From action to forcing: a solution-centered view

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Abundance is what you are stuck with; emission is what you can change.

I like the discussion of the "emission-based" and "abundance-based" dichotomy by *Shindell et al.* (2005), because it highlights a disparity between characterization and solution. The (in)famous bar chart by the Intergovernmental Panel on Climate Change (IPCC) shows what we have done to the atmosphere since pre-industrial times. This workshop is about solutions, and I propose that we ought to have another bar chart showing those. In addition, IPCC's chart identifies chemical *species* as the players in the climate game, but any *action* may cause changes in several species. The bar chart needs some revision to change it from "passive voice" (what has been done to us) to "active voice" (what we can do to affect the near and far future), and the ideas presented here are the beginning of that revision. I will need a lot of help from the other participants.

In order to compare costs and benefits of individual actions, we need some integrated measure of quantifying the benefits. The path from action to forcing (Figure 1) is already implicit in many calculations used for greenhouse gases. It does not account for the full complexity of atmospheric chemistry. But the present exercise involves comparing climate and other benefits; it requires simple metrics and first-order estimates, so Figure 1 is a sufficient beginning. We have estimates of varying uncertainty for each of the steps required to get to the "forcing" box.

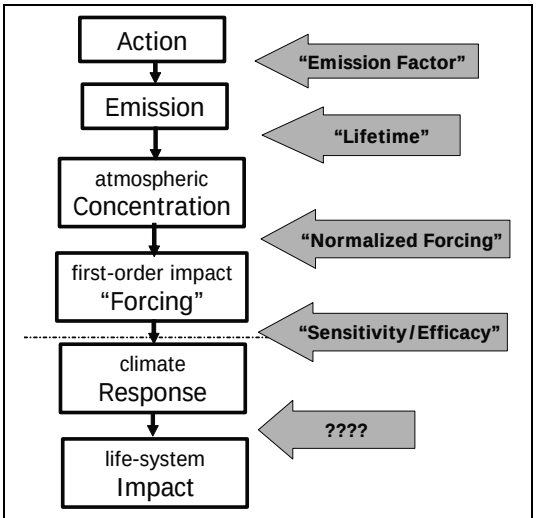

Figure 1: Path from action to impact.

It's typically been assumed that top-of-atmosphere, global-average radiative forcing is a reasonable proxy for climatic impact. This conventional wisdom should be challenged in the coming years, but it will be accepted for most of the present discussion. We would eventually like to step down to the other two boxes, but we lack consensus. Today, we have to stop at the dashed line, or perhaps slightly beyond if a temperature response can be identified.

The action-to-forcing pathway has been used to assess the benefit of many actions that reduce greenhouse gases. For some emitters, short-lived species such as ozone precursors and aerosols account for a large part of the climate forcing. There has been general reluctance to apply the pathway to these short-lived species, mainly because they have more atmospheric complexity than long-lived greenhouse gases. However, given the need for simple and understandable metrics, the thought experiment is worth trying.

For the tricky topic of light-absorbing carbonaceous aerosols (usually called "black carbon"), we have developed estimates for each of the steps leading to direct forcing, as shown in Table 1. In

the interests of objectivity, we have not used any of our own model results, instead compiling those of others. We hope that the notoriously uncertain optical properties of carbonaceous aerosols are brought closer to resolution with an extensive review (*Bond and Bergstrom, 2005*). There is still a lot of uncertainty, but we hope that the table shows where it lies. The issue of offsetting potential warming by non-absorbing "organic" carbon and by indirect (cloud) forcing is a serious one and should be addressed in the immediate future.

From tabulations like these, we can determine which parameters need further study in order to gain a more certain understanding of the link between action and forcing. It is also possible to derive a direct global warming potential—or "global forcing potential"—for aerosols. That for black carbon is about **700** times that of CO_2 over 100 years, and about **2000** times that of CO_2 over 20 years. Although preliminary and uncertain, these are the some of the tools we need to weigh climate and other benefits on the same scale.

Table 1. Estimates for the first three steps in Figure 1, for "black carbon." Emission factors from *Bond et al.*, 2004; others compiled by *Bond and Sun*, 2004.

Sample emission factors (g/kg)	**Central estimate**	**Range**
Sample emission factors (g/kg)		
Pulverized coal w/ESP	$2x10^{-4}$	$1x10^{-5}$-$3x10^{-3}$
Modern diesel vehicle	1	0.5-1.6
Wood cookstove	1.4	0.2-3.4
Lifetime (days)	5.5	2.4-8.4
Normalized forcing (W/g)	1800	1100-4100

Once we can link action and forcing, we can go back to the new bar chart. It is possible to estimate *direct* (and indirect) *forcing commitment* of specific actions over 20 years or 100 years. Forcing potentials are needed for all species, and they are very crude as yet; they need input from more experts. The emission-based, future-focused view complements the traditional species-based characterization. Again, our pathway may not reflect some of the physical complexities that climate scientists need to refine in the coming years. But it can foster useful discussions of multiple benefits, and it might prevent us from chasing the biggest red herrings.

References

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