INTERNATIONAL CRYOSPHERE CLIMATE INITIATIVE

A "Cryosphere Action Plan": Assessment of Measures and Impacts of SLCP Measures for Regional Glacier and Ice (Cryosphere) Preservation

Background:

Climate change is happening faster and in a dramatically more visible way in the Earth's "cryosphere" than anywhere else on earth. Global changes in climate are exaggerated here: average temperature has risen at over twice the global mean in the Arctic, Antarctic Peninsula and much of the Himalayas and other mountain regions, and is well above the global mean in virtually all of the cryosphere – regions of ice and snow – around the globe.

While the ecosystems and human communities – many of them indigenous -- of these regions most directly are threatened by such rapid cryosphere warming, the changes it brings will be felt by billions more, and especially in the developing world. The Himalayas store more freshwater ice and snow than any region outside the poles: nearly 10% of the global total, and impacting 40% of the world's population. Not large to begin with, yet providing freshwater to millions in all the major urban centers of the Andean nations, these high tropical glaciers are disappearing more rapidly than any others. The glaciers of East Africa have lost 90 percent of their mass in the past 60 years.

Potential global impacts prove even more widespread. The Arctic Council has projected that sea level rise from glacial melt in these regions and on Greenland, as well as from other factors may exceed one meter in this century, and the initial drafts of IPCC's Fifth Assessment generally agree with this figure. Recent research into the stability of the West Antarctica Ice Sheet and its role in past sea level rise indicates it may be more important than melting on Greenland. A rise of even one meter in sea level will impact 500 million globally, with many more made far more susceptible to flooding and tidal surges accompanying hurricanes and typhoons such as that seem in the Philippines (Typhoon Bopha) and northeastern United States (Hurricane Sandy) in 2012. Small island states and coastal communities in least developed nations face the greatest risk.

Changes in the cryosphere caused by rapid climate change also have the potential to hasten climate change globally. When Arctic sea ice disappears to a greater extent each summer, less sunlight is reflected from the northern hemisphere and the darker ocean absorbs heat, warming the entire globe. Similar regional warming occurs due to loss of this "albedo effect" as high mountain glaciers shrink. Perhaps most seriously, both the Arctic and high mountain regions hold large amounts of methane and carbon dioxide (CO_2) in frozen form, from as long as 400,000 years ago, as permafrost on land and methane hydrates in near-coastal sea beds. As these regions thaw, these greenhouse gases (GHGs) will be released into the atmosphere, speeding warming further and faster. Methane in particular is an extremely potent near-term warming agent, and sudden releases could speed warming on a global scale that would be measured in decades.

The fight to preserve these regions therefore is a global one. It is also an effort that has an increasingly short window of opportunity to impact. Facing a likely loss of summer sea ice by 2030, and disappearance of many land glaciers even earlier, efforts aimed at longer-lived greenhouse gases – while absolutely vital to the long-term preservation of these regions – will not be enough unless accompanied by reductions in these near-term forcers. Much of cryosphere is under a near-term threat of at most decades, rather than centuries, and requires measures that will act far more rapidly. This "cryosphere imperative" demands different yet complementary climate solutions to those of the globe as a whole. Slowing warming in these regions will allow both local, and global peoples a better chance to adapt; and the greatest extent possible, mitigate and reverse these changes.

The Importance of Short-lived Pollutants: Early Arctic and Himalayan Work

In the early 2000's, a number of researchers began looking at the role black carbon and tropospheric ozone were playing in Arctic and Himalayan warming and melting; and conversely, what benefits might be achieved from their reduction. Researchers gathered in New York in 2006 and Oslo in 2007 to discuss these findings; and in 2008, AMAP held the first official meeting focused exclusively on the role of these pollutants in Arctic climate change. The Arctic Council published these initial findings in 2009,[1] and in May of that year the Council's ministerial meeting and a related Norwegian initiative, Melting Ice, highlighted the role of black carbon, ozone and methane globally at both the Ministerial and at COP-15.[2] The Council commissioned AMAP and a special technical task force to continue exploring mitigation options. Additional reports were published at the Nuuk and Kiruna ministerial meetings in 2011 and May 2013, respectively.[3]

At the same time, researchers involved in the Atmospheric Brown Cloud programme (ABC), mainly sponsored by Swedish Sida and with the UN Environment Programme (UNEP) as its Secretariat, began noting the potential regional climate co-benefits to the Himalayas of their work to cut pollution for health reasons in South and Southeast Asia. Formally initiated in 2002, the ABC Programme developed in phases and at a meeting in Kathmandu in 2008, firmly established the links between greenhouse gases, air pollution and climate change. Countries such as India, China and Nepal started long-term research programs on glaciology and related issues to study all aspects of Himalayan glaciers; with the impact of black carbon a major topic of concern also for the regional monsoon regime, water budgets, agricultural production and human health.

Slowing Near-term Warming: the UNEP/WMO Assessment

In 2011, UNEP and the World Meteorological Organization (WMO) combined forces to produce the Integrated Assessment of Black Carbon and Ozone, a first effort to look at the potential to slow warming globally through reductions in particle pollution (black carbon) and ozone precursors, which previously had been considered as classic air pollutants only. They also however have the added benefit of impacting climate in the near-term, from sources that emit large portions of black carbon as part of the particle mix. Methane, which also is regulated under the Kyoto Protocol as a greenhouse gas, increasingly is considered also in air quality terms due to its impact on ground-level (trophosperic) ozone.[4]

The Assessment began with over 2000 “measures” (mostly technical ways to reduce these pollutants), and modeled their impact on health, crop yields and climate. For a measure to be included, it needed to combine health-crop benefits with climate benefits, taking into account all emissions from that source. The first phase of the Assessment found that nearly 90 percent of the climate benefits came from just 16 of these “measures,” and therefore followed up its initial screening process with more detailed global modeling for those sixteen measures. The specific sixteen measures used in the Assessment are shown in Table 1.

Table 1: Measures that improve climate change mitigation
and air quality and have a large emission reduction potential

Measure[1]	Sector
CH_4 measures	
Extended pre-mine degasification and recovery and oxidation of CH_4 from ventilation air from coal mines	**Extraction and transport of fossil fuel**
Extended recovery and utilization, rather than venting, of associated gas and improved control of unintended fugitive emissions from the production of oil and natural gas	
Reduced gas leakage from long-distance transmission pipelines	
Separation and treatment of biodegradable municipal waste through recycling, composting and anaerobic digestion as well as landfill gas collection with combustion/utilization	**Waste management**
Upgrading primary wastewater treatment to secondary/tertiary treatment with gas recovery and overflow control	
Control of CH_4 emissions from livestock, mainly through farm-scale anaerobic digestion of manure from cattle and pigs	**Agriculture**
Intermittent aeration of continuously flooded rice paddies	

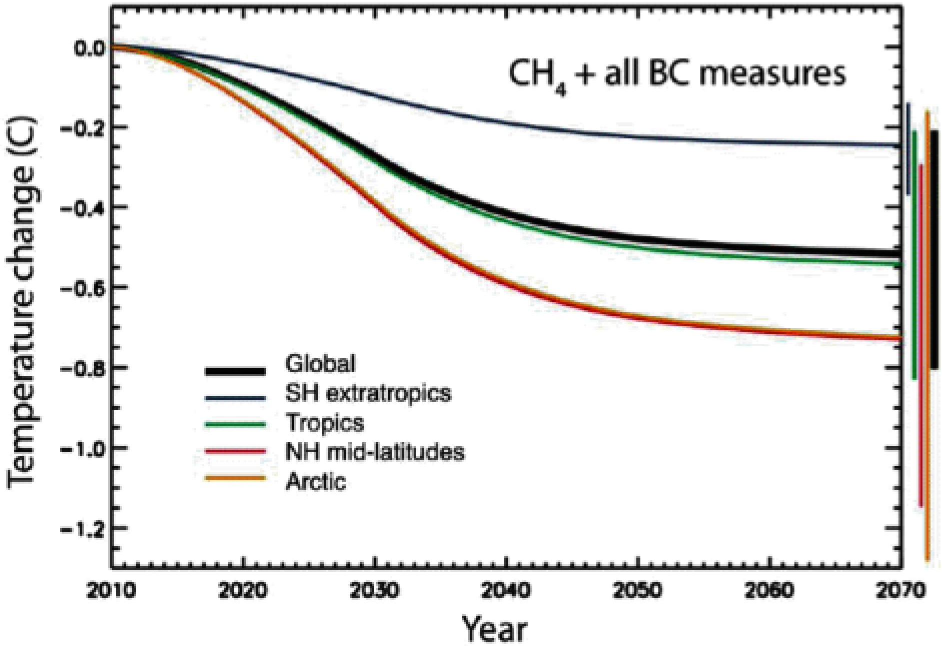
BC measures (affecting BC and other co-emitted compounds)	
Diesel particle filters as part of a Euro 6/VI package for road and off-road diesel vehicles	**Transport**
Elimination of high-emitting vehicles in road and off-road transport	
Replacing coal by coal briquettes in cooking and heating stoves	**Residential**
Pellet stoves and boilers, using fuel made from recycled wood waste or sawdust, to replace current wood-burning technologies in the residential sector in industrialized countries	
Introduction of clean-burning biomass stoves for cooking and heating in developing countries[2,3]	
Substitution of clean-burning cookstoves using modern fuels for traditional biomass cookstoves in developing countries[2,3]	
Replacing traditional brick kilns with vertical shaft kilns and Hoffman kilns	**Industry**
Replacing traditional coke ovens with modern recovery ovens, including the improvement of end-of-pipe abatement measures in developing countries	
Ban on open field burning of agricultural waste[2]	**Agriculture**

1 There are measures other than those identified in the table that could be implemented. For example, electric cars would have a similar impact to diesel particulate filters but these have not yet been widely introduced; forest fire controls could also be important but are not included due to the difficulty in establishing the proportion of fires that are anthropogenic.
2 Motivated in part by its effect on health and regional climate, including areas of ice and snow.
3 For cookstoves, given their importance for BC emissions, two alternative measures are included.

A number of policy actions have resulted in the years since. The Swedish government together with UNEP published an Action Plan that included additional regional work using the so-called FAssT approach and updated emissions inventories not included in the Assessment. While not a full modeling effort, it gave useful information on possible future priorities for Asia, Africa and Latin America. In February 2012, six nations founded the Climate and Clean Air Coalition, headquartered at UNEP's Paris offices and which at time of publication includes 31 state and 29 non-state partners. The Convention on Long-range's Gothenburg Protocol in December 2012 agreed to a revision of the Protocol that includes consideration of black carbon as a constituent of particle pollution, following the 2011 recommendations of a special black carbon working group. Meeting in New Delhi, India in January 2013, the BASIC[5] Ministerial meeting agreed to begin a program on black carbon research and potential policy actions, coordinated by the Divecha Centre for Climate in Bangalore.

Neither the Assessment nor the Action Plan focused on cryosphere regions *per se*. However, the Assessment did note one intriguing response based on latitude bands: a temperature response to all measures in the Arctic nearly twice that of the globe as a whole. Indeed, late in the evaluation stage of the Assessment, modelers were able to add one additional measure aimed primarily at a northern European source of BC -- replacement of wood logs by pellets in biomass stoves -- and were surprised when this single measure led to about 15% greater cooling in modeling of the Arctic region: a full one-tenth of a degree, an extremely large result in global modeling terms (Figure 1, below).[6]

Global and Regional Temperature Change Relative to the Reference Scenario (hybrid modelling of GISS, ECHAM informed by the literature)



Reduced Arctic warming by over 0.7 ^{o}C by 2040 compared to the reference scenario, with measures taken 2010-2030. **Mitigating ~2/3 of projected 1.2 degrees warming**

This was the only measure modeled singly, and the Arctic was the only region characterized in the Assessment using the full Assessment models: ECHAM, developed by the Potsdam Institute and run by the EU's Joint Research Centre in Arona; and GISS from NASA's Earth Sciences Center in New York. Rapidly accelerating cryosphere changes since the Assessment however – improved data on glacier retreat; the increasingly-thin, shrinking and unstable ice in the Arctic Ocean and Western Antarctic Ice Sheet – has highlighted the need for a cryosphere-specific study of the potential mitigation of black carbon, methane and ozone for the benefit of these regions, and for global benefits as well.

Why Short-lived Pollutants Have Greater Cryosphere Impact

As noted above, measures aimed at methane, ozone and especially, black carbon have a greater positive impact on slowing warming in the Earth's cryosphere. Much of this greater response arises from the greater impact from black carbon (BC) emissions over the highly reflective surface of ice and snow. No source (expect possibly kerosene lanterns) emit "pure" black carbon, but a complex mixture of pollutants that impact both health and climate. While the health impacts are well documented, uncertainty remains over the climate impacts globally, especially from biomass sources such as open burning and stoves.

Black carbon researchers today however have reached a consensus that over snow and ice, there is far less uncertainty even from sources that carry higher percentages of the more reflective, “white” organic carbon and “yellow” sulfates often co-emitted with black carbon. This is because the lighter organic carbon and sulfates reflect the sun’s rays and thus can actually cool more than black carbon from that same source might warm; but only over a surface that is darker to begin with. Such a “cooling” impact is absent over a surface that is already white and highly reflective, such as ice and snow.

Thus, atmospheric scientists and modelers now feel confident that measures aimed at black carbon from biomass burning (stoves, for both cooking and domestic heating; and field burning) will have a beneficial climate effect, in addition to their positive health impacts close to high alpine and polar areas that have snow and ice cover. From these same sources may arise also a regional springtime ozone response in the Arctic especially, that may hasten springtime melt.

Focus of the Cryosphere Action Plan Study

The ABC Programme, Arctic Council and UNEP Assessment have thus pointed the way for a cryosphere-specific modeling study that now can include all the UNEP measures and a few others – such as kerosene and diesel generators – that also have come to light very recently. While modeling SLCP impacts everywhere, our focus is the cryosphere regions due to their regional as well as global impacts, with the greater certainty attending black carbon climate impacts in these regions in particular. The goal of this study is to give national and provincial governments concerned about or directly impacted by these changes, an indication of where their efforts on these classic pollutants may most reliably bear fruit in regional climate terms, especially when combined with health and development goals.

This study does not purport to be the end word on such efforts, and may also indicate where more detailed regionally-based modeling and measurements might occur. At the same time, for those governments wishing to take no-regrets action now, it can serve as an initial base for more effective measures that have significant local co-benefits.

Regional peoples also understand implicitly the need for rapid action and even the importance of processes such as albedo in mediating the changes they see around them. One community in the Andes is expending significant time and effort in painting rocks (see picture) around 5,000 meter glaciers white. Some cryosphere scientists – alarmed at the rapid and accelerating changes shown by their research – have begun to advocate for geo-engineering on a far larger scale, with extremely uncertain impacts to regional and global ecosystems. It is the hope of this study to provide alternatives to such desperate and risky efforts, and better direct human resources to more effective, sustainable, developmentally-appropriate, and far less uncertain outcomes before it becomes too late for many of these regions to survive.

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[1] AMAP (2009), *Black Carbon in the Arctic*.
[2] *Melting Snow and Ice: A Call for Action*, Government of Norway (2009)
[3] AMAP (2001), Arctic Council SLF TF (2011, 2013)
[4] Ozone in the context of this report refers to tropospheric or ground level ozone, which contributes to the formation of smog, not to be confused with stratospheric ozone.
[5] China, India, South Africa and Brazil
[6] All temperature measurements in this study use degrees Celsius (C).