed, let's support it and do it right.
- What are the challenges ahead?
  - Resources
    - Aging icebreaker fleet – must look at the renewal
    - Sustained resources for long term systematic monitoring programs, to train new people, implement new technologies and new procedures
    - Raising money to implement the AON
    - Get international research observation stations fully operational
    - Challenge to maintain the operational capabilities that we have now, at a minimum
  - Governance
    - There is a challenge for eight Arctic states to get along more closely than ever before; the Arctic Council is making progress but there are significant political challenges.
    - A suggestion was made to create some post-doctoral fellowships for Russian or other foreign students as a means of engaging other countries.
    - Commercial activity will go ahead while governance activity lags.
    - Governance needs to influence commercial development and protect the interests of Arctic peoples.
    - NGOs must be brought into the discussion.
  - Technological
    - There is a need to develop a systematic ice thickness monitoring system.
    - It is important to develop interoperability between Canadian and U.S. Navies and amongst circumpolar nations.

        - Accurate ice information for navigation – ridges and keels – movement of ice – is required; will we need stronger icebreakers in the near term?
        - A continued stream of Synthetic Aperture Radar satellite data for ice reconnaissance is essential.
        - Get community information incorporated into forecast procedures.
    - Social
        - We are dealing with great stress to people in the north.
        - Communicating what's happening in the Arctic to citizens in the street is a challenge.
    - Other
        - There is a lack of shore infrastructure to support ships as they move north
        - Capabilities for prevention and response to hazards are required.
        - Arctic operations will go into areas that are currently outside the area of normal U.S. (and Canadian) products –international communication could be better.
        - There is a need for conventional sea surface height measurements to calibrate satellites.
- How do we ensure that something concrete comes out of this Symposium?
    - AMSA will provide some continuity – these points will be carried forward into the study.
    - U.S. Arctic Policy Review will likely happen in next 12-18 months – last time that happened it shifted U.S. from viewing the Arctic from security perspective alone to including environmental concern.
    - Interagency Arctic Research Policy Committee (IARPC) could move this agenda forward – although extending to an international basis will be challenging.
    - Every participant in the Symposium must take responsibility for moving the agenda forward.

Final Comments

- It is significant that the Navy devoted resources to this Symposium at a time when its resources are significantly stressed.
- ADM Allen's comment proposing a national and international regime in the Arctic is significant – we want to see this develop peacefully.
- Participants and attendees recommended a follow-on Symposium to be held shortly after the AMSA report is released in the Spring of 2009 where AMSA, IPY results and other significant events can be presented and discussed in depth.



SYMPOSIUM PARTICIPANTS

Hon. Lisa Murkowski
U.S. Senator for Alaska

Senator Lisa Murkowski is the first Alaskan born Senator to serve the State and only the sixth United States Senator from Alaska. Murkowski is a third generation Alaskan, born in Ketchikan and raised in towns across the state: Wrangell, Juneau, Fairbanks and Anchorage. Since joining the Senate in 2002, Senator Murkowski has made many strides on issues facing Alaskans. As she advocates for legislation on the Senate floor, her passion for improving the state of health care, education, energy, Veteran’s affairs, and infrastructure development in Alaska is unquestionable.

Senator Murkowski supports increased research into Arctic issues. She is an ardent sponsor of International Polar Year (IPY), a comprehensive scientific program focused on the Arctic and the Antarctic examining a wide range of physical, biological and social research topics. IPY presents a vital opportunity to develop the next generation of Arctic researchers to carry on the vital scientific work currently being done. Senator Murkowski believes that Arctic research must be prioritized to understand the dramatic changes in the polar regions due to climate change. During her tenure in the United States Senate, she has supported legislative efforts to improve energy efficiency and to reduce the threat of global climate change from greenhouse gas emissions. This year, Senator Murkowski introduced energy efficiency legislation to promote the development of additional forms of renewable energy and to pave the way for improved fuel consumption by vehicles.

Admiral Thad W. Allen
Commandant
U.S. Coast Guard

Admiral Thad W. Allen assumed the duties of 23rd Commandant of the U.S. Coast Guard on May 25th, 2006 after serving as the Chief of Staff. He was the Federal Principal Federal Official in charge of response and recovery operations for Hurricanes Katrina and Rita in 2005.

A 1971 graduate of the Coast Guard Academy, Admiral Allen's operational assignments include duty in Thailand, the Caribbean and throughout the U.S., including command of Group Long Island Sound, Group Atlantic City, USCGC CITRUS, the Seventh Coast Guard District in Miami and the Atlantic Area in Portsmouth, Va.

Admiral Allen earned a Masters of Public Administration from George Washington University, and a Master of Science degree from the Sloan School of Management at the Massachusetts Institute of Technology. He was elected a National Academy of Public Administration Fellow in 2003.

He is married to the former Pamela A. Hess, Assistant Dean at George Mason University. They have three children and two grandchildren. He is a native of Tucson, Arizona, and the son of Clyde and Wilma Allen. Clyde Allen is a retired Coast Guard Chief Damage Controlman and World War II Veteran.

Vice Admiral John G. Morgan, Jr.

Deputy Chief of Naval Operations
for Information, Plans and Strategy
(N3/N5)

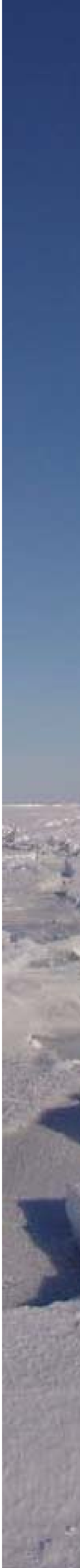
At Fort Dix, N.J., Vice Admiral Morgan was born into what was to become a joint military family. His father and three brothers served as officers in the Army, Air Force and Navy, two sons achieving flag rank. He graduated from the University of Virginia in 1972 with a degree in Economics.

Sea tours include duty in a diesel submarine, a frigate, a guided missile destroyer, an *Aegis* destroyer and cruiser, a destroyer squadron as well as the Second Fleet staff. Major deployments during those tours span duty in PACOM, SOUTHCOM, EUCOM, and CENTCOM. Command tours include the commissioning of *USS Arleigh Burke* (DDG 51), Commander, Destroyer Squadron 26 in the *USS George Washington* Battle Group, and Commander, *Enterprise* Battle Group which participated in the first strikes of *Operation Enduring Freedom* in Afghanistan.

Between tours at sea, Vice Adm. Morgan was assigned to the Joint Chiefs of Staff, OPNAV, the Ballistic Missile Defense Organization, and the Naval Surface Forces staff in the Pacific.

His Flag assignments ashore include duty as the Deputy for Acquisition Strategy in the Ballistic Missile Defense Organization and the Senior Military Assistant to the Secretary of the Navy – Gordon England.

He now serves as the Deputy Chief of Naval Operations for Information, Plans and Strategy (N3/N5).



Rear Admiral Timothy McGee
Commander, Naval Meteorology and Oceanography Command

A native of Washington, D.C., Rear Admiral Tim McGee graduated from the U.S. Naval Academy in 1978. He graduated from the Naval Postgraduate School in 1986 with a Master's degree in Meteorology and Oceanography and an advanced international certificate in Hydrographic Science.

His tours afloat include executive officer Oceanographic Unit One, *USNS Bowditch* (T-AGS-21); Oceanographer, *USS Carl Vinson* (CVN-70) where he qualified Surface Warfare Officer; Oceanographer, Commander Carrier Group 3; Oceanographer/TLAM Theater Executive Agent, Commander Sixth Fleet /Commander Strike Force South, *USS Belknap* (CG-26) and *USS LaSalle* (AGF-3).

His tours ashore include OIC, Defense Mapping Agency Office Norfolk; OIC, Naval Oceanography Detachment Diego Garcia BIOT; Advanced Ocean Technology Officer, Chief of Naval Operations (N096); Detailer, Placement Officer and Community Manager, Bureau of Naval Personnel; Commanding Officer, Naval Oceanography Facility San Diego; ACOS Resources, Commander Naval Meteorology and Oceanography Command; Executive Officer, Naval Oceanographic Office; Commanding Officer, Naval Oceanographic Office; Assistant Chief of Naval Research, Office of Naval Research; Associate Director of Operations, U.S. Commission on Ocean Policy; DACOS Plans (C_B), JTF-7, Iraq; Chief of Staff for Director of Operations and Infrastructure in Iraq, Coalition Provisional Authority, Iraq.

His awards include the Legion of Merit medal, Bronze Star, Defense Meritorious Service Medal, Meritorious Service Medal and various other awards. He was selected as Pacific Fleet Shiphandler of the year in 1989, and presented the Naval Postgraduate School Distinguished Alumni Award in May 2006.

Scott Rayder
Chief of Staff National Oceanic and Atmospheric Administration

Mr. Scott C. Rayder is the first Chief of Staff of the National Oceanic and Atmospheric Administration (NOAA), and has served in this position since 2001. In this capacity, he reports directly to NOAA Administrator Vice Admiral Conrad C. Lautenbacher, Jr., U.S. Navy (Ret.) and serves as the chief adviser on policy, personnel and budget matters. Rayder oversees a staff of 11_ people with a $2_ million budget that directly support the NOAA Administrator. Rayder is charged with integrating policy and budget priorities and aligning programs in support of the NOAA strategic plan and budget of $3.9 billion (FY 200_). Rayder works with NOAA senior management to ensure that NOAA programs are delivering products and services to the taxpayer in the most efficient and effective manner possible. Rayder works closely with NOAA's partnering organizations and plays a key role in communicating NOAA priorities to the Department of Commerce, Office of Management and Budget, and Congress.

Prior to 1997, Mr. Rayder was employed by NOAA in several capacities. In 1992, he was awarded a Presidential Management Intern position with NOAA's Office of Oceanic and Atmospheric Research. Mr. Rayder left the Office of Oceanic and Atmospheric Research in 1995 to work in NOAA's Office of Constituent Affairs where he worked with NOAA stakeholders to improve the delivery of NOAA services to its customers.

Mr. Rayder's undergraduate degree was obtained in 1990 and consisted of a dual major in Government and Geology from Hamilton College in New York. He obtained a Masters in Public Administration (M.P.A.) from the Maxwell School of Citizenship and Public Affairs of Syracuse University in the spring of 1992 with a concentration in Science and Technology Policy. He is married to Catherine Rayder, formerly Catherine DuBois of Reston, Virginia, and they reside in Alexandria, Virginia with their twin daughters, Hannah and Jenna, and son, Christopher.

Dr. Sharon L.Hays

Deputy Director for Science
White House Office of Science and Technology Policy

Dr. Sharon Hays was appointed Chief of Staff of the Office of Science and Technology Policy (OSTP) on July 10, 2005. Prior to that, she served as OSTP's Deputy Assistant Director for Technology starting in August 2002.

Dr. Hays was the Staff Director of the Subcommittee on Research of the House Committee on Science from the beginning of the 107th Congress until August 200. Prior to her promotion to Staff Director, Dr. Hays worked as a professional staff member first for the Basic Research Subcommittee and subsequently for the Subcommittee on Space and Aeronautics. She first joined the Science Committee's staff in mid-1999. Before working for the Committee, Dr. Hays acted as a consultant to Science magazine. While there, she worked on Science's Next Wave, an Internet-based weekly magazine focused on career and training issues for young scientists.

Prior to her work at Science, Dr. Hays served as an American Association for the Advancement of Science Congressional Science Fellow in the of fice of Representative Vernon Ehlers. She worked on a Science Committee project assigned to Dr. Ehlers by then-Speaker Newt Gingrich and former Science Committee Chairman F. James Sensenbrenner: to outline an updated science policy for the nation. That effort culminated in a comprehensive Science Committee report entitled Unlocking Our Future: Toward a New National Science Policy.

Before coming to Capitol Hill, Dr. Hays worked as a research assistant at the University of Southern California and then attended graduate schooling biochemistry at Stanford University, where she studied in the laboratory of Nobel Laureate Paul Berg and received her Ph.D. in 1997. Dr. Hays also holds a B.A. in Molecular Biology from the University of California, Berkeley.

Hon. Mead Treadwell
Chair
U.S. Arctic Research Commission

Mead Treadwell was appointed to the U.S. Arctic Research Commission in 2001 and was designated chair by the President in 2006.

During his 30 years residency in Alaska, Mead Treadwell has played an active role in Arctic research and exploration. His focus has been on development of natural resources, protection of the Arctic environment and fostering international cooperation after the Cold War. In business, government and the academy, Treadwell has helped establish a broad range of research programs in technology, ecology, social science and policy.

Currently, Treadwell serves as Senior Fellow of the Institute of the North, founded by former Alaska Governor Walter J. Hickel. He served as the Institute's first full time Managing Director and Adjunct Professor of Business when the Institute was part of Alaska Pacific University. Treadwell's research at the Institute focuses on strategic and defense issues facing Alaska and Arctic regions, management of Alaska 's commonly owned resources and integration of Arctic transport and telecommunications infrastructure.

Concurrently, in business, Mead Treadwell is Chairman and CEO of Venture Ad Astra, an Anchorage, Alaska based firm which invests in and develops new geospatial and imaging technologies. He is non-executive chairman of Immersive Media Company, (TVX:IMC.V), a firm Venture Ad Astra helped refinance in 2003. Since 1982, Treadwell has worked on his own account or in conjunction with Walter J. Hickel to invest in and provide support for the development of new ventures, including Yukon Pacific Corporation (a natural gas pipeline firm sold to CSX Corporation in 1989), Digimarc Corporation (NASDAQ: DMRC) and Owner State Wireless, LLC, which developed a wireless joint venture with Nextel. He is a board member of Baltimore Dredge Enterprises, a manufacturer of dredge equipment with operations in Maryland, Wisconsin and Kansas, and Arctic Transportation Services, an Alaska native-owned cargo airline operating in rural areas of the state.

With his late wife Carol, he has three children. The family enjoys skiing, hiking and camping.

Dr. Lawson Brigham
Director
U.S. Arctic Research Commission, Alaska Office
Chair, Arctic Marine Shipping Assessment

Dr. Lawson Brigham is Deputy Director & Alaska Office Director of the U.S. Arctic Research Commission in Anchorage. He is currently Chair of an international group conducting the Arctic Marine Shipping Assessment for the intergovernmental forum of the eight Arctic nations, the Arctic Council. A U.S. Coast Guard officer from 1970-1995 and 1970 USCGA graduate, he commanded cutters POINT STEELE, MOBILE BAY, ESCANABA and POLAR SEA. During 1974-79 he served as a faculty member in the Science Department and was the Academy's Head Sailing Coach. At the end of his career, he served as Chief of the Commandant's Strategic Planning Staff and Director of the Coast Guard Work-Life Study (1990-93); from 1993-95 he was Commanding Officer of POLAR SEA, sailing on four polar deployments. Captain Brigham has participated in ten Antarctic expeditions and eight icebreaker voyages in the Arctic Ocean, and has sailed aboard icebreakers in Alaska, the Great Lakes, Baltic Sea, Russian Arctic and around Antarctica. He has also served as a researcher at Woods Hole Oceanographic Institution and the Naval War College, and as a faculty member of the Naval Postgraduate School as the ONR Chair in Arctic Marine Science. His research interests for more than three decades have included studies on the Russian Arctic, ice navigation, sea ice and satellite remote sensing of the polar regions. He received a PhD in polar oceanography from Cambridge University in the United Kingdom and an MS in management from Rensselaer Polytechnic Institute. Dr. Brigham is also a distinguished graduate of the Naval War College.

Harry Brower, Jr.
Chairman
Alaska Eskimo Whaling Commission (AEWC)

Harry Brower, Jr., is a Barrow, Alaska whaling captain and Chairman of the AEWC. The AEWC represents all 10 Alaskan whaling villages, negotiates annually with the International Whaling Commission, and shares its quota with the Native people of Chukotka, Russia. Mr. Brower is a lifelong subsistence hunter and also serves as the Deputy Director of the North Slope Borough Department of Wildlife Management (DWM). The DWM is the research arm of the Borough. Mr. Brower collects traditional knowledge on wildlife and is involved in numerous projects relating the sustainability of Arctic communities.

[Because of unavoidable last minute commitments, Mr. Bower regretted not being able to attend the Symposium. Dr. Igor Krupnik covered in his presentation some of the impacts on Eskimo hunting to be addressed by Mr. Bower]

Dr. John Calder
Director NOAA Arctic Program

John Calder is the Director of the Arctic Research Program within the Climate Program Office of the National Oceanic and Atmospheric Administration (NOAA). He is responsible for the planning, coordination, and implementation of research and environmental observations in the Arctic and other high northern areas, and for focusing the results of this research on NOAA and national priorities. Current research focuses on Arctic climate variability and change. Part of his responsibilities involves coordination with many national and international groups and programs that are involved in these priority areas. He represents the U.S. in the Arctic Council's Arctic Monitoring and Assessment Program, and is currently serving as Chair of the group.

Dr. Calder has been with NOAA for 30 years and has held several science and management positions. He has served as environmental studies coordinator for the Bering Sea region, manager of NOAA's national environmental quality monitoring program, deputy director of planning for NOAA's research line office, and deputy director of NOAA's Environmental Research Laboratories. Prior to joining NOAA in 1977, Dr. Calder was Associate Professor of Oceanography at Florida State University. His research focused on marine organic geochemistry in coastal and estuarine environments.

Dr. Calder received his doctorate in 1969 at the University of Texas (Austin) in biochemistry with a sub-specialization in marine science

Commander Raymond E. Chartier, Jr.
Director, National Ice Center
Commanding Officer, Naval Ice Center
Co-Director of the North American Ice Service

Commander Ray Chartier Jr. is a New England native. He enlisted in the Navy in 1982 and was commissioned in 1988 after graduating from the University of Washington with a Bachelor of Science Degree in Oceanography. In 1995, he earned a Master's degree in Meteorology and Oceanography (with an emphasis in satellite remote sensing) from the Naval Postgraduate School. After nuclear power and submarine training, CDR Chartier served in USS NEVADA (SSBN 733 Gold) completing five Cold War deterrent patrols. He also served on the aircraft carrier USS ABRAHAM LINCOLN (CVN 72) from 1998 to 2000, completing a western pacific deployment in support of Operation SOUTHERN WATCH.

His shore duties include: Department Head, Naval European Meteorology and Oceanography Center, Rota Spain from 1995 to 1998; Officer in Charge Naval Pacific Meteorology and Oceanography Detachment, Fallon, NV from 2000-2003, with additional duties as METOC Officer, Naval Strike and Air Warfare Center; and Deputy Director PV and project manager in support of a major multi-agency program of significant national importance on the Chief of Naval Operations (OPNAV) Staff from 2003-2007.

His awards include Meritorious Service medals, Navy Commendation medals and Navy Achievement medals. In addition, he proudly wears two Meritorious Unit Commendations and various other awards. CDR Chartier has been married for 19 years; he and his wife have three active boys ages 15, 13, and 11.

Dr. Pablo Clemente-Colón

Chief Scientist National Ice Center

Dr. Pablo Clemente-Colón serves as Chief Scientist of the U.S. National Ice Center (NIC), a NOAA, Navy, and U.S. Coast Guard multi-agency center charged with the global monitoring and charting of sea ice and other cryospheric observations. He has worked at the NIC since March 200_ and within the NOAA National Environmental Satellite, Data, and Information Service (NESDIS)as an Oceanographer for nearly 30 years. Dr. Clemente-Colón received a B.S. degree in physics from the University of Puerto Rico at Mayagüez in 1977, an M.S. degree in oceanography from Texas A&M University, College Station in 1980, and his Ph.D. degree in Marine Studies from the University of Delaware, Newark in 2002. He provides remote sensing expertise to NOAA/NESDIS in areas of satellite oceanography that include sea ice, sea surface roughness, sea surface temperature, ocean winds, marine pollution, ocean color, and remote sensing fisheries applications.

Dr. Clemente-Colón has published papers and several book chapters in these areas and participates in numerous scientific organizations and technical committees in the U.S. and internationally including the North American Ice Service (NAIS) Science Committee, International Ice Charting Working Group (IICWG) Science and Technology Standing Committee, Global Climate Observing System (GCOS) Sea Ice Subgroup (SIS) Executive Committee, Alaska Ocean Observing System (AOOS) Sea Ice (SI) Working Group, NOAA International Affairs Council (IAC) Polar Committee, International Arctic Buoy Programme (IABP) Executive Committee, and the International Programme for Antarctic Buoys (IPAB) Executive Committee. Although his present interests are centered on polar issues, he is in fact a native of Puerto Rico, a tropical island with a much warmer climate.

Douglas Bancroft

Director, Canadian Ice Service Co-Director, North American Ice Service

Doug joined the Meteorological Service of Canada (MSC) in1981, starting at the Training Branch in Downsview Ontario, and then serving progressively as a forecaster, shift supervisor and operations supervisor in a variety of weather centres. He eventually became Officer-in Charge of the west coast Meteorology and Oceanography Centre. He then accepted a promotion to Fisheries and Oceans Canada in 2000 as a Senior Science Advisor. In 2003, he was promoted to the position of national Director of Oceanography and Climate Science. Doug returned to MSC in 2006, to take up his present duties as Director of the Canadian Ice Service, and Co-Director of the Canada-United States North American Ice Service.

In addition to his civil service career, Doug has been a member of the Canadian Naval Reserve for thirty four years. He joined as an Ordinary Seaman and has since served a variety of tours at sea. He has also held various positions ashore in National and Multi-National Joint Task Force Headquarters. He has commanded six HMC Ships for various periods, including HMCS YELLOWKNIFE, a thousand ton multi role mine countermeasures ship, and Port Security Unit Four.

Doug holds a B.S. in Physics from the University of Victoria, a specialized undergraduate diploma in meteorology from McGill University, and an M.Sc. in Physical Oceanography from Royal Military College.
Married for over twenty five years, with a son and daughter
both in college, Doug is also a longstanding scout leader, spending his meager spare time on long range expeditionary canoe and camping trips.

David Dickins, P.Eng.
Consultant
D.F. Dickins Associates Ltd.

David Dickins has over 30 years of project management experience focusing on offshore oil exploration and development, and the marine transportation of oil in arctic waters. Since 197_, Mr. Dickins has played a key role in seven large-scale experimental oil spills in ice and cold water off the Canadian Arctic and East Coasts. He has operated his own consulting firm, providing engineering and environmental research services for government and industry clients in the United States and Canada since 1978.Mr. Dickins has a worldwide reputation as an expert in arctic environmental studies. He has managed and completed over 100marine environmental projects for government and industry clients in the United States, Canada, UK, France, Norway, Netherlands and Finland. Over the past 2_ years, David Dickins has authored or contributed to over _0 formal papers presented at international conferences in Japan, Norway, Sweden, USA, Canada and Finland.

Over the past ten years, projects have focused on the development of oil spill response strategies for new oil production facilities, and evaluations of sea ice conditions affecting offshore structures pipelines and shipping. Examples of this work include: developing and chairing the technical program for an international conference on oil and ice in Anchorage; and preparing descriptions of oil spill fate and behavior, and response options for the Northstar oilfield off the North Slope of Alaska. Over the past eight years, he has completed a series of environmental and engineering projects for ExxonMobil and SEIC as part of their Sakhalin programs. Recent projects have also focused on marine developments in the Caspian Sea, including reviews of spill plans for the new Baku-Tbilisi-Ceyhan Pipeline Project and evaluations of logistics systems for the Kashagan Field in the N. Caspian.

Ben Ellis
Managing Director Institute of the North

Ben Ellis holds a Master's in Journalism degree from the University of Missouri-Columbia. He worked as an international journalist in Hong Kong and New York City with the Asian Wall Street Journal and its parent company Dow Jones before coming to Alaska.

Ellis became deputy director at the Institute of the North in June2003 and managing director of the Institute the following October. As managing director, Ellis has represented the Institute at international fora in the Russia Federation, the People's Republic of China, the United Kingdom, Iceland, Denmark, Canada, Finland and Norway, as well as Washington, D.C. In that role, he is leading a team of experts at the Institute to assess and improve the infrastructure within the eight Arctic Council nations in the areas of Arctic aviation, telecommunications and marine links.

He was co-facilitator, with Dr. Lawson Brigham, of the Arctic Marine Transportation Workshop 200_ held at Scott Polar Research Institute at Cambridge University and is a core-team member of the Arctic Council's Arctic Marine Shipping Assessment. Ellis is also the project leader of the Arctic Energy Summit, an International Polar Year project that investigates the Arctic as an emerging energy province.

John Goll
Alaska Regional Director
Minerals Management Service (MMS)

John Goll is the Regional Director of the MMS Alaska Outer Continental Shelf Office, since May 1997. He is responsible for oil and gas and other mineral leasing, environmental assessments and studies, and oversight of industry activities on the outer continental shelf off Alaska. During his tenure, Mr. Goll's emphasis has been to build confidence in offshore oil and gas off Alaska with its many stakeholders, which has been challenging. You may find him coordinating with counterparts in the State of Alaska or with other agencies, or visiting with Alaska Native tribal councils or communities in the middle of the Arctic winter. He is an active supporter of Alaska cross-agency coordination groups, including the Alaska Ocean Observing System and the North Slope Science Initiative.

Prior to becoming Regional Director, Mr. Goll headed the MMS's nationwide environmental program, including NEPA and research. He has participated in several training missions with Russian environmental regulators in northwest Siberia and on Sakhalin Island.

Mr. Goll holds a Bachelors Degree in Meteorology and Oceanography and a Masters Degree in air pollution meteorology, both from the University of Michigan. He especially enjoys Alaska's winters and pleasant summers, after having spent over 20 years in Washington DC's humid climate.

David Jackson
Manager Canadian Coast Guard (CCG) Icebreaking Program

Currently Manager of the CCG Icebreaking Program in the CCG National HQ in Ottawa.

Graduated from the Canadian Coast Guard College in Sydney, Nova Scotia in 1981 after studying Nautical Sciences.

CCG Fleet Officer until 1990. Extensive operational experience on Aids to navigation tenders, Search & Rescue vessels as well as Icebreakers both in Arctic operations during the summer as well as in the Gulf of St. Lawrence during winter operations.

Professional Certification as an Ocean Navigator I (ON 1) Certificate of Competency.

Experience in broad range of positions within CCG HQ:

Navigation Equipment officer for CCG Fleet. Worked on development of ECDIS technology and regulations at IMO and implementation in CCG Fleet.

National Oil Spill Response Officer: responsible for CCG Personnel and equipment deployment to Bahrain and Qatar during first Gulf War in 1991 also responsible for redefining Canada's National Oil Spill Response regime.

Navigation Specialist and Strategic Advisor in the Navigation Services Directorate where he was responsible for operational, strategic and legislative advice to the Director-General and the Commissioner of the Coast Guard spanning the gamut of the full responsibilities of the Coast Guard.

Manager of the Icebreaking Program since 2000.

Dan James

Assistant Coordinator Status and Trends of Biological Resources Program, U.S. Geological Survey

Daniel James is a wildlife biologist for the U.S. Geological Survey (USGS), currently serving as the Assistant Coordinator for the Status and Trends (S&T) of the Biological Resources Program. In addition to providing expertise on biological status and trend activities for the USGS, Mr. James manages two important competitive research and monitoring projects addressing the science needs of the National Park Service and the U.S. Fish and Wildlife Service. He recently completed a two-year project organizing and running a Federal Advisory Committee that provided recommendations to the Department of the Interior Secretary for improving the operations and management of USGS' Bird Banding Laboratory. As part of Mr. James' research administration experience in USGS he has served two details acting as the Center Director for biological research laboratories in Florida and North Dakota.

For the first 15 years of his federal career, Mr. James worked as an Endangered Species Biologist for the U.S. Fish and Wildlife Service. During this period he was involved in numerous endangered species conservation and recovery projects, including several years spent serving as the Service's National Bald Eagle Recovery Coordinator. At this Symposium Mr. James is presenting the research conducted by three scientists at USGS' Alaska Science Center:

Dr. Chadwick V. Jay -Walrus Project Leader for the Alaska Science Center

Dr. Steven C. Amstrup -Polar Bear Project leader for the Alaska Science Center

Mr. David C. Douglas – Works on sea ice, a variety of remote sensing, and satellite tracking of wildlife

[Because of busy field seasons and other prior commitments, they regretted not being able to attend the Symposium to present personally and discuss their studies.]

Dr. Martin O. Jeffries
Program Director Arctic Observing Network National Science Foundation Office of Polar Programs

Martin Jeffries is the Program Director for the Arctic Observing Network at the National Science Foundation, Office of Polar Programs. He is at NSF on detail from the University of Alaska Fairbanks (UAF) during International Polar Year 2007-2009. A graduate of the University of Sheffield, UK, he then investigated glacier hydrology in Norway for his M.S. dissertation at the Victoria University of Manchester, UK. In 1981, he entered the Ph.D. program at the University of Calgary, Canada, where he studied the structure and growth of the Ellesmere ice shelves in the Canadian High Arctic. In 198_ he became a post-doctoral fellow at the Geophysical Institute, UAF, continuing his ice shelf studies as part of an investigation of ice islands, the tabular icebergs that calve from the ice shelves. In 1990 he was appointed Research Professor at UAF.

Between 1990 and 200_, he traveled to Antarctica nine times to study sea ice thickness and formation, and was Chief Scientist on six occasions aboard the research vessel Nathaniel B. Palmer. In Alaska, his work has focused on lake ice geophysics, including ice phenology (freeze-up, break-up, duration), thickness and composition, and heat flow and heat loss from ice-covered lakes. K-12 teachers and students are important scientific partners in the lake ice research through the Alaska Lake Ice and Snow Observatory Network (ALISON), an integrated research and science education project developed by Jeffries and colleagues. His research is primarily based on field investigations, supplemented with remote sensing (mainly synthetic aperture radar) and occasionally numerical modeling.

Dr. Igor Krupnik
Curator Smithsonian Institution Arctic Studies Center

Igor Krupnik, Ph.D. (1977) is cultural anthropologist at the Arctic Studies Center, Department of Anthropology, and Curator of Arctic and Northern ethnology collections at the National Museum of Natural History, Smithsonian Institution in Washington, D.C. He
has done extensive fieldwork in Alaska, the Bering Sea region, and along the Russian Arctic coast. He has been coordinator of several international and community-based projects studying the impacts of climate change, preservation of cultural heritage, and ecological knowledge of Arctic people.

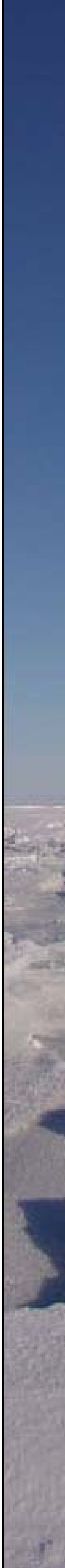
Dr. Krupnik has published several books and collections, including two recent volumes on indigenous observations of Arctic environmental change, "The Earth Is Faster Now" (2002) and "Watching Ice and Weather Our Way" (200_). He was the lead curator for the recent Smithsonian exhibit "Arctic: A Friend Acting Strangely" (2006). He is also a member of the Joint Committee for the International Polar Year 2007-2008 and was instrumental in bringing socio-cultural issues, ecological knowledge, and environmental observations of northern indigenous people to the agenda of IPY2007-2008. He is a co-PI for the international project, "*SIKU*: Sea Ice Knowledge and Use: Assessing Arctic Environmental and Social Change" (IPY # 166) that promotes local observations of sea ice conditions in indigenous communities in Alaska, Russia, Canada, and Greenland.

Commander Douglas C. Marble, Ph.D.
Program Officer Office of Naval Research, Physical Oceanography Program

Commander Douglas C. Marble, an East Amherst, New York native, graduated in 1986 from the University of South Carolina with a B.S. in Physical Oceanography. He received his commission through the Navy Reserve Officer Training Corps program. Following Surface Warfare Officers' School in Newport, Rhode Island, he reported to USS Iwo Jima (LPH-2). While onboard, he qualified as Engineering Officer of the Watch and Surface Warfare Officer, served as Boilers Officer, Auxiliaries Officer and Combat Information Center Officer and deployed to the Mediterranean Sea.

In 1989, under the Oceanography Option program, Commander Marble became a naval oceanographer and assumed duties as Executive Officer, Oceanographic Unit FIVE, embarked in USNS Harkness (T-AGS 32). After 16 months of hydrographic survey in and around Indonesia, he transferred to the Naval Postgraduate School in Monterey, California, earning a M.S. in Meteorology and Physical Oceanography.

Commander Marble's awards include two Meritorious Service Medals, four Navy/Marine Corps Commendation Medals, two Navy/Marine Corps Achievement Medals, four sea service deployment ribbons and other unit and personal awards.



Dr. Seelye Martin
Manager NASA Cyrospheric Sciences Program

Dr. Seelye Martin is a professor of oceanography at the University of Washington, Seattle specializing in high latitude oceanography. In 1967, he received his Ph.D. from Johns Hopkins University in Largo, MD. Dr. Martin has participated in numerous field expeditions to the Arctic, and has carried out remote sensing studies of the Arctic Ocean and the Okhotsk and Ross Seas. His published papers include works on Arctic and Antarctic polynyas, the Arctic and Bering Sea ice covers, and the behavior of icebergs in the Ross Sea. He has also published a book on ocean remote sensing. He is currently on a two-year leave from the University, while serving at NASA Headquarters through 2008 as the Cryospheric Program Manager.

Commander Sean C. Maybee
Federal Executive Fellow Center for Naval Analyses

Sean Maybee is a Federal Executive Fellow assigned to the Center for Navy Analysis (CNA). Commander Maybee was commissioned in the Navy upon graduation from the University of Michigan in May 1991 with a Bachelor of Arts degree in Political Science. Subsequently he earned a Masters of Science in Information Science and Systems from the University of Maryland, European Division. Following commissioning he attended Naval Flight Training in Pensacola, Florida and Corpus Christi, Texas earning his Wings in June 1993. CDR Maybee served as an EP-3E Electronic Warfare Mission Commander, leading missions throughout Europe the Pacific, the Horn of Africa and Southwest Asia including combat operations in Bosnia and Afghanistan. CDR Maybee also served as an Executive Liaison Agent for the Secretary of Defense and Chairman of the Joint Chiefs of Staff and in March 2006, Commander Maybee was selected for Aviation Command (Special Mission) and will report for duties as the Executive Officer, Training Squadron Six (VT-6) in May 2008.

George B. Newton
Advisor
U.S. Arctic Research Commission

George Newton received a Bachelor of Science degree in Electrical Engineering from Brown University in 1957 and a Master of Science degree from Rensselaer Polytechnic Institute. From 1958 to 1981, Mr. Newton was an officer in the U.S. Navy where, among his assignments, he commanded a nuclear attack submarine. He retired as a Captain (0-6).

Since entering business in 1981, Mr. Newton has had continuous involvement with Arctic science, research, and development matters. Most notable has been his continuous participation over that period in the U.S. Navy's Arctic Programs and the Submarine Arctic program, specifically.

In 1992, President George H. W. Bush appointed him to a four-year term as a member of the U.S. Arctic Research Commission. He was subsequently reappointed to second and third terms and elevated to Chairman by President Clinton in 1996. He was replaced on the Commission in August 2006, but remains serving as an appointed Senior Advisor.

Long an advocate for using submarines in the Arctic Ocean for civilian research, he conceived and coordinated the initiation of the Submarine Science (SCICEX) program, a unique, cooperative effort between U.S. civilian science agencies and the operational Navy. The program enabled six dedicated science cruises (1993-1999) under sea ice that significantly changed the world's understanding of the Arctic Ocean. Mr. Newton is a proactive supporter for accession to the Law of the Sea Treaty by the United States and is a member of the State Department's Extended Continental Shelf Task Force.

Since 2000, Mr. Newton has been employed as a Senior Engineer at Planning Systems, Inc., in Reston, VA.

Peter G. Noble
Chief Naval Architect ConocoPhillips, Floating Systems

Peter Noble is a naval architect with four decades of experience in the marine and offshore sectors. Peter first sailed north of the Arctic Circle in Norway when he worked on a fishing boat in the summer of 1966 and again sailed "down north" on the McKenzie River in 1969, as engineer on a push-tug/barge combination which he had designed and built in Hay River NWT. His career has included positions with ship design consultants, research and development companies and classification societies. Peter has had a very active involvement in Arctic and High Latitude shipping. He worked with the Arctec Group of companies in Canada and the U.S. from the mid 70's to late 80's where he led ice model basin studies, analytical work and field work in the Arctic for government and commercial clients. Peter continued his "Arctic" career when he joined Wartsila Marine (which became Kvaerner Masa Marine and now Aker Marine) in Vancouver, Canada. Immediately prior to joining ConocoPhillips, Peter served as Vice President of Engineering within the American Bureau of Shipping organization, where in addition to many other tasks he participated in the continuing development of rules for ships and structures designed for ice operations.

Peter is a Vice President and Fellow of the Society of Naval Architects and Marine Engineering, SNAME, and is active in society affairs both nationally and internationally, including chairing the Society's International Activities Committee. In 2006 Peter was awarded the Adm. Jerry Land Medal for "contributions to the marine industry". He has published extensively on a wide rangeof technical and safety issues related to the maritime, Arctic and offshore industries. He is a member of the American Bureau of Shipping.

Dr. James Overland
Oceanographer NOAA Pacific Marine Environmental Laboratory

James Overland is an Oceanographer with the NOAA Pacific Marine Environmental Laboratory in Seattle, WA and an affiliate Professor in the Atmospheric Sciences Department of the University of Washington. In his 30 year career he has authored over 90 peer-reviewed articles on climate and ecosystems, especially related to northern regions (see http://www.pmel.noaa.gov/). In 2002 he received the NOAA Administrator's award for leadership in Arctic science. He has served as an Editor for *Journal of Geophysical Research-Oceans* and guest editor for several special issues. He has served on many committees, including the panels on the coastal ocean, coastal meteorology and marine meteorology of the National Academy of Science. Dr. Overland's interest is in scientific support for decision makers in high latitudes regarding climate and climate impacts on ecosystems. He advises NOAA fisheries managers and scientists on climate change issues, who in turn provide recommendations to the North Pacific Fisheries Management Council. He provides invited talks in several international science forums each year, as well as giving popular talks on climate change. He is active in Arctic change issues and is coauthor of a recently completed *State of the Arctic Report*, and the *Arctic Report Card* due out in late summer 2007. He is currently completing research which evaluates the results of recent IPCC climate projections for application to high latitude ecosystems.

Jacqueline Richter-Menge

Research Civil Engineer Cold Regions Research and Engineering Laboratory (CRREL)

Ms. Richter-Menge graduated with a Master of Civil Engineering from the University of Delaware and has been with the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory since 1981. Her research activities have focused on developing a more comprehensive and quantitative understanding of the Arctic sea ice cover, addressing both dynamic and thermodynamics processes. Results of this research have been used to help design Arctic-based offshore oil platforms, to improve the operational capabilities of surface vessels and submarines that travel in ice-covered waters, and to better understand the role that the polar regions play in the global climate system. In association with her research, Ms. Richter-Menge has gained significant first-hand Arctic experience leading or participating in more than 15 field programs. She has presented her work in over 30 peer-reviewed journal publications. From 1997-2006, Ms. Richter-Menge served as Chief, Snow and Ice Branch.

Dr. Amy Merten
Co-Director, Coastal Response Research Center NOAA Office of Response and Restoration

Dr. Amy Merten is the Coastal Response Research Center (CRRC), NOAA Co-Director. CRRC is a partnership between NOAA's Office of Response and Restoration (OR&R) and the University of New Hampshire that specializes in spill response and restoration research funding and collaborations. Dr. Merten works to develop practical applications of R&D. Dr. Merten is the coordinator for CRRC and NOAA's participation in an international, multi-year effort to develop improved understanding, new techniques, contingency plans and capabilities for preparing and responding to oils spills in Arctic conditions. Dr. Merten worked on several major spills, including the M/V ATHOS (Delaware River), the M/VSELENDANG AYU (Unalaska AK), several spills on the Mississippi corridor caused by Hurricanes Katrina and Rita. From 19921996, she was a natural resource analyst for PCCI Environmental Engineering, Inc. (Alexandria, VA), writing oil spill contingency plans for U.S Navy facilities and commercial oil transport clients.

Dr. Merten received her doctoral (200_) and masters (1999) degrees in Marine, Estuarine and Environmental Sciences with a specialization in Environmental Chemistry from the University of Maryland. Her research focused on the sub-lethal impacts of long-term exposures of dietary PAHs on the bioenergetics of and PCB bioaccumulation in a model fish, Fundulus heteroclitus and the differences in bioavailability of PAHs associated with petrogenic and pyrogenic sources. She earned a B.A. in Environmental, Population, and Organismic Biology from the University of Colorado, Boulder in 1992.

Phillip R. Mundy

Director Ted Stevens Marine Research Institute and Auke Bay Laboratories NOAA National Marine Fisheries Services

Phillip R. Mundy is Director of the Ted Stevens Marine Research Institute and Auke Bay Laboratories, Alaska Fisheries Science Center, NOAA Fisheries, Juneau, Alaska. He received his Ph.D. in Fisheries from the University of Washington. In addition to administration, his current professional interests are fishery management and implementation of ocean observing systems. Before entering federal service he was Assistant Professor in the Department of Oceanography, Old Dominion University, Associate Professor in the School of Fisheries and Ocean Sciences, University of Alaska, and he also held positions in state and tribal fisheries agencies. He is a former member and chair of the Scientific and Statistical Committee of the North Pacific Fishery Management Council and he currently serves on the monitoring committee for the North Pacific Science Organization, PICES. He was the editor and a contributing author of *The Gulf of Alaska: Biology and Oceanography* (2005).

Dr. Richard W. Spinrad
NOAA Assistant Administrator for Oceanic and Atmospheric Research (OAR)

Spinrad earned his Bachelor's degree from the Johns Hopkins University and then earned an M.S. in physical oceanography and a Ph.D. in marine geology in 1982 from Oregon State University. He is the President of The Oceanography Society and served as Editor in Chief of Oceanography magazine. Spinrad also served on the faculty of the U.S. Naval Academy and George Mason University. His experiences include working as a research scientist at Bigelow Laboratory for Ocean Sciences, serving as the President of SeaTech, Inc., managing oceanographic research at the Office of Naval Research (including serving as the Navy's first manager of its ocean optics program), and directing research and education for the Consortium for Oceanographic Research and Education (CORE).

Spinrad has published more than 50 scientific articles, is the editor of a textbook on ocean optics and several special issues of marine science journals. He has co-authored or contributed to many fundamental documents that impact the oceanographic community such as a report by CORE entitled, "Oceans 2000: Bridging the Millennia", which he co-authored with Admiral James Watkins, and which served as the guiding document for the establishment of the National Oceanographic Partnership Program (NOPP). Dr Spinrad is the recipient of a Presidential Rank Award, as well as the Distinguished Civilian Service Award, the highest award given to a civilian by the U.S. Department of Navy. Spinrad also serves as the United States permanent representative to the Intergovernmental Oceanographic Commission of UNESCO, and co-chairs the White House Joint Subcommittee on Ocean Science and Technology.

Simon Stephenson
Director Division of Arctic Sciences National Science Foundation Office of Polar Programs

Simon Stephenson was appointed Director of the Division of Arctic Sciences in April 2006. The Division, in NSF's Office of Polar Program, is responsible for a research investment of about $ 90 M annually. The science disciplinary drivers are both broad and interdisciplinary and system approaches are common; however, the main current driver is environmental change and its relationship to human activity in a regional and global context. Mr. Stephenson joined the then Arctic Section of the Office of Polar Programs in May 1999 as the first Program Manager for Arctic Research and Logistics program. The Arctic Research Support and Logistics (RSL) program provided the necessary resources to scientific projects to conduct fieldwork in the demanding environment of the Arctic effectively, efficiently and safely.

Mr. Stephenson came to the Arctic Program with 21 years experience in polar research. His first 11 years were as a glacier geophysicist with British Antarctic Survey and then with a team based at NASA's Goddard Space Flight Center, working on the dynamics of West Antarctic ice streams. He worked as part of two-person field teams, and large integrated multi-institutional field campaigns. Mr. Stephenson then moved to NSF's Office of Polar Programs as the Research Support Manager for the Antarctic program, leading the development of support plans for over 100 projects annually, and the development of the supporting research infrastructure, in the disciplines of Aeronomy, Astrophysics, Biology, Geology, Geophysics, Climate studies and Oceanography. Mr. Stephenson also serves as the current Chair of the Forum of Arctic Research Operators http://www.faro-arctic.org.

Mr. Stephenson holds a degree in Geophysics from the University of Liverpool and a Master of Philosophy in Glacier Geophysics from the Council for National Academic Awards, UK.

Richard (Dick) Voelker

Maritime Administration Department of Transportation, Retired

Dick Voelker has over 3_ years of polar marine experience and recently served as the Chief of the Division of Advanced Technology in the U.S. Department of Transportation/Maritime Administration before retiring in April of this year.

In this position, he was responsible for a number of programs and activities. In one of these, he served as the technical project manager for the feasibility design of the Next Generation Polar Research Vessel. This effort was at the request of the National Science Foundation, Office of Polar Programs. Another project that Dick's Division initiated and developed was the Maritime Energy and Emission Program.

In the 1990s he was responsible for technical activities in connection with the acquisition and ultimate lease of the U.S. Antarctic research vessel NATHANIEL B. PALMER by the NSF/OPP. This included all activities from preparation of the proposal technical specification, evaluation of proposals, construction oversight and ice tests in Antarctica.

From 1979 to 1986, Dick lead the multiyear Arctic Marine Transportation Program to assess the feasibility of year-round shipping in the Bering, Chukchi, and Beaufort Seas. This program was sponsored by several agencies of the federal government, private industry and academia. The program employed the U.S. Coast Guard POLAR Class icebreakers and he served as Chief Scientist for over a dozen voyages in the Arctic and Antarctic.

Dr. John Walsh

Chief Scientist Alaska Center for Climate Assessment & Policy
University of Alaska Fairbanks

John Walsh is the President's Professor of Global Climate Change at the University of Alaska, Fairbanks, where he is also the Director of the NOAA Cooperative Institute for Arctic Research. He earned his B.A. from Dartmouth College in 1970 and his Ph.D. from M.I.T. in 197_. He then spent 30 years on the faculty of the University of Illinois. His primary research interests are polar climate, severe weather, and linkages between the Arctic and middle latitudes. He was a lead author for the Arctic Climate Impact Assessment and for the Polar Regions chapter of the most recent IPCC assessment.

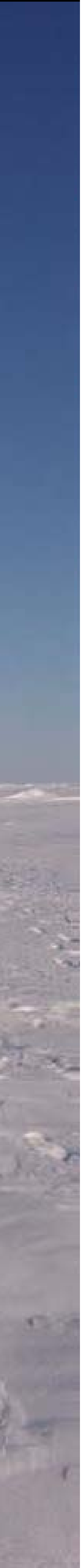
Commander Thomas Wojahn
Ice Operations Program Manager, U.S. Coast Guard

Commander Tom Wojahn has served as the Coast Guard's Ice Operations Program Manager for four years. In this role, he oversees Coast Guard polar icebreaking, domestic icebreaking and the International Ice Patrol programs. Commander Wojahn is a native of Waupun, Wisconsin and graduated from the U.S. Coast Guard Academy in 1989. In 1996, he received a Masters of Science degree from the Naval Postgraduate School in Monterey for Oceanography and Meteorology.

Commander Wojahn has seven years of sea time on medium endurance cutters, patrol boats and polar icebreakers. He served with the International Ice Patrol for five years and accumulated 650 flight hours searching for icebergs in the North Atlantic.

Malcolm Williams, CAPT, USCG (Ret.)
Strategic Analysis Staff, U.S. Coast Guard

Malcolm Williams, serves as Strategic Analysis staff at the U.S. Coast Guard Academy under the USCG Headquarters Policy and Planning Directorate's Office of Strategic Analysis. In 2002, CAPT Williams was appointed by the U.S. Commission on Ocean Policy as Associate Director for Stewardship of the Commission. CAPT Williams has served as Chief of the Coast Guard's Office of Maritime and International Law in Washington, D.C., as Director of Admissions, United States Coast Guard Academy, and as panelist and contributor in many maritime policy and international law panels and publications.



POSTER ABSTRACTS

National Ice Center Remote Sensing Support of the USCG Icebreaker *Healy* trans-Arctic Crossing in 2005

Pablo Clemente-Colón[1] Gene Swope[1] Jonathan Berkson[2]

[1]U.S. National Ice Center, NOAA Satellite Operations Facility, Washington, DC

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The U.S. Coast Guard (USCG) Icebreaker *Healy* undertook a trans-Arctic cruise during August and September 2005. The *Healy* departed from Pt. Barrow across the Arctic led by the University of Alaska Fairbanks and undertaken in coordination with the Swedish Maritime Administration's Icebreaker *Oden*. The cruise took both vessels to the North Pole and ended near Svalbard shortly after exiting the pack ice. The science objectives of the cruise included describing the large-scale spatial variability of the morphological and optical properties of the summer ice. Tactical sea ice support was provided by the U.S. National Ice Center (NIC) in collaboration with the Canadian Ice Service (CIS) under the auspices of the North American Ice Service (NAIS). The NIC was responsible for providing an onboard sea ice analyst for operational ice reconnaissance and imagery interpretation support as well as providing nowcast products and satellite imagery. The NIC analyst, in collaboration with an ice observer provided by CIS, made available to the *Healy*'s commanding officer and the scientific personnel critical ice analyses that assisted the icebreaker in both navigating through Arctic sea ice and accomplishing the science objectives. Images and sea ice charts were pulled-down by the *Healy* via ftp through the use of the CIS IceVU system. Imagery was also downloaded directly via a shipboard TeraScan acquisition station and analyzed using MapServer. Satellite data available included synthetic aperture radar (SAR) from RADARSAT-1 and Envisat, visible and infrared data from the Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS), NOAA Advance Very High Resolution Radiometer (AVHRR), visible data from the DMSP Operational Linescan System (OLS), and microwave data from DMSP Special Sensor Microwave/Imager (SSM/I). A review of some of the remote sensing observations of sea ice conditions found during the cruise is presented.

Primary Productivity at High Latitudes and the Role of the Arctic as a Carbon Sink

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High latitude regions are among the most productive regions in the ocean in part because of the presence of sea ice. SeaWiFS data since 1997 indeed show that phytoplankton blooms are dominant at high latitudes, especially near or in areas covered by sea ice in winter. Plankton concentrations are also high in the Arctic basin, especially in the shallow shelf regions. With the perennial ice cover rapidly declining at almost 10% per decade, the question has been whether or not the Arctic Ocean will become a carbon sink. Ocean color data in the summer indicate that pigment concentrations in the Eastern (Laptev Sea) Region are on the average three times higher than those in the Western (Beaufort Sea) Region. This is in part because of much wider shelf regions which are relatively shallow in the Eastern Region. Net primary productivity in the pan-Arctic region has been estimated using pigment concentration, PAR, surface temperature, and a model. The large spatial variability in the location of the perennial ice allowed for the study of a large fraction of deep ocean areas in the Arctic. Our results show unusually low productivity in the deep regions of the Arctic Ocean. Although the melt of sea ice has been associated with enhanced blooms, this appears not to be the case in the central and deep portions of the Arctic because of possible nutrient and iron limitations. Nutrients are usually entrained to the bottom of the ocean during ice formation in autumn and winter and in deep regions, they are unlikely to resurface. The chance for the Arctic Ocean as becoming a carbon sink is thus likely improvable.

Seasonal Predictions of Ice Extent in the Arctic Ocean

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How well can the extent of arctic sea ice be predicted for lead periods of up to one year? The forecast ability of a linear empirical model is explored. It uses as predictors historical information about the ocean and ice obtained from an ice-ocean model retrospective analysis. The monthly model fields are represented by a correlation-weighted average based on the predicted ice extent. The forecast skill of the procedure is found by fitting the model over subsets of the available data and then making subsequent projections using independent predictor data. The forecast skill, relative to climatology, for predictions of the observed September ice extent for the pan-arctic region is 0.77 for six months lead (from March) and 0.7_ for 11 months lead (from October). The ice concentration is the most important variable for the first two months and the ocean temperature at a depth of 234 m is most important for longer lead times. The trend accounts for 76% of the variance of the pan-arctic ice extent, so most of the forecast skill is realized by determining model variables that best represent this trend. The forecast skill relative to the estimate from the previous year is lower than the climate-relative skill but it is still greater than 0.__ for most lead times. Six-month predictions are also made for each month of the year and regional three-month predictions are made for __-degree sectors. The ice-ocean model output significantly improves the predictive skill of the forecast model.

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Naval Postgraduate School Arctic modeling effort (NAME): Towards Advanced Prediction of Arctic Sea Ice Melt

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Details of the recent Arctic sea ice melt, its causes and effects are not fully understood and require improved knowledge of interactions and feedbacks in the Arctic system. Environmental changes in the Arctic Ocean present great challenges to the U.S. Navy in particular and to the Department of Defense and Homeland Security in general. Although the Arctic is not currently a common operating area, a sustained research program is necessary to ensure the Navy is prepared for the contingency of increased international commercial and tactical operations in the Arctic. This is especially important in the marginal ice zone region of the Western Arctic Ocean, including the Bering, Chukchi and Beaufort seas, where due to the recent warming a significant reduction of the summer sea ice cover has already occurred.

In support of operational and climate research activities, a high resolution coupled ice-ocean model of the Pan-Arctic region forced with realistic atmospheric data from ECMWF for 1979-2004 has been developed at the Naval Postgraduate School (NPS) and used to investigate causes and variability trends of Arctic sea ice cover and the regional climate system. Our model results, validated against satellite and submarine observations, suggest that the rate of melt represented by sea ice thickness and volume might be faster than that of ice extent/concentration. We argue that the recent decrease of sea ice cover might be in significant part a result of an anomalous sea ice export through Fram Strait in the mid-1990s. This has been followed by the increased advection of warm Atlantic and summer Pacific waters into the upper Arctic Ocean, which acts to increase thermodynamic interactions at the ice-ocean interface. Sustained modeling studies of the past and present Arctic environment and prediction of its future states are necessary and critical as they can address the most outstanding questions related to Arctic environmental change.

Operational Sea Ice Charts: A Tool to Evaluate Passive Microwave Estimates of Arctic Sea Ice and Track Interannual Variability

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Operational sea ice charts produced weekly by the U.S. National Ice Center have been gridded to a 2_-km EASE grid and are available for the period 1972-200_. These charts use manual interpretation of satellite imagery and other information to create accurate analyses of Arctic sea ice conditions. Though they employ passive microwave data when other sources are not available, they are a relatively independent estimate of sea ice concentration and extent, particularly after 199_ when use of synthetic aperture radar data became prevalent. Also since 199_, partial ice concentrations were reported in the ice charts, including multi-year, first year, and thin ice categories. Thus, the ice charts provide a unique data set to track trends and to compare with the passive microwave data sets on a hemispheric and regional scale. The results show deficiencies in the passive microwave data particularly near the ice edge and during summer conditions. Such information can provide insights into quantitative errors of the passive microwave estimates and indicate possibilities for improvements.

Reduction of Arctic Perennial Sea Ice

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A poster is presented at the Symposium on Impact of an Ice-Diminishing Arctic on Naval and Maritime Operation (Washington, DC, July 10-12, 2007) to show the large reduction of perennial sea ice in 200_-2006 based on our published results [*Nghiem et al*., 2006]. The extent of perennial sea ice in the East Arctic Ocean (0-180^{o}E) decreased by nearly one half with an abrupt reduction of 0.9_×10^{6} km^{2}, while the West Arctic Ocean (0-180^{o}W) had a slight gain of 0.23×10^{6} km^{2} between 200_ and 200_, as observed by satellite scatterometer data during November-December. The net decrease in the total perennial ice extent is 0.72×10^{6} km^{2}, about the size of Texas. Perennial ice in the East Arctic Ocean continued to be depleted with an areal reduction of 70% from October 200_ to April 2006. With the East Arctic Ocean dominated by seasonal sea ice, a strong summer melt may open a vast ice-free region with a possible record minimum ice extent
largely confined to the West Arctic Ocean. Simultaneous scatterometer measurements of sea ice and winds will be crucial for sea ice monitoring and forecasts.

Nghiem, S. V., Y. Chao, G. Neumann, P. Li, D. K. Perovich, T. Street, and P. Clemente-Colón, Depletion of perennial sea ice in the East Arctic Ocean, Geophys. Res. Lett., 33, L17501, doi:10.1029/2006GL027198, 2006.

A Diminishing Arctic Shown by the Polar Ice Prediction System (PIPS)

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Ice forecasting systems, developed by the Naval Research Laboratory (NRL), have been predicting conditions in the Arctic for operational use by the U.S. Navy since the late 1980's. The Polar Ice Prediction System (PIPS 2.0) was implemented operationally at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) in 1996 and is currently run at the Naval Oceanographic Office (NAVOCEANO). PIPS 2.0 is a forecast system that consists of the Hibler ice model coupled to the Bryan and Cox ocean model. PIPS 2.0 forecasts conditions in all sea-ice covered areas in the northern hemisphere (down to 30° N in latitude). The horizontal grid resolution of the model is 0.28 degrees with 15 vertical levels.

Since 2002, NRL has been developing and validating a new ice forecasting capability called PIPS 3.0. PIPS 3.0 will cover the same area as PIPS 2.0 but with higher resolution (9 km). The PIPS 3.0 system will use the Los Alamos ice model, CICE, containing improved methods for model thermodynamics, physics parameterizations, energy-based ridging and has the ability to predict multi-category ice thickness. The CICE model is presently being coupled to the Navy's operational global ocean model and is expected to be operational by late 2007 or early 2008. The CICE code is also being coupled to the next generation global ocean model, HYCOM. The resolution of this grid will be 1/12th degree and expected delivery to NAVOCEANO is FY08.

Forecasting the Condition of Arctic Sea Ice on Weekly to Seasonal time Scales: NOAA transition of Research Applications to Climate Services (TRACS)

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The extent of arctic sea ice during summer has declined to near-record minima during the last four summers. Can we predict future minima? We plan to answer this question, and improve our operational capability to predict the conditions of Arctic sea ice on weekly to seasonal time scales. The forecasts provided by the National/Naval Ice Center help resources managers, navigators and hunters make better decisions regarding Arctic sea ice. Accurate sea ice information is important to naval operations, and increasing safety of life at sea.

The International Arctic Buoy Programme (IABP): Monitoring the Arctic Ocean for the International Polar Year (IPY) and Beyond

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http://iabp.apl.washington.edu

The International Arctic Buoy Programme (IABP, http://iabp.apl.washington.edu) has monitored the Arctic Ocean since 1979. For the International Polar Year, the Participants of the IABP plan to deploy over 170 buoys, which provide critical atmospheric, sea ice, and upper ocean hydrographic measurements on various space and time scales that cannot be obtained by other means.

The Arctic and global climate systems are changing. These changes threaten our native cultures and ecosystems, but may also provide economic and social opportunities. The IABP provides the longest continuing record of observations, which can be used to monitor, understand and respond to these changes.

Arctic Sea Ice Decline: Faster than Forecast?

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Climate models are in near universal agreement that Arctic sea ice extent will decline through the 21st century in response to atmospheric greenhouse gas (GHG) loading. From 19_3-2006, Arctic sea ice extent at the end of the summer melt season in September has declined at a rate of -7.8%/decade. Over the period of modern satellite observations (1979-2006) the trend is even larger (-9.1% per decade). Trends for March (the climatological maximum ice extent), while much smaller, are also downward, at -1.8% and -2.9%/decade over these two time periods. Although it is tempting to attribute these trends to GHG loading, the observed sea ice record has strong imprints of natural variability. However,
a role of GHG loading finds support in Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR_) model simulations that indicate downward trends in the annual mean ice cover over the observational period.

This study makes two main points:
1) If the IPCC AR4 multi-model mean time series properly reflect the response to GHG loading, then both natural variability and forced change have been strong players in the observed September and March trends, with the latter becoming more dominant during 1979-2006;
2) Given evidence that that the IPCC models as a group are too conservative regarding their GHG response, the GHG imprints may be larger.

Impact of an Ice-Diminishing Arctic on Naval and Maritime Operations

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