Structuring Useable Science – The Example of Black Carbon Observations from the IASOA network

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1. Introduction

The International Arctic System for Observing the Atmosphere (IASOA) is an International Polar Year (IPY) legacy project whose founding vision was to coordinate pan-Arctic atmospheric observing research to address broad science questions about Arctic change. During the IPY, IASOA efforts developed observing inventories for nine partner stations (Figure 1), created a data portal to facilitate data sharing (iasoa.org), increased value-added observing assets at key locations, and contributed to the development of a clean air observatory in Tiksi, Russia to fill an important spatial gap. Moving beyond IPY, IASOA's long-term vision for contributing to pan-Arctic synthesis and assessment science is poised for implementation. The network science leads have prioritized relevant and actionable assessment themes, which include: understanding the role of black carbon and other short lived climate forcers (SLCF's) on regional warming; understanding the role of Arctic clouds in the regional climate system; and contributing to atmospheric-surface flux process understanding.

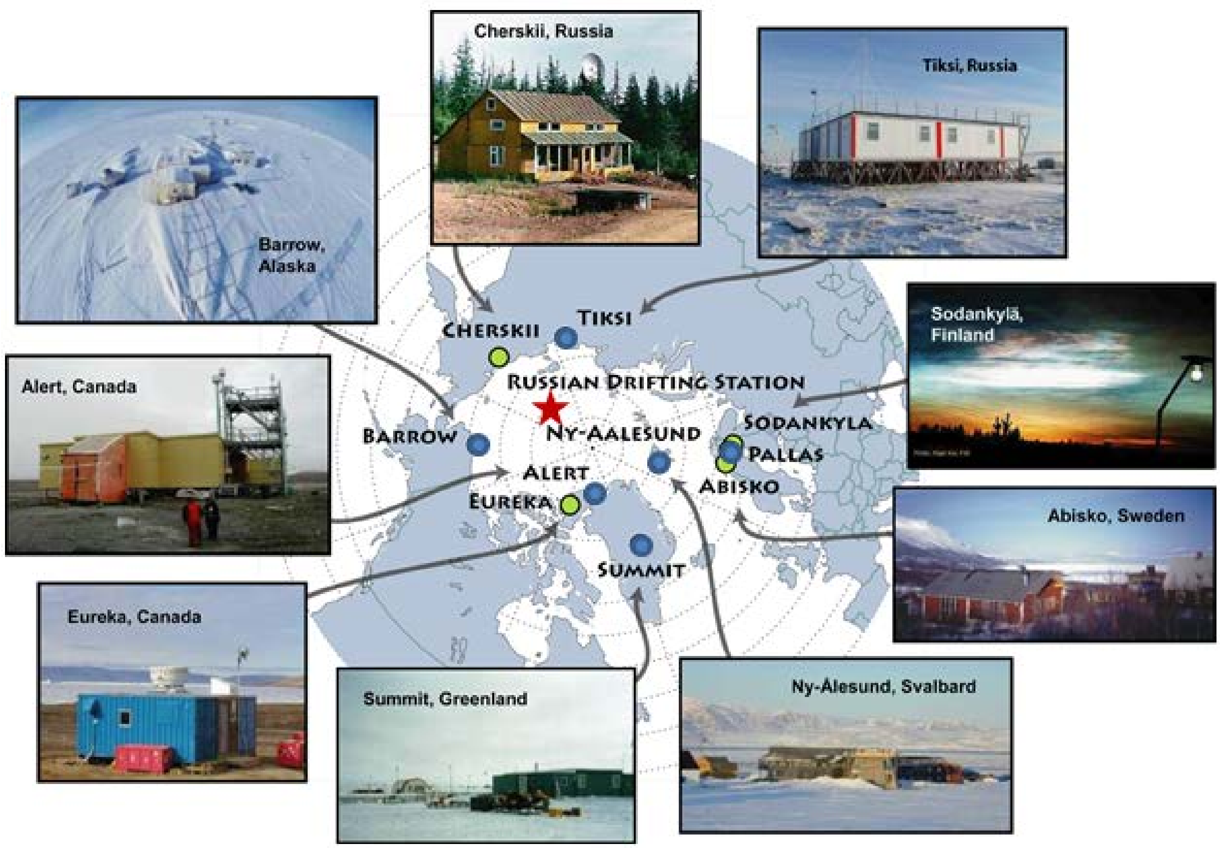

Figure 1: The International Arctic Systems for Observing the Atmosphere (IASOA) member observatories. The red star represents the Russian North Pole drifting station which is the newest member of the consortium. Blue dots indicate current locations of relevant black carbon observations.

1.1 Structuring Assessment Science

Critiques of assessment and other forms of usable science (e.g. forecasts) have demonstrated that many climate assessment products are not put to use by the intended audience, often because the needs of that audience have not been sufficiently considered in the assessment framework (Cash, Borck and Patt 2006, Dilling and Lemos 2011). Cash et al. (2006) notably recognized the "loading dock" approach as one where scientists generate assessments under the flawed assumption that stakeholders will come along and pick them up off the "loading dock". In an extensive review of seasonal weather forecast users, Dilling and Lemos (2011) found that intrinsic and contextual factors will influence the usability of science information and recommended that these factors are iteratively addressed with stakeholders. Intrinsic factors consider the inherent limitations (spatial, temporal, length of record, uncertainty in measures, etc.) of the data, related to its production. Contextual factors consider the context in which the information will be used. There are multiple use contexts for information products derived from Arctic atmospheric observations including: basic research (e.g. modeling), operations (e.g. forecasting and management), and decision making (e.g. policy making and regulation). Each context presents unique requirements for usable information. Establishing a framework, and in some cases a process, for addressing the intersection of these intrinsic and contextual factors is an important preliminary step to developing useable information.

1.2 Study Approach

In this study, I take the IASOA assessment theme of understanding the role of black carbon on Arctic regional warming as an example and consider the contextual requirements from different audiences. In Section 2, I present an overview of the issues of relevance for understanding the role of black carbon in the Arctic. In Section 3, I explore the intrinsic factors that affect the usability of IASOA observations from two instruments measuring relevant black carbon optical parameters, the aethalometer (AE) and the particle soot absorption photometers (PSAP). In Section 4, I present the context-specific requirements of three different information end use case studies. To systematically explore this context, I developed a survey to gather requirements from these users. I then use these requirements to analyze the intersection between the intrinsic and contextual factors. This intersection reveals both limitations to and opportunities for making better use of existing IASOA black carbon observations. It points to investment directions for future observational and human capacity that is better matched to stakeholder needs. Findings from this process will also inform potential IASOA contributions to assessments of other SLCF's, including methane and tropospheric ozone.

2. Background

Trends and variability in surface air temperature tend to be larger in the Arctic than in other parts of the globe. This phenomena of Arctic amplification is recognized as an inherent characteristic of the global climate system (Serreze and Barry 2011), that is also enhanced by anthropogenic influences including heightened black carbon concentrations in the atmosphere. Black carbon (BC), a by-product of incomplete combustion, is an aerosol that absorbs solar radiation and warms the atmosphere. It falls in the category of short-lived climate forcers (SLCFs), which also includes ozone and methane. SLCFs are atmospheric constituents with relatively short residence times (days to years). They are thought to have an enhanced influence on Arctic radiative forcing relative to mid-latitudes (Quinn et al. 2008); in addition to increased atmospheric radiative forcing over high albedo surfaces, once deposited on the surface, BC can contribute to reduced albedo and enhanced melt (Hansen and Nazarenko 2004). The magnitude of these impacts is regionally distinct across the Arctic and at present poorly understood. The potential for a pan-Arctic network of intensive atmospheric observations to contribute to improved understanding and as well as on-going BC assessments is significant. We will first review some of the details of the science and mitigation challenges, followed by an overview of IASOA observing assets that are of relevance to these challenges.

2.1 Arctic BC – Science Challenges

BC and other light absorbing aerosols cause atmospheric warming through a variety of mechanisms, as summarized in Table 1. The magnitude of these effects varies seasonally, as shown in Figure 2. Seasonality in these effects is driven by Arctic seasonality in: shortwave radiation; surface albedo; isentropic transport from mid-latitudes to the Arctic; the strength of the surface-based temperature inversion; moisture availability for wet deposition; and the occurrence of wildfires. The combined result is that BC warming in the Arctic is strongest in the late winter and spring. It has been shown that Arctic warming is highly sensitive to the onset of the spring melt, making the potential impact of BC in the Arctic during this sensitive time all the greater.

Table 1. Globally and Arctic Annually Averaged TOA forcing for BC *(BC + OC).

BC Effect	Description	Globally Averaged BC Forcing	60˚- 90˚N Averaged BC Forcing
Direct Effect	Absorption of solar and reflected radiation and re-transmission of the absorbed heat to the atmosphere and surface	0.34 Wm^{-2} (±0.25); Forster (2007)	0.53 Wm^{-2} (±0.??); Koch and Hansen (2005) *0.55 Wm^{-2} (±0.??); Flanner et al. (2009); *0.40 Wm^{-2} (±0.??); Bond et al. (2011)
Semi-direct and Indirect Effect	Multiple and sometimes opposing forcing due to semi-direct aerosol interactions with clouds, which can include the dissipation of clouds through their warming due to the heat generated by absorbing aerosol within the cloud (Hansen et al., 1997; Ackerman et al., 2000; Johnson et al., 2004) and the indirect effect of interacting with cloud droplets to modify the longevity of Arctic clouds	Highly uncertain, thought to negative.	Highly uncertain, thought to be weakly negative.
Surface Albedo Effect	Warming the surface through reducing the albedo of snow and ice surfaces	0.10 W/m^2 (±0.10); IPCC (2007) 0.04 Wm^{-2} (±??); Bond (in prep)	0.27 Wm^{-2} (±??); Flanner et al., (2007)

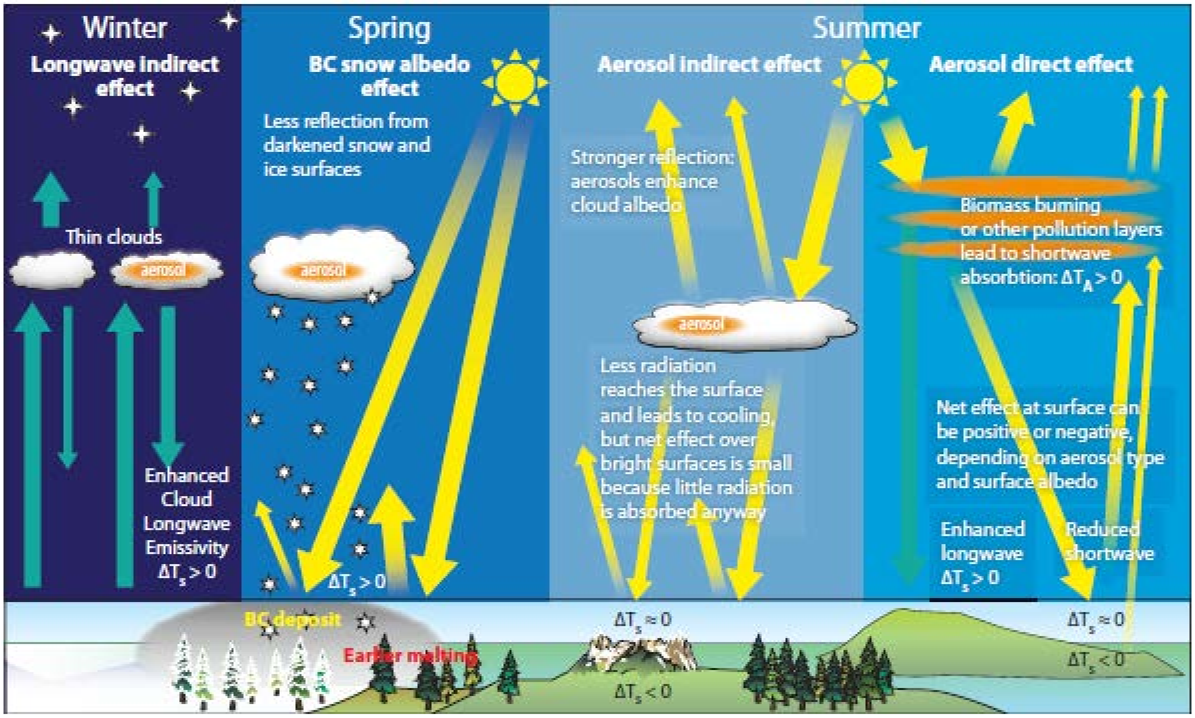

Figure 2: Forcing mechanisms in the Arctic due to short-lived pollutants. ΔTs indicates the surface temperature response(Quinn et al. 2008, AMAP 2011).

In order to better understand the magnitude of these impacts, more information is needed on historical concentrations of BC in the Arctic and their trends; sources and timing of BC transported into the Arctic; production of BC within the Arctic; the regional and vertical distribution of BC in the Arctic; the impact on surface warming from BC in the atmosphere; the interactions between BC and clouds; factors controlling the wet and dry deposition rates; the impact on surface warming from BC on snow and ice. To better understand sources and transport, it is imperative to understand the speciation of BC, which reveals the relative contribution of fossil fuel sources and biomass sources.

2.2 Arctic BC – Mitigation Considerations

Arctic warming is thought to be primarily attributable to greenhouse gas (GHG) warming, thus long-term mitigation will ultimately depend on reducing atmospheric CO_2 concentrations. However, mitigating black carbon has been identified as a potentially useful short-term strategy for slowing the rate of currently observed Arctic warming. Bond (2007) supports the idea that aerosols in general and black carbon in particular should be considered as an important part of the climate management portfolio because aerosol mitigation is economical with rapid results. Unlike traditional greenhouse gases (GHGs), aerosols have diverse concentrations, characteristics and forcing in different regions. As the impact of BC aerosols in the Arctic is highly dependent on seasonality, source regions and transport (Stohl 2006, AMAP 2011, Quinn et al. 2008), surgical policies, even those limited to Arctic nations, could have a big impact on Arctic BC concentration. Hirdman et al. (2010) found that an Arctic source of BC emission makes 10-100 times the impact in the Arctic of a mid-latitude source of equal strength. This is a significant finding given the projected growth in Arctic-based source emissions from expanded shipping and resource development (Corbett et al. 2010). As a result of these considerations, Arctic SLCFs elicited a strong policy response at the 15th session of the United Nation's Conference of Parties (COP-15). There, the U.S. Department of State committed $5M towards a tri-partite mitigation study focused on Russian source emissions. These studies are being led by EPA, DOE and USDA to focus on source emissions and mitigation strategies in the Russian mobile, stationary-industrial and agricultural sectors respectively.

There are many stakeholders that enter into mitigation consideration, both those that are responsible for source emissions and those that are affected by them. Black carbon sources to the Arctic include those from the surface and ocean transportation sectors, agriculture, forestry management, district and residential heating, resource development (particularly oil and gas), and industry. The International Maritime Organization (IMO) is considering Arctic-specific regulations for BC emissions controls on vessels entering the region, which would add costs and regulatory overhead to the industry. Existing multinational protocols on transboundary air pollution (e.g. CLRTAP) could be affected by new findings specific to BC, with attendant economic and regulatory implications for the BC source sectors. On the impacts side, environmental change is a big driver as is human health. BC is a component of fine particulate matter, which is linked to adverse respiratory and cardiovascular health effects. The UNEP Integrated Assessment of Black Carbon and Tropospheric Ozone found that globally 2.4 million premature deaths could be prevented through adopting the BC and methane mitigation recommendations of the study (UNEP 2011).

With so much at stake, it is no surprise that the research community has been called to assist with mitigation studies, evaluating proposed regulations and assessment reports. In addition to the State Department initiative described above, the Arctic Council and its working groups have organized a series of assessment reports. In 2009, the Senior Arctic Officials (SAOs) charged a SLCF Task Force "to identify existing and new measures to reduce emissions of these [short-lived climate] forcers and recommend further immediate actions that can be taken and to report on progress at the next Ministerial meeting. (Arctic Council 2009)" The Arctic Council's Arctic Monitoring and Assessment Program (AMAP) just released a Black Carbon specific assessment (AMAP 2011). Both activities are targeted primarily at the Senior Arctic Officials (SAOs) of the eight Arctic nations, who could be empowered by their respective nations to enter into multilateral BC mitigation agreements. Assessment approaches are informed both by ground up inventories of black carbon sources (Lamarque et al. 2010, Corbett et al. 2010) and complex transport models (Cheng and Lin 2001, Lin, Cheng and Schroeder 2001, Andreas Stohl) that project trajectories of air pollution transport. In-situ observations are used to evaluate these inventories and transports models; investigate the speciation between BC related to fossil fuel versus biomass; and capture information about BC concentration and concomitant measures of surface energy balance and other aerosol properties. The AMAP BC assessment (2011) specifically recommends that long-term surface monitoring of BC and light absorbing aerosols is required to characterize the spatial distribution of Arctic BC. Yet participants in the AMAP BC assessment process have noted that the assessments are heavily biased towards modeling and campaign results and have yet to entrain long-term observations. Such long-term surface monitoring of the atmosphere and its constituents is central to the mission of each IASOA observatory.

2.3 **IASOA's Role**

Various techniques have been employed to measure the optical properties of absorbing aerosols and BC at IASOA observatories since 1990 (Figure 3). Many of these observations were established to monitor Arctic Haze rather than to assess current concerns (Quinn et al. 2007, Schnell 1984). By 2010, six IASOA stations had initiated continuous aethalometer (AE) measurements of equivalent black carbon mass concentration. Starting in 1998, five stations progressively added continuous measurements of the aerosol absorption coefficient using either a particle soot absorption photometer (PSAP) or a multi-angle absorption photometer (MAAP). These measurements constitute an important pan-Arctic perspective on long-term trends of effective black carbon in the Arctic atmosphere. As with all in-situ measurements, observing techniques introduce assumptions, bias and errors into reported values. To make best use of these assets, it is essential for various end users to understand how to interpret and apply this data. In Section 3, we examine these and other intrinsic factors that affect the usability of in-situ observations.

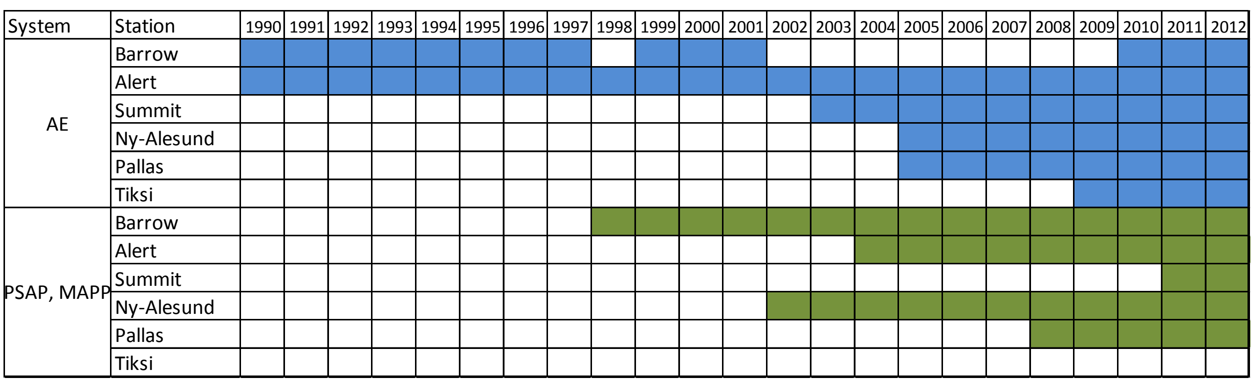

Figure 3. Relevant Black Carbon Measurement Inventories at IASOA Member Observatories

3. **Black Carbon Observations – Intrinsic Factors**

Intrinsic limitations of the IASOA BC monitoring network will limit how it can contribute to BC information of use to stakeholders, these limitations include: spatial and temporal resolution; length of historical record; accuracy and uncertainty. One important consideration is that the definition of BC itself is still a source of debate; different measurement techniques, be they optical or thermochemical will measure concentrations of particles that are collectively described as BC. According to Hansen (2005) who developed the optically-based AE, BC is operationally defined by the instrument which measures it and for the AE that has the following attributes: the portion of particulate matter that insoluble; stable in a pure oxygen atmosphere to a temperature of 350 ˚C; displays both graphitic structure and microcrystalinity; and which is strongly absorbing in the visible spectrum. However, the AE cannot quantitatively separate out the contribution of "brown" organic carbon (OC) or other absorbing particles. Instruments like the Single Particle Soot Photometer (SP2) directly measure the mass concentration of refractory elemental carbon (EC) but that measurement includes carbon which is optically non-absorbing, or not black. Poschl (2005) suggests a classification scheme for BC, EC and OC that is based on their optical and thermochemical properties, but cautions that these properties exist along a spectrum without defined limits. As a result of these and other issues, absorbing aerosols in general, and BC measurement techniques in particular, are the subject of disagreement within the observational community, to the extent that the World Meteorological Organization's (WMO) Global Atmospheric Watch (GAW) expert body has not even provided a common definition of BC (WMO-GAW 2003), though they have provided guidelines for measuring Absorption Coefficient with the PSAP. Following the recommendation of John Ogren, chair of the GAW expert group on aerosols, the discussion of these in-situ measurements will refer to *equivalent* BC.

In-situ equivalent BC measurement techniques fall into two main categories: those that measure light absorption (either on a filter or across an air sample) and those that measure mass concentration directly. The equivalent BC parameters of interest are:

- BC Absorption Coefficient [1/m]
- BC Mass Concentration [$\mu g/m^3$]

For long-term monitoring, IASOA observatory leads have deployed both AE's and PSAP's for their relative affordability, ease of operation and stability in cold environment. MAPP & COSMOS are two instruments that have addressed some of the limitations of the AE and PSAP design. Both are commercially available, but have not been deployed in the Arctic for very long. The following discussion will focus on intrinsic limitations of filter-based measurement of BC and highlight issues and uncertainties specific to AE's and PSAP's.

3.1 Filter-based Measurement Principles

The AE (Magee Scientific, Inc.) and the PSAP (Radiance Research) use similar physical principals to measure light transmittance through a filter that has been loaded with aerosols from an ambient air sample stream. Both instruments measure the ratio of light intensity passing through loaded (I_s) and unloaded (I_r) portions of the filter as a function of time. The change in the ratio of these intensity measurements is converted to an apparent absorption coefficient, σ_{ap}, following Beer's Law using the spot area (A) on the filter and flow volume of air (V) passing across the filter during the time interval Δt to represent the "column" of air sampled.

$$\sigma_{ap} = A/V*[\ \ln(I_s/I_r)_{t+\Delta t} - \ln(I_s/I_r)_t\ ]$$

The AE automatically converts this apparent absorption coefficient into an equivalent BC mass concentration (M_{bc}) using the empirically-derived BC absorption cross-section at the filter. This conversion assumes:

1. The observed decrease in light intensity is only due to absorption by BC (i.e. it assumes no other scattering or absorbing aerosols affect I_s). NOTE: multi-wavelength measurements can qualitatively detect the occurrence of absorbing particles with a different spectral dependence of absorption than that expected for BC;

2. Instrument setting for black carbon cross section (sigma) assumes constant value at each wavelength, though strong regional and temporal differences have been observed.

The PSAP does not make this conversion; however, anyone using the PSAP to report equivalent BC mass concentration must explicitly make the above assumptions. Conversion methods for the PSAP have been described by Sharma (2002) and Bond and Bergstrom (2006).

3.2 Calibration Schemes

Comparisons between both the PSAP and the AE with other reference methods indicate that each over-predicts the absorption coefficient (which would lead to an over-prediction of equivalent BC mass concentration). The results of calibration experiments suggest three corrections that should be made to apparent absorption coefficient measures determined from these filter-based instruments; specifics are instrument-dependent. The PSAP (Bond et al., 1999) and AE (Arnott et al., 2005; Collaud Coen et al., 2010; Weingartner et al., 2003) have been tested in independent laboratory environments where independent measurements of α_{ap} were made to develop calibration schemes and quantify measurement uncertainty. . The PSAP, AE and MAAP were all compared in two workshops, the results of which have been summarized by Muller et al. (2011). The instrument-specific recommendations are very detailed and not presented here, however overall uncertainty for the instruments derived from this study are in summarized following an overview of the sources of instrument uncertainty are listed below.

1. (Response to Scattering) Non-absorbing particles on the filter can falsely contribute to apparent extinction by scattering a portion of the photons away from the detector. This effect is further enhanced when there are both scattering and absorbing particles on the filter as the scattering particles can direct photons towards the absorbing particles. Finally, the size distribution of the scattering particles will influence the asymmetry parameter and thus the magnitude of this effect.
2. (Response to Absorption) Sampled particles are embedded in a multi-scattering media, so photons get more than one chance to interact with absorbing particles (as is the case with scattering by particles above). This is considered to increase apparent absorption by a factor of ~2 over that in the atmosphere and it is site dependent.
3. (Response to Filter Loading) This effect varies depending on the filter loading, i.e., the ratio of I_s/I_r at time *t* to the ratio at time *t=0* (blank filter).

Other sources of error include inaccuracies in flow measurement (V) and spot size measurement (A). Also, an internal correction is applied within the AE. The so-called “mean-ratio” is a factory setting that accounts for instrument variations from an instrument standard at Magee.

These calibration schemes do not account for other issues encountered when measuring equivalent BC, which include:

1. The effect of particle coatings on the optical properties of the black carbon
2. The effect of particle size distribution

Instrument precision for each instrument has been determined for both the AE and the PSAP. Unit-to-unit variability in the PSAP was measured by Bond et. al (1999) to be +/- 6% (95% confidence). Hansen (personal communication) reported that the side-by-side testing yielded results within 10% of one another. Muller et al. (2011) found unit-to-unit variability for the PSAP and AE31 respectively to be 8% and 8.9% with the standard deviation for the AE31 to be much larger. They could not find a good explanation for this. The AE10 was not tested for unit-to-unit variability by Muller et al. (2011), but was found to have more than four times the noise of AE31. Total error in the final result will be a function of the relative magnitude of the absorption and scattering coefficients. For the NOAA-ESRL-PSAP configuration (which employs concomitant nephelometer readings in correction schemes), this error is estimated at 15% (95% confidence) for 60 second samples and typical atmospheric absorption levels.

3.3 Other Considerations

The ground-based perspective of measurements at IASOA observatories constitutes an important limitation on the usability of these measurements. Deposition processes result in the lowest concentrations of BC near the ground. Models and aircraft observations have demonstrated that the vertical distribution of light absorbing particles varies considerably throughout the air column. Koch et al. (2009) evaluated more than a dozen aerosol models against the results of various measurement campaigns, including aircraft. Not only did they find orders of magnitude disagreement amongst the results, they found orders of magnitude differences between BC aloft (e.g. 500 hPa) and that at the ground. Many of the radiative processes of interest (i.e. atmospheric radiative forcing and cloud longevity) are occurring aloft, so surface measurements will provide diminished value in process studies or climate models that seek to understand these interactions effects.

Another important consideration when evaluating equivalent BC measurement techniques is evaluating their ability to inform speciation. Hansen describes speciation as the “holy grail” of BC research (personal communication). Absorbing particles from diesel exhaust, wood smoke, agricultural burning and coal smoke might appear similarly “black” but have very different hygroscopic properties, thus influencing their interactions with clouds and their climate impact. The 7-wavelength AE can be used to qualitatively identify the presence of “brown” OC or mineral dust through shifts in absorption across different wavelengths. In the Arctic, speciation between BC and OC is particularly meaningful as studies indicate that other absorbing aerosols (e.g. mineral dust) occur in very low concentrations in the Arctic. Other speciation techniques involve simultaneous measurement of CO and CO_2, or isotopic carbon. Speciation is extremely valuable information as it supports process studies and model development to ascribe different climate impacts to different types of particles; it supports receptor analysis and transport models to understand source regions of different types of particles; and it supports regulatory and policy measures targeted at particular emissions sources.

3.4 Summary

This discussion underscores the inherent complexity and uncertainty associated with applications of observational data from two commonly-used equivalent BC monitoring instruments. While these instruments are affordable and run robustly with minimum attention, there are limitations in their accuracy and considerable uncertainty in how information derived from these instruments should be applied. In spite of the limitations and uncertainties described above, filter based methods do offer the benefit of having lower detection limits than other measurement techniques. This is an important factor when sampling relatively clean Arctic air. In the following discussion, we will consider how different end users of this information make sense of these intrinsic limitations and map it on to their own requirements.

4. BC Information – Contextual Factors

The Science and Technology Policy Research (STPR) community actively investigates the effectiveness of the science enterprise (researchers and funders) at delivering useable information (Pielke Jr 1995, Pielke Jr and Glantz 1995, Sarewitz and Pielke 2007, Cash et al. 2006, Dilling and Lemos 2011). Useable information may take the form of value-added data processing to support a range of science application, forecasts for expert and novice audiences, assessment for expert and novice audiences, or even the form of iconic time series data such as the "Keeling Curve" (Scripps 2008) or "Arctic Sea Ice Minimum"(NSIDC 2011), images that tell compelling stories. Critiques of the science enterprise's delivery of usable science have consistently found that usability is positively impacted when the needs of the stakeholder audience are considered.

In the case of Arctic black carbon, these stakeholders are found within multiple contexts both within and outside the traditional research community. Some actors span more than one context, such as the case of a scientist becoming involved in policy advising. Within the research community, long-term monitoring observations are an essential tool for those charting trends through long-term time series analysis, improving instrumentation design and modeling the dynamics of the global climate system. Modeling applications for observations include evaluating front-end boundary conditions and back-end diagnostics. Observational data can also be used to develop model components through the design of process studies. Outside the traditional research community, applications include operational air quality monitoring and forecasting, evaluation of mitigation strategies, informing regulations, technology investments and policies, and informing the public.

The needs of each context are unique as is the capacity for effectively using observational data within that context. In the sections that follow, we will investigate three specific cases that represent a sampling of needs and capacities; they also represented a range of maturation in information needs. In order to systematically evaluate information requirements from these cases, I developed a survey (Appendix A). The core purpose of the survey was to solicit qualitative and quantitative information needs within the context of each case study. Quantitative questions gage the relative value of different types of information and observational data through a scale outlines in Table 2.

Table 2. Relative value ranking applied in survey for BC stakeholders for different types of information and observational data.

Ranking	Description	Numeric Value
Essential Value	This information is essential for my application, I cannot succeed without it.	10
Value	This information is valuable for my application.	7
Contingent Value	This information is only valuable if it is accompanied by information on (blank).	4
Limited Value	This information might be useful in a limited way.	1
No Value	This information is not relevant for my application.	0

Respondents were first asked TRUE/FALSE if they found the general category of information important. The two categories were Value-added Information and Observational Data. If they chose FALSE, any rankings they provided were ignored (this didn't happen.). If they chose TRUE, any piece of information left blank in that category was given a score of "No Value". Qualitative questions in the survey gage the types of factors that constrain data or information use within a given context.

One purpose of the survey was to learn lessons to inform a broader survey effort. Thus very small and select audiences were chosen for to test survey. Though the sample sizes were small (2 to 5 respondents per case), my hypothesis was that needs, capacities and opportunities would cluster according the types of applications and the role of the information user. In addition, surveys provide an important means to initiate a learning process between information providers and information users. In the following sections, I will describe each case study, present survey results for the case and case-specific findings.

4.1 Black Carbon Modeling – Case Study 1 (Atmospheric Chemistry and Climate Model Intercomparison Project, ACCMIP)

This first case study considers the context of the Atmospheric Chemistry and Climate Model Intercomparison Project, ACCMIP. ACCMIP was organized under the auspices of high-level international science organizations, including the International Global Atmospheric Chemistry (IGAC) program and the World Climate Research Program (WCRP). The project was designed to contribute a broad and rigorous evaluation of atmospheric chemistry modeling to the Intergovernmental Panel on Climate Change's upcoming 5th Assessment (IPCC-AR5). Model intercomparison projects constitute an important activity for 1) understanding the sensitivity of different models to similar or identical boundary conditions and for 2) interpreting those differences for expert and non-expert audiences of both the IPCC and other peer-reviewed outlets. These intercomparisons provide one bound on confidence around the range of possible climate change projections. Models yield different results to similar (or identical) inputs as a result of decades of development efforts that prioritize different aspects of the climate system or are built upon very different physical assumptions. Throughout their development histories, strategic decisions have balanced model skill against model cost – or computational requirements. As a result, only 8 of the 23 models evaluated in Coupled Model Intercomparison Project "3" (CMIP3) included black carbon. In the current evaluation, CMIP5, that number has grown to 80% (Shindell, personal communication).

To accurately simulate historical and projected climate, historical and projected data on radiatively active gases and aerosols are supplied as an input to climate models in the form of gridded emissions inventories. Historical emissions inventories are developed from ground-up reconstruction techniques using historical records of energy use (or agricultural burning) by different sectors across global locations; projections assume growth in each sector. Determination requires historical information on fuel consumed by source, emissions factors (g species emitted/kg fuel) by source and the geospatial distribution of these sources. The quality and attendant uncertainty of such historical data varies by region.

As with other climate model diagnostics, emissions inventories must be evaluated against independent sources such as long-term observations. Consistent, gridded emissions inventories were compiled for ACCMIP and CMIP5 from ground up sources by Lamarque et al. (2010). This inventory includes 40 regions and 12 emissions sectors and covers the period 1850-2000. Lamarque et al. (2010) evaluate their data set against a relevant range of observational data. In the Arctic, this includes snow samples (Doherty et al. 2010), shallow ice cores (McConnell et al. 2007), and surface observations from long-term observatories. Shallow ice cores provide good temporal coverage of the data set back to 1850, but at extremely low temporal resolution (usually annual) and are only available at specific locations such as the Greenland Ice Sheet. For the ACCMIP team, long-term surface observations of aerosol optical depth (AOD), aerosol absorption coefficient and BC mass concentration are need for evaluation.

Even though ACCMIP is a science endeavor occurring within the confines of the traditional research community, there are disciplinary boundaries that separate observationalist from modelers and create impediments to effective application of observational data to model evaluation. These boundaries can result in surprising disconnects as observational schemes have traditionally not been developed with model diagnostics in mind.

4.1.1 Case Study 1 - Survey Response

Three ACCMIP team members were asked to respond to the survey and all three responded. Two are heavily involved in evaluating the Lamarque et al. (2012, to be submitted) revised gridded emissions inventory, the third is more broadly involved in ACCMIP. Each described their domain as science, one also included engineering. Each also selected “modeling”, “model development” and “model evaluation” as their application, one included “informing regulations or policies” as part of the application. Two of the three respondents agreed that value added information was important for their application. They then characterized the “climate” value added selections as either of Essential Value or Value. Each found the “health” value added selection as low value.

All respondents found the observational data “important”, but were selective in the specific data of interest (Figure 4). All respondents ranked Equivalent BC Mass Concentration, Aerosol Optical Depth and Speciation as of “essential value” for their application. Other aerosol observations were ranked highly, while non-aerosol observations fell into the range of “conditional” to “limited” value. Two respondents noted other speciation of interest: mineral dust and isotopic carbon. One noted the concomitant value of data on the deposition flux of BC measured along with its mass concentration.

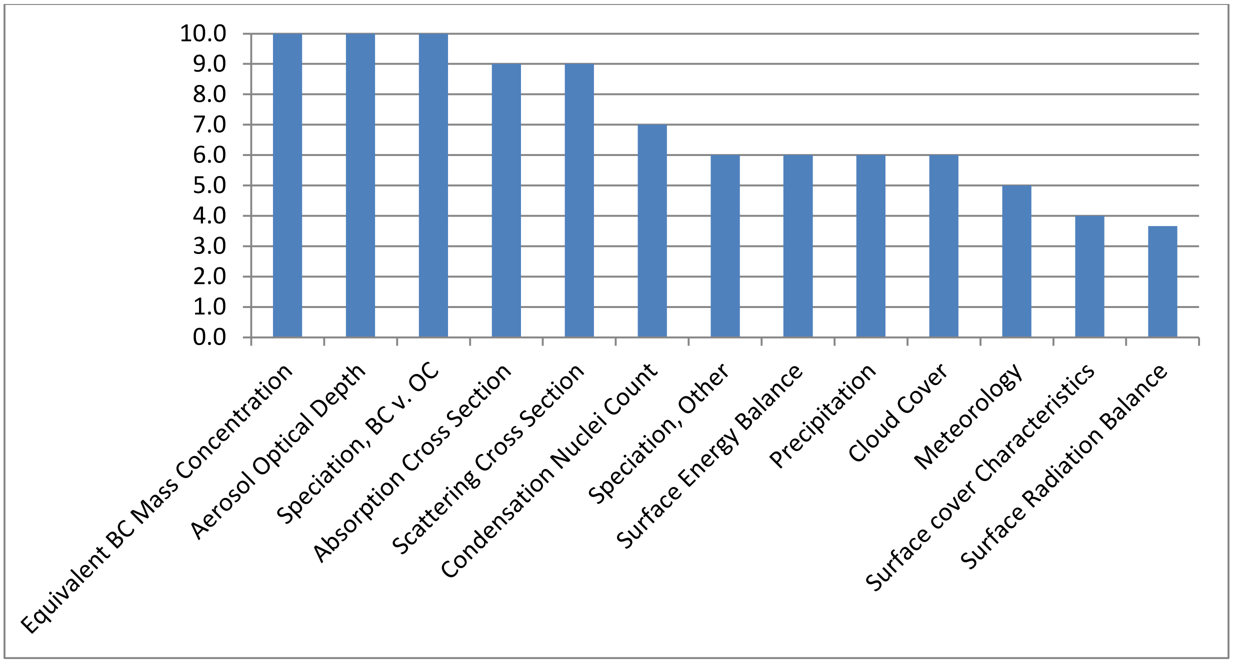

Figure 4. Averaged value responses for observational data from the ACCMIP team. 10 = Essential Value; 7= Value; 4= Conditional Value; 1= Limited Value; 0 = No Value.

For data characteristics related to the spatial, vertical and temporal resolution, the respondents were less consistent in their responses. One respondent listed gridded data as having no value for the application of evaluating gridded data. Two indicated that value-added data averaging to monthly or annual values was important. All use specific measures of uncertainty in their application. All three respondents answered “FALSE” to the question: I have the Arctic Black Carbon Information that I need. They listed the following important data gaps: insufficient spatial coverage of BC concentration, limited aerosol optical depth (AOD) due to limited coverage in AERONET network, and no information on vertical resolution. One team member also responded that there is some information available, but that it is not usable. Those reasons are elaborated below.

In considering contextual factors, the ACCMIP team all commented on the need for “readily available data” from websites. The comment below suggests what “readily available” might look like for this specific application:

“As a global aerosol modeler, I am generally looking for a long-term and monthly (or annual) average BC observation (as many as possible) for the model evaluation. For my needs, temporal coverage is more important issue than whether it has a monthly average or not. However, I tend to avoid using if the data is not available as monthly or annual average. I am not confidence to do this conversion without deeply understanding this observation (e.g., instrument, site, and any unusual circumstances […] during the measurement period) unless it is clearly [sic] address how to do this conversion. “

4.1.2 Case Study 1 – Survey Conclusions

- Observational data gaps that could be addressed by the IASOA network include: increase spatial coverage for BC concentration and AOD (AERONET), information on vertical profiles of BC.
- The Lamarque inventory spans 1805-2000, IASOA observations can only be used to evaluate 1-2 of 16 decades. IASOA observations can be used to evaluate 6 regions within the Arctic.

	Data Sets	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
Lamarque, et al. (2010)	Gridded, Arctic Wide																
AE	Barrow																
	Alert																
	Summit																
	Ny-Alesund																
	Pallas																
	Tiksi																
PSAP	Barrow																
	Alert																
	Summit																
	Ny-Alesund																
	Pallas																
	Tiksi																

Figure 5. Overlap between Lamarque inventory and IASOA BC observations.

- The aerosol modeling community sampled placed low value placed on information from other domains like human health.
- Readily available, processed data that includes QA/QC, a description of calibration schemes, specific uncertainty measures associated with monthly and annual values will enable greater use of IASOA data by teams like ACCMIP.

4.2 Mitigating Black Carbon in the Russian Arctic – Case Study 2 (EPA & DOE mitigation)

As introduced in Section 2, BC elicited a significant policy response from the US delegation at COP15 leading to a $5M initiative "Mitigating Black Carbon in the Russian Arctic" to be coordinated by the U.S. State Department. Technical contributions are being led by EPA, DOE and USDA to focus on source emissions and mitigation strategies in the Russian mobile, stationary-industrial and agricultural-forestry sectors respectively. The focus on the Russian Arctic was formulated due to relatively high uncertainty in BC inventories in the region, an understanding that deteriorating energy infrastructure would provide an excellent opportunity for mitigation, the influence of the U.S.-Russian Presidential Commission's Working Group on Science and Technology's emphasis cooperation on climate science.

The three (EPA-DOE-USDA) mitigation studies are circumscribed differently by each agency, but must address some or all of these items for each sector in question: identify sources, determine emissions factors[1] by source, create emissions inventories, establish a baseline of current emissions, project potential growth in emissions/activity, install pilot project measures or develop best practice exchanges, evaluate the efficacy of measures and develop exchange networks. At this time, the DOE team leads the groups with expertise in interpreting speciation and transport pathways for BC from Russia to the Arctic. Their approach is based on a receptor analysis framework (Lin et al. 2001, Cheng and Lin 2001). In-situ observations within the Arctic are critical to the receptor analysis approach. Each team is responsible for determining the relative contribution of emissions from their sector towards BC transport into the Arctic. In background material, two teams claim that different sectors are the greatest contribution to BC in the Arctic: DOE claiming the industrial sector and USDA claiming the agricultural/biomass sector. Each group references peer-reviewed studies that support their conclusion. This difference reveals how even in a single team, scientific evidence can be inconsistently applied, making the challenge of coherent study framing more difficult.

4.2.1 Case Study 2 – Survey Response

Five of the team members associated with "Mitigating Black Carbon in the Russian Arctic" study were asked to respond to the survey and all five responded. The respondents domains reflect the diversity of the multi-agency team (2 – Science, 2 – Engineering, 1- Advising, 2- Management, 3-Policy, 4-Other, project management.) There was a similar diversity in their description of their application (3-Modeling, 1 – Instrument Dev. or Eval., 1 – Time Series Analysis, 3- Monitoring, 3- Informing Regs or Policies, 3-Education or Public Understanding).

All five respondents considered value-added information important (Figure 6) and four out of five ranked Sources of BC to the Arctic as "Essential Value", the fifth considered it "Valuable". The second highest ranked form of information was "Health Impacts of BC". Overall, the team showed a diversity of ranking that was reflective of the team's diversity.

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[1] Emissions Factors: gram emitted species per kg fuel (stationary); gram emitted species per vehicle mile travelled (mobile). Specified by source. By using the emission factor of a pollutant and specific data regarding quantities of materials used by a given source, it is possible to compute emissions for the source.

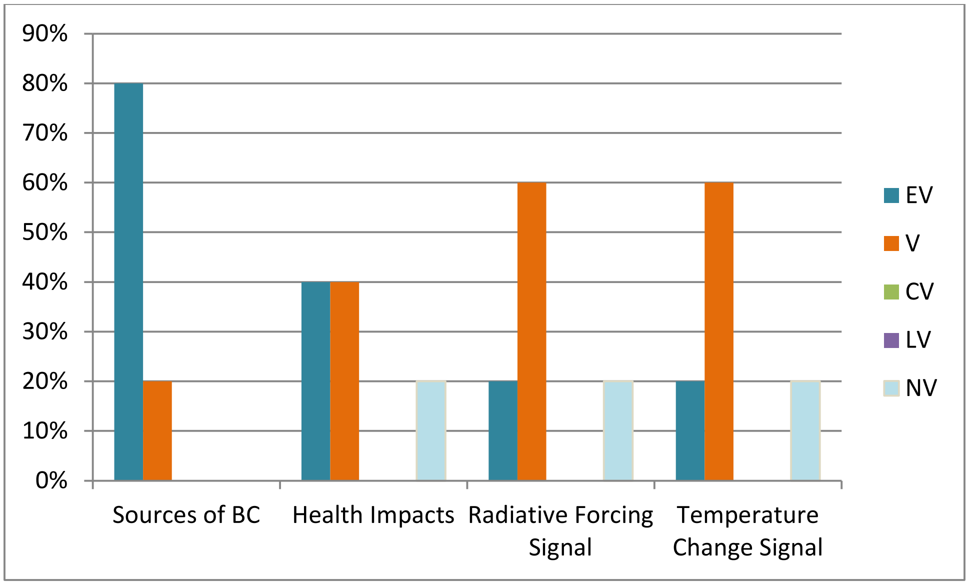

Figure 6. Relative value of different types of value added information to the U.S. multi-agency Russian Mitigation Study respondents.

Three of the respondents also included additional value-added information that is important for their project. These include:

- Transport and "fate" of Russian BC to the Arctic
- What are the most important sources of Black Carbon to the Arctic and where are they located?
- What parts of the Arctic are most affected by Black Carbon?

Four of the respondents considered observational data important, but two noted that they are not the direct consumers of this information. They did choose to fill out the selections according to what they understood the technical leads on the project require. A surprising outcome was that respondents found meteorology the most important, more important than BC measurements themselves (Figure 7). The group also ranked surface cover characteristics as important.

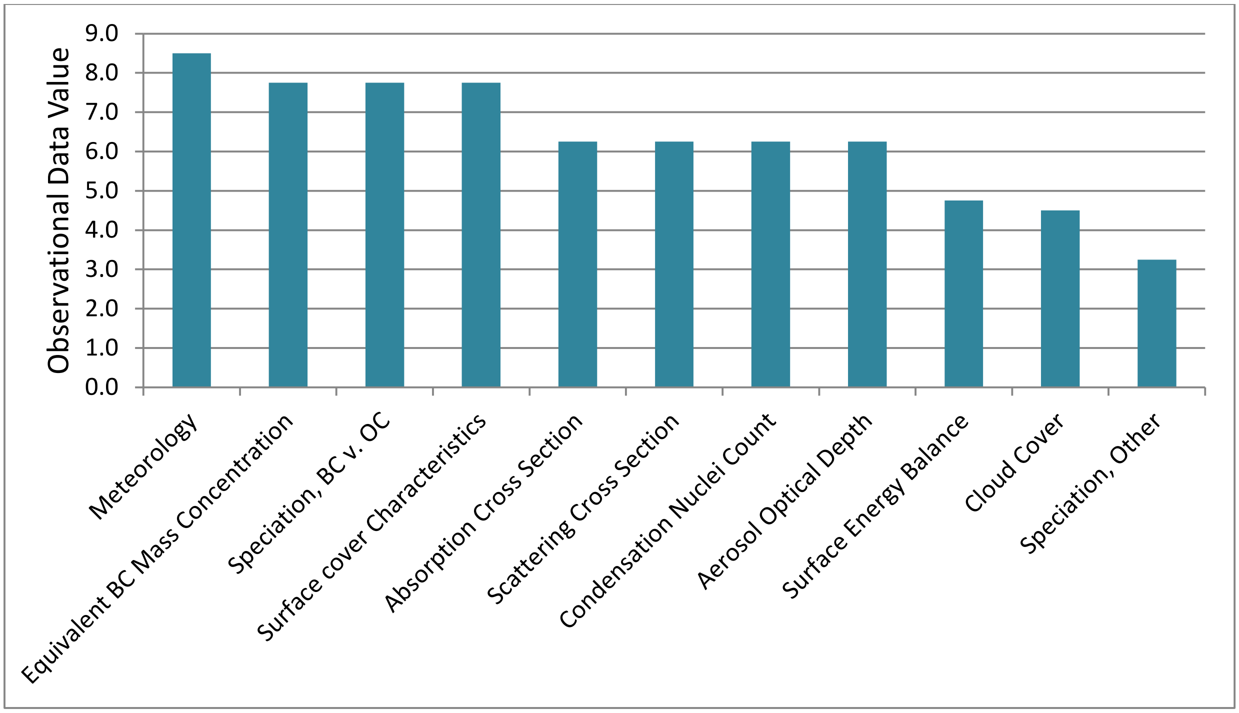

Figure 7. Relative value of different types of observational data to the U.S. multi-agency Russian Mitigation Study respondents.

Four of the five team respondents said that they did not have the information they needed for their application. The gaps listed included:

- Diesel sources of black carbon throughout the Russian Arctic
- Black carbon air monitoring
- Emissions inventories (for all sources in Russia)
- Understanding transport to and from the Arctic

When considering the other contextual factors that are affecting this project, four of the five respondents felt they needed more access to expertise and understanding of technical issues. Two mentioned that data formatting was "important". Another added: "There are a variety of projects on black carbon going on in the Arctic, so data harmonization is key."

One respondent expressed this combination of challenges on working with Russian data sources:

"Right now, we don't know what the sources are, who collects the data, what information they have and how it is formatted (except for the site visits we recently took to Murmansk and Salekhard where some power plant level data collection was noted and some regional ongoing efforts in the Murmansk region were noted). We have no information on how they are collecting. We are pretty sure there are sources and information is collected it's there."

4.2.2 Case Study 2 – Survey Conclusions

- Team was diverse. Each respondent listed more than one domain and more than application. This diversity suggests at least two things: 1) that survey responses will reflect the synthesis of these roles; and 2) that the team will already be accustomed to integrating usable information across domains of practice or has at least considered the value of that.

- Team valued source information above all other types of value-add information, but Health ranked second.
- Team found many types of observational data valuable. A focus group would be a good tool for tapping into how specifically they might synthesize this information.
- Team felt there was a lack of expertise in this area or that they did not have access to expertise that does exist.
- Data formatting was affecting usability for this team.
- Working with foreign data sources can present particular hurdles

4.3 Black Carbon Regulatory Policy – Case Study 3 (Arctic Council & IMO)

Dramatic declines in sea ice extent, punctuated by recent record minimums in 2007 and 2011 (NSIDC 2011), are a leading indicator of Arctic change, with implications for the environment and human activity. The northwest (North American to Asia) and northeast (Europe to Asia) sea routes through the Arctic represent respectively a 25% and 50% decrease in trip length, with an attendant economic advantage. In-Arctic shipping to support resource development and trans-Arctic shipping are both expected to increase dramatically in the decades to come. The institutional response to this concern has been significant. The Arctic Council's Protection of the Marine Environment (PAME) working group produced the Arctic Marine Shipping Assessment - AMSA report (Arctic Council, 2009) to explore concerns and identify where policy can balance economic opportunity with potentially harmful impacts, which include increased in-Arctic emissions of SLCFs. The International Maritime Organization has also contributed significantly to global assessments of shipping-sector pollutants and GHG emissions (IMO 2011) to inform its own International Convention to Prevent Pollution from Ships (MARPOL), Annex VI of which deals specifically with air pollution. International shipping contributes ~2% of global BC from all sources. In-Arctic ship emissions constitute a relatively small proportion of current global emissions, however growth of in-Arctic ship emissions and the disproportionate effect of both BC and ozone precursors in the Arctic make future emissions a relatively greater concern. As a result, the IMO will convene a body of scientists, engineers and regulators in 2012 to consider Arctic-specific emissions controls. In the words of the U.S. EPA delegate, "Clearly, one of the big hurdles we face is persuading the global maritime community that SLCF emissions and impacts in polar regions, particularly the Arctic, is highly significant and worthy of action at the IMO."

Though IMO is just beginning this process, the requirements for informing such a regulatory policy are similar to those in the EPA study: establish a baseline of current emissions, identify sources, create inventories, project potential growth in emissions/activity, evaluate the efficacy of measures and potentially monitor on-going air quality. Corbett et al. (2010) created high resolution (5km grid) Arctic-specific shipping emissions inventories for transport vessels and projected future (2050) scenarios for BC emissions based on projected diversion rates of global shipping through the Arctic. They used the AMSA database to derive historical and geospatial information on vessels and trips. For a given vessel and trip, emissions will be a factor of: fuel-specific emissions factor (g/kg); engine load factor (maneuvering, slow cruise, full cruise, etc.); engine rated power; engine efficiency; duration of the trip. Individual regulatory measures can be evaluated as they impact these independent variables, i.e. engine efficiency. The Corbett inventory has not been evaluated against observational data.

4.3.1 Case Study 3 – Survey Response

Four of the IMO participants were asked to respond and two responded. Of these responses, both noted that they are very early in their process and have not yet clarified their needs. Given the small sample size, I will not summarize the value findings, but will provide some interesting contextual comments about how information will be used in this process.

One of the respondents is an observational scientist and intimately familiar with various measurement techniques. His perspective on the measurements is summarized below:

"Measurement quality is a real concern. Filter based techniques are notoriously variable and they are starting to be applied to BC filtered from snow. Many mass techniques are also of questionable quality."

The second respondent is more involved in the regulatory considerations. Her perspective is well summarized by this comment:

"From a policy standpoint we don't need data in a specific format or resolution, we do need to ensure reliable data over time that is internally consistent (i.e. tells a consistent story) in order to utilize it appropriately for regulatory purposes."

4.3.2 Case Study 3 – Survey Conclusions

Though it is early days for the IMO BC regulatory work, the two respondents point towards two perspectives on a very challenging issues for science policy work related to BC: the internal community debates over the reliability of observational BC data and the external community needs for confidence and consistency in any observational data that will be used to make a case for stricter regulations.

4.4 Combined Survey Responses

Combing the results of the ten respondents across all case studies reveals broader findings. Nine out of ten respondents said they did not have the Arctic BC information or data that they needed for their application. Six of the ten respondents further added that they did not have the expertise they needed to use data or information confidently. This response included two scientists. Another cross cutting issue was raised by two groups. This concerned the lack of harmonization in data standards, formats and methodologies for observational black carbon data. It was identified as particularly acute when data sources were outside the US or resided in the archives of stand-alone institutions, as opposed to World Data Center types of archives.

For value-added information, respondents clustered in a dramatic way around interest in health impacts (Figure 8). Of the respondents, 5 listed "science" as their domain of practice, while 5 listed "regulatory" or "project management". Both groups found physical and climatological information of value, but scientists found distinctly less value in health impacts information. Since the scientists are not in the health sciences, this is not entirely surprising. The mangers and regulators surveyed are not directly related to the health sciences either, but seem to value a broader range of societally-relevant information. Such disconnects between scientists and the regulators they aim to serve could cause issues at the framing stage of research if scientists are not taking as broad a view as societal intermediaries (regulators and managers) expect or require.

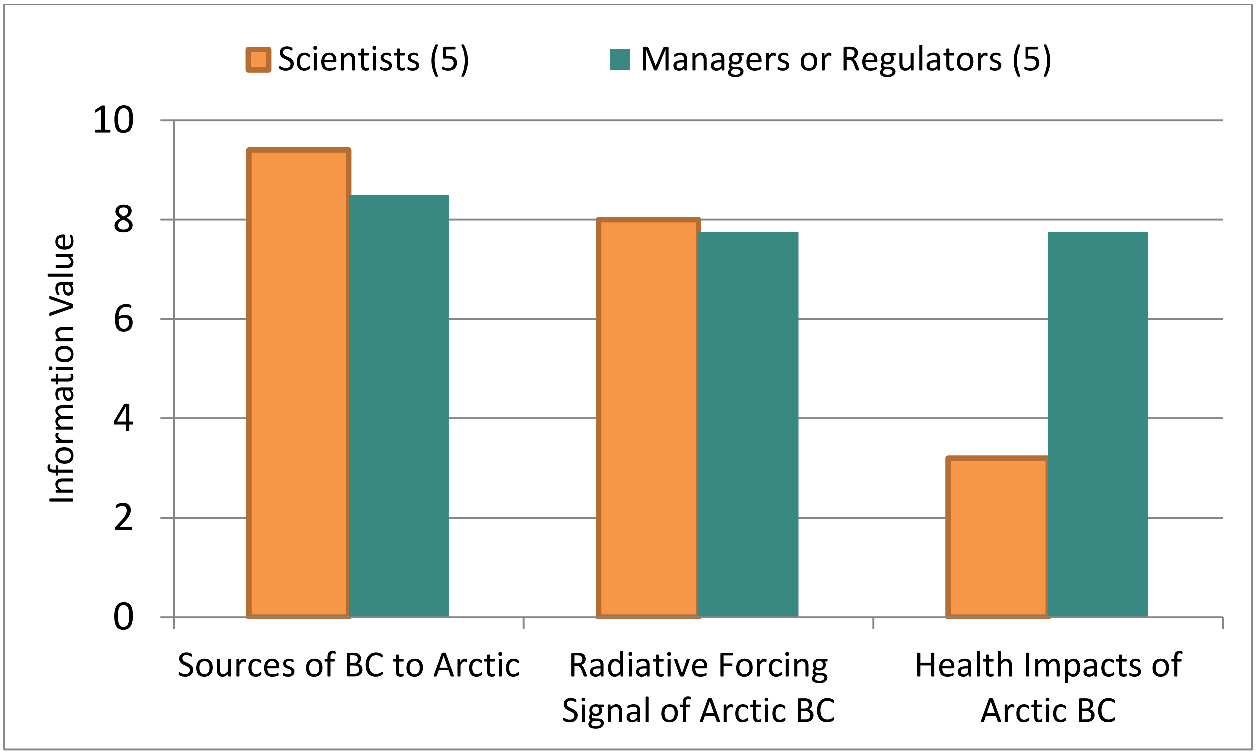

Figure 8. Black Carbon information value as viewed by respondents in either Science or Management/Regulatory domains.

The view across observational data value reveals interesting findings as well (Figure 9). It is not surprising that each group craves a different basket of goods for their applications, but it is a strong reminder of why stakeholder consultation is an important effort. There is no *a priori* way of specifying the needs of an observational network without such consultation. If only modelers are consulted (i.e. ACCMIP) it is clear that the needs of more regulatory stakeholders would not be met. Another interesting observation for a group like IASOA is how this feedback supports the value of observatories with broad, long-term observing missions. Many of these observatories were developed in an *ad hoc* fashion, driven by the subject matter and curiosity of the fundamental research community. The resulting breadth of measurements (represented on the x-axis in Figure 9), even if originally specified for very different purposes, does meet a wide range of applications.

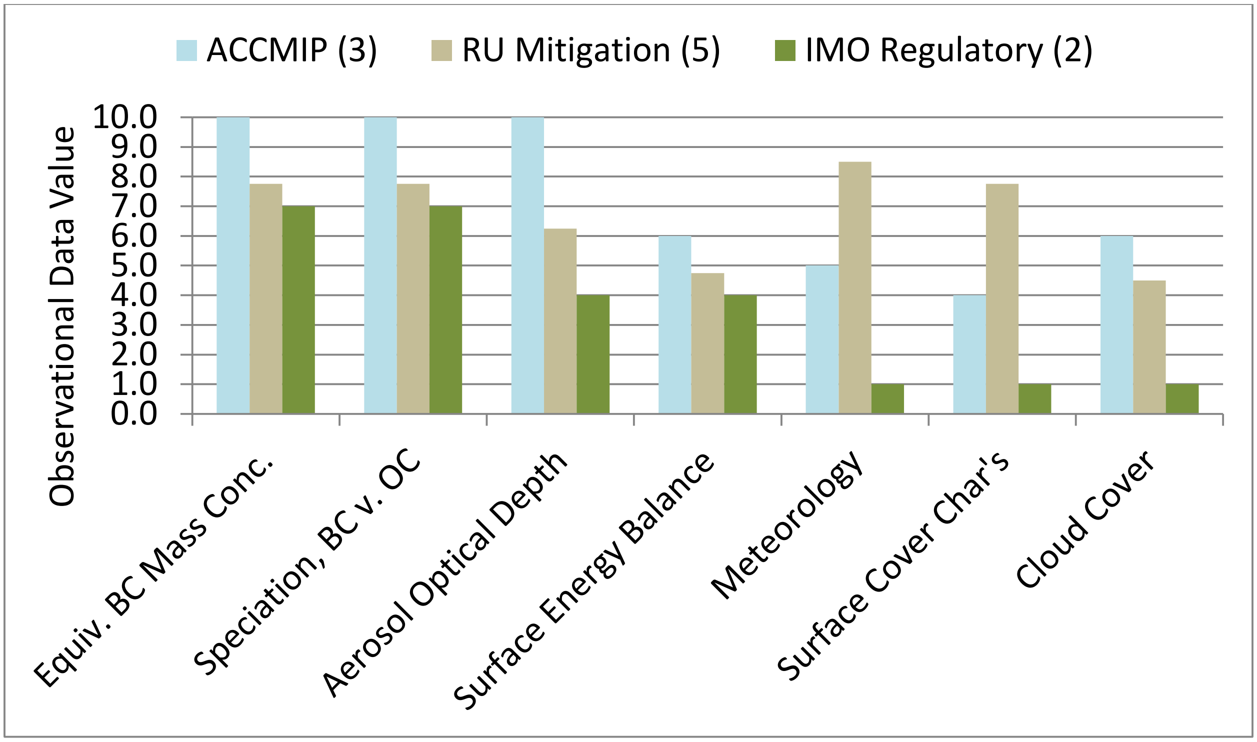

Figure 9. Observational data value as viewed by respondents across all case studies.

5.0 The Intersection of Intrinsic and Contextual Factors

Three case studies were presented to demonstrate a range of information use contexts and to explore the intersection of intrinsic and contextual factors that will yield greater usability. Though the sample size was small, 10 respondents provided some valuable perspectives about the opportunities and limitations for IASOA observational data in their application. Findings and conclusions from the individual cases were presented in Section 4. Here, the collective findings and conclusions are summarized, as is their intersection with the intrinsic issues of filter based BC observational data.

5.1 Intersections and Opportunities

Of the three case studies identified, respondents from each indicated an interest in using IASOA observational data and supported the value of the historical pan-Arctic record from the observatories. Both ACCMIP and Russian Mitigation case study respondents have already begun to entrain IASOA observations into their application. These specific opportunities are being explored to increase usability:

1. For the ACCMIP team: Apply Bond (PSAP) and Muller (AE) calibration schemes consistently to all existing data; process into monthly and annual mean values. Report with uncertainty measures.
2. Explore the speciation information in 7-wavelengths AE measurements from all observatories to evaluate accuracy of receptor analysis results. Explore the possibility of brief campaigns to monitor advanced speciation information and tie back to long-term records.
3. Provide observational expertise to national delegations involved in framing IMO BC regulatory work. Emphasis will be on confidence and consistency.

More general opportunities were identified as well. While a coordinating effort like IASOA cannot change how data was collected at the observatories, it can influence how it is processed and archived to create greater uniformity in the final product. Further, it can facilitate access to a breadth of observations available from the observatories that will be of use to the stakeholders. Many were not familiar with these other datasets because they were retrieving station data from measurement-network specific websites like AERONET or EBAS.

5.2 Disconnects and Limitations

Some observational data limitations cannot be overcome, particularly in the historical observations. In the case of filter-based BC observations, the biggest limitation is the confidence of the user community in the value of AE data. While side-by-side experiments with more robust instruments can improve interpretation, historical data will likely never be more accurate than +/-20%. Given that the BC radiative forcing signal is estimated to be rather weak, this level of uncertainty in the measured values will limit the detection of any long-term forcing signal from the observational data. Other limitations relate to the ground-based perspective of the long-term records. It is understood that wet and dry deposition yield a strong gradient between surface and aloft BC concentrations. Surface observations only tell a limited story. Ultimately, their best application may be for speciation and determination of source regions rather than providing a picture of background atmospheric BC levels. Other confounding factors like internal mixing of BC (coatings by other types of particles) cannot be resolved by filter-based techniques. Limitations such as these cannot be remedied, but they can inform network design moving forward and motivate the community to address important issues.

6.0 Conclusions

This paper presented three case studies where stakeholders, both within and outside the fundamental research community, were consulted about the observational information data needs for black carbon. In no case could those needs be readily met, even from a pan-Arctic set of decades long black carbon data. This paper explored both the intrinsic and contextual factors that give rise to this disconnect.

The most important intrinsic limitations of the filter-based measurements (aside from length of record) concern limitations in the instruments themselves. Filter-based measures of BC are relatively affordable and functionally reliable (operating consistently and predictably for long periods), but what exactly is being measured is the source of continuous debate. The world expert body on atmospheric measurement, GAW, has yet to generate a common definition for BC, which leaves observationalists, their funding agencies and end users without a common target. This leads to divergence within the community and competition amongst advocates of different approaches. While such competition is healthy within the science community, it can propagate outward into stakeholder groups as discord and lack of confidence. This greatly hampers the potential for BC data to tell the “consistent story” that one responder requires. Workshops that support side-by-side testing of diverse instrument are invaluable to reducing the uncertainty in how BC is measured and should be continued. IASOA can play a role for regional observations by hosting in-situ platforms for such testing. Organizations like GAW play a key role in supporting quality, uniformity and confidence around measures; it is timely and imperative for them to develop a standard definition for BC. One step that IASOA can take to further manage this type of limitation is to adhere to existing GAW observational protocols (PSAP and MAPP), seek to increase harmony in the calibration schemes (AE) and converge on common standards for key measurements for the network.

Contextual factors were more diverse across the case studies considered, but one common theme was the need for greater expertise, which several respondents also linked to confidence. In considering the complexity of the filter-based measures and proliferation of calibration schemes, this call for greater confidence is understandable. This is particularly true in the case of regulatory applications where mitigation legislation will create financial winners and losers. It can be anticipated that any regulatory recommendations derived from observational data will be aggressively vetted by potential losers. Those making recommendations will not want to expose themselves to unnecessary controversies.

But the call for greater expertise appears broader than the need for common standards or understanding how to process such data. BC is inherently a complex issue, linking global pollutant sources to regional effects at several scales. There is currently a proliferation of assessments on the topic (no less than six recent undertakings related to global or Arctic BC or SLCFs), each with a slightly different focus. How would a stakeholder be able to understand which assessment is the most authoritative or comprehensive for their needs, particularly when conclusions appear to conflict as it did within the DOE-EPA-USDA study framework. How would a regulator be able to understand the potential magnitude of the unintended consequences of reducing co-emitted species like sulfates, which keep a lid on climate warming. Beyond assessments and data portals, there is a need for reference experts or those that can assist with emerging needs.

Another type of expertise drawn out through the surveys related to regional expertise. In the case of the Russian mitigation study, it was very difficult for U.S. researchers to reach into Russian institutions to track down the data they needed. An international consortium like IASOA provides inroads to institutions around the Arctic, as well as cultural and language translation when data was not initially created for international applications. IASOA should continue to focus on how it can serve transnational access to both observing infrastructure as well as legacy data.

The Russian Mitigation and IMO cases both showed higher diversity in information and data interests than the ACCMIP team. There could be at least two reasons for this. The first is that the ACCMIP project is further along than the other cases, so it is likely that the team's interests became more coherent over time as the project took shape. Another possible reason is the diversity of the respondents themselves. All ACCMIP team members identified themselves as scientists, while the other two cases showed a broader range of disciplinary domains. Disciplinary diversity may result in a diversity of interests that does not become more coherent with project maturity. If so, disciplinary diversity could be considered both a strength that yields more inclusive frameworks or an incoherence that results in slow or ambiguous progress. It would be valuable to track the latter two cases to see if greater coherence emerges with time or to understand if the research agenda becomes more inclusive of a range of objectives.

This analysis found justification in the critiques from the Science and Technology Policy Research community that point to the deficiencies of the science enterprise (researchers and funders) at providing usable science. Scientists often employ the rhetoric of societal value to justify public funding of their undertakings, yet it is rare that these undertakings explicitly investigate the needs or diverse perspectives of stakeholders in designing networks, modeling studies or even assessments. The community of researchers is not solely accountable for the disconnect between their undertakings and stakeholder needs. Investigating such needs is not a routine part of the scientific approach or the cultural norms that value curiosity-driven experimentation over other methods or motivations for inquiry. Funding agencies have not traditionally required such investigations, nor would they have likely wanted to invest discovery research funds into what has classically been defined as "applied research". But as a growing body of researchers locate the justification for their undertakings within environmental change research, particularly those with frameworks that include Responding to Change (SEARCH, ISAC, ACCESS), it is natural to expect that pressure will increase to develop methodologies to entrain stakeholder needs into the research agenda. Ultimately, the intersection between intrinsic and contextual factors that yields usable science will be best served by an explicit funding focus on increasing it. I would argue that this should be addressed in two ways: 1) developing methodologies with the physical science community to investigate and entrain user needs into scientific undertakings; 2) developing the institutional spaces for linking expertise with needs.

The survey employed in this paper was one method for investigating stakeholder information and data needs. The survey was informed by both engineering and social science methods. Another technique which was not employed was focus groups where more interactive discussions could draw out more details and iterate on solutions. Part of the value of exploring context with any tool is explicitly developing a network of awareness around what is being done and who is working on what. Formal concepts like knowledge networks and collaboratories (e.g. EarthCube) could prove an excellent means of bridging the expertise gap while elevating the capacity of both knowledge producers and consumers. A motivation for the science community to consider is that the integration of production and use context could uncover new lines of discovery-based inquiry.

The second way to explicitly create a focus on increasing useable science is identifying the types of institutional spaces where expertise can be linked with needs. Mission-based agencies like NOAA and USGS have institutionalized such spaces in areas from weather prediction to mapping. They offer excellent examples of how institutions can be structured to respond to societal needs, provided both information and expertise. As needs for more climate-based information emerge, these institutions can play a valuable role in framing usable science. The Regional Integrated Sciences and Assessments (RISAs) at NOAA have experimented with a range of physical and social science as well as engineering to help provide more usable information on droughts and coastal management. Another excellent recent example that addresses this gap is the NSF Science Engineering and Education for Sustainability (SEES) investment area. This investment area, though funded through a basic research foundation, recognizes that new methodologies are required to frame science explicitly to address the imperatives of sustainability. For collaborative approaches to increase data access and usability, the NSF Organization of Projects on Environmental Research in the Arctic (OPERA) call and ACADIS response also both recognize the need for greater, value-added efforts to go into increasing the broad usability of data generated for discovery science.

Ultimately, scientists and funders alike should own the gap that leaves science assets underutilized and stakeholder needs unmet. As the IASOA network leads look beyond the IPY and embrace the call from the final IPY conference for moving from “Knowledge to Action”, they should consider the types of activities that will be most impactful for creating usable science. What is clear from this limited investigation is that business as usual will result in unused observations and unmet needs of downstream users.

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Appendix A

April 2, 2012

Dear Colleague:

I am writing to request your input on the attached survey: *Information Needs for Arctic Black Carbon*. The purpose of this survey is to inform the development, accessibility and usefulness of value added data products from the International Arctic System for Observing the Atmosphere (IASOA). The results of the survey will be presented in an IPY Knowledge to Action Poster (Session 3A401): ***Structuring Usable Assessment Science – Investigating Frameworks for Assessing Climate Impacts of Black Carbon in the Arctic from the IASOA Network.***

The International Arctic System for Observing the Atmosphere (IASOA) is an International Polar Year (IPY) legacy project involving 9 Arctic research stations whose founding vision was to coordinate pan-Arctic atmospheric observing research. As an IPY-legacy initiative, the network science leads have prioritized relevant and actionable assessment themes, which include understanding the role of black carbon and other short lived climate forcers (SLCF's) on regional climate.

Critiques of assessment and other forms of usable science (e.g. forecasts) have demonstrated that many climate assessment products are not put to use by the intended audience, often because the needs of that audience have not been sufficiently considered in the assessment framework (Cash et al. 2006, Dilling and Lemos 2011). This survey is intended to address this deficiency by gathering requirements about your needs as a potential end user of IASOA black carbon-relevant data products.

The survey should take about 15 minutes to complete thoroughly. I am asking for completed surveys to be returned April 9, 2012. If you play more than one *distinct* role or have more than one distinct application using Arctic black carbon information, please consider completing the survey once for each role so we can better interpret results. Feel free to contact me if you have any questions about the survey or how this information will be used.

Kind Regards,

Sandy Starkweather

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1. **Your Contact Info (Please supply if you are OK with a follow up phone call or email – I won't SPAM. Individual names will not be included with any public information used from this survey.)**

Name: Email: Phone:

2. **Your Domain of Practice (Highlight all that apply):**

Science/Engineering /Advising/ Operations/Management/Education/Regulatory/Policy/Other (specify):

   a. **Your Specific Area of Emphasis or Organization (specify):**

3. **Your Application (Highlight all that apply, please include brief description):**
   - Modeling (Global? Regional? Transport? Etc.?):
   - Model Development:
   - Model Evaluation:
   - Model Initialization and/or Data Assimilation:
   - Forecasting:
   - Instrument Development or Evaluation:
   - Time Series Analysis:
   - Monitoring:
   - Informing Regulations or Policies:
   - Education or Public Understanding:
   - Other (Please describe):

4. **Value Added Information on Arctic Black Carbon (BC) is important for my application (TRUE, FALSE).**

5. **If you responded TRUE to Question 4, please characterize the type of *Value Added Information* that is valuable to you in the table below, following these codes (Otherwise Proceed to Question 7):**

   EV – Essential Value; V – Valuable; ***CV – Contingent Value***; LV – Little Value; NV – Not Valuable

   CV – Contingent Value means that information is only valuable ***if*** it comes along with ***Concomitant Measure(s)*** of other variables or information. If this is the case, please list other variables or information.

Value Add Information	**Value (Highlight One)**	**Concomitant Measure(s), list if applicable**
Radiative forcing signal of BC in the Arctic.	EV, V, CV, LV, NV	
Temperature change signal from BC in the Arctic.	EV, V, CV, LV, NV	
Health impacts of BC in the Arctic.	EV, V, CV, LV, NV	
Sources of BC to the Arctic.	EV, V, CV, LV, NV	

6. **Other *Value Added Information* on Arctic BC that is important to you includes:**

7. **Observational Data on Arctic BC is important for my application (TRUE, FALSE).**

8. **If you responded TRUE to Question 7, please characterize the type of *Observational Data* that is valuable to you in the table below, following these codes (Otherwise Proceed to Question 9):**
   EV – Essential Value; V – Valuable; ***CV – Contingent Value***; LV – Little Value; NV – Not Valuable

   CV – Contingent Value means that information is only valuable ***if*** it comes along with ***Concomitant Measure(s)*** of other variables or information. If this is the case, please list other variables or information.

Observational Data	**Value (Highlight One)**	**Concomitant Measure(s), list if applicable**
Equivalent BC Mass Concentration	EV, V, CV, LV, NV	
BC Mass Concentration	EV, V, CV, LV, NV	
Absorption cross section	EV, V, CV, LV, NV	
Scattering cross section	EV, V, CV, LV, NV	
Single scattering albedo	EV, V, CV, LV, NV	
Condensation nuclei count	EV, V, CV, LV, NV	
Aerosol optical depth	EV, V, CV, LV, NV	
Speciation, BC v. OC	EV, V, CV, LV, NV	
Speciation, Other (please specify):	EV, V, CV, LV, NV	
Surface radiation balance	EV, V, CV, LV, NV	
Surface energy balance	EV, V, CV, LV, NV	
Surface cover characteristics	EV, V, CV, LV, NV	
Meteorology	EV, V, CV, LV, NV	
Precipitation	EV, V, CV, LV, NV	
Cloud cover	EV, V, CV, LV, NV	
Other (please specify):	EV, V, CV, LV, NV	

a. **Spatial Resolution**
- Point (EV, V, CV, LV, NV)
- Gridded (EV, V, CV, LV, NV)
- If gridded, indicate grid size:

b. **Vertical Information**
- Surface measure (EV, V, CV, LV, NV)
- Vertical profile (EV, V, CV, LV, NV)
- Vertical column (EV, V, CV, LV, NV)
- TOA (EV, V, CV, LV, NV)

c. **Temporal Information (Specify or State if it Does Not Apply)**
- Reference Period:
- Raw Data Resolution:
- Value Added-Averaging (Hourly, Monthly, Annual, Other, DNA)
- I require long term data (TRUE/FALSE);
- If TRUE, minimum length of record: __________

9. Please describe the type of uncertainty measures your application requires (Highlight One):

DU – I don't use uncertainty measures with my information;
GM – I use general measures (e.g. highly certain, fairly certain, uncertain);
SM – I use specific measures (e.g. +/- values with confidence intervals)

10. How would you characterize your geographic information needs (Highlight One):

- Global
- Arctic Wide
- Arctic Sub-region (please describe):
- Specific Arctic location (please describe):
- Non-Arctic Region or Location (please describe):

11. I have the Arctic Black Carbon Information that I need (TRUE, FALSE).

- **If FALSE, please list gaps (information type, spatial coverage, time coverage, etc.):**
- **If TRUE, please indicate where you get your information:____________________________________ ____**
    - **I am able to use this information effectively in my application (TRUE, FALSE).**
    - **Why or why not?**

12. Using the rest of this page (or more if needed), please describe <u>other factors</u> that will affect the value of black carbon information for you or your application. These might include, but are not limited to:

- Timeliness of Information (Quasi Real-time, Monthly Updates, Annual Updates, Etc.)
- Data distribution (pushed out through updates or available through websites & portals)
- Your confidence in the information on Arctic Black Carbon
- Your understanding of the technical issues related to Arctic Black Carbon
- Constraints in your organization that affect how technical information can be used
- Having a single authoritative source of information on Arctic Black Carbon
- Access to expertise on Arctic Black Carbon
- Data formats

Thank you for your time!