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Special Issue: Saving the Arctic

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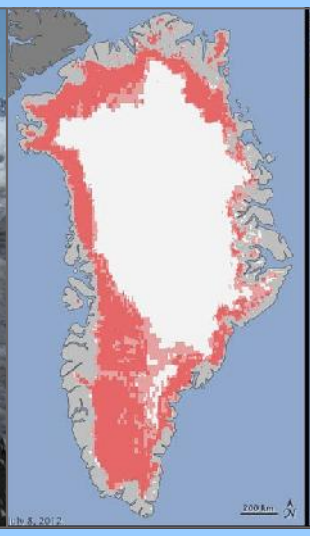

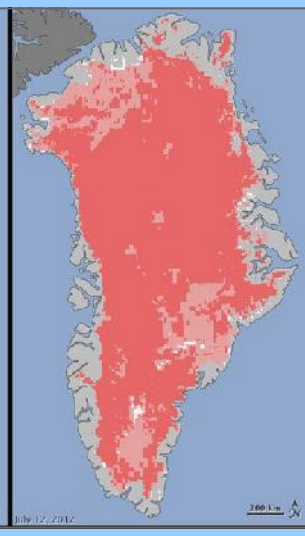

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A Message From the President

Arctic Climate Mitigation: Both an Imperative and a Key to Ending the Global Climate Gridlock

Commentary by John C. Topping, Jr.

The Arctic may be embarking on a climate change more rapid than at any time in the history of the human species. Reports in August indicated that Greenland glacial melting over the summer had already exceeded anything in the observational record. The same month scientists at the US National Snow and Ice Center reported that summer sea ice extent fell below the previous record low set in 2007. Reports by Russian and US scientists have raised concerns that a warming Arctic may be experiencing accelerated release of methane from the tundra, from lakes and ponds and even from ocean sediments, and that this could further speed a rapid warming already underway in the Arctic. The Arctic may be reaching a critical tipping point where disappearance of year round summer sea ice could, especially during the cold seasons, disrupt weather and ocean circulation patterns with effects well past the northern polar regions and with albedo changes that could speed warming both in the Arctic and on other parts of Earth. Coastal regions across the planet, already threatened by rising sea level from thermal expansion of upper layers of the ocean and melting alpine glaciers, would be further imperiled by rapid melting in Greenland.

Rapid action is essential if we are to avert irreversible ecological changes and highly disruptive climate change in the Arctic. This all is occurring as international action on climate change is gridlocked. Fortunately some traction is now being realized in a growing global effort to reduce emissions of short-lived climate forcers (SLCFs), such substances as black carbon, methane and other tropospheric ozone forming compounds. The intellectual rationale for this effort was first set forth by the Climate Institute's Chief Scientist, Michael MacCracken, in June 2008 in a seminal paper in the ***Journal of Air and Waste Management***, later followed by an important 2011 UNEP report; much of the political heft for action has been provided by US Secretary of State Hillary Clinton, who has been a driving force behind a burgeoning Climate and Clean Air Coalition.

This effort recognizes that 1) action on SLCFs such as black carbon and ozone forming compounds yields significant health as well as climate benefits; 2) action on methane often has considerable economic benefits through energy harvesting and safety benefits such as reducing risks of coal mine accidents; 3) many SLCF mitigation measures can be started quickly and enable us to leapfrog past the protracted wrangling associated with CO_2-focused negotiations; and 4) control of SLCFs can yield dramatic reductions in the radiative forcing that drives climate change.

The relatively short residence time of these compounds in the atmosphere means that actions to curb emissions of black carbon (which also darkens sea ice), methane and ozone forming compounds affecting the Arctic will have a near-term effect in slowing the ongoing increase in radiative forcing, possibly before the Arctic has passed irreversible tipping points.

The proposed ANSI Life Cycle Assessment Standard, which is likely to become final in the US by early 2013, includes a specific metric for contributions to Arctic warming that would lay the groundwork for estimating the relative effectiveness of reductions in emissions of black carbon and ozone forming compounds. This could be a very important step because present emissions reduction proposals give a zero valuation for the reduction of black carbon and a relatively low valuation for methane.

Recognizing the importance of the proposed new ANSI LCA Standard, the Climate Institute in collaboration with leading Arctic and other environmental scientists, forestry and life cycle experts, indigenous leaders, and environmental organizations including the Worldwatch Institute, National Wildlife Federation, Southern Alliance for Clean Energy, Heinz Center, and Environmental and Energy Study Institute, has stepped forward to create an Arctic Climate Action Registry (ACAR) to promote and facilitate reductions in emissions of black carbon, methane and ozone forming compounds that have significant near-term effects on the Arctic.

This Special Issue of ***Climate Alert*** delves into some sticky scientific issues (e.g. variation of transport and albedo effects by season and feedback mechanisms that can often amplify warming) and potential mitigation measures, including forest and agricultural management (especially reducing forest fires and grassland burning), oil and gas extraction and production, air travel and shipping. Action to avert irreversible and highly disruptive Arctic climate change is essential in its own right; it could also energize badly stalled climate negotiations.

The Potential for the New ANSI Life Cycle Analysis Standard to Slow Arctic Warming

By Michael MacCracken, Climate Institute Chief Scientist

To move to the next level of evaluating and scoring the health, environmental, and resource implications of human activities, the American National Standards Institute (ANSI) is nearing the conclusion of a multi-year process of developing, proposing, reviewing, and completing the approval of a new life cycle standard. This standard, entitled "Life Cycle Impact Assessment Framework and Guidance for Establishing Public Declarations and Claims" is being prepared by the Standards Committee on Type III Life-Cycle Impact Profile Declarations for Products, Services and Systems, whose Subcommittee on Impacts of Greenhouse Gases and Black Carbon is Chaired by Climate Institute President John Topping.

The areas encompassed by the proposed standard include: depletion of energy, water, minerals and metal, and biotic resources; impacts on land use, ecological systems, and critical species; impacts of emissions of greenhouse gases and black carbon on global climate change, the amplified changes going on in the Arctic, ocean acidification, and ocean warming; regional environmental consequences resulting from regional environmental acidification (i.e., acidification of precipitation), stratospheric ozone depletion, ecotoxicity, and eutrophication; the impacts of emissions on human health, including near surface ozone, particulate matter, toxic chemicals, toxic emissions, indoor air pollution and ingestion of toxic materials; and risks from untreated hazardous and radioactive wastes. The intent of being so broad is to help ensure that the full range of possible impact categories are considered so that a comprehensive synthesis can be presented and considered instead of an analysis or claim omitting important implications of an activity, product, or service.

The key advance taking place in Type-III analyses is that the standard not only will now take account of the implications of the activity itself (so the resources and energy required and the emissions and waste products), but also takes account of how these implications then cause impacts themselves. As an example, the standard accounts not just for the amount of air pollutants emitted, but also for the health and environmental effects of the resulting atmospheric pollution, making it matter whether an industrial plant is located in an urban or rural area as well as its control of emissions.

Consideration of the environmental implications of activities on climate would be a major advance. At present, compilation of CO_2-equivalent emissions using the 100-year Global Warming Potential (GWP) is the metric that is the basis of international negotiations because of the interest in limiting long-term global warming. The new standard proposes to also consider the implications for near-term warming (so out to 2050, which is when global average warming is projected to be near 2ºC), for ocean acidification, for Arctic warming, and for ocean warming (which is coupled to the potential for long-term warming). In broadening the set of impacts of greenhouse gases to this broader set of metrics, this increases attention on the importance of reducing emissions of methane and black carbon, as was highlighted in the recent UNEP Assessment as well as earlier in research by Michael MacCracken, the Climate Institute's chief scientist for climate change programs. With the especially rapid pace of climate change in the Arctic, sharply reducing the emissions of these short-lived species is especially important because the moderation of warming influence can occur over decades and less. While it has unfortunately been proving difficult for nations to so far agree on reductions on emissions of CO_2 and long-lived species, the many co-benefits of reducing the emissions of short-lived species (including especially reduced air pollution and health impacts) can hopefully serve as added incentives for expanding on the present efforts in this area (unfortunately mostly voluntary in the US, at present, but proposals to strengthen these regulations are in progress).

Because of this broadening of the metrics that the standard proposes be used, it is important that its review and adoption proceed apace. Since being approved earlier this year by the Standards Committee as ready for external review, the proposed standard has been posted by ANSI for widespread review and comment. This open review process is just concluding, and the coming few months will be spent reviewing the comments and revising the proposed standard. The intent is that, assuming the review and revision effort is successful, will be to present the proposed standard for formal ANSI approval by the end of 2012 or soon thereafter. Once approved, the next steps will be to move toward international adoption of the standard and to encouragement, both voluntary and eventually regulatory, of the use of the standard in promoting actions to cut emissions and impacts, especially in the near-term in the Arctic as a key step to slowing global climate change.

A Changing Arctic
By Michael MacCracken, Climate Institute Chief Scientist

The Arctic is more than just a geographic area; it is a location with unique flora and fauna, a place to which species migrate and draw upon its resources, and home for many thousands of years of peoples who have figured out how to survive, and even thrive, in conditions so harsh that their culture has necessarily had to be built on the basis of sharing and cooperation to survive. And the Arctic is also being changed more rapidly by human-induced climate change than anywhere else on Earth. While most of those living in the mid- and low-latitudes cannot understand why those in the Arctic would not want to be warmer, those living in the Arctic have attuned their practices and cultures to the cold, and are having a very difficult (and expensive) time figuring out how they can survive with much less cold.

The Arctic is cold compared to lower latitudes because, over the course of a year, it receives much less solar radiation. During the summer, as much solar radiation reaches the top of the atmosphere in the Arctic as at the equator, and temperatures in the Arctic rise to well above freezing, melting back snow and ice. In the winter, however, the Arctic receives no solar radiation, and so depends on the oceans and atmosphere to carry heat poleward from lower latitudes (primarily from heat stored in the tropical and subtropical oceans) where the Sun is providing energy year round. The cold conditions in the winter freeze rain into snow and open ocean waters into sea ice, turning the surface white. To the extent the snow and sea ice last into the times when the Sun is shining in the Arctic, they, along with clouds in the region, reflect a substantial fraction of the incoming solar radiation back to space, allowing the region to stay cool and, at least in the past, the sea ice to persist through the summer and the surface of the region's many mountain glaciers and the Greenland Ice Sheet to lose no more mass than was gained from each year's snowfall.

With the region's climate changing only very slowly over the past several thousand years, the flora and fauna that survived and succeeded in the Arctic were those that were best adapted to the relatively stable baseline conditions and the variations that could occur. Thus, the polar bear could survive because it learned how to capture seals when they came up to breathe at holes in the ice, the walrus could survive because it had sea ice as a resting spot as it sought food on the continental shelves, and the caribou could survive because the frozen land surface (i.e., the permafrost) melted just enough each summer for plants they could eat to grow enough to sustain them, but there was not so much warming in the spring that river ice melted, making river crossings with their calves much more difficult as they migrated to the edge of the Arctic Ocean each year.

The Indigenous Peoples of the Arctic figured out how to succeed in similar ways—how to capture whales and seals as they surfaced in cracks and holes in the sea ice, and before the sea ice melted or broke away from land and took them to their deaths; how to share the bounties of their harvest with all in the community, just as they would share in the work of their community, for doing otherwise, would likely end in death during a particularly harsh winter or as a result of an injured leg that prevented harvesting a seal or whale during the very busy, and very short, warm season.

Now, the climate of the Arctic is changing, and changing dramatically. Emissions of carbon dioxide and other greenhouse gases are preventing the Arctic from cooling as much during the winter and retaining more of the incoming heat during the summer, especially as a result of the snow and ice melting back earlier in the year and so darkening the surface and allowing more absorption of solar radiation. The melting back of the sea ice means less area for walrus and polar bear to use in getting the food they need, less time and support for the peoples of the Arctic to catch the seals and whales that provide vital food for their communities, and less suppression of ocean waves that erode the barrier islands where the communities have been established. The melting back of the permafrost not only replaces transportation routes to melted marshes, tilting and cracking roads and foundations when refreezing occurs in winter, but also leads to release to the atmosphere of the carbon stored in the soils, either as mostly carbon dioxide, which would lead to some additional global warming, or with a significant fraction of methane, which would lead to a good bit of global warming. The melting back of glaciers and the Greenland ice sheet adds water to the oceans, raising global sea level, presently at a rate of inches per century, but potentially at a devastating rate of feet per century for coastal areas around the world.

For those of us in middle latitudes, warming of the Arctic and the amount and changes in the timing of the cold air that is created there from fall

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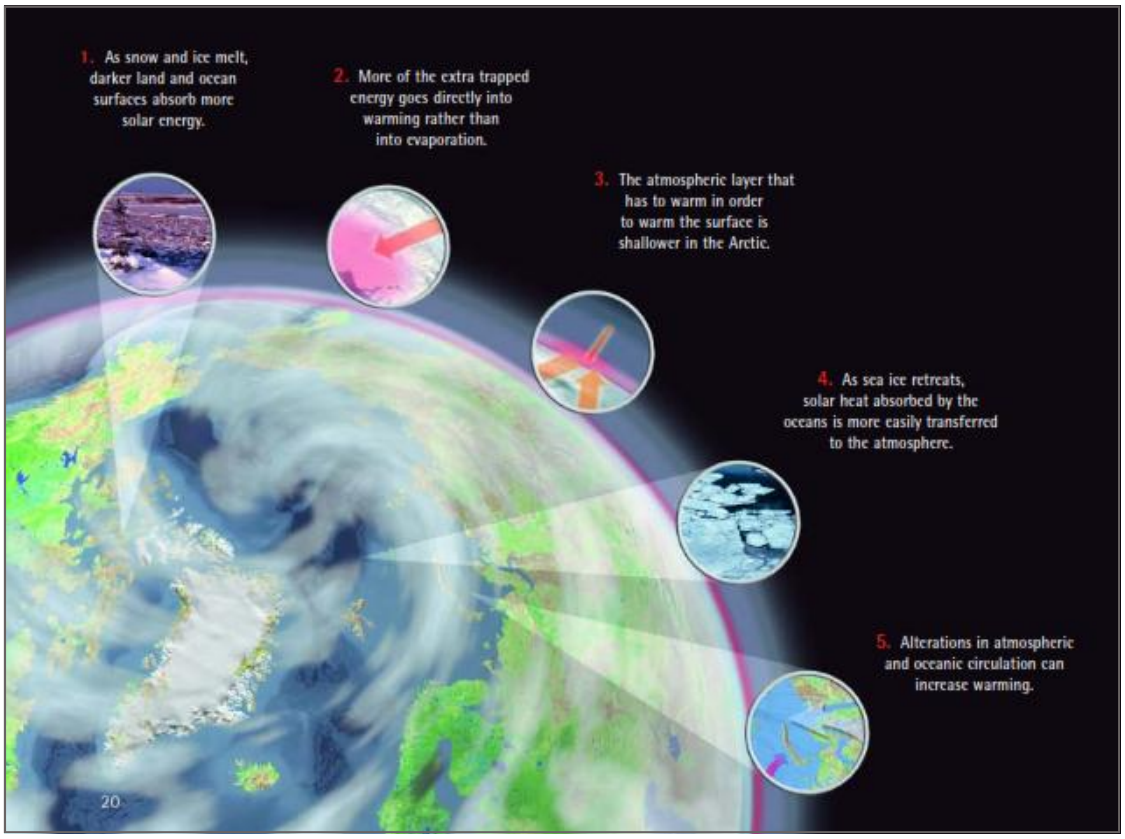
through spring affect the weather in mid-latitudes.

The weather in the eastern half of North America is a result of cold air moving to lower latitudes from the Arctic across central Canada and the Great Plains colliding with warm, moist air mostly from the Gulf of Mexico, Caribbean Sea, and the Atlantic Ocean. This collision creates the fronts and convective storms that bring precipitation and storms, including high winds and tornadoes. Before the Arctic warmed, there was typically enough cold air to push this collision of air masses in wintertime to near the Gulf Coast; with the Arctic warming, the timing and location of the collision is shifting poleward, with the warm season tending to become longer across much of the contiguous 48 states. When a La Niña occurs in the eastern tropical Pacific Ocean, the warm moist air is able to push further north across North America, this past winter pushing so strongly that the polar air was kept in the Arctic as it blew across northern Canada, only to then spill out in force over Europe, making their winter very cold. In the few preceding years when the Pacific was more in an El Niño state, the reverse happened, and cold air outbursts from the Arctic could push the moist air back toward the Gulf of Mexico, leading to big snowstorms along the US East Coast when the collision of cold and moist air occurred in the Mid-Atlantic states, causing significant disruption.

Weighed against the significant disruption to the flora and fauna of the Arctic, to the peoples and traditional lifestyles of the region, to the increasingly disruptive consequences of the Arctic's contribution to sea level rise, and to the disruption of the weather of the mid-latitudes, it is suggested by some that there are benefits from Arctic warming. Indeed, for a few months of the year, shipping routes from the Atlantic to Pacific basin nations will be reduced (although there will be costs to ensure this is done safely and without damage from pollutant emissions in this sensitive region), and there will be easier access to natural resources (although there will be significant costs to ensure there are not damaging spills). As for the results of assessments of relative costs and benefits in regions around the world, the benefits tend to be financial and of quite limited magnitude, whereas the costs and damages tend to be much more fundamental and disruptive for the Earth's biosphere and cultures, with many species likely to go extinct and long established communities having to relocate, not just the villages of Indigenous Peoples in the Arctic, but, as a result of global sea level rise, cities around the world.



In addition to warming caused by emissions of greenhouse gases and warming aerosols in and near the Arctic, a number of Earth system processes tend to amplify polar warming. Source Arctic Climate Impact Assessment, 2004.

The disruption that is occurring and the risks of much more seem far in excess of potential benefits, and it is for this reason that the Climate Institute is committed to limiting warming in the Arctic to the greatest extent possible (see page 19).

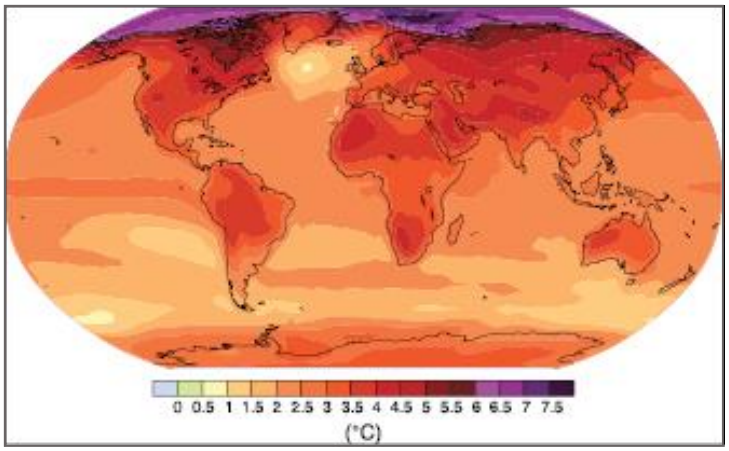
Arctic Climate Feedbacks and Projections
By Lauren Smith

Arctic climate is an important indicator of global climate change. Global warming is most pronounced in this region, with warming occurring at twice the rate as the rest of the world. Temperature increases of 2-3° C since the 1950s have been recorded, with increases of up to 4°C in winter months. The IPCC projects annual warming of 5°C by the end of the 21st century in the Arctic, according to the ensemble mean of the A1B scenario, with a range across all scenarios of +2-9°C. In contrast, global projections are in the range of 1.1°C to 6.4° C, with "best estimates" of 1.8-4.0°C.

The "northern, high-latitude maximum in warming consistently found in all AOGCM simulations" is referred to as arctic or polar amplification (IPCC, 2007). Arctic amplification occurs as a result of positive climate feedbacks, namely the ice-albedo feedback, the melting of permafrost and subsequent release of greenhouse gases, and the formation of wetlands. The reduction in the amount of time that sea ice insulates the atmosphere from the Arctic Ocean is another positive feedback in the Arctic.

The ice-albedo feedback refers to the fact that snow and ice melt with rising temperatures, and this decreases albedo, or reflectivity, and the amount of shortwave radiation that is reflected back to space. Since snow and ice are highly reflective, the newly exposed surface absorbs more radiation than before which leads to additional melting of snow and ice. Hence, the initial decrease in albedo propagates a further reduction in albedo. Because the earth's energy budget is partially dependent on albedo, the decrease in albedo increases surface temperatures and accelerates global warming.

Melting of permafrost is another positive feedback. Permafrost is permanently frozen subsurface material (rock, soil, sediment, etc.) that remains at or below O°C continuously for two or more years. It contains deposits of carbon and methane (e.g. coal, gas, decayed plant matter), which can be released as permafrost melts. Because carbon dioxide and methane are greenhouse gases, emissions from permafrost would contribute to additional warming. Methane is much more potent than carbon dioxide on a per molecule basis, so the potential for accelerated warming is a concern, especially in the near term due to methane's short lifetime in the atmosphere.



Geographical pattern of surface warming in ˚C. Source: IPCC, 2007.

Thawing permafrost is also a concern because microbes and methanogens consume and release carbon and methane, and this process is made easier with warmer temperatures. Similarly, permafrost sometimes contains methane hydrates. Some studies suggest warming could result in rapid decomposition of hydrates and release of methane into the atmosphere.

Wetlands also contribute to methane releases and are a positive feedback. As ice melts, the environment is more conducive to wetland formation via higher temperatures and a longer thaw season, which means additional releases of methane through diffusion, gas bubbles, and plants. Wetlands also house methanogenic bacteria, which enhance emissions. The long-term net effect of wetland formation is complicated; however, as a recent study from *Nature Geoscience* suggests, an increase in soil drainage with warmer temperatures could regulate the extent of wetlands.

Lastly, a positive feedback occurs as the insulating effect of sea ice is reduced. This contributes to increases in global warming through air-sea heat exchange. As higher latitudes warm, sea ice extent decreases, which diminishes its insulating properties.

In addition to positive feedbacks that amplify warming, higher temperatures also trigger negative feedbacks that reduce warming. One of the main negative feedbacks discussed in the context of Arctic and global climate change is the potential weakening of thermohaline or overturning circulation, the ocean "conveyor belt" that distributes heat and matter across the earth's oceans. As the oceans warm, salinity and density decrease, which means less deep water formation. Weakened thermohaline circulation is a negative feedback because it prom-

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otes colder conditions and increased albedo in the Arctic as less heat is transported poleward, which causes a weaker circulation still. Most studies express uncertainty about changes to the overturning circulation over the next century. The IPCC AR4 suggests this would cause some regional cooling but also emphasizes the much stronger effects of greenhouse gases on surface temperature.

Other negative feedbacks include increased freshwater input into the ocean which results in less ocean mixing and reduces temperature increases, increases in vegetation which absorbs CO_2, and increases in moisture supply and evaporation that could restore glaciers.

Impacts and Projections

One of the most pressing issues associated with warmer temperatures is sea level rise from melting glaciers and thermal expansion. Sea level rise is projected to increase 0.18 to 0.59m at 2090-2099 relative to 1980-1999. This poses serious economic and social consequences for coastal communities, with considerable adaptation and relocation costs. In one study, it was estimated that relocation of Kivalina, Alaska to a nearby site would cost $54 million.

Other projections for Arctic climate include: positive trend in the North Atlantic Oscillation during the 21st century, increases in temperature extremes and heat waves, increases in precipitation (10-28% by the end of the 21st century), and decreases in sea ice (~22-33% by 2080-2100).

Warming also affects local ecosystems. A warmer climate means species adapted for colder climates will be in danger of losing their habitat and other species will thrive further north. Arctic plants and animals are vulnerable to attacks from pests and parasites that develop more effectively in warmer conditions, and impacts to individual organisms and food sources impact the entire food chain. Melting permafrost also means loss of habitats and human infrastructure, and melting of glaciers and sea ice increase the freshwater supply to the ocean and affect marine ecosystems. Impacts on culture and communities are also discussed on page 10.

Short-Lived Climate Forcers in the Arctic
By Ashwin Kumar

Mitigating Arctic climate change is urgent, but there are limits to what can be achieved. The earth's temperature field is not in equilibrium with radiative forcing; that would require hundreds of years for the global oceans to warm. While the oceans and surface are warming, the earth is emitting increasing amounts of radiation back to space. But in the meantime there persists an energy imbalance which causes temperature to rise for a long time. Even if we were to immediately stop all anthropogenic forcing, cumulative emissions since the industrial revolution have committed the earth to a global mean surface temperature rise of approximately 0.6 degrees Celsius. For the Arctic region, this figure is much higher because temperatures here rise much faster than in lower latitudes (Arctic amplification).

Because radiative forcing from carbon-dioxide already present in the atmosphere cannot be eliminated soon, the only option to significantly mitigate near term climate changes in the Arctic is via short-lived climate forcers. These are methane, ozone and black carbon and have an important effect on radiative forcing in the Arctic, albeit one that is secondary to carbon-dioxide. Methane and ozone are both greenhouse gases, they make the atmosphere more opaque to outgoing longwave radiation and enhance surface warming. Black carbon suspended in the atmosphere absorbs sunlight, but instead of emitting photons as a result it converts the energy to heat. Where it deposits on ice and snow, black carbon darkens the surface to sunlight so that more of it is absorbed. Methane, ozone and black carbon are called short-lived climate forcers due to their short lifetimes in the atmosphere. So mitigating their emissions will, in about a decade at most, eliminate them from forcing. Therefore, action on short-lived forcers can hold back some part of Arctic climate change. But this cannot be a substitute for early action on carbon-dioxide abatement. For, long-term temperature changes in the Arctic would depend on cumulative emissions of this gas, and delaying abatement would only make it more difficult to keep this under the required target. In contrast, mitigating short-lived forcers might appeal as flexible measures to be used at the right time. However the climate changes already happening in the Arc-

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tic suggest that there is no time to lose.

Furthermore, eliminating black carbon and ozone emissions that have a high chance of causing radiative forcing in the Arctic is potentially more cost-effective, compared to reducing global carbon-dioxide emissions, at mitigating Arctic climate change over the next several decades.

Where do these short-lived forcers come from? In a generic sense, they come from natural and anthropogenic sources throughout the world. Methane is produced from coalmines and from natural gas deposits, rice-cultivation, waste disposal, burning wood, and in the gut of certain animals. There are also large underground deposits of methane in the Arctic which would become difficult to contain as overlying ice melted. Ozone is produced as a product of complex reactions involving gaseous and volatile compounds in the presence of sunlight. The main ozone precursors include nitrogen and nitric oxides, methane, volatile organic compounds, and carbon monoxide, and there are multiple pathways in which they can combine to yield ozone. Black carbon is produced from the incomplete combustion of fossil fuels and biomass; and deliberate fuel burning and natural fires contribute to its emissions.

Carbon dioxide in the atmosphere lasts much longer than the 1-2 years it takes to mix air around the globe. As a result this gas is well-mixed and can be mitigated anywhere on the earth for the same effect on Arctic climate. In contrast, ozone and black carbon have atmospheric lifetimes measured in days, so understanding their sources and transport becomes paramount. Methane has an atmospheric lifetime of about 9 years. So it is relatively well-mixed, and mitigation benefiting the Arctic can occur globally. In Section 2.1 we elaborate on the sources and transport of these short-lived pollutants, and examine mitigation strategies that might make a difference.

SOURCES AND SEASONALITY OF SHORT-LIVED CLIMATE FORCERS

By Ashwin Kumar

Unlike most elsewhere in the world, short-lived forcers in the Arctic primarily originate in other regions and are transported over long distances. There are local sources in the Arctic; the main ones being methane from wetlands, as well as ozone precursors and black carbon from ships and from boreal forest fires. But mitigation of near-term Arctic climate change requires attention to distant sources of these pollutants; and these sources and long-range transport effects must be understood. The exception is methane. Being long-lived and well-mixed, its mitigation can be undertaken anywhere to affect Arctic forcing. Here there are opportunities for reduction such as capturing methane gas from coal mines and from solid waste in landfills. Furthermore, the captured methane can be used for power production or heating. Possibilities also exist for repairing methane leaks from various stages of natural gas production and transport wherever this occurs.

The picture is different for ozone and black carbon with their much shorter atmospheric lifetimes. Long-range transport of these short-lived pollutants emitted in mid-latitudes is dominated by westerly winds. These are poleward winds blowing through much of the mid-latitudes from west to east and throughout much of the year. Westerlies increase in strength with height, and are more intense in winter months when north-south temperature gradients are higher. Therefore pollutant transport is generally more efficient in winter. And for pollutants that are lofted higher into the atmosphere, longer distances from the Arctic become increasingly important as source regions. The eastern coasts of Asia and North America lie near the origins of their respective oceanic mid-latitude storm tracks; where these storms are accompanied by significant rising motion, pollution from these regions can be transported to high altitudes in the Arctic. The result is that emissions from northern Eurasia are the largest long-range contributors to near-surface black carbon in the Arctic. But at rising altitudes in the Arctic atmosphere, emissions from East Asia play an increasing role so that high up in the troposphere these emission are the largest source of Arctic black carbon. Elimination of black carbon in the Arctic would require widespread controls throughout the northern hemisphere. But since low altitude black carbon exerts the strongest influence on surface temperature, aggressively targeting emissions originating in northern Europe could be a priority; of course in addition to emissions occurring within the Arctic from stationary

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and marine fuel sources, and from forest fires.

The strongest influence on Arctic ozone is from nitrogen and nitric oxide emissions in North America. However, owing to the chemistry of ozone formation, controls on these pollutants will be most effective when combined with controls on other precursors: methane, volatile organic compounds, and carbon monoxide. Reducing transportation and industrial emissions from source regions in North America, together with controlling agricultural fires in northern Eurasia, can contribute to controlling ozone in the Arctic. Furthermore, if shipping in the Arctic grows in volume, controlling emitted nitrogen oxides might also become crucial to this effort.

Seasonal variation in emissions and in the various chemical and physical processes involved in long-range transport causes some source regions of short-lived Arctic pollutants to become more important during some parts of the year. However, the Arctic summer is when the surface temperature response closely follows the magnitude of the Arctic surface radiative forcing. During other seasons, the Arctic temperature response is more strongly associated with overall northern hemispheric forcing.

This highlights the importance of large scale intra-hemispheric energy transport for the Arctic surface temperature during months besides the summer. A corresponding mitigation strategy might be to prioritize those sources which, in summer months, originate much of the long-range transport of short lived pollutants to this region. With black carbon and ozone, surface air concentrations in the summertime Arctic are most sensitive to emissions from Europe; emissions from North America and East Asia have a significant but much smaller effect, particularly for black carbon. Likewise, European black carbon emissions are the largest source of surface deposition in the Arctic, and for deposition over Greenland in the summer months. In spring, emissions from North America are most important for deposition over Greenland. On a per-mass basis during spring and summer, deposition of black carbon over Greenland is most sensitive to emissions from North America while deposition over the rest of the Arctic is most sensitive to emissions from Europe.

Prioritizing the mitigation of black carbon emissions from Europe, followed by emissions from North America, will likely have the largest impact on Arctic surface forcing during the months when the sun is shining brightest and when local forcing plays the major role. While the effects of black carbon mitigation will only be felt during the sunlit months in the Arctic, some measures such as energy efficiency improvements can also reduce emissions of greenhouse gases that play a warming role year-round. As for ozone, emissions reductions from Europe will be important to decrease summer forcing in the Arctic; and the necessary investments will yield benefits throughout the years. Ultimately, however, the fate of Arctic ice is influenced by surface regional conditions and the phase of precipitation at all times of the year. Outside the summer months, energy transport to the region plays an important role in the energy budget; so short-lived forcers throughout the northern hemisphere must be eventually brought under control. Measures to mitigate long-range transport of short-lived forcers can thus have indirect benefits for the Arctic, by decreasing warming closer to the source, particularly when implemented in mid-latitudes. In addition, local co-benefits of reduced air pollution and improved crop yields from decreased surface ozone could also be considered in planning such actions.

Conditions in the summer pose an important challenge. Present-day aerosols in the Arctic tend to produce clouds brighter and longer-lasting than they would otherwise be, by distributing cloud water over more droplets. In the summer when the sun is shining brightly, this leads more sunlight to be reflected back to space. Reducing black carbon aerosols in the Arctic would tend to diminish this effect, offsetting some of the beneficial effect of mitigating direct warming. In the crucial summer months, it would then be important to know what the net effect of mitigating black carbon on surface warming is, and there haven't been any studies till date of this issue. In winter over the Arctic, aerosols have the same effect on clouds but the consequences for radiation balance are opposite because longwave radiation plays the major role. As a result by reducing longwave cloud forcing of the surface, mitigating black carbon during winter months could yield a further advantage for surface climate.

In summary, there are many options for reducing Arctic climate forcing. At the same time, climate effects of actions will be influenced significantly by factors outside human control. Therefore it is necessary to explore robust strategies that demonstrably reduce summer radiative forcing in the Arctic, while also creating conditions for reductions throughout the mid-latitudes and for much of the year.

Effects of Climate Change on Native Alaskans
By Molissa Udevitz

Alaskan Ice Cellar. Photo: Kenji Yoshikawa.

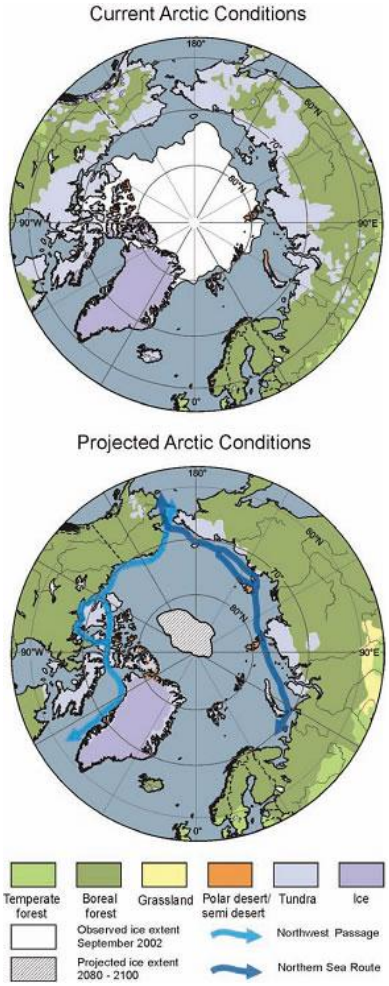
Residents of northern Alaska and Canada are expected to experience the most disruptive impacts of climate change. Approximately 65,500 people live in areas of Alaska that are currently dealing with some of these disruptive impacts. Native Alaskans make up the majority of this population, and they continue to practice traditional subsistence lifestyles, living in small villages inaccessible by roads. As the climate changes at an unprecedented rate, their traditional way of life and their villages are threatened.

Climate change has brought more extreme and variable weather to the Arctic, creating hardships for Native Alaskans. The unpredictable weather makes gathering subsistence resources more dangerous. Ice conditions caused by later freezes and earlier thaws are especially hazardous to hunters and can even prevent hunting trips. Warmer winters and less snow fall makes traveling by snow machine difficult if not impossible. Melting sea ice has forced hunters to travel farther distances in order to reach the edge of the ice to find game.

The unpredictable weather has also brought more large storms, resulting in flooding and erosion that endanger entire villages. A 2004 U.S. Government Accountability Office report recognized 86% of Native Alaskan villages face risks of flooding and erosion, with four facing imminent threats. By 2009, 31 villages were identified as facing imminent threats. Twelve villages are currently in the process of relocating or exploring relocation options, and the residents have been called the first U.S. climate change refugees. In addition to the emotional toll of leaving their village, Native Alaskans are facing financial and bureaucratic challenges before being able to relocate. These are especially difficult hurdles for communities that are used to being largely self-sufficient.

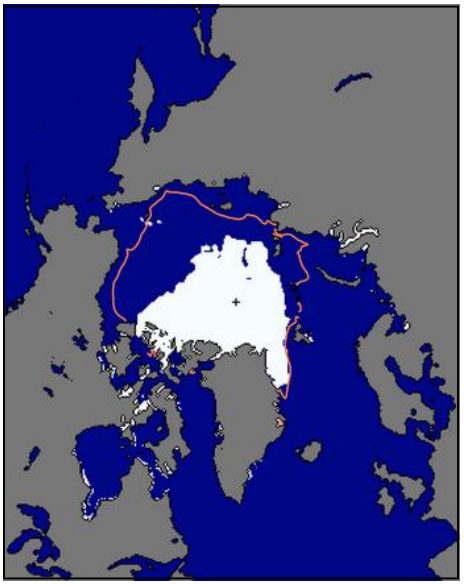
As Native Alaskans struggle with extreme weather, they are also dealing with food storage concerns. Not only is melting permafrost damaging village infrastructure and hindering travel, but it is harming traditional ice cellars. Some Native Alaskans have discovered their permafrost "freezers" no longer keep whale meat and muktuk (whale blubber) frozen year round. This creates the potential for health risks as a result of eating spoiled food and presents a new challenge for communities that may harvest one whale annually and make it last all year. Additionally, entering damaged ice cellars is dangerous because they have a greater chance of collapsing.

These are just a few examples of how Native Alaskans have already been affected by climate change. As climate change continues, they will face new challenges and further threats to their traditional culture. Mary Pete, a Native Alaskan and the Commissioner of the U.S. Arctic Research Commission, explains the importance of her lifestyle, "Through subsistence, indigenous peoples are able to connect with the land and our place in it; we derive our identities from our homeland." If climate change is allowed to run its course, a culture may be lost.



Current and projected sea ice and vegetation conditions in the Arctic. Projections for sea ice are 2080-2100; vegetation 2090-2100. Source: IPCC, 2007.

Benefits and Hazards of a Warming Arctic
By Charles ffoulkes



Sea Ice Extent—Aug 27, 2012. National Snow and Ice Data Center, Boulder, CO

Evidence in the scientific literature clearly indicates that the Arctic is warming at an unprecedented rate, which is likely to have many impacts on the environment and climate at both the local and global scale. Whether a particular impact is perceived as negative or positive often depends on one's interest and is an extremely controversial topic, despite the fact that most 'positive' impacts tend to have negative implications for the environment.

In terms of the potential economic gain, a warming Arctic seems favourable for many industries. As land and sea ice melt, the Arctic becomes much more accessible, allowing for the exploration of many natural resources that were once considered non-beneficial to extract, including the mining, oil and gas, and fishing industries. In addition, a reduction in sea ice opens up new trade routes for commercial shipping lanes, which can save significant amounts in terms of time, energy and capital. Other positive impacts include greater potential for agriculture at higher latitudes, an extended growing season, and increased energy security for the countries lucky enough to have boundary claims within the Arctic region.

However, all of these 'positive' aspects have knock-on effects, resulting in negative environmental impacts, such as habitat destruction, pollution, human-made disasters, conflict of resources, and positive feedback mechanisms for further climatic warming. Even with the most rigorous health and safety guidelines and industry protocols implemented, the chance of disaster occurring in the Arctic is significantly greater than most other places on Earth, due to its inhospitable environment, its unpredictable and changeable weather, and the remoteness and unfamiliarity of the Arctic to invasive human species. As a result, increasing human presence in the Arctic region is only increasing our vulnerability to hazards and consequential disasters, since nature is far more prominent in these foreign conditions.

The effects of Arctic warming are going to have negative implications which are felt globally. Unlike the Antarctic which essentially has a relatively self contained climate that may take decades or even centuries to be significantly affected by climate warming, the Arctic is considerably influenced by anthropogenic climate warming. If warming continues at the current rate, there is a chance that fundamental consequences will occur, such as Arctic summers being free of sea-ice, a disruption to ocean circulation patterns, rising sea-levels, increased conflict for natural resources, melting permafrost, increased erosion, and a loss of many Arctic species which depend on the ice to live. Not to mention the cultural implications on native communities who require the sea-ice to travel, hunt, and live their lives in traditional ways.

Some of these consequences are already being felt in the Arctic, and are likely to become more severe as positive climate feedback mechanisms persist, thus enhancing the rate of warming. Of particular concern is the thawing permafrost around the Arctic Circle. In addition to the direct effects of permafrost melting, such as building foundations sinking and roads buckling, there are indirect consequences of much greater significance. Methane that has been trapped underground for thousands of years is being released into the atmosphere as the ice melts. This greenhouse gas is 20-25 times more powerful at trapping heat in the atmosphere than carbon dioxide, and has the ability to speed up warming in the Arctic exponentially as critical thresholds in the climate system or reached.

As a result, the economic gain from some industries in the Arctic in the imminent future will likely be dwarfed by the cost of global adaptation to climate change. As the climate system adjusts to warmer conditions, sea levels will rise, environments and wildlife will be affected, and natural weather events will likely become more extreme, affecting the vast majority of the planet in some form.

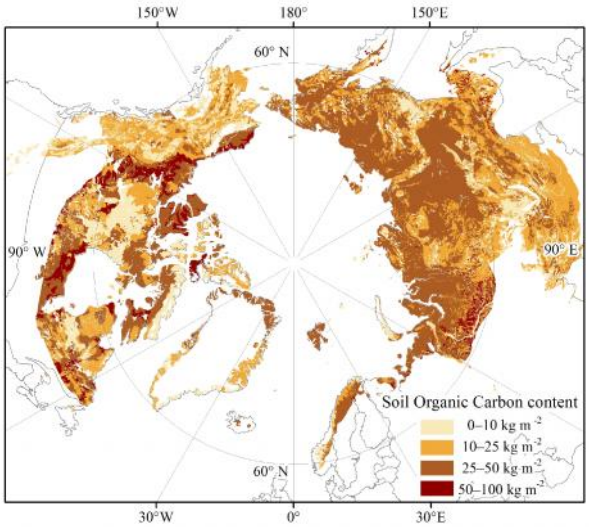
IS METHANE REDUCTION THE KEY TO SLOW ARCTIC WARMING?

By Charles ffoulkes

The Arctic region exhibits vast reservoirs of methane (CH_4), found in frozen Arctic tundra soils, marine sediments including gas hydrates, and the Arctic Ocean itself. Despite the natural variations of Arctic methane release into the atmosphere, it can also act as a dangerous positive feedback mechanism in anthropogenic climate change, which enhances the warming process as increased levels of the gas are released.

The Intergovernmental Panel on Climate Change (IPCC) indicate that methane concentration in the atmosphere has increased by 150% (increased by 2.5 times) since 1750. Furthermore, ice core records suggest that methane levels are currently higher than any point in the past 650 ka, indicating that the influence of anthropogenic activities has had a profound impact on the climate. The importance of methane in the climate warming battle is due to its heat trapping properties. Methane is a potent greenhouse gas which is approximately 20-25 times more efficient than Carbon Dioxide (CO_2) at trapping heat in the atmosphere. As a result, even relatively small releases of the gas can have a significant influence on regional climates. Current estimates suggest that the present 'global warming' effect from greenhouse gases is comprised of approximately 60% CO_2 emissions, 20% CH_4 emissions, 14% from halocarbons and 6% from nitrous oxide emissions.

Methane is found in natural gas deposits and is generated naturally by bacteria that break down organic matter, such as in the guts of farm animal. About two-thirds of global methane comes from man-made sources. The release of methane is therefore a key concern for warming in the Arctic, which despite the fact it has a relatively short atmospheric lifetime of only 12 years or so (comparative to CO_2 which is around 100 years), it still contributes an increased radiative forcing of approximately 0.5 w/m^2.



Extent of the northern circumpolar permafrost region and soil organic carbon content to a depth of 1 m, estimated using the Northern Circumpolar Soil Carbon Database.

Large quantities of methane are stored in permafrost or cryotic soil, which is soil at or below the freezing point of water 0 °C (32 °F) for two or more years. In the Northern Hemisphere, permafrost accounts for 24% of the land, where surface air temperatures only fluctuate above freezing for short periods of the year, which maintains the frozen ground for multiple years/decades. However, due to anthropogenic warming, the Arctic soils are melting for longer periods, causing noticeable quantities of methane to be released into the atmosphere from the soil, cracks in sea ice and cracks in frozen lakes.

Although these rates are still relatively small in comparison to global CH_4 emissions, it is likely that within the next few decades they will be much more significant as the ground continues to warm, partially associated with changes in surface albedo.

The significance of Arctic methane release was emphasised in a recent study, which indicated that in 2003, 2% of global CH_4 emissions came from the Arctic latitudes. However, findings showed that by 2007, methane emissions from the Arctic had increased by 31% (more than any other region), representing an added 1m extra tons of methane each year. The melting of permafrost also has additional implications in the Arctis region. As the ground becomes ice-free, the soil subsides and moves, destabilising the foundations of buildings, roads, pipelines etc that were once established in the frozen ground. In the next few decades, it is likely that melting permafrost will have added economic implications, as repairs and maintenance of infrastructure is required throughout the Arctic.

Arctic amplification associated with methane release is therefore a serious matter for concern, leading some scientists to describe melting permafrost as a ticking time bomb that could overwhelm efforts to tackle climate change. Conversely, some experts believe greater attention should be made to curb methane production, since reductions in methane emissions could bring faster results in the fight against climate change due to its short-lived occurrence in the atmosphere.

WHERE IN THE WORLD IS THE CARBON? – THE ROLE OF FORESTS AND FOREST FIRES

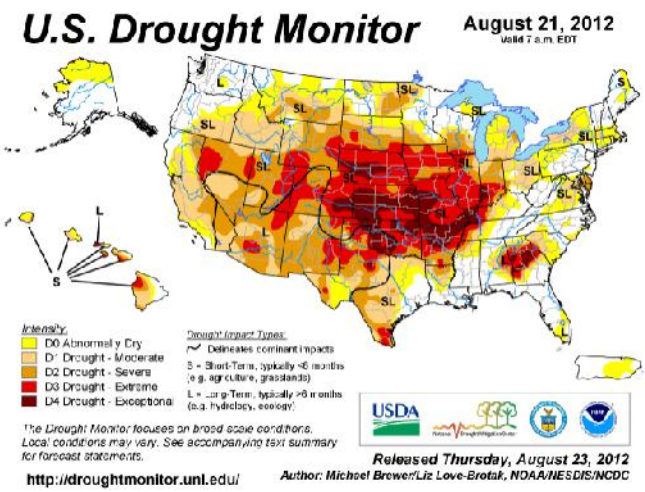
By Devin Routh

Before humans take measures to limit the amount of carbon flooding into our atmosphere, we must answer the basic question: where in the world is the carbon?

The lithosphere (the geological part of the earth closest to the surface and the location of our fossil fuels) is the number one source of carbon in the world, with the oceans following as the second largest source. But what about the terrestrial parts of Earth – the places where we build our cities and homes, raise our families, and live our lives.

Forests represent the largest source of terrestrial carbon on the planet. In fact they store nearly all of the Earth's terrestrial carbon and continue to sequester more every year (forests sequestered an estimated 2.4 gigatonnes of carbon per year from 1990 to 2007). Thus, it is no surprise that the management and conservation of forests constitutes a crucial point of leverage for mitigating the effects of climate change.

Of course, simply stating "forests store the most carbon of any terrestrial biome" lacks depth and detail. What kinds of forests store the most?



Though most imaginations might be drawn to luscious scenes of a tropical rain forest dense in biodiversity, the tropical forests of the world do not hold the highest amount of carbon. It should be noted, however, that tropical forests do play a large role in Greenhouse Gas emissions – 20% of global emissions, according to conservation biologist Stuart Pimm of Duke University. "But," Pimm notes, "-- and it's a very big 'but' -- if you look at where the biggest reserves of carbon are, they're actually in the boreal forests of Canada and Russia and that's because the forests there accumulate large amounts of carbon, especially in the peat."

A recent study sponsored by the Boreal Songbird Initiative reveals that boreal forests (also known as the taiga) alone store more carbon than any other terrestrial ecosystem and store twice as much per unit of area as tropical forests. As well, these forests span the largest area of any terrestrial biome. As the executive summary of their report indicates, "The global boreal forest presents the world's best opportunity to apply conservation as a climate change strategy…"

Due to their location, the fate of the boreal forests inextricably affects the fate of the Arctic. The main threat to the Arctic specifically comes in the form of forest fires and the subsequent release of pyrogenic (black) carbon. Some studies have suggested that 20-50% of the black carbon observed in Arctic during the month of July originated from boreal forest fires. Recent observations also corroborate earlier findings and confirm black carbon from the boreal forests, as a source for reducing the albedo of the arctic ice and snow (therefore expediting both the summer melting process and climate change in general). With such a high percentage of black carbon originating from boreal fires, the need to limit their occurrence, or control them in such a way as to minimize the black carbon output, becomes crucial.

Though speculation might attribute these fires to human related sources, lightning actually sparks more fires than any other cause. Of all the fires that occur, 5% of the total occurrences account for 85% of the land area burned (i.e. large fires that occur less frequently account for the greatest amount of damage). These large fires have increased in frequency in the last four decades of the twentieth century, an increase that can be attributed in part to global warming and associated droughts (though it should be noted that a simply warmer planet does not necessarily mean more forest fires). Combined with the recent proliferation of the mountain pine beetle (alternatively known as spruce beetles), which have continued to spread northward due to higher annual temperatures and have resulted in major swathes of dead trees serving as perfect tinder for fires, the boreal forests offer a critical point of leverage for the situation in the Arctic. We can either allow the current levels of black carbon from forest fires to persist — and possibly increase, or we can search for strategies to reduce the transfer of black carbon to the Arctic.

GRASSLAND FIRES AND ARCTIC WARMING

By Gerard Wedderburn Bisshop

Many of us know that black carbon is responsible for 30% of Arctic warming, but few are aware that three quarters of the black carbon and brown carbon on Arctic ice and snow comes from crop stubble burning and grass (pasture) fires, all lit intentionally.

Timing of pasture fires (in Kazakhstan and Siberia particularly) may reduce Arctic black and brown carbon warming by as much as 9%, based on the Australian Carbon Farming Initiative experience.

How do grassland fires compare to other emission sources?

Biomass burning stands out as the largest source of several Arctic climate forcers. The ARCTAS mission found that biomass burning contributed 39% of the Arctic black carbon, 69% of Arctic methane and 48% of Arctic carbon monoxide (a precursor to ground level ozone and smog). ARCTAS also mapped the transport pathways whereby black carbon reached the Arctic.

To examine biomass burning more closely, we find that agricultural and grassland fires are responsible for 69% of fire activity, and forest and shrubland fires responsible for just 24%, despite record forest fires in the boreal forests of northern Russia.

Previously underrated, we are starting to fully appreciate the impact of crop stubble and pasture grass fires:

- Agriculture and grass fire smoke plumes rise as high as the lower stratosphere, then can be carried great distances;
- ARCTAS found that agricultural and grass fires have higher enhancement ratios of black carbon than forest fires;
- Lower fire temperatures and significant smouldering releases more methane, NMVOCs and carbon monoxide – products of incomplete combustion.

Ice samples tell the story

But critical evidence comes from extensive surveys of Arctic sites in 2008 and 2009, tracing the source of light absorbing aerosols black carbon and brown carbon to crop and grass fire, boreal forest fire, marine shipping and other pollution. They found that 75% of black carbon and brown carbon in Arctic ice and snow originated from grassland and agricultural fires.

If we break this down in the proportion of fire incidence above, we find that grassland fires may be responsible for 18% of black and brown carbon on Arctic ice and snow, and stubble burning responsible for 56%.

Huge mitigation potential

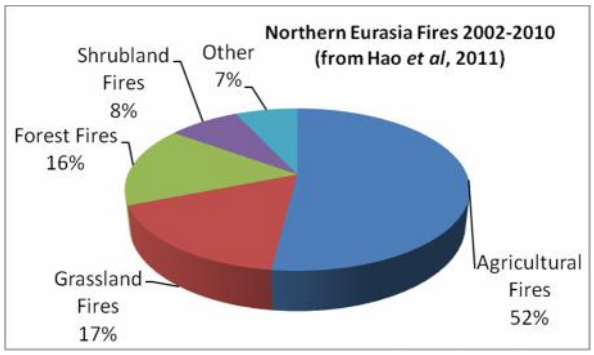
Russia is the world's fourth largest wheat producer, with extensive cropping areas, and the biggest Arctic contributor of black carbon from open burning; Siberia is experiencing deforestation fires for agricultural expansion; and Kazakhstan has extensive pasture burning. Crop stubble is often burned following harvest and pasture grassland is burned to remove unpalatable old growth. Forest fires can be started by lightning strike; however 30% originate from runaway agricultural fires.

Each year an average area of 8.2 million hectares of Russia is burnt. Many would remember the catastrophic Russian wildfires of summer 2010, initiated by a prolonged drought and extreme temperatures. Again in May and June 2012 hundreds of wild fires burned eastern Russia and the Far East, mostly initiated by agricultural and deforestation fires. Following the collapse of the USSR, burning to remove crop stubble became far more common, and the huge mitigation potential has been discussed by many so will not be addressed here.

Grassland fire mitigation potential

However, grassland fires (responsible for 18% of Arctic black and brown carbon) have received little attention. Australian experience has shown that timing of pasture fires (burning early in the dry season rather than late) can reduce emissions by as much as 52%, leading to the Carbon Farming Initiative, which will compensate Australian cattle and sheep farmers for changing their burning practices.

Pasture fire is also very effective in suppressing woody forest re-growth. A dramatic example of this was given in a 2011 paper in *Nature* that found 51% of the African continent would revert to woodland and forest if the continual pasture burning was stopped. Other studies have proposed this radical change in land use as the lowest cost, large scale global mitigation option, as the world's pastures reverted to their original forest cover, soaking up carbon in the trees and soil. Clearly, stubble burning and grassland fires must be a prime target for mitigation.



Arctic Climate Change and the Aviation Sector

By Chanelle Mayer

Aircraft emissions can influence Arctic climate in one of two ways. The products of emission can directly warm the Arctic, or they can warm air in other regions that is then transported to the Arctic. Carbon-dioxide and water vapor comprise the largest products emitted in jet plumes. The effects are not negligible: aviation accounts for about 2% of anthropogenic carbon dioxide emitted globally. As a result of the long atmospheric residence times of carbon-dioxide, the long-term effects on the Arctic would be the same no matter where the aircraft is located. Water vapor is a greenhouse gas, and emissions in both the troposphere and stratosphere contribute to warming the surface. In addition, stratospheric concentrations of water vapor can contribute to ozone destruction. At high latitudes where the height of the tropopause is lower, flights can spend a longer time in the stratosphere while cruising. The stratosphere does not exhibit the weather of the troposphere in all its manifestations, so pollutants last longer there. However ozone in the Arctic stratosphere does not simply stay there until destroyed. Instead there is a net downward transport to the troposphere. Therefore, while surface ozone concentrations usually have a larger effect on surface climate, high altitude (especially stratospheric) emissions of ozone precursors can initiate a more long-lasting effect.

However, the above account doesn't acknowledge the complexity of ozone formation. Airline flight contributes to ozone formation by emitting nitrogen oxides. Aircraft engines also produce carbon-monoxide to a similar extent as nitrogen oxides; this too is an ozone precursor. However the emissions of carbon-monoxide from natural and anthropogenic sources are much more abundant than for nitrogen oxides. Therefore airline emission of nitrogen oxide is its primary influence on the rate of ozone formation. Ground-level ozone is more sensitive to nitrogen oxide emissions when these occur at altitudes where jet aircrafts fly. This is because nitrogen oxides at these heights persist longer in the atmosphere, being immune to rapid deposition to the ground via precipitation and being less susceptible to dissolution in water to form nitric acid.

In the Arctic, these effects can be more severe. So aircraft emissions of nitrogen oxides can significantly affect ground level ozone. In addition, aircraft emit black carbon aerosol, which absorbs sunlight and thereby warms the atmospheric layer where it is found. Because of the high altitude at which this is emitted, aircraft emissions of black carbon can be transported long distances -- so the effect doesn't come from Arctic over-flights alone. One study has estimated that global aircraft emissions contribute to about 10- 20% of high altitude black carbon found in the Arctic troposphere.

Therefore mitigating nitric oxide emissions by Arctic over-flights, together with practical measures to reduce aircraft emissions of black carbon, nitrogen oxides, and carbon-dioxide and water vapor can contribute to moderating Arctic warming. Global passenger traffic has been estimated to have risen 5.3% each year between 2000 and 2007. There is no reason to expect such trends to abate. Large growth in flights dedicated to freight traffic is also likely. No single action will reduce Arctic forcing from airlines, and a range of solutions is required. Possible solutions range from avoiding airline travel where possible, technological solutions to improve energy efficiency of flight and emissions intensity of jet fuel, logistic innovations in air traffic control that reduce the time spent taxiing or airborne, and altering the composition of flights towards larger ones to improve the efficiency of fuel use for transporting masses long distances. Serious efforts in these different areas are already being developed.

Reducing Arctic over-flight might also be part of the solution. In a paper examining the effects of such rerouting, Mark Jacobson and co-authors report a 32.1% rise in the number of over-flights between 2004 and 2010, to over 50,000 over-flights in 2010. Rerouting such flights to avoid the Arctic would have different effects: rerouted flights would have to traverse longer paths to reach their destinations, so total emissions would be higher. However, Arctic region emissions of short-lived forcers could be avoided. The study of Jacobson and colleagues suggests that global surface temperature rise would be slightly moderated by reducing Arctic over-flight. The main reason for this is that higher precipitation around the new routes would decrease the time spent by most aircraft pollutants in the atmosphere, as they would be washed out more quickly. Numerical estimates of such effects are likely to be uncertain. However, as long as aircraft pollutants contribute to Arctic warming, re-routing a large fraction of flights to avoid the Arctic can be a part of efforts to slow Arctic climate change. This could also have the additional benefit of moderating concentrations of water vapor in the Arctic stratosphere, and thereby reduce stratospheric ozone depletion in the Arctic.

Improvements in Shipping Efficiency

By John-Michael Cross, Environmental and Energy Study Institute

In 1969, the Humble Oil Company modified an oil tanker into a 1,000 foot-long ice-breaker that then sailed from New York City to Alaska's Prudhoe Bay and back via the Northwest Passage. While the trip was a success, the company abandoned its plan for a fleet of mammoth icebreakers, in part because the icy voyage was deemed too risky. Today, however, shipping routes through the Arctic are becoming increasingly popular as the ice disappears.

With the ships come concentrated black carbon emissions to the vulnerable region, where they deposit on snow and ice to accelerate melting. It is estimated that shipping emissions of black carbon in the Arctic may double or triple over the global rate by 2050. Cost-effective technologies to reduce marine black carbon and other emissions are therefore especially critical for climate mitigation.

International shipping is responsible for 2.7% of global carbon dioxide emissions, roughly equal to 870 million metric tons per year. The International Maritime Organization (IMO) estimates that shipping emissions will increase by a factor of two to three by 2050 under business as usual conditions. Black carbon emissions from shipping, are currently estimated to be between 71,000 and 160,000 metric tons per year, approximately 1-2% percent of global black carbon.

The nations of the Arctic Council, which currently account for 90% of Arctic shipping activities, have become proactive in addressing the potential impact of shipping in the region. Norway, Sweden and the United States submitted a document to the IMO in 2010 that laid out potential approaches to reduce black carbon emissions in the Arctic.

A 2011 agreement among the 170 member nations of the IMO presents massive implications for the entire shipping sector and, by extension, the Arctic. The newly-established Energy Efficiency Design Index (EEDI) will set energy efficiency standards for all large ships constructed beginning in 2015. The EEDI will initially require 10% efficiency improvements over the 1999-2009 baseline, scaling up to 20% in 2020 and 30% in 2025.

The EEDI represents the first major global and legally binding effort to control emissions from an entire sector, and should help to overcome many of the economic barriers to increasing marine efficiency, namely that ship owners typically charter out their vessels to ship operators. Operators are responsible for fuel and other operating costs, leaving owners little incentive to invest in more efficient technologies.

If implemented on schedule, the EEDI is estimated to save $52 billion in fuel and 263 million tons of CO2 per year (over business as usual) by 2030. However, any country can choose to delay the requirements by up to four years. In conjunction with the EEDI, the IMO also established the Ship Energy Efficiency Management Plan (SEEMP), which will require that all ships have an operations plan to optimize energy efficiency, but does little to approve or enforce such plans.

Apart from the EEDI, speed reduction remains one of the greatest opportunities to decrease emissions and fuel use from all ships. A 10% speed reduction would decrease fuel consumption 15-19%, while a 20% speed reduction would decrease consumption 36-39%. Slower speeds would not necessarily impact a ship's port-to-port travel time, because many ships sit offshore upon arrival for one or more days waiting for space to open up in port. Slower transoceanic speeds could reduce port congestion and, with proper traffic control or booking systems, allow ships to pull straight into port.

Shore-based power allows a docked ship plug in to the local grid to run its auxiliary systems rather than idle its engine for the duration in port. Both ship and port must have the proper infrastructure, and both sides must act for either to see a return on its investment. Emission reduction technologies that ships can adopt independently include waste heat recovery systems for their engines, upgrades to the propeller and the autopilot system, and air lubrication systems that pump compressed air across the hull to reduce friction between the boat and the water.

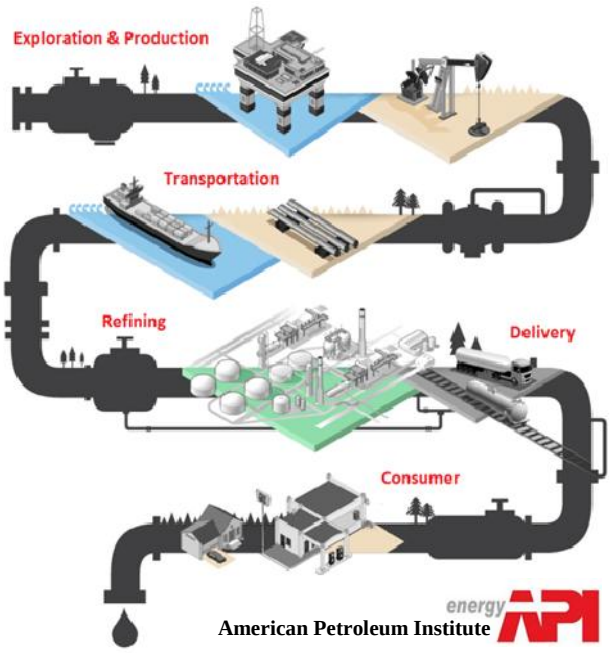
Several technologies are available to specifically reduce shipping emissions of black carbon and other particulate matter (PM). Diesel particulate filters (DPFs) placed in the ship's exhaust stream can scrub out black carbon emissions by 70-90%. Slide valves can also inexpensively reduce PM emissions by approximately 25%, and water-in-fuel emulsification (WiFE) on-demand systems for ships can reduce PM emissions 25-50% at relatively low-cost. Additionally, WiFE systems can pair with slide valves for further PM reductions, and both technologies also provide large NOx emissions savings.

Shipping efficiency technologies are poised to become much more prevalent due to the IMO's strong actions on energy efficiency and increasing pressure to protect the Arctic from shipping impacts.

OIL AND GAS IN THE ARCTIC – A FUEL FOR CLIMATE WARMING

By Charles ffoulkes

The Oil and Gas Industry in the Arctic region is fast becoming a serious concern both for environmental and economical reasons. Over the past century, rapid temperature increases in the Arctic region have initiated significant reductions in both land and sea ice, with 2012 setting a new record for minimum summer sea ice. The 'convenient' melting of this ice has seen the once inhospitable Arctic environment become much more accessible for the extraction of fossil fuels during a time when global energy security is crucial.



Phases during the Oil and Gas production process which are associated with the release of dangerous emissions.

The US Geological Survey estimates that the Arctic may be home to 30% of the planet's undiscovered natural gas reserves and 13% of its undiscovered oil, which may equate to around 1669 Trillion cubic feet of natural gas and 90 billion barrels of crude oil, with an estimated economic value at the wells of $3.3 Trillion and $9 Trillion respectively.

The economic war for resources in the Arctic is being led by *Shell (RDS/A)*, which has already spent $4.5 billion since 2005 preparing to explore for oil off Alaska's north coast. *ConocoPhillips (COP)*, *Statoil Asa (STL)*, and *Exxon Mobil Corp. (XOM)* also have agreements to explore the Arctic fields, in addition to plans from *BP Plc (BP/)*, *Imperial Oil Ltd. (IMO)*, *Chevron Corp. (CVX)* and others to explore the region.

However, new resources of fossil fuels in this region will have fundamental consequences for the fragile ecosystems which flourish in the Arctic, both directly through leakage and spills, and indirectly through habitat modifications, as a result of a warmer climate associated with emissions released in the oil and gas process.

There are many mechanisms in which GHG emissions are released during the process of oil and gas extraction. This includes the Exploration and Production process, the Transportation, Refining and Delivery phases, as well as the final Consumption of the fuel. Carbon Dioxide (CO_2) is released during most phases of extraction from the wells to the consumer, due to combustion emissions from fuel used to power the equipment and transportation emissions from trucks and shipping.

In addition, short-lived climate forcers are also a product of oil and gas extraction, which are potentially more significant for the Arctic over the short-term than CO_2 emissions.

The fundamental concern is methane (CH_4), which is largely released into the atmosphere through fugitive emissions from rock fracturing, equipment leaks, flaring and from compressor stations. The implications of this are severe, since methane is some 20-25 times more efficient than CO_2 at trapping heat in the atmosphere. Furthermore, during the primary and secondary production phases, nitrous oxide (N_2O) and hydrocarbon Volatile Organic Compounds (VOCs) are emitted from the dehydrator equipment and wastewater disposal. Although relatively less significant as an emission source, when released, hydrocarbon VOCs indirectly contribute to the tropospheric ozone load, as well as assist in prolonging the life of CH_4 in the atmosphere, therefore enhancing GHG warming.

In recent years, the US has seen a surge in natural gas production through a process known as hydraulic fracturing, which is aimed at reducing coal consumption as an energy source and therefore reducing CO_2 emissions. However, new research from the National Oceanic and Atmospheric Administration (NOAA) suggests that natural gas may not be as clean as first thought, due to a 3-4% loss of the gas, and therefore CO_2 and CH_4 to the atmosphere.

Evidently, the planned exploration for oil and gas reserves in the Arctic will have profound effects on the local climate, which has already seen a winter temperature increase of 3-4°C (5-7°F) since 1960. Consequently, the oil and gas industries need to enforce rigorous risk management strategies in order to minimise the effects on both the Arctic environment and climate if they are to persist with exploration.

Emissions from Flaring and Venting
By Lauren Smith

Offshore flaring operation (Photo: Elvidge, 2007)

Flaring and venting of natural gas often occur as part of the oil and gas production process, as well as in metal and chemical industries. Flaring is the burning of natural gas in an open flame and venting is direct release of natural gas into the atmosphere.

The Canadian Centre for Energy Information details potential reasons for flaring and venting, which include: volumes of solution gas from crude oil wells that are too small or remote to justify infrastructure such as pipelines and processing facilities; to safely dispose of gas during incidences or "upsets" in drilling, production, processing, or pipelining; to establish flow rates and gas composition at wells; to dispose of natural gas that has been contaminated with mud, fluids, or acids; and to dispose of gas containing H_2S.

While there may be safety reasons for these practices, it is common for gases to be flared or vented simply as a way to dispose of unwanted natural gas released during crude oil extraction or in the gas refining process. These activities waste substantial amounts of natural gas that could otherwise be used as energy. In fact, the World Bank estimates that the annual volume of natural gas being flared and vented worldwide each year is about 110 billion cubic meters (about 3% of all gas marketed in the world), enough to provide natural gas for the annual consumption of Central and South America or that of Germany and Italy. NOAA estimates that these figures are even higher, with flaring in the oil industry wasting 150-170 billion cubic meters of gas each year, which equates to 5% of global natural gas production and at least $40 billion in natural gas sales.

In addition, flaring and venting emit carbon dioxide, methane, and other gases that contribute to global warming. In venting, methane is released directly into the atmosphere. Vented gases can also include other hydrocarbons, water vapor, and carbon dioxide. Flaring mainly produces carbon dioxide and water as waste products of combustion; however, combustion is often incomplete which can result in emissions of carbon monoxide, nitrous oxide, unburned hydrocarbons, particulate matter (including soot or black carbon), and VOCs. The EPA estimates that properly-operated flares achieve 98% combustion efficiency and that hydrocarbon and CO emissions are less than 2% of hydrocarbons in the gas stream. While these emissions are small compared to CO_2 emissions, methane is a potent greenhouse gas with a global warming potential about 23x greater than carbon dioxide on a 100-year time horizon and 56-72x greater on a 20-year time horizon.

It has been estimated that developing countries account for over 85% of gas flaring and venting, with international reduction efforts focused on countries such as Nigeria, Iraq, and Iran. This has been attributed, at least in part, to lack of clear operational processes and regulatory framework.

In the context of global greenhouse gas emissions, emissions from venting and flaring represent 4% of anthropogenic methane emissions. EPA estimates global methane emissions from the oil and gas industries equivalent to 1,354 million metric tons of CO_2 in 2010, which translates to roughly 20% of global methane emissions (18% and 2%, respectively). This figure includes losses throughout the production process from leaking equipment, transmission, storage, and gas distribution lines.

In 2002, the World Bank created the Global Gas Flaring Reduction Public-Private Partnership, and countries responsible for 70% of flaring emissions have signed on as partners. The partnership emphasizes legal, regulatory, and financial environments to encourage use of natural gas, including carbon markets. This and program also promotes best practices in industry.

In a stakeholder consultation with Norway, the World Bank recommended international gas markets and reinjection as major solutions to flaring emissions. Specific actions recommended were: increased liquefied natural gas exports, regional pipelines, gas-to-liquid technology (e.g. synthetic diesel), regulation, and small-scale use for liquefied petroleum gas and distributed power. In the United States, the EPA's Natural Gas STAR program was created to encourage natural gas and oil companies to reduce methane emissions.

Arctic Climate Action Registry
By Alison Singer

The Arctic Climate Action Registry (ACAR) is dedicated to mitigating greenhouse gases and emissions that directly affect the Arctic region. The Arctic is at particular risk to warming temperatures due to reductions in snow cover and sea ice. The loss of these valuable cooling and albedo effects has amplified regional warming in the Arctic. In addition to an increased rate of regional warming, Arctic climate change has set into motion feedback loops that have potentially devastating implications for the entire planet.

ACAR's mitigation efforts revolve around reducing emissions of three major contributors to Arctic warming – black carbon, tropospheric ozone, and methane. These short-lived pollutants are significant drivers of climate change, and also contribute to both human and agricultural health problems. ACAR seeks to stimulate projects with immediate plans to reduce these emissions.

ACAR is currently focused on a variety of activities: a project registry in which companies and other entities can register their projects aimed at reducing the targeted emissions; the application of life cycle assessment (LCA) to determine an Arctic Climate Impact Profile; and participation by individuals, agencies, institution, and companies in the Arctic Climate Protection Network, which will help publicize a commitment to reversing Arctic warming; and outreach and education for businesses, schools, and the interested public.

The initial executive director of ACAR is John Topping, President of the Climate Institute. Steering Committee members include three members from outside the US, Luis Roberto Acosta of Mexico , Executive Vice President of the Climate Institute; Senator Heherson Alvarez , Climate Change Commissioner from the Philippines; and Peter Globensky, Principal Consultant, BASA, and former CEO, Canadian Council of Ministers of the Environment . US based members are Daniel Wildcat, founder of the American Indian Alaska Native Climate Change Working group and a professor at Haskell Indian Nations University; Robert Corell, Chair of the Arctic Climate Impact Assessment; Michael MacCracken, Chief Scientist at the Climate Institute; Linda Schade, Executive Director of the Black Carbon Reduction Council; Stephen Leatherman, Director of the Laboratory for Coastal Research at Florida International University; Gary Dodge, Director of Science and Certification at the Forest Stewardship Council of the United States; Charles Bayless, a former utility CEO and board chairman of the North American Energy Alliance ; Robert Engelman, President of the Worldwatch Institute; Steve Apfelbaum , President, Applied Ecological Services; Tim Warman, Vice President for Climate and Energy of the National Wildlife Federation; Stanley Rhodes, president of Scientific Certification Systems; John Noel, President of the Southern Alliance for Clean Energy; Carol Werner, Executive Director of the Environmental and Energy Study Institute; Conn Nugent, President of the Heinz Center; Ata Qureshi , who coordinated the first major climate change country studies in Asia; and Paul Bartlett, an environmental scientist expert in pollutant transport. In anticipation of the broadening of ACAR's coverage well past the US, efforts are underway to recruit Steering Committee members in Canada, Russia, Greenland and Scandinavia.

Charles Ffoulkes, who received an M. Sc. from University of Exeter and is serving as Graduate Research Fellow at the Climate Institute's Center for Environmental Leadership Training (CELT), has been coordinating activities of a team of 21 Virtual Fellows and Interns working in support of ACAR. He has worked with Lauren Smith, Editor -in -Chief of Climate Alert, to produce this Arctic Special Issue of Climate Alert. Christopher Phillipp, an Emmy winning film producer, who is leading new media education efforts for the Climate Institute, is preparing a short film on climate change and the Arctic focused on reduction of short- lived climate forcers. He has created a website, http://gamelab.info/ to empower CELT members and others to master play and even design problem solving games. Several CELT participants including Ma Ko Quah Jones, Anda Zhang and Xiaomimg He at Dartmouth and Devin Routh at Yale School of Forestry and Environmental Studies are collaborating to produce a problem solving game focused on Arctic climate mitigation. Meanwhile ACAR has benefited from work of Linda Schade, Executive Director of Black Carbon Reduction Council, and Linda Brown, Senior Vice President of Scientific Certification Systems in helping develop a work plan. Working in collaboration with Climate Institute Chief Scientist Michael MacCracken, Ashwin Kumar, who recently earned his PhD at Carnegie Mellon University, is seeking to develop an agenda of research issues which will enable ACAR to optimize effectiveness of its investments in reducing radiative forcing affecting the Arctic.

CLIMATE INSTITUTE

Founded in 1986, the Climate Institute was the first non-profit organization established primarily to address climate change issues. Working with an extensive network of experts, the Institute has served as a bridge between the scientific community and policy-makers and has become a respected facilitator of dialogue to move the world toward more effective cooperation on climate change responses.

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The Climate Institute's mission is to ...

CATALYZE innovative and practical policy solutions toward climate stabilization and educate the general public of the gravity of climate change impacts.

ENHANCE the resilience of humanity and natural systems to respond to global climate change impacts especially among vulnerable groups (e.g. Native American tribes and Small Islands).

WORK internationally as a bridge between policy-makers, scientists and environmental institutions.

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ON THE COVER:

Top: Seawall built for erosion in the village of Kivalina, AK.
Photo by Bretwood Higman, Erin McKittrick, Ground Truth Trekking.

Bottom, Left: Melt ponds on the surface of Arctic sea ice. Photo: NASA/Kathryn Hansen.

Bottom, Center: Black carbon deposits on snow. Photo: NILU, Norwegian Institute for Air Research.

Bottom, Right: Greenland ice sheet surface melt in 2012.
Photo: Nicolo E. DiGirolamo, SSAI/NASA GSFC, and Jesse Allen, NASA Earth Observatory.