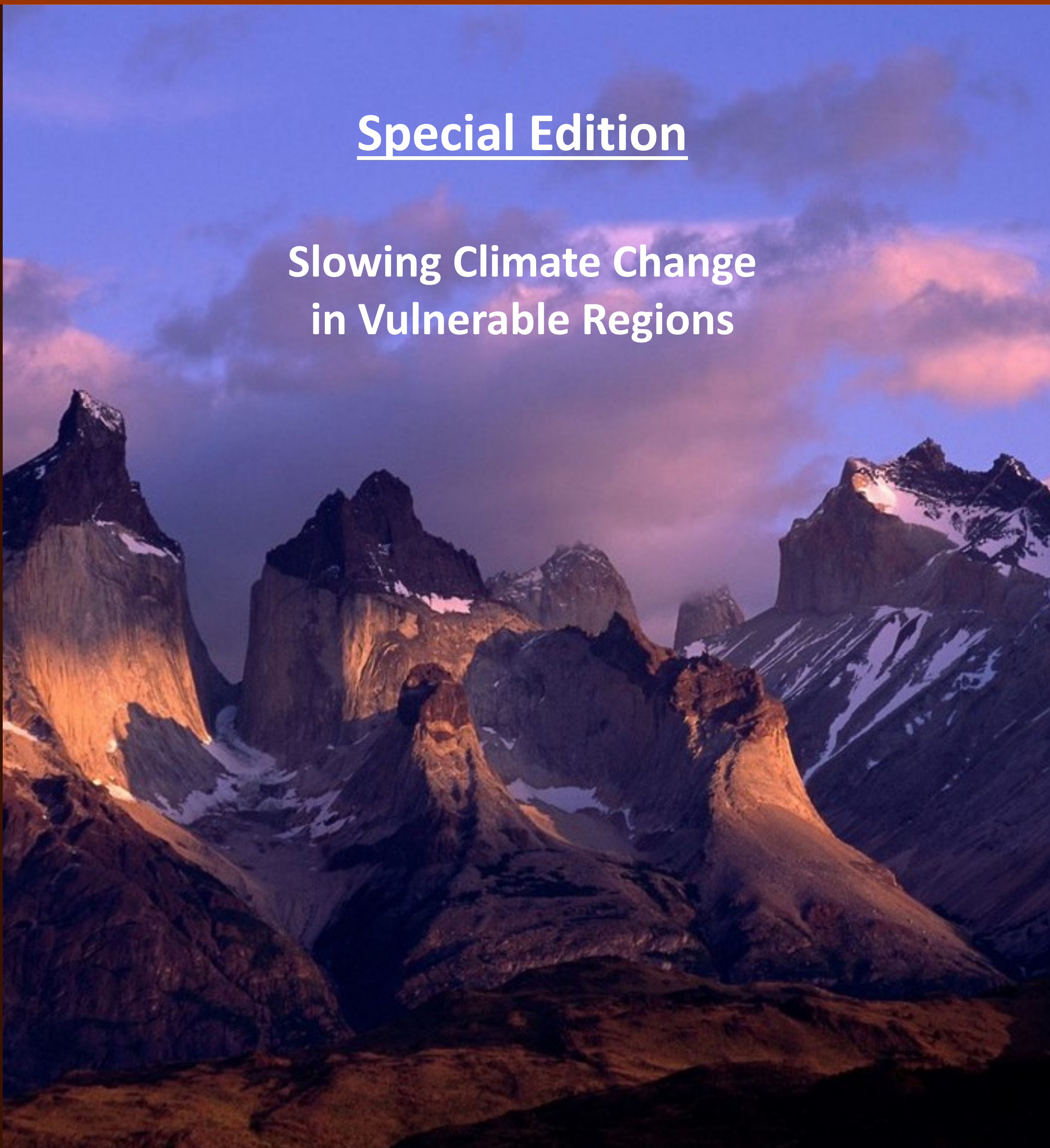
Summer 2013 – Volume 25, No. 1

Climate Alert

A Publication of the Climate Institute | *Protecting the balance between climate and life on Earth*

Special Edition

Slowing Climate Change in Vulnerable Regions



Climate Institute

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A MESSAGE FROM THE PRESIDENT

There is a Need for a Dramatic Change!

Commentary by
John C. Topping, Jr.

Evidence mounts that climate change may be proceeding at a pace that could exceed the capacity of humanity and ecosystems to adapt. Perhaps the most publicized indication of this came in mid-May when the Mauna Loa Observatory recorded a level of carbon dioxide of 400 parts per million, believed to be the highest in human existence. Soon after, the International Energy Agency reported that annual global carbon dioxide emissions from fossil fuels had risen 1.4 percent from 2011 to 2012. Even more disturbing than this seemingly inexorable rise in CO_2 concentration is growing evidence of rapid change in polar regions that may already be disrupting weather patterns worldwide and accelerating sea level rise, threatening island and coastal nations. One of the most dramatic indications of this change is the shrinkage of minimum Arctic sea ice volume over the past third of a century, from 16855 cubic kilometers in 1979 to 3261 cubic kilometers in 2012. There is, as NASA glaciologist Robert Bindschadler reports in his article in this special issue, evidence that glacial melt and ice sheet change in both Greenland and Antarctica have helped increase the annual rate of global sea level rise from 1.8 to 3.8 millimeters.

Although there have been heartening developments on climate protection in recent weeks—including a US- Chinese agreement to seek rapid reduction of hydrofluorocarbons (HFCs) under the Montreal Protocol, China's initiation of an aggressive regional cap-and-trade system that may soon go nationwide, President Obama's announcement of proposed US executive branch mitigation and adaptation responses, and New York Mayor Michael Bloomberg's proposal for sweeping coastal protection—the relatively languid pace of climate negotiations and increasing global emissions underscore the need for a radical shift in climate mitigation strategies. A first step already underway is a much greater focus on reducing short-lived climate forcers (SLCF) such as black carbon, tropospheric ozone-forming compounds, and methane. Collectively, the 21st-century emissions of these substances have a combined warming effect during this century that is slightly greater than for 21st-century CO_2 emissions. Moreover, their relatively short atmospheric residence times mean reductions in SLCF emissions can yield near-term benefits in reduced climate warming while also reducing air pollution deaths and crop damage. The Climate and Clean Air Coalition launched in 2011 by then-US Secretary of State Hillary Clinton now encompasses 25 nations and numerous organizations and focuses attention on opportunities to reduce SLCF and HFC emissions.

Inertia in the Kyoto-related climate trading system, in which the reductions of black carbon emissions that would produce both the greatest near-term climate benefits and significant public health advantages have zero value, is a real impediment to action. Two projects in Asia hold promise for surmounting these obstacles by engaging voluntary emission credit groups in valuing black carbon reductions. Project Surya in South Asia proposes cleaner cookstoves and reduced kerosene emissions in South Asian villages, and an effort in Metro Manila between an Australian firm, Rotec, and jeepney owners seeks to retrofit a quarter million of these vehicles. In the Americas the US Life Cycle Assessment Standard that the American National Standards Institute (ANSI) is developing would provide value for reductions of black carbon and ozone-forming compounds, and Chinese policymakers are considering building similar valuations into their emerging climate trading systems.

Besides incentivizing reductions of black carbon and ozone-forming compounds worldwide and establishing a more robust valuation for methane, an effective climate mitigation effort might augment these efforts by emphasizing reductions of the emission and deposition of SLCFs perilously close to irreversible tipping points—the Arctic, Antarctic, Himalayas, and interconnected South American ecosystems of the Amazonian Basin and the Andes.

Building on the September 2012 "Saving the Arctic" issue of *Climate Alert*, this issue makes a case for regional climate change mitigation strategies. It provides an update by Gerard Wedderburn-Bisshop on grassland burning, the Arctic's most significant driver of warming in the Arctic; discusses progress by the Arctic Climate Action Registry (ACAR) in creating a mechanism to incentivize reductions of emissions affecting the Arctic; and explores Arctic-focused geoengineering strategies that might complement a primarily emission reduction-based strategy in an article

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by Michael MacCracken, Matt Vetter, and Rebecca Fields Green. In addition, Humiun Miah outlines a strategy for simultaneously reducing Himalayan glacial melting and eliminating air pollution deaths in South Asia, and Walter Vergara and Ana Rios explore how reduction of black carbon emissions from the Amazonian Basin might slow glacial melting in the Andes. Another article by Ms. Green describes the potential dangers from mining and drilling in Greenland, and Charles Ffoulkes has written an article which discusses the effects of black carbon on Arctic sea ice. Each of these regions has unique vulnerabilities (e.g., the Arctic is the only one affected greatly by aircraft emissions and is likely to face growing emissions from vessels and oil and gas development). Nevertheless, there is a common thread. Black carbon emissions can change the albedo of sea ice, glaciers, and ice sheets, speeding melting and contributing to possible changes in weather patterns and rates of sea level rise. Given both the extreme dangers these regions face and the promising mitigation options available in them, it makes sense to design strategies tailored to the unique environments and opportunities that now demand our attention in the four most rapidly changing areas of the globe.

Recent Talks and Lectures

By Sir Crispin Tickell, Chairman and John Topping Jr, President

Arctic Regional Climate Change Mitigation Strategy
Columbia University, June 2013
Given by John Topping Jr, Climate Institute President

Climate Institute President John Topping gave a lecture on an Arctic regional climate change mitigation strategy at Columbia University on June 13, 2013 as part of the Hertog Global Strategy Initiative series. After engaging in a lively class discussion with students beforehand, Mr. Topping spoke on the need to focus immediate attention on reducing the effects of global warming in the Arctic both because it is warming more rapidly than the rest of the world and because Arctic warming poses a severe risk for the globe by fostering changes in weather patterns and sea level rise. As strategies for combating Arctic warming, Mr. Topping focused in particular on the need to reduce the worldwide emissions of black carbon and other short-lived climate forcers that intensify warming in the north. He also argued for worldwide vigilance in reducing methane release in natural gas exploration and distribution. Above all, he stressed that the Arctic, perhaps more than any other region, is now at a tipping point and requires immediate attention from the international community. He suggested that success in reducing short-lived climate forcers affecting the Arctic can help shape climate protection strategies for other vulnerable regions such as the Himalayas, the Andes, and the Antarctic.

The Human Future
Arizona State University, April 2013
Given by Sir Crispin Tickell, Chairman

Sir Crispin Tickell, Climate Institute Chairman, delivered the Wrigley Lecture on “the Human Future” at Arizona State University on April 11. Emphasizing the “symbiotic” relationship between humans and the earth, he described how humans are rapidly transforming their natural environment and how such change is already altering the rules of nature as the planet reacts. He also focused on the uncertain but powerful role that information and other technology is playing today and concluded by envisioning a future world with more decentralized, smaller communities and a retreat from the scramble for “development.”

To view the Power Point presentation and video for “Slowing Arctic Melting: Beginnings of a Regional Strategy to Mitigate Climate Change,” please visit our website: http://www.climate.org/programs/acar/arctic-climate-change-news.html#topping-ppt

To view the video for “The Human Future” April 11, 2013, from the Wrigley Lecture Series, please visit http://vimeo.com/64643400. For the lecture transcript, please visit http://www.climate.org/PDF/sircrispintickelltalks-arizona2013.pdf

ICE SHEETS ARE IN TROUBLE!

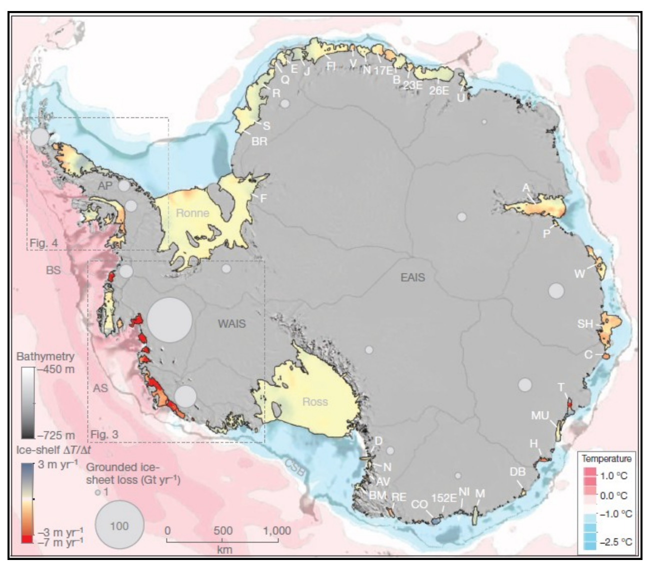
By Robert Bindschadler, Emeritus Scientist for NASA

Ice sheets are in trouble, and that is bad news for us. Paleoclimate data are unequivocal: ice sheets shrink whenever climate warms—and the climate is warming. Humans have experienced small fluctuations in glacier and ice sheet size, but we have never experienced the loss of ice sheets and glaciers on the scale that is now written into our future and even appears to be starting. The first indications of widespread loss began slowly and quietly with the gradual increase in the proportion of shrinking glaciers around the world versus the numbers of growing and advancing glaciers. In the last two decades, this ubiquitous loss of ice has spread to the two great ice sheets on earth (in Greenland and Antarctica), and the pace of ice loss continues to increase.

Ice loss affects humans directly through an increase in sea level. Sea level has increased gradually through the industrial period (1850 to present) at the seemingly sluggish pace of 1.8 mm/year, but most of this was attributable to an expansion of the ocean waters as they warmed. However, now that first glaciers and more recently ice sheets are losing mass, that rate of sea-level increase has reached 3.8 mm/a and continues to increase. This may not seem like anything to worry about, but these rates are expressed as vertical change. Slopes at the shore are often 0.001 or less, causing just a 1 mm vertical rise in sea level to shift the shoreline inland by a meter or more. Thus, an annual 3 mm increase in sea level shifts these shores 3 meters. Sustained over a decade, the horizontal shift becomes 30 meters (100 feet). Moreover, paleoclimate data indicate past rates of sea level rise exceeding 50 mm/year that were sustained for more than a century, resulting in increases of many meters in a few centuries and shoreline shifts measured in miles. Enough ice exists on earth's continents today to raise sea level over 200 feet, so even a small net loss holds the potential to stress nations around the world, in particular coastal communities and island nations that have nowhere to hide.

Climate affects ice sheets both by providing additional mass through snowfall and removing mass through melting. These processes are reasonably well understood and can be accurately calculated by the large complex climate models that project how earth's climate will evolve. If ice sheets were as static as they often appear to be, it would be easy to account for the net effect of these mass gains and losses; in short, warmer temperatures increase snowfall, expanding ice sheets, but melting is also increased, leading to an overall decrease in ice sheet mass (and to sea level rise).

But these effects are not what have glaciologists concerned. Ice sheets are not static, and it is ice flow that introduces a dynamic element into predicting their future size. Ice flow can change an ice sheet's size and shape much more quickly than either snowfall or melting. Near the center of the ice sheet, ice typically flows at modest speeds of about 10 meters per year. However, closer to the coast, the ice is funneled horizontally and thins vertically into faster flowing outlet glaciers that begin their race to the perimeter at about 100 meters per year and continue to accelerate to 1000 meters per year and more by the end of their journey (terminating either on land or in the ocean). In Antarctica, most of these outlet glaciers reach the ocean and proceed to form plates of floating ice, called ice shelves, that are hundreds of meters thick and extend tens of kilometers out into the ocean. Northern Greenland is similar, but in the southern half of this subcontinent, the ice is warmer and the glaciers terminate in narrower fjords and have shorter floating tongues. In Antarctica, nearly all ice leaves the continent by flow; in Greenland the mass loss is shared between outlet glacier discharge and surface melting, in roughly equal



Antarctic ice-shelf ice-thickness change rate, 2003–2008. Seaward of the ice shelves, estimated average sea-floor potential temperatures (in °C). Source: Pritchard et al (2012).

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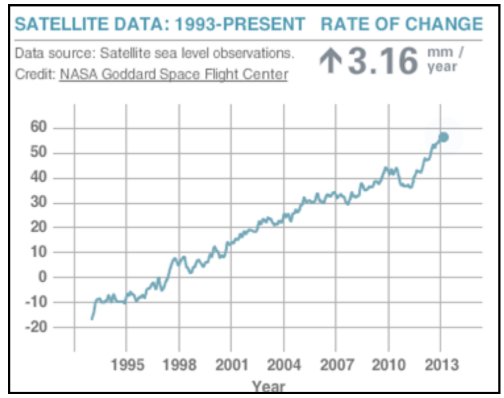
measure.

Glacier dynamics is the field of study focused on determining what controls the speed of flowing ice. Gravity (acting through the surface slope) provides the push, while resistance can arise from both friction (at the glacier base or along the sides of a valley) and forward obstructions (like the ocean). In the most common case, the resistance of the ocean is balanced by the outlet glacier pushing its ice shelf into the ocean. An instructive metaphor is to think of an ice shelf as a valve that controls the speed of the outlet glacier upstream, the rate at which ice can leave the ice sheet and, thus, the ice sheet's effect on sea level. In a climate that is stable for millennia, the ice sheet has time to adjust its shape and flow to the pattern of mass input, and its many "valves" (outlet glaciers) each adjust to the necessary setting. But how do these valve settings change in a changing climate?

Never having witnessed global-scale ice loss, scientists are working both to place recent losses in a longer-term context and to provide credible projections of future ice losses (and consequent sea level rise). Valuable monitoring of the ice sheets continues to be provided by a suite of satellite sensors that routinely orbit the earth, augmented by targeted scientific aircraft campaigns. Their data have revealed telling spatial patterns to the ice loss that not only locate the most active areas, but also provide clues as to the causes of the change. Such information is doubly important because it enables scientists to concentrate their ground-based field studies at the sites of greatest activity. These active sites are generally on the thickest outlet glaciers that flow into relatively warm water; the overwhelming majority of changes are of ice loss, not gain, expressed as an increase in flow speed, a reduction of ice thickness, and a retreat of the position where the ice first comes afloat. The consistent spatial pattern of thinning shows the largest change at the seaward end of the outlet glaciers and progressively smaller changes inland.



Rate of Sea Level Change (mm/yr) since 1993. Source: NASA Goddard Space Flight Center

The observations generated by persistent staring from space have allowed scientists to infer the primary cause of the changes. It is the oceans that are forcing the ice sheet to give back more of its volume. Warm water has opened the "valves" of many of the largest outlet glaciers. The details of this response have illuminated yet more insights into how the ice sheets and oceans interact. In Greenland the most dramatic ice losses are concentrated at the portals of three of its largest outlet glaciers: Jakobshavns Isbrae on the west coast and Helheim and Kangerdlussuaq glaciers on the east coast. All three lie in fjords whose mouths are brushed by the relatively warm currents of the north Atlantic Ocean fed by the Gulf Stream. In Antarctica the most rapid ice losses are occurring within the Antarctic Peninsula and along the coast of the Amundsen Sea—again, sites where warm water resides. These inferences have now been confirmed by recent field observations.

A person dipping his or her hand into these disruptive waters would react to their chill, not their warmth, but ice sheets have a different reference point. Water at 2^0C can melt ice twice as fast as water at 1^oC, a rate that increases by 10 m/year of ice for every extra degree of warmth in the water. It is along the underside of the floating ice shelves (or at the vertical calving face of the southern Greenland outlet glaciers) that an inexorable thermal battle between water and ice is taking place. Beneath the surface and out of the view of satellite sensors, warmer water is thinning the ice shelves, opening the valves of the ice sheet and leading to the increased rate of ice delivery to the ocean by the accelerating outlet glaciers.

These conclusions prompt two other important questions: what has led to the change in water temperature reaching the ice, and why is it occurring at the sites it is and not elsewhere? Neither question has a purely glaciological answer, but experts from oceanography, geology and climatology have stepped in to help. The seabed surrounding the ice sheets is incised by deep channels eroded by longer ice-age versions of many of the same glaciers that exist now. In most cases, these channels extend to the edge of the continental shelf beyond which the deeper ocean lies.

It is in this deeper ocean that the warmer water resides, contained within either the massive Antarctic

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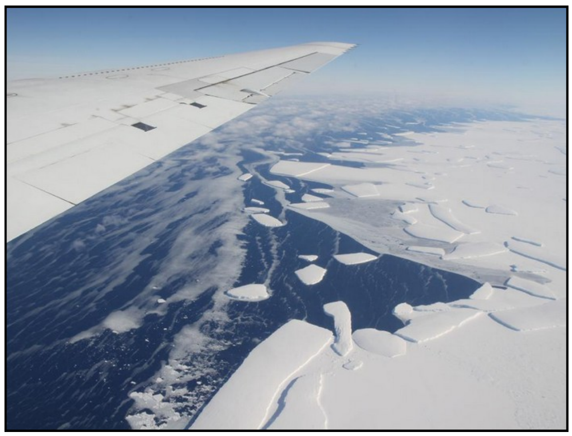
Circumpolar current or the Irminger current around the southern perimeter of Greenland. Due to contrasts in temperature and salinity (together determining density) among the different water masses in these large currents, the warmest waters occur at hundreds of meters' depth. In places like the Amundsen Sea, these major currents brush against the edge of the continental shelf, but ordinarily, they are too deep to interact with the shallower water on the continental shelf. However, stronger winds, both predicted and measured in our now-warmer climate, has the effect of drawing some of this deeper, warmer water to shallower depths, where it can reach the deeper glacially eroded troughs. Once introduced into these troughs, the warm water remains in the trough because it is denser than the cold, fresh water occupying most of the continental shelf seas. Finally, most of these continental shelves are tilted downward toward the ice sheets due to the bending of the shelves by the extreme weight of the ice sheet. The troughs then steer this dense warm water to the underside of the ice sheet's fringing ice shelves, where the thermal battle between water and ice is raging. Wherever glaciologists have enough data to infer melt rates, it is at the deepest, upstream regions of the ice shelves, where the ice first floats and loses contact with the underlying seabed, that the melt rates are the highest. Melt rates in excess of 100 m/year have been calculated, forcing outlet glaciers to flow very fast to replace this rapid loss.

A pattern of past sea level that is sometimes overlooked is its noisy character. This should not be surprising, given the significant degree of variability in each of the links in the long chain of linked climatic processes that connect warming climate to accelerating sea level rise. This multiple variability can mask connections and confound attempts to validate predictive models. Nevertheless, each link in this chain has been observed, and most are the focus of one or more field studies that seek to determine the quantitative relationships that predictive models require. At the glaciological end of this chain is the fact that outlet glaciers retreat episodically, permitting temporary quasi-stability when grounded on higher regions of their submarine beds. However, subsequent thinning forces eventual loss of this stabilizing contact, leading to a period of rapid retreat to the next elevated bed region upstream.



Aerial photograph of icebergs calving off floating Antarctic ice shelves. Source: NASA Goddard Space Flight Center

The future we face elicits another metaphor—one of a drunkard stumbling downhill. The path the ice sheets are on is well determined; warming climate is a driver that absolutely demands the waning of ice sheets. What cannot be predicted yet with great certainty is the detailed timetable of the consequent sea level increase. Ice sheet models that cannot yet include these important processes project ice sheet contributions to future sea level of less than 20 cm by 2100. Empirical approaches that also lack any explicit treatment of these processes but include them implicitly universally project more than a one meter total rise in sea level by 2100. Sobered by the recent unexpected and dramatic observed activity of ice sheet outlet glaciers, glaciological experts are wary of ignoring them and tend to favor the larger projections.

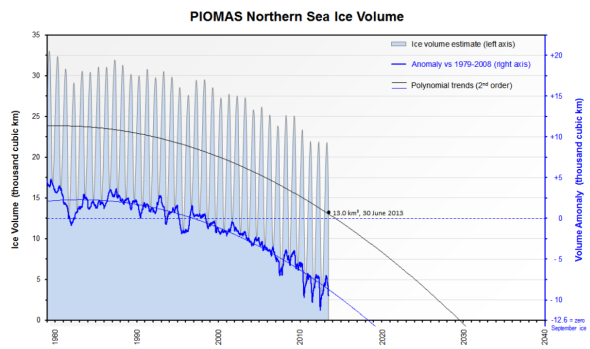
Increased certainty will come in the next decade as scientists achieve answers to ongoing studies and new multidisciplinary studies are initiated that can verify expected predictive improvements. We need not be too concerned or distracted by smaller, thinner glaciers or future warming of the oceans; these surely can make a bad situation worse, but there is already more than enough heat in the oceans that can perpetuate the dramatic ice losses already observed from the largest deepest outlet glaciers discharging ice at increasing rates into warmer seas around both ice sheets. Scientists know enough to expect only more of the same, and we all should be wise enough not be fooled by any temporary hiatus. Variability is a characteristic of this linked system; variability of the wind, the changing extent, and the properties of the water masses within the ocean will alter the annual and decadal changes in sea level that are to come. Such variability, however, will be superimposed on increasing rate of sea level rise as the affected outlet glaciers retreat episodically upstream, discharging ever more ice as they go.

The Effects of Black Carbon on Arctic Sea Ice

By Charles Ffoulkes, Graduate Research Fellow

The Arctic is warming at an unprecedented rate, contributing to the thinning and reduction of sea ice, particularly in the summer, and the loss of mass from the Greenland ice sheet and associated increases in the rate of rise of global sea level observed in recent years. The timing and pattern of the warming make clear that increased concentrations of greenhouse gases in the atmosphere resulting from anthropogenic activities since the start of the industrial revolution are the primary cause.

In particular, the atmospheric carbon dioxide (CO2) concentration has increased by approximately 42%, rising from a value near 280 ppm for thousands of years prior to 1850 to a present level nearing 400 ppm (Mauna Loa CO2 Records, 2013). However, recent research suggests that higher loadings of black carbon (BC) are also likely contributing to the amplified warming, particularly in vulnerable regions such as the Arctic where reductions in the albedo can have a significant impact. The BC in the Arctic is the result of a combination of both local activities (such as shipping, mining, drilling etc), and atmospheric transport of BC from North America, Europe and Asia. The transmitted BC comes mainly from four sources: (1) exhaust from diesel engines used for transportation and industrial use; (2) combustion of residential solid fuels such as wood and coal; (3) open forest and savanna burning, both natural and initiated by humans for land clearing; and (4) industrial processes, usually from small boilers (Moore et al., 2009).



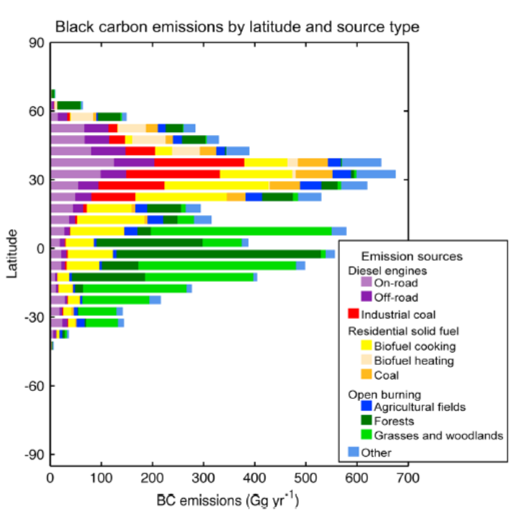
Arctic Sea Ice Volume. Source: Polar Science Center

In terms of its direct forcing, BC observations suggest that it is the second most important contributor to warming in the Arctic. This happens because the dark colored, light-absorbing particles absorb solar radiation in the atmosphere and convert it to heat. In addition, BC has an indirect warming effect by reducing the reflectivity (albedo) of ice and snow.

BC's direct and indirect warming effects make it one of the most important contributors to the retreat of Arctic sea ice, efficiently heating the Arctic surface because of the strong Arctic temperature inversions and the insulating properties of snow. As a result, recent increases in BC, or soot as it is commonly known, have had a profound impact on the Arctic, contributing to regional temperature increases and reductions in summer sea ice.

During the Northern Hemisphere winter of 2012/13, Arctic sea ice reached its maximum extent for the year on March 15 at 15.13 million square kilometers (5.84 million square miles). This year's maximum extent was the sixth lowest in the satellite record (the lowest maximum extent occurred in 2011), and the ten lowest maximums in the satellite record have occurred in the last ten years between 2004 and 2013 (NSIDC, 2013), illustrating the increasing significance of the BC emissions.

Minimum summer sea-ice extent in 2013 is also on track to be considerably below the long-term average, potentially getting close to, or out-melting the lowest minimum that occurred in 2012. Unless global mitigation strategies are implemented in the near future, the Arctic is likely to experience days with nearly no sea ice within a decade and no sea ice for most of the summer within just a few decades.



BC emissions by latitude and source type. Source: Bond et al (2013).

References:

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R.D. Moore et al., *Glacier Change in Western North America: Influences on Hydrology...*, 23 Hydrological Processes 42 (2009).

NSIDC—National Snow and Ice Data Center (accessed 22/07/2013) at: www.nsidc.org

Petition for water quality criteria for black carbon on sea ice and glaciers under section 304 of the clean water act, 33 U.S.C. § 1314 (2010).

CLIMATE AND ENERGY POLICY – RETHINKING ECONOMIC IMPLICATIONS

By Michael MacCracken, Climate Institute Chief Scientist

Based on the global disruption of traditional weather patterns, climate and energy policy is clearly not adapting fast enough. Policies are needed that will slow changes in the hydrologic cycle that have been causing an increase in drenching, and often flooding, rains; slow the rapid drying of soils that occurs with higher temperatures and reduced occurrence of low and moderate rain events; slow the rising snowline and melting of low latitude glaciers that are reducing warm-season water resources; and halt the shift toward a climate regime where unprecedented, extreme temperatures become the new normal.

The failure of climate and energy policy to adapt quickly enough is particularly evident in high latitudes. Action to slow the loss of sea ice and mountain glaciers is essential to sustaining critical wildlife and indigenous cultures, yet thus far, we have not seen these policies materialize. As the world continues to delay action, the Arctic Ocean continues to absorb heat in the summer, resulting in disruptive changes in mid-latitude weather when the heat is released during the rest of the year and in thawing of the region's frozen soils and sediments, which initiates natural carbon feedbacks that amplify the effect of global warming. In the Arctic, global warming is already causing significant impacts that are, in turn, affecting weather patterns and sea level outside the region.

As early as the mid-nineteenth century, some scientists understood the role of greenhouse gases in determining the Earth's energy balance. Additional research, especially since the 1960s, has increased understanding of the growing risks and consequences of human-induced climate change, leading to international approval of the 1992 UN Framework Convention on Climate Change. Despite its passage, however, national climate and energy policies have only slowly been adjusted. To date, actions have failed to limit the ongoing rise in greenhouse gas concentrations, and existing national commitments offer dim hope for early action. Meanwhile, climate changes are already so significant that the prospects for a substantial loss of biodiversity are increasing, extreme weather is adversely affecting agricultural productivity, and the subtropics are expanding into higher latitudes, particularly in the Northern Hemisphere.

With climate impacts intensifying so rapidly, might it be that policymakers should reinterpret a key phrase in the UNFCCC? In particular, should we rethink the qualifying provision that stabilization "should be achieved within a time-frame sufficient to ... enable economic development to proceed in a sustainable manner"? This phrase has generally been interpreted to allow for and even encourage a slow transition away from reliance on coal, petroleum, natural gas, and shale-derived fuels in order to limit economic disruption. Yet with virtually unconstrained use of fossil fuels, the world economy is just puttering along, with large numbers unemployed or underemployed and with rising costs for vital natural resources and for the consequences of damaging and disruptive weather.

I would suggest that it is time to turn the interpretation of this provision on its head. Arguably, it has been the slow approach to limiting climate change and moving toward sustainable development that has restrained the global economy and limited job growth. Moreover, continuing on this path seems likely to lead to more climatic disruption and to even greater allocation of wealth to rebuilding after disasters and relocating away from rising seas, tinder-dry vegetation, and over-stretched water resources.

Former President Bill Clinton argued in a September 2007 speech that greening the global energy system was just what was needed to rejuvenate the global economy. Six years later, however, the US as a nation is only modestly pursuing this approach to creating new jobs. At the same time, on the state level, California has embraced going green and has enjoyed powerful economic resurgence, replacing longstanding deficit problems with a budget surplus. A few other states and some car companies are also pushing ahead, responding not only to regulatory controls but also to market opportunities.

What is so problematic today is that economic analyses are heavily focused on immediate and very-near term effects on energy prices, ignoring or heavily discounting the likely costs of the slow-change approach for future generations. As a society, we make a significant commitment to education to ensure the long-term success of young people. It is essential that we make the same level of investment to ensure the viability of the environment that we bequeath them. If not, a greatly increasing share of earnings will have to go to

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recovery and adaptation, dragging down the quality of life for our children and grandchildren.

The prospects for the future appear so challenging and the time for taking action so short (if not already past) that a growing number of scientists and engineers are exploring whether there may be options to counter-balance global warming, at least partially. Most of these inquiries into the potential for climate engineering are undertaken not with the intent of finding an alternative solution, but out of a sense of desperation arising from the inadequacy of current policies. This frantic search for possible complements to mitigation comes from those who generally have an optimistic view of what society can accomplish if it chooses but who are perplexed by widespread inaction on climate change, given the solid scientific data of the past half century.

There is still time, but not much, to take actions to avoid the most severe consequences of global warming. The longer we wait, the more aggressive and expensive actions will need to be, not only to ensure the long-term benefits we owe future generations, but also to make sure that there are not near-term crises due to severe disruptions in agriculture, public health, coastal habitability, and public access to water resources. The time for action is now—and the action needs to be significant.

BURNING UP THE ARCTIC

By Gerard Wedderburn-Bisshop, World Preservation Foundation

Our understanding of black carbon (soot) and its impact on Arctic warming has increased dramatically, but we need to focus mitigation efforts on Eurasian crop stubble and pasture fires.

In June 2013 University of Illinois Professor Tami Bond and thirty other researchers published an exhaustive review of the latest climate science on black carbon. Considerable uncertainty has surrounded black carbon and its atmospheric interactions that contribute to global warming, but the latest finding is that black carbon is the second greatest human emission after carbon dioxide. Warming from the many impacts of black carbon since 1750 has been 1.1 W/m^2, compared with total human warming of 2.86 W/m^2. On ice or snow, black carbon causes an additional 0.13 W/m^2. While the error bounds are still large, this is an extraordinary finding and gives black carbon a new level of importance.

Aerosols co-emitted from combustion tend to mask or counteract the warming from black carbon, and the large uncertainties surrounding aerosols, their effect on clouds, and the resulting warming or cooling has led policymakers and climate scientists to overlook these emissions. Open burning, in particular, while it is the greatest source of black carbon (about 37%), has high levels of co-emitted aerosols (smoke), and these are thought to cause net cooling. This has directed mitigation efforts to well known net heating sources, such as diesel engines and cookstoves.

However, in the Arctic it appears that open fires are in fact the main culprit, with a group of University of Washington scientists finding that 90% of black carbon from Arctic snow samples was from biomass burning. In a separate 2010 study, they found that 75% of black and brown carbon (light absorbing particles) in a larger number of snow and ice samples was from biomass burning. Forest fires are an interesting part of this burning: boreal forest fires actually have a net cooling effect when dark (light absorbing) canopies are burnt off, exposing snow-covered

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(light reflecting) ground. Likewise, aerosols from boreal forest fires more than balance the warming effect of black carbon. The airborne ARCTAS mission also discovered that crop stubble and pasture are the dominant emission source, and only 24% of black carbon emissions originated from forest fires (Hao et al., 2011). Instead, the analysis showed the main culprit for biomass black carbon emissions (nearly 70%) to be agricultural and grassland fires. Of these, the greatest source was stubble burning (56%) and grassland (pasture maintenance fires), responsible for 18%.

Black carbon deposits on ice and snow in the Antarctic have been found by Brazilian, UK, US and Australian researchers to be dominated even more by biomass burning (particularly grass fires) from South America, Africa, and Australia. This corresponds well to other studies showing biomass burning in the southern hemisphere to overwhelm other sources of black carbon. However, black carbon concentrations measured in the Antarctic are 1%-20% that of Arctic concentrations, therefore do not have the same warming impact.

So mitigation efforts driving Arctic warming in particular would have great impact if they focused on agricultural fires and grassland fires. The breakup of the USSR saw dramatic relaxation of crop stubble fire controls. As a result, these fires have been the focus of attention in recent years. Conferences in St Petersburg in 2010 and 2012 organised by the Clean Air Task Force, Bellona, the International Cryosphere Climate Initiative, and the Swedish Institute of Agricultural and Ecological Engineering brought together many policy makers, experts, and scientists from countries bordering the Arctic to address directly the problem of open burning. These conferences looked at crop and pasture fires in particular and examined existing administrative and legal controls and their suitability in reducing fires. Results of several farmer surveys were presented, and remediation activities involving education, agricultural practices, and monitoring were targeted. Both Arctic Council member nations and countries and groups working with the Climate and Clean Air Coalition of countries launched by Hillary Clinton are now active in researching and monitoring across a range of mitigation options. The newly-launched Arctic Climate Action Registry seeks to incentivize reductions of emissions affecting the Arctic.

Agricultural and pastoral activities also contribute to climate change because they are the major source of Arctic warming gases methane, carbon monoxide, and the ground-level ozone that develops from these. Clearly, agricultural practices generally, including burning, cropping, and grazing, must receive the critical attention they warrant if we are to slow Arctic warming.

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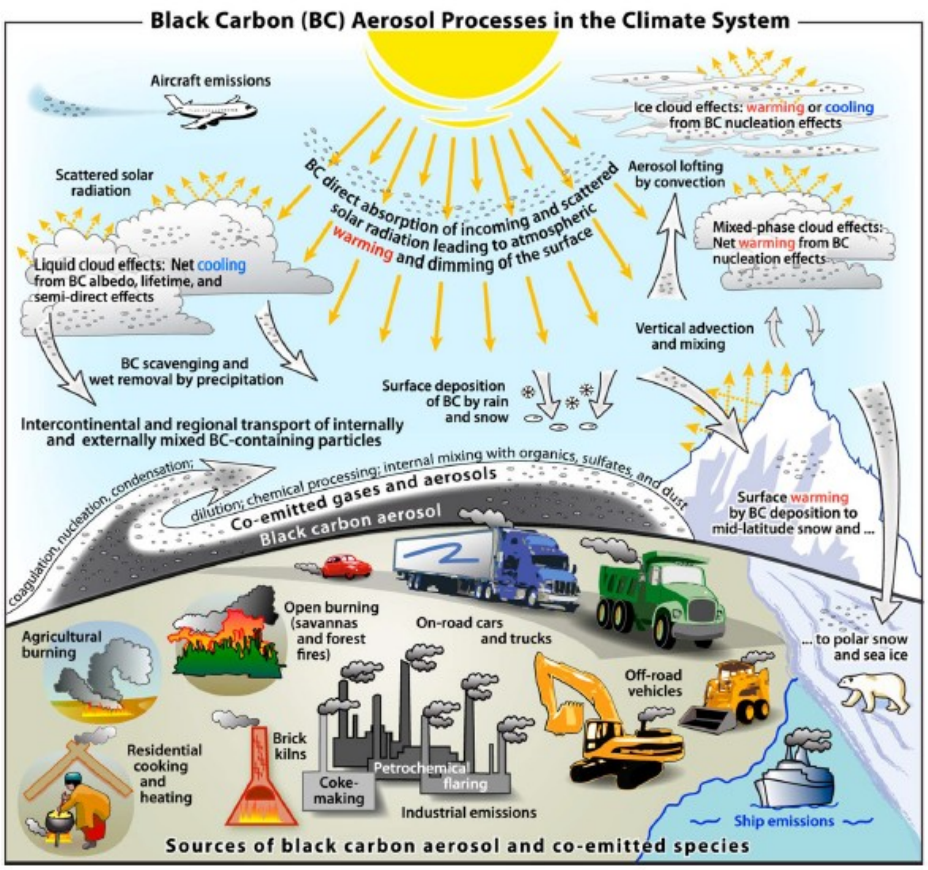

Schematic overview of the primary black-carbon emission sources and the processes that control the distribution of black carbon in the atmosphere and determine its role in the climate system. Source: Bond et al (2013).

THE IMPACT OF BLACK CARBON IN ANDEAN GLACIER MELTING:
AN OPPORTUNITY FOR LINKING LOCAL ACTION WITH LOCAL CLIMATE EFFECTS

By Walter Vergara and Ana R. Rios, Inter-American Development Bank

The inter-tropical area of the Andes is home to the vast majority of the world tropical glaciers (Kaser, 1999) with a total area estimated at about 1920 km^2 in 2000 (Francou and Vincent, 2007). Countries with glacier cover in this region include Venezuela, Colombia, Ecuador, Peru and Bolivia. However, most of the glaciated area is located in Peru's Cordillera Blanca. These glaciers do not only represent a cultural icon of the Andes, since humans first populated this part of the planet, but also provide a number of environmental services critical to the local and regional ecology and economy of the Andes, including provision of potable water for mountain settlements, water for agriculture and for power generation, and mountain habitat integrity (Vergara et al., 2011).

Major variations in the ecology of mountain ecosystems and in the net provision of economic services are anticipated in the Andes as a result of climate change (Ruiz et al., 2012). These impacts include changes in surface area of mountain lakes, fluctuations in dew points, impacts on cloud forest composition and stability, drying up of mountain wetlands, migration and possible extinction of high altitude flora and fauna and, rapid glacier retreat. While the net cumulative impacts of these changes await further study, it is already clear that the affected value of services provided by glaciers and associated mountain ecosystems is substantial reaching the range of billions of dollars per year in some of the affected locations (Vergara et al., 2007).

Glaciers in the tropical Andes are now quickly losing mass primarily as a result of higher air temperatures and a reduction in albedo. This rapid net reduction in glacier area has been widely documented (most notably by Vuille and Bradley, 2000; and, Francou et al., 2003) and is generally acknowledged to have already resulted in major changes in net surface runoffs and a loss of stability in local hydrological regimes. Continuation of this trend is likely to lead to the complete disappearance of lower altitude glaciers in the next few decades resulting in considerable changes in mountain hydrology.

Glacier and mountain wetland in Khotia Khota, Bolivia, part of the tropical glacier system of the Andes, an important source of water for multiple services in the region. Photo: Jennifer Doherty-Bigara, 2012.

While these changes are a result of global warming, there are two local aspects that may be contributing to the rapid net retreat of glaciated areas: a) land use changes and forest fires in the piedmont of the Andes; and b) emissions of soot (particulates and black carbon) from the transport sector. Deforestation by itself may be contributing to alter local climate as solar radiation previously used for latent heat would now available to warm up soil cover and affect local weather patterns (Dickinson and Sellers, 1988). Forest fires in the upper Amazon region (the piedmont of the eastern cordillera) may also be contributing more than originally thought to changes in albedo in the glacier surface by depositing soot transported to the Andes, and contributing to a weakening of the cloud cover (Koch and Del Genio, 2010). This concern is particularly relevant for Peru which presents the highest rates of deforestation in the piedmont region and contains the largest glaciated area in the tropical Andes, but is also valid throughout the North-Eastern Andes, where glaciers and tropical rainforest are located within a few hundred kilometers.

Net changes in albedo resulting from the deposition of regional emissions of black carbon from mobile sources nearby glaciated basins (UNEP, 2011) are also particularly relevant in the tropical Andes, where growing populations are combined with major urban transport hubs. The quality of diesel and its use in the transport sector in major cities in the Andes has traditionally been a source of concern for local air quality but can also be contributing, on account of

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the significant emissions of black carbon to the atmosphere to local changes in albedo. Most of the urban transport fleets in urban areas such as Bogota, Quito, La Paz and Cuzco −all major urban centers located above 2600 m− have been using low quality diesel and have generally lacked particulate traps.

Fortunately, black carbon emissions in Latin America and the Caribbean could be reduced significantly through efforts focusing on: i) reducing and controlling forest fires in the Piedmont of the Andes and local mountain habitats; ii) implementation of emission standards for vehicles, including shifting away from diesel use over time, and in the short term implementing stringent standards for particulate emissions; and, iii) ban of open burning of agricultural residues (UNEP, 2011). These are local actions that could have a visible local effect of relevance for the stability of glaciated area in the Andes and more generally, the stability of mountain ecosystems. The adoption of these measures represents a clear win-win opportunity for the region: it would tackle a source of local air quality with immediate impacts on public health as well as contribute to the slowing down of the glacier retreat process.

Whereas the elimination of black carbon contributions to change of albedo in the glaciated areas of the Andes will not change the course of glacier retreat, its local impact on climate change may delay the process and provide some much needed respite while adequate adaptation measures are implemented to face what is an irreversible consequence of climate change.

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THE IMPLICATIONS OF MINING IN GREENLAND

By Rebecca Fields Green, Graduate Research Fellow

Even as the international community moves very slowly to reduce carbon emissions and mitigate the effects of anthropogenic climate change, businesses from all over the world are moving quickly to pounce on what they see as a golden business opportunity. While climate change has most scientists and many of the world’s citizens concerned about melting glaciers, rising seas, and dramatically altered weather patterns, the realization that global warming is starting to make warm and bare areas of the planet previously covered in snow and ice has sparked great excitement among mining and drilling companies that hope to harvest billions of dollars’ worth of rare earths, iron ore, oil, and other valuable mineral substances from the Arctic and Greenland. London Mining and Chinese partners are seeking to build a mine in southwest Greenland that could produce as much as fifteen million tons of iron ore each year. An Australian company wants to mine rare earths, while Edinburgh-based Cairn Energy drilled for oil off the coast in 2011. If newly unfrozen mining areas appear a blessing for multinational mining operations, however, climate scientists and many Greenlanders foresee that the damage to Greenland’s ecology and climate will greatly outweigh the potential financial benefits from mining (Macalister, 2013).

The question of whether to allow foreign companies access to Greenland’s minerals has become so contentious in the sparsely populated country—granted home rule by Denmark only in 2009—that it proved decisive in the March 2013 election victory of Prime Minister Aleqa Hammond over her rival, incumbent Kuupik Kleist. Many Greenlanders feared that Kleist was too generous in giving mining rights to the Chinese and multinational companies that are seeking to develop Greenland’s fragile environment. They fear both potential environmental damage and an influx of low-paid Chinese workers to exploit

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the mines. London Mining and its Chinese partner, Sichuan Xinye Mining Investment Company, have proposed to conduct mining using Chinese labor, an unattractive prospect to Greenlanders who lack the jobs that industrial mining might be expected to provide. Thus, while the prospect of royalties and foreign investment in developing the island is understandably attractive to Greenland's government, many Greenlanders themselves are wary of allowing the mining to go forward (Hickey, 2013).

That mining operations hold potential for great environmental degradation is clearly evident in areas like West Virginia, where mountaintop removal for coal mining has blighted the region physically and ecologically. Yet mining operations in Greenland would come with the added menace of greatly increasing the rate of warming in the Arctic as a whole. Although most black carbon emissions deposited in Greenland come from the United States and Canada, mining operations—with accompanying road-building, trucks, and heavy machinery—would pose a substantial threat not only to Greenland but to the rest of the Arctic by releasing black carbon and greenhouse gases in the middle of a region that is already experiencing the effects of climate change much faster than the rest of the world. Deposited on Greenland's remaining ice and elsewhere in the Arctic, soot from trucks and other mining equipment would reduce albedo, thus increasing the region's warming from radiation absorption. For this reason, it is imperative that the mining, which will undoubtedly happen in some fashion, be conducted in as clean a manner as possible.

The danger to Greenland is great, but so is the opportunity for action. Even if mining proceeds, Greenland's government should try to leverage the country's mineral wealth to impose some environmental standards on the companies reaping that wealth. These standards could focus not only on the safe disposal of toxic wastes and protection of Greenland's ecology, but also on minimizing mining operations' emissions of greenhouse gas and black carbon emissions. And there may be a role for non-governmental organizations like the Arctic Climate Action Registry to work with companies on reducing their black carbon footprint in the region. Though the task of mitigating global warming in general appears to be an impossible, gargantuan undertaking, Greenland provides a specific, immediate example of a place where swift action could help slow the rapid changes in climate and weather patterns that are becoming more and more apparent every year. Imposing emissions requirements on mining will not "save" Greenland and the Arctic, but it could very well slow it down, giving people from Nuuk to New York, from Vancouver to Vladivostok time to adapt to the disruptive changes in climate and weather that are already accompanying the retreat of Arctic ice.

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Greenland's Minister of Industry and Minerals, Jens Erik Kirkegaard addressed investor concerns in March. Source: http://naalakkersuisut.gl

CLIMATE AND HEALTH EFFECTS OF SLCPs IN SOUTH ASIA

By Humiun Miah, Graduate Research Fellow

Mitigation Strategies to Benefit Himalayan Tibetan Plateau

Ice in the Himalayan Tibetan Plateau (HTP), known as the 'Third Pole' has been rapidly decreasing over the last 30 years. It is widely acknowledged by the UN Climate and Clean Air Coalition (CCAC) and a number of climate focused academics that short-lived climate pollutants (SLCPs) are the regional driver of climate change in South Asia. SLCPs have a short atmospheric life span—weeks to days—compared to other long-lived greenhouse gases like carbon dioxide (CO_2). This provides a window of opportunity during which well-targeted mitigation of SLCPs can have a swift and noticeable impact on near-term climate change within the next several decades and at the same time prevent millions of premature deaths from air pollution.

Regional Effects

Climatologists' analysis of temperature trends on the Tibetan side of the Himalayas indicate warming in excess of 1 °C since the 1950s. These changes are affecting river systems, water supplies, regional weather patterns and public health for the 1.4 billion people residing in the region.

Black carbon (BC), an SLCP and a component of soot, is the second strongest warming pollutant behind CO_2. It forms from the incomplete combustion of fossil fuels, biofuels, and biomass. BC particles in the atmosphere absorb both incoming and outgoing radiation, thus warming the surrounding area. Through its short lifetime in the atmosphere and subsequent soot deposits, BC darkens snow and ice surfaces, reducing snow albedo and increasing solar absorption. Black carbon thus speeds glacial melt. BC can also change regional weather patterns, as it alters the properties and distribution of clouds. Climate observers have noted the weakening of the Pacific Walker circulation in spring, which could lead to more frequent failures of monsoon rainfall in India. Reduced precipitation has already been observed in Southwest India, the Bay of Bengal, Burma, Thailand, and Malaysia. Decreased rainfall and disappearing glaciers may endanger seasonal water supplies in the future.

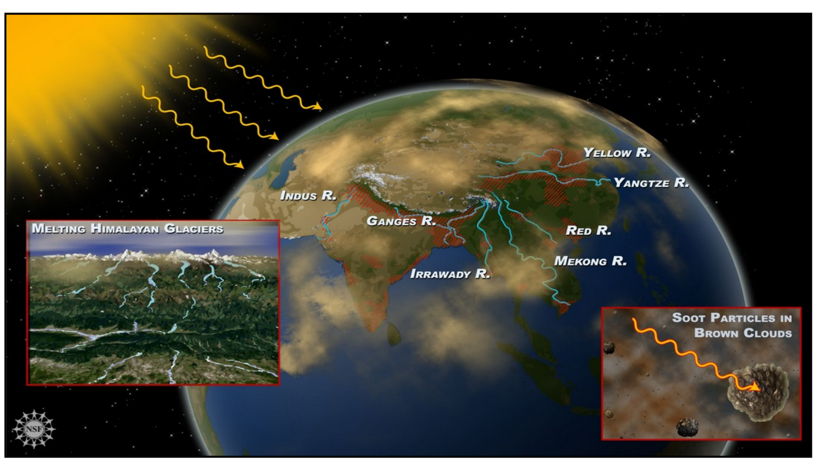
In addition to producing adverse effects on the region's climate and water supplies, biomass-fuelled fires in South Asia are also a silent killer. BC is a primary component of particulate matter (PM), and the inhalation of these particles is known to trigger cardiovascular and lung problems. The World Health Organisation estimates that BC-related health problems account for 1.8 million deaths worldwide annually, the most affected persons being women and children who live by home cook fires.

Mitigating BC in South Asia

The three main sources of BC are residential fires, industrial operations, and the transport sector. Technology to reduce BC emissions already exists, yet it must become more widely adopted and cost-effective in South Asia.

<u>Domestic Sector</u>—The residential sector in India alone produces 40% of BC emissions. Much of it comes from the inefficient combustion of fuel: 650 million rural Indians must burn cheap fuel such as wood, coal, dung, and crop residue for cooking, lighting, and home heating.

Project Surya, a non-profit, improved cook stove program led by Dr. Veerabhadran Ramanathan of University of California – San Diego, aims to mitigate indoor air pollution, including BC, in rural India by focusing primarily on low-cost, efficient-burning technology, like biofuel cookstoves and zero-BC solar stoves. Another option is improved combustion stoves that emit up to 50% less BC than conventional stoves. The pervasive adoption of cookstoves across South Asia could reduce BC by 70-80%. Surya has already distributed efficient stoves in the Indian village of Khairatpur, and project organizers hope to extend their reach to the Himalayas and the northern regions of India.



The regional effects of melting Himalayan Glaciers on river supply.
Source: National Science Foundation

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However, the cost of efficient cookstoves has hindered their adoption in South Asia. Even when solid fuel, biogas, and solar stoves are widely available for $50 - $90 USD, this tends to be unaffordable for rural residents, especially when accounting for fuel supply, distribution, and maintenance of stoves. Consequently, mitigation strategies in the residential sector need to focus on affordability, stove performance, usability, and long-term adaptation.

Surya's Carbon Credit Pilot Project looks to bridge this financial hurdle by integrating SLCPs into carbon markets, which theoretically could provide funds to subsidize the purchase of efficient cookstoves. SLCPs previously have not been included in the carbon market trading. However, due to the short-term effectiveness of their reduction, the project is looking for SLCPs to be traded on the market and at a far higher price, as they have greater potential to mitigate regional climate than longer-term climate pollutants like CO_2. Thus, including SLCPs in carbon credit calculations would empower individuals and organizations to mitigate SLCPs and gain financially from selling surplus credits.

In order to get SLCPs onto carbon exchanges, Surya measures SLCP emissions from traditional stoves and then estimates the potential climate gains from efficient stoves, generating Surya Climate Credits (SCC). Local banks supported by program then provide low interest loans to women to adopt efficient burning stoves. Ultimately, Surya directs the funds raised from the traded SCC, back to the women to repay loans and to incentivize further adoption.

Industrial Sector—The industrial sector is also a large emitter of BC emissions, with two thirds of Indian industrial BC emissions produced from brick kiln manufacturing. India is the world's second largest producer of clay-fired bricks, an industry that consumes around 25 million tons of coal annually. Traditional fixed chimney bull's trench kilns (FCBTK) are heavy polluters and require coal every 10 – 20 minutes, resulting in inefficient combustion and high BC emissions. The 2012 U.S. EPA assessment of SLCPs in South Asia suggested the replacement of brick kilns with more efficient ones could help reduce BC significantly. Technologically advanced zigzag brick kilns emit 85% less BC than traditional FCBTKs by allowing increased airflow rates.

Additionally, advanced training of kiln employees can also help curb BC emissions. Continuous feeding of fuel by workers ensures consistent internal kiln temperature and thus more efficient combustion, resulting in lower BC emissions. The adoption of efficient techniques and technological advancements in the brick kiln industry is estimated to boost annual revenue per kiln by $20,000-$30,000 USD and reduce the health impacts, especially for employees.

Transport Sector—The transport sector is a growing contributor to outdoor pollution of SLCPs. Heavy-duty diesel vehicles and engines produce large quantities of PM, including BC. Diesel vehicles alone produce 17% of global BC emissions. Since the majority of diesel emissions take place in dense urban areas and in close proximity to people, this source of pollution has a disproportionate impact on health.

Long-term mitigation strategies include increasing efficiency in fuel combustion engines, improving vehicle design, and greater regulation of PM emissions for new vehicles. However, setting standards for new technologies and fuels, though important, fails to address substantial BC emissions from the existing fleet of diesel engines. For this reason, technology for adapting vehicles already in use represents a more realistic opportunity for short-term gain.

Diesel particulate filters (DPF) inserted as part of the vehicle's exhaust stream have the potential to eliminate 90% of PM emissions. In the US, Europe, and Japan, DPFs are already required to be fitted on new diesel vehicles. However, South Asia has been slow in mandating the compulsory fitting of DPFs on existing vehicles. Ultra-low sulphur diesel (ULSD) also reduces BC emissions, yet again, South Asia has been slow to adopt this fuel due to higher consumer costs. Nevertheless, there are encouraging trends, with 11 cities in India having wider access to ULSD. Moreover, in New Delhi a court recently mandated a switch from diesel to compressed natural gas for municipal transport vehicles, the first step towards a longer-term approach of moving away from diesel fuels altogether to reduce BC in the city.

Mitigation strategies for BC are slowly gathering momentum in South Asia, but there is a need to accelerate this action. Technologies present and abundant in various sectors have the potential to exert significant influence on near-term climate in the next few decades. The benefits would provide valuable time to take action against longer-term climate pollutants such as CO_2. But most importantly, adopting community level strategies, especially in the residential sector, would save millions of premature deaths and at the same time slow down regional climate change.

CLIMATE ENGINEERING AS A TOOL TO MODERATE ARCTIC WARMING

BY MICHAEL MACCRACKEN, MATTHEW VETTER, AND REBECCA GREEN

As the warming of Arctic land and sea ice accelerates and international negotiations to slow climate change crawl at a snail's pace, scientists and engineers are making a widening search to identify possible approaches for slowing the region's climate change. Reducing emissions of black carbon and other short-lived climate forcers is likely the most practical approach for slowing Arctic melting in the near-term, but the pace of warming is so large that additional approaches will be necessary to preserve the particular conditions needed to sustain the region's unique flora, fauna, and indigenous communities.

As a possible near-term palliative, a number of approaches that may be capable of favorably modifying the region's energy balance appear worthy of further investigation. Strategies drawn from global geoengineering might be applicable in limited areas or in combination to address larger regional challenges. They include seasonal breaking of sea ice, cloud and atmospheric brightening, surface brightening, and the use of methanotrophs. While these tactics might only be able to stave off global warming for a few decades, such options for slowing the rapid deterioration of the Arctic's climate may be easier to implement over the next decade than global-scale approaches because they could be undertaken on a regional basis, perhaps by several nations or even by one country acting alone. Regional geoengineering strategies require much further investigation, yet because the goal of the interventions would be to keep the climate from changing and thus within the bounds of our experience and knowledge, the uncertainties and unintended consequences of these actions are likely to be less dire than those of global-scale geoengineering. Moreover, the ill consequences of regional geoengineering are likely to be much less dire than the unprecedented changes in climate that are projected to result from the on-going, nearly unconstrained emissions of carbon dioxide and other greenhouse gases.

Ice-breaking ship cutting through ice to reveal the dark sea underneath. Source: National Oceanic and Atmospheric Administration

Although breaking up of sea ice may seem counterproductive to limiting Arctic climate change, if carried out when ice is being formed rather than when it is being melted by absorption of solar radiation, such breaking up of the ice could increase transfer of heat from the ocean to the surface, from which much would be radiated to space. This occurs because sea ice acts as an insulator between the relative warmth of the ocean waters and the cold temperatures at the surface of the ice during winter. Breaking up the ice thus leads to the release of additional heat into the atmosphere and the formation of additional sea ice, thus making the overall ice pack thicker and, once covered with snow, better able to withstand springtime warming (MacCracken, 2011).

Cloud brightening (Latham et al., 2012), which can be induced in some types of marine clouds by injection of a mist of sea salt particles, has the potential to reduce regional absorption of solar radiation, thus counterbalancing the increased warming caused by the rising concentrations of CO_2 and other greenhouse gases. In a manner similar to that by which the emissions of sulfur dioxide from electric power plants create sulfate aerosols, brightening of clear skies in the Arctic may also be possible, further reducing the absorption of solar radiation. An interesting research question is whether the very high SO_2 emissions from power plants in Eurasia and North America from roughly the 1950s to 1990s may have exerted a cooling influence on the Arctic and whether the reductions in emissions to limit acid precipitation might have reduced the overall Arctic albedo, thus contributing to Arctic warming. Were cloud and/or sky brightening to be done in the future, it would not be done by power plants and would only be done during the brief spring- and summertime peak in solar radiation so that it would not contribute to the winter-time accumulation of sulfate that leads to the serious ecological consequences from

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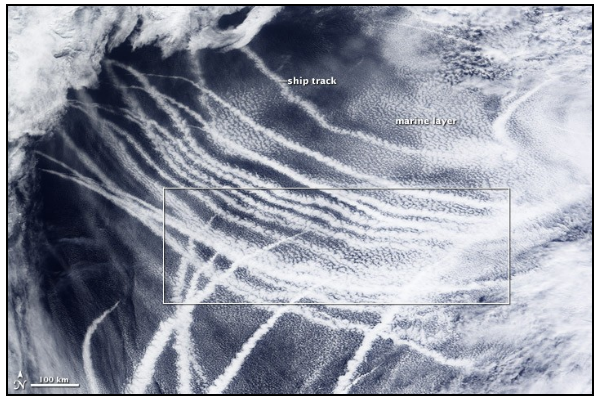
acid deposition.

Over some limited regions, it may also be possible to brighten the surface. Analogous to the brightening of seawater caused by a ship's wake, the reflectivity of Arctic waters in critical regions might be able to be increased by injection of very small microbubbles (Seitz, 2011). Thus, in relatively confined and limited regions such as Hudson's Bay, Davis Strait, Baffin Bay, or the Labrador Sea, microbubble injection during the few summer months that sea ice is not now present might help to reduce absorption of solar radiation and restore colder conditions. This approach could reduce the water body's ability to affect cold-season weather and to contribute both to the loss of ice and to the consequent sea level rise from glacial streams.

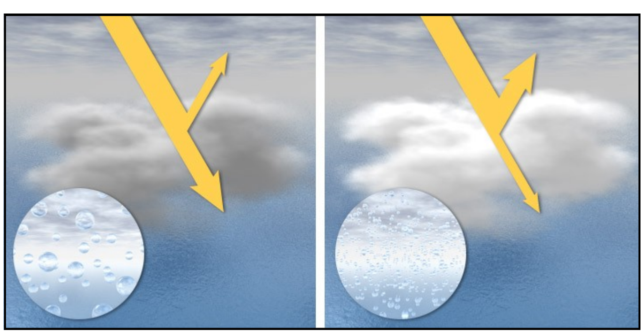
A final geoengineering strategy is the potential encouragement of methanotrophic bacteria and archea to consume emissions of methane before it is released to the atmosphere, where it acts as a very potent greenhouse gas. Methanotrophs exist naturally around many sources of methane, and they have proven to be a useful tool for mitigating methane spills. For instance, a methanotrophic bacteria bloom after the Deepwater Horizon spill in 2010 eliminated most of the methane released in the accident before it entered the atmosphere, thus reducing the effect of the disaster on climate (Kessler et al., 2011). Encouraging the growth of methanotrophs and their consumption of methane may thus offer the potential to convert possible methane emissions from coastal sediments and thawing permafrost to CO_2, which has a lower potential for near-term warming.



Brightening of marine stratus clouds as a result of ship exhaust particles acting as extra cloud condensation nuclei. Source: NASA Earth Observatory

Although these approaches have the potential to counter-balance Arctic climate change, there still exists much to investigate before they might be considered possibilities that policy makers and the region's peoples might want to consider. Ice breaking, for example, would require a significant number of ice-breaking ships to be effective; at the same time, many such ships are being planned to aid in the increased extraction of the region's natural resources. Cloud brightening remains to be tested but can be complicated by the presence of sea ice if done from ships, and surface brightening is limited by the lifetime of the bubbles – likely one or two days.

In addition to questions of efficacy, cost and technology, there are also significant issues of consent and governance that would need to be addressed. First, the nations and peoples of the region would need to agree on the need for a cooling strategy and to accept any unintended consequences as the price to pay for the cooler conditions. Second, although these approaches would likely benefit many of the nations outside the Arctic by slowing global warming and the rate of sea level rise, the types of stop-gap climate engineering approaches discussed here could only have a sustained regional effect if accompanied by global reductions in greenhouse gas emissions. Thus, though initially regionally focused, such efforts would need to be implemented as part of a broader, long-term global action plan aimed at slowing climate change and disruptive weather; absent that, the Arctic that we know will likely disappear, and along with it, the barrier to massive sea level rise and a key generator of the traditional weather patterns in the Northern Hemisphere mid-latitudes.



Brightening clouds with injections of seawater mist to boost density and reflectivity. Source: NASA Earth Observatory

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CLIMATE INSTITUTE
News and Updates since Winter 2012

CLIMATE INSTITUTE CHIEF SCIENTIST

In early April, our Chief Scientist **Mike MacCracken** was in Mexico City as an invited participant in the *Expert Focus Group Discussion on Climate Change* organized by the World Bank. This group brought together a selected number of international experts to share their insights as part of the World Bank's review and update of its environmental and social safeguard policies. While in Mexico City, he also presented a lecture on climate change and geo-engineering at the invitation of the Environmental Advisory Board of the Miguel Alemán Foundation, on which our vice-president **Luis Roberto Acosta** serves; on this occasion, he was also awarded the 2013 Miguel Alemán Medal. Mike's visit also prompted a dinner discussion that included Nobel laureate **Dr. Mario Molina** to discuss Climate Institute collaborations in education, outreach, and science, as well as two Climate Institute Board members, **Senor Acosta** and **Oriana Tickell de Castello.**

Later in April, Mike participated in the *White Arctic, Blue Arctic: Exploring Sea Ice Restoration* workshop at the Earth Institute of Columbia University in New York City. The purpose was to explore in detail the state of the rapidly changing climate in the Arctic, and the potential for approaches to slow Arctic warming.

ARCTIC CLIMATE ACTION REGISTRY (ACAR)

Charles Bayless assumed the Chairmanship of the **Arctic Climate Action Registry (ACAR)** in May. In the past Bayless has served as the president of West Virginia University Institute of Technology and as the CEO of two electrical utilities and has a longstanding interest in practical solutions to climate change problems. Thanks to work by Climate Institute Arctic and CELT Fellows, the ACAR site is now up in Russian, Dutch and Norwegian as well as English with Chinese, Danish, French, German, Swedish and Spanish versions anticipated by September.

ACAR has received considerable visibility since its unveiling by **John Topping**, Climate Institute President, and **Ma Ko Quah Jones**, Dartmouth 2014, October 25, 2012 in Washington at the Smithsonian Inuit Studies Conference. Their joint presentation was "ACAR: A Means of Slowing Displacement of Arctic Indigenous Peoples." On February 19, 2013 Topping delivered the Inaugural Lecture of the University of Oklahoma Global Sustainability Series on Climate Change, the Arctic and International Security and that same day was interviewed on KGOU, the local NPR affiliate.

Charles Bayless, Chair of ACAR

On February 27, 2013 ACAR organized a pre-conference workshop, "Tackling Climate Change in the Arctic: A Climate Emergency," before the Washington, DC Climate Leadership Conference. Speakers were **Tim Warman**, Sustainable Enterprise Management; **Charles Bayless**, Chair, Essential Power; **Michael MacCracken**, Chief Scientist, Climate Insitute, **John Kadyszewski**, Director, American Carbon Registry; and **Tobias Schultz**, SCS Global Services.

On May 14, **Paul Bartlett**, air quality expert who is a member of the ACAR Steering Committee, organized a webinar from Svalbard, Norway to introduce ACAR to a European audience. Participating remotely from the US were **Stan Rhodes**, President, SCS Global Services; **Charles Bayless;** and **John Topping**.

On June 13,2013 **John Topping** delivered at Columbia University a Hertog Global Strategy Initiative Lecture entitled "Slowing Arctic Melting: Beginnings of a Regional Strategy to Mitigate Climate Change." The 79-minute lecture and question period were live streamed and filmed by Columbia and can be viewed on YouTube.

CENTER FOR ENVIRONMENTAL LEADERSHIP TRAINING (CELT)

The Climate Institute's **Center for Environmental Leadership Training (CELT)** based in Hanover, NH, has grown past its Dartmouth base to include virtual fellows and interns from Carnegie Mellon, Harvard, Yale, Vermont Law School, Columbia, Middlebury, Virginia Tech, the University of Virginia, Haverford, the University of North Carolina, North Carolina State University, the University of Copenhagen, the University of Cambridge, the University of Exeter, the University of Edinburgh, Lafayette, Purdue, and the University of California system. On March 28, 2013 five student representatives of CELT**—Ma Ko Quah Jones, Leehi Yona, Kripa Dongol, Anda Zhang and Patryc Wiggins**—together with CELT Steering Committee Chair **Bob Bartles** and **John Topping** met with Dartmouth President **Carol Folt** to discuss how Dartmouth might spur environmental innovation.

In April 2013 CELT member **Celeste Winston**, Dartmouth 2014, who interned at the Climate Institute in the summer of 2011, was one of only 20 college juniors in the US named as a Beinecke Scholar, receiving funding for PhD studies.

CELT's climate education games project is gathering steam. The "Saving the Arctic" Core Game Team, including **Christopher Philipp** (an E-Learning Professional with many years of teaching experience), **John "Fritz" Wallace** (a UNH '16 student with an extensive background in game design and production), and **Devin Routh** (a Yale FES master's student who works with landscape scale natural resource and forest management), will spend the summer continuing the evolution of the game script and begin its translation it into an operable computer program. **Alex Grant**, a New Hampshire high school junior with an in-depth knowledge of programming languages, has recently joined the team to aid in the technical aspects of programming. A myriad of other CELT and ACAR members and associates have also aided with the production.

The game as currently planned will feature short-lived climate forcers, specifically black carbon, as the central "antagonist" that the player will work to reduce (and from which the player will consistently attempt to "escape"). The project team has spent considerable time designing the plot so as to integrate pedagogy with entertainment: the player should come away feeling satisfied with the game experience and also knowledgeable about his/her ability to take proactive steps in reducing short lived climate forcers. Later in the development process, the project team will interface closely with the CELT and ACAR web presence to engage as much promotion capability as possible. Players will also be able to connect with both organizations and access their informational and other resources.

If you have any questions about the development process or would like to participate, feel free to contact **Devin Routh** at:
devin.routh@gmail.com

GLOBAL SUSTAINABLE ENERGY ISLANDS INITITATIVE (GSEII)

Climate Institute together with several partner organizations launched the VISION 20/30 at Rio+20 Conference in June 2012. This initiative that presents a vision for independence of small islands from fossil energy, in the first phase is seeking to identify island nations that want to take a very aggressive approach to transform their energy sector to renewables and achieve energy independence by 2020. In partnership with Carbon War Room's 10 Islands Challenge program, and working closely with partners like SIDS DOCK, IRENA, IADB and others, this initiative it is expected to identify and announce the plans for these leading islands at the Barbados +20 conference in September 2014 in Samoa. VISION 20/30 has been recognized as one of the High Impact Initiatives of the UN Secretary-General's Sustainable Energy for All initiative.

The Republic of the Marshall Islands, a nation of scattered reefs and atolls in the North Pacific, is under grave threat from sea level rise associated with climate change. Source: gseii.org

CLIMATE INSTITUTE

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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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Front cover image: Photograph of the Andes Mountains in South America
Back cover image: Photograph showing the retreat of melting glaciers in the Himalayas

Editor's note: For all citations and references, see the electronic version of this newsletter at www.climate.org