Exploring the third pole

Welcome to thethirdpole.net reader

PART 2: GLACIERS AND CLIMATE CHANGE

Exploring the third pole
Editor's note

Welcome to thethirdpole.net reader

Since its launch in 2009, thethirdpole.net has provided a unique platform for information, reporting and discussion on the ecology, environment and climate of the Hindu Kush-Himalayas, the Qinghai-Tibet Plateau and the rivers that originate there. We aim to facilitate the free flow of accurate information and analysis and thereby support well informed policymaking in this region. Good governance is crucial to protecting ecosystems on which around 1.3 billion people depend directly or indirectly for their food, water and other vital services.

Using thethirdpole.net's unique reach across the region, we have been able to publish articles by journalists and experts from the various countries that share the benefits and risks of the world's highest mountain range and plateau, from Tibet to Bangladesh. Recognising the continued and pressing need for a regional perspective in a part of the world where access to accurate information is problematic, we are launching the first of a series of thethirdpole.net readers. These special publications will offer invaluable background material to policymakers, academics and other stakeholders.

Important articles are classified by theme and this reader is free to download. We hope that you find it useful and we encourage you to circulate the link. Please also help us to improve and develop this resource by sending your comments and feedback to joydeep.gupta@thethirdpole.net or beth.walker@thethirdpole.net.

Isabel Hilton and thethirdpole.net editorial team

June, 2012

Part 2: Glaciers and climate change

The impact of climate change on Himalayan glaciers is as complex as it is perilous. Reports about the melting of some glaciers in the Himalayas – and the advancing of others – have sparked heated debate. But comprehensive scientific data on climate change's effects on Himalayan glaciers are woefully lacking. Since its inception, thethirdpole.net has reported on the science that is beginning to emerge from this understudied region.

In this section, Isabel Hilton talks to development specialist Andreas Schild about the current state of scientific knowledge in the region and the need for greater regional cooperation. Glacier scientist Kenneth Hewitt explains regional variance in glacier melt and warns against oversimplification. Former water minister of Nepal, Dipak Gyawali, explains the importance of approaching Himalayan climate change from the grass-roots level. And Jenny Johnson warns policymakers to pay more attention to the power of black carbon to accelerate ice melt in the region.

Cover image shows view of Imja glacier in Nepal by marklkelly

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Glaciers and guesswork

The "third pole" is hugely vulnerable to the effects of glacier retreat – but the science is scarce. Isabel Hilton speaks with Andreas Schild, a specialist in the Hindu Kush-Himalayan region.

Andreas Schild was director general of the International Centre for Integrated Mountain Development (ICIMOD), based in Kathmandu, between 2007 and 2011. ICIMOD works to develop an economically and environmentally sound mountain ecosystem to improve the living standards of high-altitude populations in the Hindu Kush-Himalayas and to sustain vital ecosystem services for the billions of people living downstream. A development specialist, Schild spoke at the "Kathmandu to Copenhagen 2009" conference, which focused on South Asian countries' vulnerabilities to climate change and aimed to catalyse a common Himalayan response. Isabel Hilton, editor of chinadialogue, spoke to him before the conference.

Isabel Hilton (IH): Since the last IPCC report – the Fourth Assessment Report of the Intergovernmental Panel on Climate Change – many scientists have said that climate change is moving faster than was reflected by that assessment. Is this your observation with respect to the "third pole" – the Himalaya and the Tibetan plateau?

Andreas Schild (AS): We cannot confirm this statement and the main reason is that we do not have directly available reliable and consistent data. This is also the reason why the IPCC Fourth Assessment hardly mentions the Hindu Kush-Himalayan region. We are presently involved in a review of the situation of the glaciers and we can confirm that the retreat of glaciers, which has already been reported, is taking place and is accelerating.

However, we hesitate to make such a statement, because we have to see what kind of glacier we are speaking about. We also have to be aware that certain glaciers – large glaciers in the Karakorum, for instance – are growing. But even this statement tends to create misunderstandings: the growing is probably due to changing precipitation patterns, perhaps more precipitation in the winter season due to westerly winds. But this is an intelligent guess, which for the time being cannot be supported by science. Glaciers, which depend on the monsoon in the western Himalayas, tend to be receding quicker.

> *"The bottom line is that for the Hindu Kush-Himalayan region, we do not have reliable data and we do not have the monitoring instruments in place to make clear statements."*

Glaciers are excellent indicators because change is immediately visible and understandable for the layman. But addressing the changing precipitation patterns of the monsoon and changing biodiversity require much more refined monitoring tools. The bottom line is that for the Hindu Kush-Himalayan region, we do not have reliable data and we do not have the monitoring instruments in place to make clear statements.

IH: Is it possible to detail the projected impacts on regional downstream countries? Do you see any connection, for instance, between the retreat of the glaciers and such phenomena as the failure of the Indian monsoon this year, or the floods and typhoons in China and Taiwan, or are these coincidental phenomena?

AS: It is very dangerous to take punctual, one-time events and interpret them for the explanation of a global phenomenon. We need multi-annual data chains and have to apply modelling techniques, which indicate certain trends. To refer to isolated events and interpret them directly is very risky. Studies of such major events as floods in South Asia since the 1960s tend to indicate that they are the product of locally isolated outbursts, which as typical for mountain systems. The trend is that they are recurring more frequently and with greater amplitude.

IH: What do we know and how do we know it? It is a vast and varied region, but in some respects it is one huge ecosystem fragmented across several countries. How important is it to reach a comprehensive scientific understanding of the region scientifically, and is that possible?

AS: We have to accept that within the Hindu Kush-Himalayan region there are great variations. In mountains, we have to accept that there are very local and rapidly changing extreme situations and events. From this point of view, it is not possible to make sweeping statements for the whole region. However, what is possible is to make longitudinal and latitudinal transects, which allow observations and conclusions for sub-regions, water basins or specific systems. ICIMOD is working on such a concept with the regional partners and finds an encouraging interest among the specialists.

In order to become relevant, this needs firm and long-term commitment from the governments. At this point, we have to define relevant sub-regions where comprehensive statements can be made. Political borders do not usually define these: they are transboundary and cross political borders. I am referring here to river basins, to landscape corridors and so on.

The difficulties are that, in the past, data gathering and interpretation has been done on an ad hoc basis, project-wise and without continuity. The governments have not given priority to such phenomena. The consequences are a high presence of external actors, such as universities, which do a lot of research but do not necessarily coordinate. Another difficulty is the different level of capacity of the institutions, which does not facilitate the exchange of information, and a lot of data are not exchanged because of institutional, political and personal reasons.

IH: What role does satellite monitoring play in advancing our understanding of what is happening? Is it enough?

AS: Remote sensing instruments and satellite imagery is very useful indeed and is making quick progress. Such instruments are very useful for the indication of trends and for general interpretations. In practice, though, these instruments have to be accompanied with in situ investigation and observation. Modelling based exclusively on remote sensing has too great a variability compared with field observation.

For example, we have a fairly good view of the growth and retreat of glaciers and glacial lakes based on remote sensing. However, we cannot estimate reliably the quantity of ice available, the mass balance and the evolution of the ice quantity. This is highly relevant to estimates of the water stored in the form of ice, and water availability during dry season for irrigation. Even more critical is the assessment of permafrost through remote sensing. Such observations are of great importance in order to assess such disaster risks as moraine breaks and landslides.

IH: How would you assess the region's readiness in terms of awareness of the impacts, adaptation and mitigation strategies?

AS: It is very difficult to answer a question that encompasses so many countries and the substantial differences between awareness, adaptation and mitigation. We can safely say that the awareness of the consequences of climate change has substantially increased. Some regional countries make a substantial effort. However, their positions depend greatly on the prevailing situation in the respective countries.

There are extreme cases in the region, such as Afghanistan, Nepal and Myanmar. All the three have very specific internal agendas and priorities. Nepal is an extreme case because it is potentially a main loser and winner at the same time. However, climate change is very low on the political agenda.

In the conference at the end of August – which is exclusively donor-driven by the World Bank, DfID [the UK Department for International Development] and Denmark – the interest is mainly in how much participants can get through the carbon trade facilities. At the other extreme is Bhutan, which is branding itself as a green, environmentally conscious country. India and China are doing a lot in terms of adaptation and are very active. The same can be said of Pakistan, which is extremely worried because of the consequences for food security. Bangladesh can make important investments thanks to donors like DfID.

Mitigation is a completely different chapter and cannot be answered in a professional way in this context. The difficulty for the big regional countries is that mitigation is directly linked with growth. From the mountain perspective, ICIMOD is focusing clearly on adaptation. The global debate on mitigation will only have long-term effects. In the meantime, it is essential to strengthen adaptation and build resilient communities. Practically, this means that the adaptation agenda has to be linked closely to other agendas. Poverty is the overriding issue; for mountain communities, globalisation, migration and isolation also are concerns.

Mountains are largely suffering from climate change and are not the polluters. On the other hand, they have not benefited from the carbon-trading facilities. The global architecture, data availability and transaction costs do not favour them. We fear their potential will also be limited in the future. This could have dramatic consequences. Mountains are very sensitive systems and are fragile. The ecosystem services in terms of water, biodiversity, cultural heritage, space for recovery, tourism and so on will be affected. This will influence food security, particularly in Asia, where the main rivers are highly dependent on mountain and snow and ice discharge.

IH: What are the risks of lack of preparedness?

AS: Again, a very difficult question. Talking of preparedness, let's look at disaster preparedness. Most dangers are not new; local communities have learned to adapt to new risks and have developed a substantial amount of resilience. They continue to learn. Most critical is the arrival of change due to external actors. Very often schoolhouses are built on marginal land or in very exposed situations. The same holds true for health posts. Thanks to the availability of soft money in poverty alleviation funds, some of the most popular investments are access roads. Because they are built ignoring all principles of engineering, new vulnerabilities due to climate change are created. The effect on water, biodiversity, required land cover and land use are rather slow processes.

The most immediate risk of lacking preparedness is the loss of life and assets. To ignore the risks is to create prospective loss and the destruction of investment goods. The higher the investments, the more relevant knowledge is, rather than preparedness. High investments require a good knowledge of risks that originate in climate change and the prospective investment.

For example, on the Tama Kosi, a river in the Kosi system, hydropower stations for an installed capacity of 938 megawatts are planned. Upstream, on the Chinese side, 40 potentially dangerous glacial lakes are identified. The planners have no long-term data of the water flow and have to plan to protect these investments from undue and incalculable risks. The planners must include so many safety measures to protect the investments that either the investment costs or the risks are very high. The lack of knowledge is therefore making it difficult to take well-informed decisions, which implies the danger of promoting unproductive investments.

IH: In what areas do we need greater cooperation?

AS: First of all, we should close the knowledge gaps. This means making knowledge and data that basically exists available and accessible. Then we need institutions and mechanisms to build up knowledge banks and monitoring facilities. This means institution-building, which is highly unpopular among the donors, and increased research capacity in local specialised institutions and universities. The third important element is the promotion of the transboundary exchange of information and co-operation. Fourthly, the donors: the traditional development agencies have made a lot of progress, at least verbally, in donor coordination, basket funding [joint funding by several donors] and national ownership.

On the other hand, we realise that within the frame of globalisation, traditional donor countries have created new instruments of international cooperation. In a globalised world, there are no external politics, just global interior politics – so technical ministries have received funds to cooperate with stakeholders around the world. Climate change means that for one specific country, different actors make contributions, cooperate and do research without any substantial coordination capacity within the respective country. Climate change is creating new channels of cooperation, without clear coordination and consultation mechanisms.

From ICIMOD's point of view, we think more information and awareness has to be created in what in the west is called civil society. Knowledge has to be increased among multipliers to be able to influence the political agenda. Such information should definitely illuminate the dangers and risks, and at the same time create new opportunities, particularly for mountain countries.

IH: How can this situation be improved?

AS: Probably the single most important element in the countries, but also for the donors, is the commitment to more long-term objectives – for continuity, which also implies awareness creation and institution building. I think another very important element is the promotion of development potential in the countries themselves and being aware that there are other important agenda points as well as climate change.

IH: What are the risks of failure to achieve cooperation?

AS: The risks are increased vulnerabilities, less-than-optimal allocation of resources and increasing development gaps.

Andreas Schild was director general of the International Centre for Integrated Mountain Development (ICIMOD) between 2007 and 2011.

Isabel Hilton is editor of chinadialogue.

Image by Charles Masters

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Understanding glacier changes

The impact of climate change on Himalayan glaciers is as complex as it is perilous. Kenneth Hewitt explores the hotly debated world of melting – and expanding ice.

Image shows the upper Chiring-Panmah Glacier, and illustrates the prevalence of steep rock walls in the upper parts of these glacier basins. The avalanches coming from them have left cones of snow at the base of all the slopes. June 2005.

Glaciers are quite sensitive to climate change and, recently, there have been many reports of major changes in the Himalaya and other parts of High Asia; mostly of glaciers retreating fast. Impacts of a range of glacier hazards, and on the reliability of water resources, are of concern at local, national and transnational scales. However, there is also a growing recognition that glacial conditions in the region are very diverse, and so are their responses to climate change.

> *One must qualify the notion that threats only arise from 'disappearing' glaciers or in proportion to the rate of reduction.*

There are some very different implications in different societal contexts, not least in relation to rapid socio-economic changes, water resource projects and security crises. The latter are often more urgent or immediate problems that disrupt or undermine peoples' capacities to adapt to environmental change. Such complexities are the focus of this article. The reality of climate change is not questioned, but some recent oversimplifications are, and claims about a narrow range of glacier hazards. In particular, unresolved problems of understanding high altitude glaciers and climate are emphasised, and the inadequacies of available information and monitoring. Recent evidence of glacier advances in the Karakoram Himalaya, and the author's work there, illustrate many of these complexities.

Ablation zone conditions where annual ice losses are high: dust, dirt and scattered debris areas on Kaberi-Kondus Glacier, late June, at 4,000 metres above sea level. 1998.

Globally, most glaciers are reported to be diminishing more or less rapidly. Reports of "disappearing glaciers" have come from many parts of High Asia. However, this is not the case in the upper Indus and upper Yarkand River basins. Here, the glaciers have been holding their own for several decades and recently, in the Karakoram Himalaya, many have started thickening and advancing. Not only is this opposite to the broader picture for Eurasian glaciers, but also to what had been happening to Karakoram glaciers. Through most of the twentieth century they too diminished and retreated. There is no question that today's behaviour is a regionally distinct response to climate change. It may sound like good news, given the dominant lament for the loss of glaciers, but that too would be misleading. Advancing glaciers bring dangers as well.

Of immediate concern are a number of glaciers on the Indus and Yarkand Rivers, whose past advances gave rise to large ice dams and catastrophic outburst floods. In the longer term, existing and planned water resource uses, dependent on glacier-fed streams or at risk from glacial floods and sedimentation, are of major concern. However, the largest challenges stem from inadequate information and monitoring, and limited scientific understanding of these high elevation glaciers. Misleading or exaggerated reports based on assumption rather than evidence are also a problem. Some high profile reports have suggested that the Indus basin is in imminent danger of losing its glaciers. Glacier hazards, notably "dangerous lakes" associated with retreating ice in other regions, have been assumed to be equally present in the Karakoram. The reports are simply wrong in this case.

Meanwhile, if the main trend in most of High Asia does seem to be glacier retreat, various lines of evidence show that it is occurring at very different rates in different mountain ranges, even within the same mountains. A 2006 survey of 5,020 glaciers in the mountains of western China and the Tibetan Plateau found widely differing rates of reduction. It also found 894 glaciers, about 18%, have advanced in recent decades. The jury is still out on a 2009 report from India, which questions the scale and reality of the extreme rates of retreat formerly reported for the Himalayas, and projections based on them.

None of this is to suggest that climate change is not a serious issue in the Karakoram. In every valley of the region farmers tell me the winters have grown shorter in the past couple of decades, there is less snow and more rain. They report an increase in windstorms and rain during summer. Formerly, clear, sunny weather in autumn was reliable and perfect for drying grain, fruit and winter fodder, and for post-harvest chores around the villages. Not any more. They report increasing problems with damp and mildew from insufficient drying days. Rain and wind threaten the harvest and damage buildings. These are, in fact, more immediate hazards for the mountain communities than anything that may be happening to the glaciers. This refers to the inhabited areas at lower elevations, where more, and more severe, rainstorms have been reported in recent years, notably a disastrous storm on September 9, 1992. It triggered rockfalls and debris flows that damaged many villages, closed most roads and stranded tourists. Again, advancing glaciers are also a response to climate change – and are not necessarily good news.

The surge of the Maedan tributary of Panmah Glacier. Notice severe crevassing of ice. June 2005.

Panmah Glacier accumulation zone, showing surrounding rock walls up to 2,500 metres high around the Latok Peaks, June 2005.

Although there have been reports and discussions of Karakoram glaciers since the mid-nineteenth century, they have been patchy in space and time and of varying quality. The glaciers are not, and have never been, consistently monitored. Few glaciers anywhere in the inner Asian mountains meet the criteria of the World Glacier Monitoring Service, and hence have not been tracked by it. The cries of concern for these glaciers should at least highlight the need for more reliable data and a better grasp of climate-glacier interactions in the world's highest mountains.

The glacier cover of High Asia exceeds 110,000 square kilometres, the number of identifiable glaciers more than 50,000. There are major concentrations in about a dozen mountain ranges, forming watersheds of all the major rivers of the central, south and south-east Asian mainland. The Upper Indus and Yarkand basins have around 21,000 square kilometres of glaciers, the larger fraction in the Greater Karakoram, or about 16,500 square kilometres. Most of the biggest valley glaciers outside polar regions are found here. While there are more than 5,000 individual glaciers, just 12 make up almost half the ice cover. Melt waters from glacier basins comprise more than 40% of the average annual flows of the Indus and the Yarkand, with a potential to affect the lives of some millions of people downstream. While there was a roughly 10% reduction of the Karakoram ice cover in the first 60 years of the twentieth century, no significant reduction has occurred in recent decades and, as noted, many glaciers are undergoing advances.

One must qualify the notion that threats only arise from "disappearing" glaciers or in proportion to the rate of reduction. This is certainly a cause for concern, in itself or in what it implies about humanly induced atmospheric changes. But growing glaciers are not necessarily benign. In most glacierised mountains, certainly the Karakoram Himalaya, the worst consequences experienced in recent history came with the enlarged ice cover of the Little Ice Age: a period of several centuries, ending just over 100 years ago, when glaciers grew throughout the northern hemisphere. From those events come most of the stories and fears about glaciers recalled in Himalayan towns and villages. The considerable reduction of the glaciers observed between about 1910 and the 1960s was, in effect, removing ice stored in the Little Ice Age, a process that is not yet complete. Today's glaciers are larger than a few centuries ago. Meanwhile, the evidence of advances in the Karakoram not only indicates a different response here to changing climate. It raises the prospect of a return to the hazards of advancing ice not seen since the Little Ice Age.

Accounting for variety

Climate change is obviously having different consequences in different mountain areas of Asia. The situation in the Karakoram must represent some distinctive conditions. Three features of the regional environment seem critical. The first two relate to snowfall and the nourishment of these glaciers. They are intermediate in type between the summer accumulation (snowfall) glaciers of the greater Himalayas, and the winter accumulation glaciers of, say, the Caucasus and European Alps to the west. In each of the latter, more or less strong glacier retreat is reported. Second, the zone of maximum precipitation in the Karakoram is much higher than in these and most other mountain ranges. It is also entirely within the accumulation zones of the glaciers. This relates to the third factor, the exceptional elevations and, especially, elevation range of these ice masses.

The glaciers of large and intermediate size originate at very high altitudes and many of them descend much lower than elsewhere in the sub-tropics. Five glaciers span more than 5,000 metres in elevation, 15 over 4,500 metres and more than 30 over 3,000 metres. In the Hunza valleys of the central Karakoram, glacier termini advance below 2,300 metres above sea level. Those on the north flank in the Yarkand drainage do not descend so low because the valleys are at greater elevations, but they include several descending more than 4, 000 metres, due to location in the very highest parts of the range around K2 (8,610 metres). All of the glaciers recently observed to be growing are in these high-relief basins. Of special interest, but poorly understood, is how elevation and topography interact with the regional climatic influences to determine the behaviour of the glaciers.

The regional climate of this south-western part of the Inner Asian mountains comes under the influence of three different, seasonally varying, weather systems. First, the winter half of the year is dominated by a westerly or "sub-Mediterranean" circulation. Second, in summer, moisture comes from the Indian Ocean to the south and the climate becomes "sub-monsoonal". Third, inner Asian high-pressure systems, especially involving the Tibetan Plateau, interact with the other two systems to affect storm paths and the incidence of clear weather. The last is critical, since direct solar radiation is responsible for 80% to 90% of melting on the glaciers.

Investigations on the glaciers at higher elevations have revealed how different conditions are from the valley weather stations – mostly below 3,000 metres above sea level – whose records had dominated climatic interpretations.

Global climate change is expected to alter the absolute and relative roles of all three systems, a likely factor in recent developments that complicates forecasting of future glacier changes. Meanwhile, investigations on the glaciers at higher elevations have revealed how different conditions are from the valley weather stations – mostly below 3,000 metres above sea level – whose records had dominated climatic interpretations.

Station records from the inhabited areas of the Karakoram show two-thirds or more of precipitation occurs in winter, mainly February through May. The average annual precipitation in these valleys is 150 millimetres to 300 millimetres water equivalent – an arid or semi-arid environment with severe summer drought. However, a very different story emerged

Icefall on Charakusa Glacier, east-central Karakoram. June 2005.

from our measurements on the glaciers in the 1980s. At elevations above 4,800 metres we found that snowfall amounts are roughly the same in summer and winter, with roughly equal amounts coming from the west and the Indian Ocean. Summer drought was not observed on the glaciers especially in their accumulation zones above 4,500 metres above sea level. Moreover, the zone of maximum precipitation turned out to be between 5,000 metres and 6,000 metres above sea level – much higher than in, say, the eastern Himalaya or any other reports from tropical mountains. Moreover, accumulation zone snowfall is equivalent to between 1,000 millimetres and 2,000 millimetres of water; far more moisture than the valley stations suggest. What is identified here is a powerful gradient in climatic conditions with elevation – a five- to 10-fold increase in precipitation from glacier termini around 2,500 metres above sea level, to where the snow falls that nourishes the glaciers. A recent, pioneering study based on satellite imagery – conducted by Bibi S Naz and colleagues at Purdue University in Indiana – suggests snowfall amounts and the extent of perennial snow cover have increased in the past couple of decades at high elevations in the Central Karakoram.

Vertical gradients also define key conditions for the melting of the glaciers, and their contribution to water supply. In fact, although many ice tongues descend much lower, the decisive conditions for melting occur between 3,800 metres and 4,800 metres above sea level. Here lie more than 80% of the ice surfaces where melting occurs in summer. Ablation conditions – under which ice melts – also identify complexities that arise with timing and seasonal rhythms as well as elevation. Nearly all the melting and water production of the glaciers occurs in just a few weeks of summer, when temperatures rise above zero and strong sunlight occurs. In turn, this explains why 70% to 80% of the flow of the upper Indus and Yarkand rivers occurs in six to 10 weeks of summer – usually in July and August – lagged until winter snow sitting on the ablation zone has melted away to expose the ice. Moreover, melting is very sensitive to summer cloud cover or storms. A sudden summer storm can shut down melting for days at a time. Just when and for how long rapid and extensive melting occurs varies greatly from week to week, and year to year. It is one of the most sensitive variables affected by climate change.

Another huge and poorly understood fact is that most Karakoram glaciers are largely or wholly avalanche-fed. The accumulation zone areas of these glaciers, above about 4,600 metres above sea level, are generally 70% to 80% steep rock walls. The larger part of high altitude snowfall in the region is on to these unstable slopes, and is avalanched more than 1,000 metres before incorporation into a glacier. It seems likely that changes in snowfall amounts, with season or in storm intensities, will alter the timing, temperature relations, and extent of avalanching. This can, in turn, affect glacier behaviour. The trouble is, there are no data or research to help predict what climate change does to this all-important part of the nourishment of the glaciers.

What can be said is that what happens between 3,800 metres and 7,000 metres above sea level is absolutely critical to the role of climate and climate change in glacier behaviour and survival. These are also the elevations where the reasons for the seemingly anomalous recent responses of Karakoram glaciers must be sought. However, it is here that the least research has been done. There are no permanent measuring stations or long-term monitoring. To recognise how unfortunate that is, we need to address changes that are, or may become, unusually threatening to human communities and activities.

Summer storm on the Baltoro Glacier at 4,600 metres above sea level, at the limit of rain (below) and snowfall (above). The exceptional height to which there was rain seems to reflect climate warming. However, at the height of the ablation season the storm virtually shut down melting here and greatly reduced it lower down. August 2005.

Middle ablation zone of Biafo glacier after the first winter snowfall in October, 2009. The main glacier is over 500 metres thick here and 3.5 kilometres wide. 2009.

Understanding risks

Glaciers and their immediate environs present many dangers for humans, such as crevasses and glacier mills into which one might fall, heavily crevassed ice falls, snow and ice avalanches from the side walls and, along the flanks, dumping of great boulders, ponding and floods from melt water. For these reasons, there are hardly ever permanent settlements on or right beside the ice. These are hazards mainly to mountaineers, hunters, travellers and military expeditions. The more serious dangers arise from processes in the glacial environment that may extend their impacts beyond existing glacial areas. The more serious tend involve ponding of water that leads to glacial outburst floods, or releases that generate debris flows.

The risk of glacier lake outburst floods has received particular attention in other parts of the Himalaya, notably Bhutan, Nepal and Tibet. In Nepal, some 25 glacial lake outburst floods have been recorded since the 1930s, with especially destructive events in 1985 and 1991. Bhutan also has a number of dangerous lakes, one of which burst with disastrous consequences in 1994. Reports suggest all of these lakes and the triggers for outburst floods are related to climate warming and glacier retreat. There is also a history of such outburst floods from Karakoram glaciers. However, the problem here is also very different from that recently reported elsewhere in the Himalayas. In particular, the most serious threats involve, specifically, much larger impoundments by short-lived, unstable ice dams. Crucially, all recorded examples have been associated with advancing glaciers.

In fact, the Karakoram presents two rather different groups of outburst floods. The most frequent are relatively local events. Collectively, they threaten dozens if not hundreds of small settlements in the higher valleys and examples occur in most years. They involve a wide variety of dam compositions, forms and outburst types, including ice-, moraine-, and mixed-barriers. Conversion of outburst floods into debris flows is quite common, usually the more severe risk. For the upper Indus, these are the only types of damaging outburst floods reported in the past several decades. Moreover, they occur whether glaciers are advancing, retreating and relatively stable. Conversely, the larger Karakoram dams involve

All-season avalanches that descend to the surface of Barpu Glacier are the main way ice is nourished. This one falls more than 2000 metres, is two kilometres wide and will travel several kilometres down the glacier. August 2006

impoundment of a main river valley by a relatively large tributary glacier. Most important, in the present context, these dams only form from a vigorous forward push of the ice.

More than 60 glaciers of intermediate-to-large size (10 kilometres to 65 kilometres in length) have a history of advancing into and interfering with tributaries of the upper Indus and Yarkand rivers. Not all are known to have created actual dams, but at least 30 have done so and involved outburst floods of exceptional size and destructiveness. However, while there have been several large dams recently on the Shaksgam, on the Indus the last major ice dam was in 1933. "Major" refers to outburst floods that were large enough to register hundreds of kilometres downstream at the river gauge at Attock, where the river leaves the mountains.

The most urgent questions today involve some Karakoram valleys whose glaciers created ice dams and catastrophic outburst floods in the past and that are advancing right now. Will they impound the rivers again? Three locations require special attention; the Shaksgam, upper Shyok and Shimshal valleys.

The Shaksgam is a tributary of the upper Yarkand. According to satellite imagery, five glaciers that have formed ice dams in the past are advancing at present. One of them, the Kyagar, has created several recent dams. An outburst from the one in 1999 caused severe damages along the lower Yarkand River in Kashgar district. In the summer of 2009, Kyagar again impounded the river and a 3.5 kilometre-long lake was formed. Fortunately it drained slowly but was close to dimensions that have led to disastrous floods in the past. There were great difficulties in obtaining satellite coverage and scientists were unable to visit the site and monitor the lake so as to predict its behaviour. This raises serious issues about what would have happened if a large outburst had occurred, and what will happen in future cases. It seems a new impoundment will form at Kyagar in 2010, and the four other glaciers are across or entering the river and may impound it.

On the Indus, three glaciers in Shimshal and three on the upper Shyok, that have formed ice dams in the past, began advancing about a decade ago. They have not yet reached positions where a dam could form, but could do so quite soon. Historically, the most dangerous have been the Chong Khumdan and Kitchik Khumdan on the Shyok. In 2009, satellite imagery revealed a sudden and large increase in thickness of the Chong Khumdan, and advance of its terminus into the river. Between 1926 and 1932, this glacier formed a series of large ice dams. At least four outburst floods were reported that caused appreciable rises in the river 1,100 kilometres away at Attock. The 1929 event was the largest on record, and did great damage throughout the mountains and to the Indus Plains. The lake reached over 15 kilometres in length but drained in less than 24 hours. The Kitchik Khumdan also formed large ice dams in the nineteenth century, and its terminus

Icefalls descending to the main glacier at Kaberi-Kondus Glacier, east-central Karakoram. 1998.

Heavily debris-covered ice, Panmah Glacier Central Karakoram, around 4,000 metres above sea level. Note that even the heaviest debris on active ice is rarely more than 2 metres thick. The relief of mounds and cones is almost entirely ice cored and the debris is constantly shifting around. June 2009.

is back in the river and has advanced across the river which passes beneath the ice. However, 2009 satellite imagery suggests it is beginning to waste back again. Conversely, its immediate neighbour the Aqtash Glacier which has also formed dams in the past advanced across the river in 2008 and 2009 and seems to be advancing very rapidly.

These glaciers highlight problems of security and the legacies of conflicts that exist in many parts of High Asia. They are in a militarised zone disputed by China, India and Pakistan. Apparently the Khumdan glaciers fall under the control of Chinese forces, but the dangers from the outburst floods are primarily in Indian and, especially, Pakistan-controlled areas. Given existing tensions, including the India-Pakistan "war" on the Siachen Glacier nearby, it is unclear how necessary studies, monitoring and warning systems can be set up.

Other hazardous phenomena

The focus here has been on glaciers, but it needs emphasising there is a range of cold climate or cryosphere phenomena that may become hazardous through climate change. Communities, infrastructure and related activities confront changes in snowfall, snow-on-the-ground and permafrost, specifically ground ice. They will also be affected by changes in distribution and intensities of freeze-thaw, the quantities and timing of surface and ground waters and their quality (water temperatures, turbidity and dissolved matter, for instance).

The entire mountain area is covered by seasonal snowfall, varying in duration and depth with elevation. Its melting provides about half of stream flows in an average year. Permafrost – perennially frozen ground – at intermediate altitudes is much more extensive than glaciers and includes hundreds of ice-cored rock glaciers. Freeze-thaw cycles affect even larger areas, as do erosion and deposition forms created by snow avalanches. All of these are affected by climate change. Their responses interact physically, and in ways that modify the scope or significance of glacier-related risks.

Retreating glaciers and warming permafrost are associated with destabilised slopes. They can lead directly to landslides, or reduce the strength thresholds for, and the likelihood or size of, slope

A series of ice margin lakes along Nobonde Sobande arm of Panmah Glacier, central Karakoram seen from Drenmang (4,500 metres above sea level). Some are behind old lateral moraines, others ponded against the edges of active ice. The glacier is about two kilometres wide here and 10 kilometres of the main ice stream are visible. 1994.

The terminus of Yazghil Glacier, north-west Karakoram, where it enters the Shimshal River. This is one of several Karakoram glaciers on the upper Indus and upper Yarkand Rivers that have caused ice dams and glacier outburst floods in the past, and are presently advancing across the rivers. 1998.

failures due to earthquakes or storms, which trigger most of the more destructive landslide events. For example, a dangerous landslide occurred on January 4, which blocked the Hunza River in the central Karakoram and probably involved destabilisation by changing moisture and temperature conditions in the slopes. The lake has already grown to 5.5 kilometres in length, forcing the evacuation of thousands of residents. Moreover, the lake behind a similar landslide dam in 1858, immediately upstream of the present one, lasted seven months then burst with catastrophic effects all the way to the Indus plains. Meanwhile, slopes exposed by reduced ice or snow cover may dry out and become useless. Conversely, some may also become vegetated and economically useful for timber, firewood, for pastoralists and even for cultivation.

The more immediate glacier hazards and response needs in the region involve communities and activities in the high mountains. Only the Andean highlands rival inner Asia in the numbers and diversity of settlements close to and at direct risk from glacier change. However, for the broader national and international contexts, the major issues raised concern water resources and their reliability.

Some caution is needed here. A commonplace of recent reports is to say that the lives and livelihoods of in excess of 1.5 billion people are critically dependent upon the glaciers in the headwaters of the largest Asian rivers. This is a misleading generalisation. Yes, such are the numbers of people living in river basins with tributaries coming from glacierised mountains. However, in most cases the glaciers are a tiny part of the river flows, notably in the most heavily populated areas of China, India and the south-east Asian mainland.

Snowfall affects much vaster areas than the glacier cover, and is more critical. For the vast majority of these populations, rainfall and ground waters are far more important than snowfall. Glacier change can have impacts on these other parts of the hydrological cycle or may compound changes in them, but

The accumulation zone of Biafo Glacier near Hispar Pass (5,150 metres), showing the development of cornices along ridge lines due to wind action, avalanched steep walls and heavy build up of snow on gentler slopes. June 1999.

High elevation conditions on Karakoram glaciers: rockwalls, ice falls, avalanches of Broad Peak (8,050 metres), part of the watershed of Baltoro Glacier. 2005.

the processes are mostly indirect and too poorly known to make such generalisations. Whether and how far there are significant risks for most of these populations, even from the "disappearing" glaciers' scenario, is far from certain.

The Indus and Yarkand basins do involve large populations directly, or potentially, dependent on the glaciers. Even here, however, there have been exaggerated or misleading claims. Yes, glacier melt waters comprise more than one-third of the flow of the main stem of the Indus, snow and ice together providing over two-thirds. It has the largest ratio of melt water to population of any river, anywhere in the world. At the moment, however, nearly all the glacial melt water goes to the sea. It happens to coincide with the heavy monsoonal rains, making flooding the greater problem, and Pakistan lacks the capacity to store much or any of the melt waters at that time.

More exactly, the key roles of glacier melt waters have little to do with the total size of the ice cover, total melt water yields, or trends. Rather they turn upon demand in just a few weeks of the year and, in rare, extreme cases when the winter rains or monsoon are very weak, poorly timed, or fail. Even for Pakistan, the main dangers for the country as a whole are, therefore, potential rather than actual, and not so much in relation to glacier change as to planned and possible water resource developments. These seem to be being undertaken with inadequate understanding and assessment of how climate and glacier fluctuations will affect them.

This will become increasingly acute for all countries of the region and raise important transboundary concerns. There are the huge commitments being made now, to hydroelectric power, irrigation, urbanisation and other developments for which water from snow and ice will become increasingly crucial. More than 100 existing dams depend partly on glacial melt waters. Several hundred more, and some of great size, are under construction or planned for China, India, Pakistan, Nepal and Bhutan.

Given the present state of monitoring and scientific understanding, it is hard to believe any of these have adequate or accurate assessments of climate- and glacier-change impacts. For the Karakoram it is of singular concern to determine whether, as global warming continues, there will be a return to glacier retreat as some believe, or if the factors responsible for the present advances will intensify. Either way, there are serious implications for how communities in Pakistan, China and India, especially, are affected and need to respond.

The importance of climate change is not in doubt, but research and policies should be based on actual evidence. Where unavailable, that should be acknowledged, not – as has happened with glacier change in the Karakoram – simply replaced by supposition based on developments or models from elsewhere. Much of what is being said fails to recognise the patchiness of past research in space and time, and a nearly-total absence of glacier monitoring at elevations where the most critical ice and climate changes occur.

The limited evidence surely reflects, in part, the sheer scale, diversity and logistical difficulties of scientific work in much of the region. Now, as more resources become available to investigate these problems, it is important to identify what sorts of information are needed, where and how they can be best obtained. Science and information systems and regional cooperation need to address the complexity and diversity of the greater Himalayan region. Some practical suggestions being promoted by new programmes include the following:

- To set up improved monitoring systems that combine remotely sensed and automatic station measurements with ground control related to basic glaciological and hydrological research;
- To expand comprehensive, multi-disciplinary research that addresses environmental and cultural complexities in the region;
- To pursue regional cooperation in data sharing, risk and resource assessments; and
- To actively involve local communities in the mountains, so that their ecological knowledge and practical concerns inform understanding and help to shape appropriate development.

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Images by Kenneth Hewitt

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Taking the toad's-eye view

Dipak Gyawali, former water minister of Nepal, explains how to approach Himalayan climate-change science from the grass-roots level. Interview by Isabel Hilton.

Dipak Gyawali is a former minister of water resources in Nepal and research director of the Nepal Water Conservation Foundation. Here he tells chinadialogue editor Isabel Hilton about new research that demands science gets down to the grass roots to help people adapt to climate change in the Himalayan region.

Isabel Hilton (IH): How accurate are predictions of future climate impacts in the region?

Dipak Gyawali (DG): Here is a sense of confusion: the implications of what is happening seem more and more horrendous and some things are pretty certain in terms of the effects. Beyond that, though, the models predict all kinds of things. The question of the Himalayas has not really begun to be addressed and the science has a very long way to go on precipitation and the social effects.

IH: How can science become more relevant to the region?

DG: The effects in different parts of the Himalaya and south Asia will be very different and it's not all about glaciers. The Maldives will be drowned; Sri Lanka may have more tsunamis and more intense storms; Bangladesh will have its own problems. They will not be impacted directly by the glaciers; the interest in the glaciers is that they are powerful indicators: they tell you clearly that something is wrong. It's like going to the doctor with a fever: you know you are sick. But we don't have the kind of science that we need to be able to make accurate predictions of impacts over a hugely diverse region. If you look at the last IPCC [Intergovernmental Panel on Climate Change] report, for instance, the whole of the Himalayas was a blank. People are already suffering but whether we can take any one instance as a directly related with climate change is not certain.

> *"The conventional wisdom is that the most vulnerable people are the poorest of the poor, but we have found that it is actually the lower middle classes."*

We did a series of local consultations from every part of Nepal, bringing farmers together to ask them what they are actually experiencing now as a result of climate change. Many of them cannot relate what they are experiencing to CO2 [carbon dioxide] emissions, and one problem we have is that over a large part of the region is that there is no difference between the word for climate and the word for weather. But when we asked them what is happening to their agriculture, we discovered a whole series of impacts.

Some of them are predictable: spring is coming a week earlier, for instance; things begin to grow, but it is not "real" spring and it can be followed by a blast of terrible cold weather. It seems to be having an impact on cucumbers: they are getting a much higher volume of male flowers to female flowers, so the crop is smaller. The mangoes come into flower and start to grow, but then the fruits shrivel up and drop off, so the mango harvest is shrinking. Lowland pests have started moving up into the mountains; certain weeds from the lowlands are being found at higher altitudes.

We also looked at some major regional catastrophes, signature events like the failure of the Indian monsoon or the floods in the Terai, to see how people were affected. It's essential to find out what is happening, and we believe we need to rethink development in the light of climate change. That has not happened yet.

IH: Presumably it has not happened because the development agencies have not had this kind of detailed input?

DG: That's precisely the point. The remote sensing and the satellites give us the eagle-eye view, which is essential but not enough. In a country as diverse geographically and socially as Nepal – there are more than 90 languages and 103 caste and ethnic groups – the eagle-eye view needs to be complemented by the view from the ground, what I call "toad's-eye" science.

IH: Because high level science can't be broken down into what is happening in any given local area?

DG: Yes. You are dealing with such diversity: ecological diversity, geographical diversity, cultural and ethnic diversity. The reason that we focussed on this toad's-eye view is that we found that people were not sitting around waiting for an agreement at the COP15 in Copenhagen. Millions are voting with their feet every day at the grass-roots level, reacting with civic science and traditional knowledge. This is what people are basing their everyday decisions on.

There's a real need for high science to come down off its high horse and meet up with civic science and traditional knowledge, in order to understand what is happening, so that national governments can also plan. The high science has to start looking at why there are more male flowers on the cucumbers, why berries are ripening at the wrong time.

Just to take one example: nobody has studied what is happening to soil fauna. Soil fauna are essential to everything and they are one of the first indicators that things are going wrong. They affect everything from plants to birds and nobody knows what is happening with them. Scientists will have to re-orientate themselves, to listen to local people and then to do the work that will make their strategies more robust.

IH: Have you a better idea of who is vulnerable as a result of this work?

DG: Yes. The conventional wisdom is that the most vulnerable people are the poorest of the poor, but we have found that it is actually the lower middle classes. The reason is that the poorest of the poor have never had enough land to keep their families for the whole year, so they have always had to diversify their sources of income: they go and do seasonal labour for part of the year, and they have those networks and connections already. They have a built-in resilience, so if their harvest is worse than usual, they just go and work longer.

The lower middle classes, though, have had enough land to be able to depend on their crops. They might survive one bad year, but two or three wipe them out, and then you get what you are seeing in India – farmers committing suicide. That is also happening in Nepal. The poorest are suffering, but it is not fatal. The people who are really being hit are the lower middle classes and upwards, which has implications for social stability.

IH: What adaptation is possible in these circumstances?

DG: The solutions have to come out of the watershed and out of the problem-shed. You can talk about big solutions – building high dams – which can take 40 years. We don't know in Nepal if a government will last 40 days. The solutions have to be what these millions of households can take. Can they be helped? How can they be helped? We just haven't done the science for that. We need civic science; ground-level truth.

We have some suggestions for how to do it. At the moment we just don't have the data to model anything at local level. But if, for instance, you put a weather monitoring station in every school in Nepal, and get the children to do the readings and get the schoolmaster to fax the readings back, your data points increase from around 450 to around 4,000. You are suddenly rich in data, and the local people get involved in understanding the dimensions of the problem.

It will be a long, drawn out process, but it is starting with rain gauges in the schools, linked up with the local FM radio stations. Suddenly the FM stations are very excited because they are talking about what is happening in their area instead of reading out a weather report that has come from Kathmandu and might have no relevance at all for them.

We hope our report will point to some things that are essential and some things that local people are already doing in terms of adaptation: building houses on stilts, for instance, so they can move upstairs during the flood season and the people will be safe – their rice will be safe and they can move back down again when the danger is past. Some villages have raised the level of their plinths, just a little bit, but enough to get above the floods.

IH: But won't future floods be much worse?

DG: Not all major floods are caused by high volumes: the Kosi Breach, for instance, happened at a time when the flow was lower than usual. It was the failure of a poorly constructed dam and 3.5 million people were displaced in the state of Bihar, India, and 6,500 in Nepal. If tomorrow the floods get worse, expect more Kosi Breaches. We expect that the intensity and frequency will be greater, but we don't know exactly what is going to happen.

Dipak Gyawali is a former minister of water resources in Nepal and research director of the Nepal Water Conservation Foundation.

Isabel Hilton is editor of chinadialogue.

Image by World Bank

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Soot strategies

As the power of black carbon to accelerate ice-melt becomes clearer, climate-change policymakers are giving more time to this long overlooked pollutant. Jenny Johnson reports.

> *Estimates are that black carbon may have contributed as much as 50% of the 1.9 degrees Celsius warming in the Arctic since 1890.*

Global efforts to mitigate climate change are beginning to take aim at a once-obscure pollutant called "black carbon" in a shift that may bring policies to cool the planet to families preparing meals at home and farmers readying plots of land for planting.

A series of new scientific studies have confirmed the potent warming effects of black carbon on melting ice and snow in the Arctic and the Himalayas, spurring a new focus on attacking sources of those emissions. The latest research identifies open burning in agricultural fields in Eurasia as a key source of black carbon in the Arctic. Evidence also indicates emissions from the burning of coal, wood and other biomass for domestic cooking and heating throughout Asia are heavily impacting the Himalayas.

Black carbon is part of a chemical mix of particulate matter that has long been an air-pollution concern due to its impacts on human health. But the pollutant also acts to reduce the reflectivity of ice and snow, allowing heat absorption and hastening surface melt. Research indicates reductions could immediately help save ice and snow in the Arctic and the Himalayas, two areas of critical global importance that are proving particularly sensitive to climate change.

Melting of Arctic ice presents several dangers for the planet. The process could undermine the region's ability to act as a cooling mechanism for Earth by reflecting incoming solar radiation back into space and disrupt global ocean circulation by decreasing the salinity of water. Greenland, meanwhile, holds enough frozen water to raise sea levels – if melted – by as much asseven metres. These scenarios are increasingly realistic, as catastrophic loss of ice in the Arctic has accelerated in recent years, well beyond the predictions of climate models.

The Arctic is warming at two to three times the rate of the rest of the planet, with its rising temperatures constituting a possible global "tipping point", which could result in rapid global warming and a cascade of changes through the ecosystem. Black carbon may have contributed as much as 50% of the 1.9 degrees Celsius of warming seen in the region since 1890, according to a 2009 paper published in Nature Geoscience.

Research shows that black carbon is also heavily impacting the glaciers of the Himalayas, another region of global significance. The "third pole" or "Asian water tower" feeds some of the world's biggest rivers, including the Ganges, Yangtze and Yellow River, which together supply drinking water and crop-irrigation for some 1.5 billion people across 10 countries. According to estimates published last year in the journal Atmospheric Chemistry and Physics, black-carbon emissions have caused nearly 10% of the ice-cover loss in the Himalayas from 1990 to 2000, of which about 36% is attributed to Indian coal and biofuel burning.

Previously seen as a distraction from capping and reducing carbon dioxide, the nexus of air pollution and global warming is finally coming to the forefront of the climate-policy debate as evidence grows that so-calledshort-lived climate forcers like black carbon have big effects.

The shift in focus also comes against a background of continuing failure to set credible global policy on carbon-dioxide emissions. Black carbon can be effectively reduced through targeted, regional programmes that can help limit warming in the near term, something that cannot be done with carbon dioxide due to its longer atmospheric lifetime. And black carbon's large and direct human health impacts, plus the fact it is already targeted by rapidly urbanising countries, make it an attractive target.

What next?

The latest research shows that due to a seasonal shift in a climatic anomaly called the Arctic Front, smoke from the widespread open burning of grass and straw that takes place in Eurasia in the late winter and early spring efficiently travels north to the Arctic, where particles from it land on the ice and snow.

Scientists have identified open burning in northern Eurasia – Russia, Kazakhstan, Mongolia and north-west China – as the single biggest source of black carbon in the Arctic and say that, at certain times of the year, it may constitute an even bigger contribution to warming in the region than carbon dioxide.

Sarah Doherty of the University of Washington in the United States used field samples to trace the origins of the black carbon coating snow in the Arctic to biomass burning in Eurasia. At a St Petersburg conference in November, she cautioned that the cooling effects of other particles in the smoke are "highly uncertain" and may dampen the warming impact of black carbon in the region. However, Doherty said that decreasing biomass burning in Eurasia would likely have the biggest single impact on reducing Arctic warming in the near term.

Controlling open burning is a major challenge. Farmers in China and Russia are officially prohibited from disposing of waste, recharging the soil and ridding their fields of pests through burning, but such bans have proved ineffective.

"In order to reduce China's springtime black carbon emissions, farmers need a viable alternative method of crop waste removal," a May 2009 report from US-based non-profit the Clean Air Task Force stated. Researchers are testing ideas for alternatives, such as using straw as a source of bioenergy, which would result in lower emissions. Processing waste for fertiliser is another leading idea.

In Russia, fire policy is coming under the spotlight following the summer's wildfires that burned vast areas of forest amid record heat and drought, destroying 30 villages and killing dozens directly and indirectly from smoke, smog and carbon monoxide effects. While the summer blazes are unlikely to have affected the Arctic on the scale of the spring fires due to climate patterns, critics say the events demonstrated a general lack of capacity on the part of the government to control fires across its large territory. They argue that, without greater capacity, it will be impossible to control the fires in the spring.

Several researchers have reported that the Kremlin is currently reviewing its forest code, which was changed in 2007, doing away with a unified forest protection system and giving more power to the regions. Major changes to the forest code are a top priority for environmental groups in Russia today and there is international pressure on Russian officials to act in time for the next fire season.

Action to decrease the black carbon affecting the Himalayas is more advanced. Several international development programmes are focused on distributing more efficient cooking stoves that greatly reduce emissions. However, the scale of the problem and the expectation that black-carbon emissions will continue to increase alongside Asian industrial development, still hinder effective policy.

The China-based group Third Pole Environment is conducting research into the many unanswered questions about sources and effects of emissions and how the region will respond to global environmental changes and has stressed the need for further work in this area. It is clear that even beginning to address the climate impacts of activities like grass and straw burning in Eurasia will take time. There are many knowledge gaps that prevent robust policy solutions, such as basic data on the types of crops in Russia and its land cover. The willingness of the countries to act remains an open question.

At a supranational level, there is some progress. While black carbon is not among the greenhouse gases addressed under the United Nations Framework Convention on Climate Change, a separate UN convention is set to begin shaping reduction policies to mitigate climate change. In December, the Convention on Long-range Transboundary Air Pollution (under the UN Economic Commission for Europe) agreed to revise one of its protocols in 2011 to include black carbon, as well as other short-lived climate forcers, such as carbon monoxide and methane.

This step will make it the first international body to begin shaping policies that account for the air pollutant's climate effects. Europe, the United States and Russia are among signatories to the convention. China is not, but the work plan for the coming year specifies the creation of policies that could be applied outside the area currently covered by the convention.

A series of new studies on black-carbon sources, effects and mitigation options are set to be published in 2011 by the United Nations and several high-profile research institutions. As understanding of the issue improves, advocates are hoping united solutions and action will quickly follow.

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Image by nick_russill