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COMMENTARY:

Planetary vital signs

Stephen Briggs, Charles F. Kennel and David G. Victor

After Paris, policymakers will need new goals for protecting the climate. Science can help with a basket of measures because ‘climate change’ isn’t just about temperature.

For too long, diplomats and scientists have been avoiding the need to take a fresh look at the goals for managing global climate change[1]. Over the past decade, nearly all policy efforts have been unchanged in their focus on the goal of stopping warming at 2 degrees C above pre-industrial levels[2]. Insofar as there has been much scientific discussion about setting goals, it has been to look at even less achievable, stricter standards, such as 1 degree or 1.5 degrees[3]. Actual progress in cutting emissions has been slow, a sobering fact that is unlikely to change — even with all the momentum generated by the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) to be held later this year in Paris.

Using temperature to set goals, although simple and intuitive, barely captures the range of real dangers that arise as the planet warms[4]. Average surface temperature, the standard measure, does not reveal the much larger amount of heat building up at various depths in the oceans[5]. Policymakers who are already planning for a warmer world are not worried principally by rising temperature *per se*; instead, they are increasingly focused on more tangible impacts such as rising sea level, extreme weather, damage to crops and other hazards all caused by the same physical processes that give rise to increased average temperatures.

Vital signs

A new list of ‘planetary vital signs’ is needed to help guide policymakers towards realistic goals that also reflect the full range of dangers lurking with climate warming. Crafting better indicators is a task that must begin now, so that useful answers are ready when diplomats need them. Realistically, the diplomatic script for COP21 is already written, and there is no space for complex and indeterminate scientific debates at this late hour. But after Paris it will become clear that the goal of stopping warming at some pre-determined temperature may be helpful as a proxy for cumulated emissions but is only one crude measure of the planet’s health. Politicians will need access to a wider range of vital signs to understand the full range of consequences of climate change and to measure practical progress in implementing policies. Over the next two years, the scientific community can organize a coherent suite of indicators.

There are many lists of indicators already. The Global Climate Observing System[6] has identified several dozen essential climate variables that should be monitored in support of climate science. The US Environmental Protection Agency’s list[7] contains four indicators relating to greenhouse gases, four relating to oceans, six to weather and climate, six to snow and ice, five to health and society, and five to ecosystems. The United Nations’ new sustainable development goals, to be adopted in September, include some measures linked to climate[8,9].

Creating indicators that are useful for policymakers requires a strategy that integrates practical policy needs with the best science. It must include policy goals that reflect what policymakers actually control — and thus what they can manage. And it must begin with the climate impacts that the policymakers most fear — and thus where they must prepare for change. The left column of Table 1 offers an illustrative first draft. A high priority after Paris, one that requires a mandate from the Paris meeting itself, is to convene a process that would crystallize climate policy concerns into a manageable first column for Table 1.

Turning column 1 into a practical programme requires a careful assessment of what can be measured. In column 2 we show proxies for each of the phenomena that can be measured today. Some of these measures, such as temperature and sea level, have been mainstays of the climate policy debate. They have improved incrementally as scientists learn more about how to make reliable measurements and aggregate them into global indicators, such as in temperature[10]. Other indicators are more recent entrants — such as the incidence of extreme (three-sigma) temperature events[11,12] and the reliable operation of the Argo float network that allows for systematic measurement of ocean heat content (OHC)[13]. Focusing on climate dangers that matter to people and policy could lead to persuasive indicators that reflect the incidence of heat stress[14], exposures of populations[15] and even the monetary cost of climate extremes.

Table 1 | Present and future indicators for climate policy and impact.

Phenomenon	Best measures today	Possible future measures
Changing weather patterns	Global average temperature	Regional indices
Extreme weather	Incidence of three-sigma temperature events	Cost of extreme weather events
Threats to coastal ecosystems and infrastructure	Sea level rise, globally averaged	Local sea level rise and probability of damaging storm surges
Greenhouse warming	Atmospheric concentrations of greenhouse gases	Anthropogenic warming potential
Energy addition to climate system	Ocean heat content	Top-of-atmosphere radiation balance

A research strategy

A key task for science is to distinguish columns 2 and 3, as that will guide the indicators that will be needed in future. Research, measurement programmes and probably new instruments will be needed. Indeed, the growing capacity of today's satellites, observational networks and analysis techniques makes it possible to support a basket of vital signs much better than just a few years ago. Sea level, an excellent integrator of many aspects of change (ocean warming, mass loss from the ice sheets, glacier melting and groundwater changes) is measured accurately and globally by a series of satellite altimeters that goes back over 20 years and will continue into the future owing to the Sentinel 6 series of satellite missions. Another example is atmospheric CO_2; in addition to over 50 years of atmospheric CO_2 observations from Mauna Loa, we now monitor from space the spatial distribution of atmospheric CO_2 worldwide. With investment it would be possible to measure with adequate precision the energy imbalance at the top of the atmosphere, which would be the best measure for the actual human perturbation of the climate system — a measure that might even replace global average temperature as a leading indicator.

Vital signs do not commit nations to collect the same observations *ad infinitum*. All observational programmes are subject to human and institutional failure: budgets change, spacecraft fail, research campaigns only last a finite time; that is reality. There are technical challenges as well; data come from different platforms and instruments, and data sets have gaps and discontinuities in coverage. It is also essential to capture the benefits of technological progress by changing platforms and instruments. The climate science community is skilled at using models and statistical methods to blend data from such diverse, incomplete and intermittent sources.

The politics of measurement

The political use of goals requires not just that they be bold and inspirational but also that real governments be able to plan around them. Indeed, studies of conspicuous goals in other areas of international environmental policy show that goals must be visible to inspire political action but also plausibly within reach of what governments can implement[16,17]. This connection to practicality is missing from the 2 degree goal; it is also missing, to a lesser extent, from goals expressed in terms of a 'budget'[18] of cumulative allowable emissions of CO_2.

A better model, for example, is the set of the eight bold Millennium Development Goals (MDGs) adopted by the United Nations in 2000 with goals set for 2015. By themselves the MDGs did not inspire the practical actions needed to achieve them. The eight goals had to be turned into 21 targets and 60 detailed indicators — measurable, practical and connected to what governments, non-governmental organizations, aid organizations and others could actually deliver[19]. A new set of MDGs, reframed for the broader effort to achieve sustainable development, was adopted in September 2015 by the United Nations[20]. A plan for climate change rooted in a diversity of goals and targets is overdue.

A policy–science strategy for goals must focus on a list that is small enough to be relevant yet large enough to reflect the diversity of causes and consequences of the changing climate. It is often said that the public won't pay attention to more than one indicator — indeed, that simplistic logic has inspired, in part, the political support for 2 degrees. But this view of politics, and of what politicians and the public can comprehend, has little basis in reality. Policymakers regularly deal with complex policy challenges, such as employment and economic growth, for which they must rely on many indicators. In health, patients can have maladies such as cancer without running a temperature; vital signs for humans have many dimensions, as do vital signs for the planet.

Getting serious about climate change requires wrangling not just with the agenda that will dominate diplomacy on the road through Paris. The cost of emission goals, sharing the burdens and crafting new international funding mechanisms are all important. The run-up to Paris is auspicious: for the first time in 18 years, diplomats seem likely to leave a major climate conference with a new deal in hand. But that deal will be just the first step. Future steps will need strategy — starting with goals. We in the expert community must help them to understand the limits of the current 2 degree goal, and how better goals might be crafted. ❐

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