The Difference between Deterministic and Probabilistic Detection of Emission Changes: Toward the Use of the Probabilistic Verification Time Concept

Tatiana Ermolieva, Matthias Jonas, Yuri Ermoliev, Marek Makowski*

International Institute for Applied Systems Analysis,
Schlossplatz 1, A-2361 Laxenburg, Austria
**Email: ermol@iiasa.ac.at*

Abstract

The assessment of greenhouse gases (GHGs) emitted to and removed from the atmosphere is high on both political and scientific agendas internationally. The Kyoto Protocol to the UN Framework Convention on Climate Change, due in 2008–2012, contains the first legally binding commitments to limit or reduce the emissions of six GHGs or groups of gases (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6). For Annex I Parties, the targets agreed upon under the Protocol add up to a decrease in GHG emissions of 5.2% below 1990 levels in terms of CO_2 equivalents.

We see two major problems that require a scientific solution before the Kyoto Protocol is extended beyond 2012. Firstly, under the Protocol each government calculates how much CO_2, CH_4, N_2O, etc., its country emits by adding together estimated emissions from individual sources. These so-called "bottom-up" estimates have long been accepted by atmospheric scientists, even though they have never been independently verified. However, in the meantime, scientists have convincing evidence that the emission figures reported by many countries are wrong (House et al., 2003; Nilsson et al., 2003; Rödenbeck et al., 2003).

Secondly, a technique that allows detecting highly uncertain emission changes (also called emission signals) that are reported since and with reference to 1990 is not in place. For almost all countries the emission changes agreed upon under the Protocol are smaller than the uncertainty that underlies their combined (CO_2 equivalent) emissions. Clearly, such a technique would be the key to determine the "make or break" of compliance, especially in cases when countries claim the fulfillment of their reduction commitments.

The focus of our study is on the second problem. Jonas *et al.* (2004) distinguish between preparatory signal detection (SD), midway SD, and SD in retrospect, of which the first is most advanced. Preparatory SD allows generating useful information beforehand as to how great uncertainties can be depending on the level of confidence of the emission signal, or the signal one wishes to detect and the risk one is willing to tolerate in not meeting an agreed-upon emission limitation or reduction commitment. We are aware of at least six different preparatory SD techniques, some of which have been presented at the 1st Workshop on Uncertainty on GHG Inventories (Gillenwater *et al.*, 2007; Jonas and Nilsson, 2007; Nahorski *et al.*, 2007). These techniques need to be scrutinized further before a discussion on which of them to select can take place.

The aim of our study is to support a future selection by advancing our insights on the robustness (validity) of these techniques. With the exception of two, these techniques are formulated (in a first step) deterministically. Here, we revisit one of them, the so-called verification time (VT) concept,[1] which has been put on a probabilistic basis by Hudz (2002) to address the detection of net carbon emission changes at the global scale. The VT concept permits assessing emission changes, which are characterized by uncertainty distributions, in terms of their verification times. The VT (more correctly: detection time) is the time until an emission signal outstrips its underlying uncertainty.

To fully explore the pros and cons of this technique, we investigate emission systems under a range of dynamics-versus-uncertainty conditions on a multi-year time scale. For emission systems that exhibit small dynamics and great uncertainties (e.g., comparable to emission signals, as is typical for many ‘land use/change and forestry systems’), the probabilistic VT technique should be given preference over the deterministic one as probabilistic and deterministic VTs can differ considerably.

For emission systems that exhibit strong dynamics and small uncertainties (as is typical for many fossil fuel emissions), the difference between the probabilistic and deterministic VTs is small and appears irrelevant in comparison with a base year-to- commitment year/period time span. However, proceeding deterministically and characterizing emission changes by equal-sided (symmetric) uncertainties (as practiced by the IPCC) can leave valuable information unutilized.

For emission systems of any dynamics, if subjected to commitment conditions, the uncertainty becomes paramount if agreed-upon emission limitation or reduction commitments are too small (as is the case under the Protocol). This situation is also typical for many emission reduction projects. Probabilistic and deterministic VTs can differ markedly.

We illustrate the ‘economic value’ of using the probabilistic VT concept for pricing and trading emission credits. With the help of the sequential bilateral trading scheme proposed by Ermoliev *et al.* (2000) and Godal (2000), we show that in order to achieve detectable emission reductions under commitment conditions, Parties to the Protocol are better off investing in the reduction of uncertainty in addition to striving for an emission target that undershoots the committed target. The application of the probabilistic VT concept can be shown to be cost-effective. In practical situations, the estimation of the probabilistic VT may be complicated by scarce or missing data. To overcome this problem, we discuss methodological challenges related to combining scarce information with expert opinion and simulation models.

---

[1] The term ‘verification time’ was first used by Jonas *et al.* (1999) and by other authors since then. Actually, a more correct term is ‘detection time’. The detection of emission changes does not imply the verification of emissions. The implicit thinking behind the continued use of ‘verification time’ is that signal detection should, in the long-term, go hand-in-hand with bottom-up/top-down verification (see Jonas *et al.*, 2004: Section 2.3).