Uncertainty in Greenhouse Gas Inventories:

How to Go About It

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Coping with Uncertainty (CwU) Workshop 2007:
Robust Decisions

IIASA, Austria; 10–12 December 2007

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2^{nd} International Workshop on *Uncertainty in GHG Inventories*

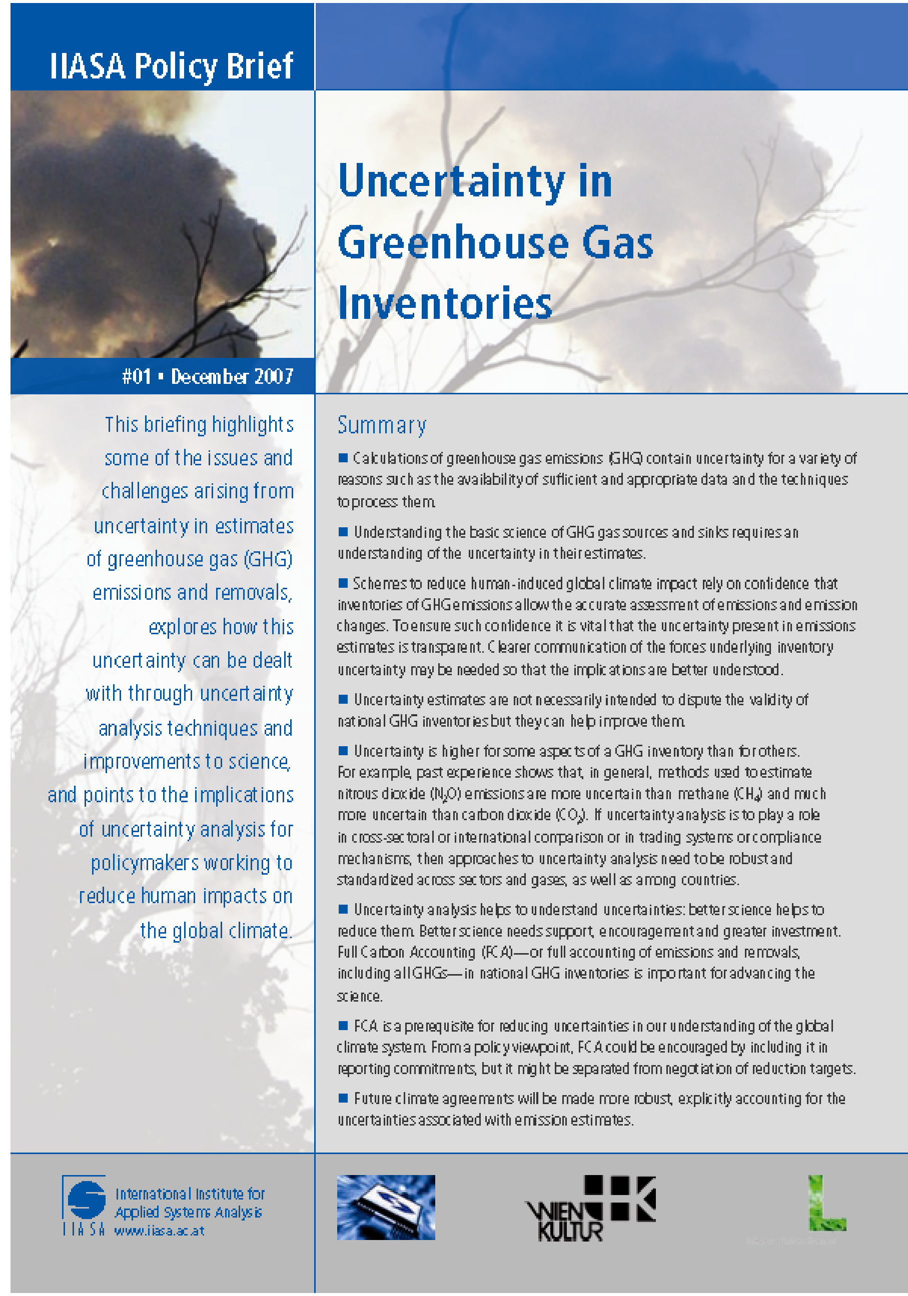
IIASA, Austria; 27–28 September 2007

Web: http://www.ibspan.waw.pl/ghg2007/

UN Climate Change Conference 2007
Bali - Indonesia
3–14 Dec. 2007

CwU '07 Workshop

1. Background: SPM Summary for Policymakers



IIASA Policy Brief

#01 • December 2007

Uncertainty in Greenhouse Gas Inventories

This briefing highlights some of the issues and challenges arising from uncertainty in estimates of greenhouse gas (GHG) emissions and removals, explores how this uncertainty can be dealt with through uncertainty analysis techniques and improvements to science, and points to the implications of uncertainty analysis for policymakers working to reduce human impacts on the global climate.

Summary

- Calculations of greenhouse gas emissions (GHG) contain uncertainty for a variety of reasons such as the availability of sufficient and appropriate data and the techniques to process them.
- Understanding the basic science of GHG gas sources and sinks requires an understanding of the uncertainty in their estimates.
- Schemes to reduce human-induced global climate impact rely on confidence that inventories of GHG emissions allow the accurate assessment of emissions and emission changes. To ensure such confidence it is vital that the uncertainty present in emissions estimates is transparent. Clearer communication of the forces underlying inventory uncertainty may be needed so that the implications are better understood.
- Uncertainty estimates are not necessarily intended to dispute the validity of national GHG inventories but they can help improve them.
- Uncertainty is higher for some aspects of a GHG inventory than for others. For example, past experience shows that, in general, methods used to estimate nitrous dioxide (N_2O) emissions are more uncertain than methane (CH_4) and much more uncertain than carbon dioxide (CO_2). If uncertainty analysis is to play a role in cross-sectoral or international comparison or in trading systems or compliance mechanisms, then approaches to uncertainty analysis need to be robust and standardized across sectors and gases, as well as among countries.
- Uncertainty analysis helps to understand uncertainties: better science helps to reduce them. Better science needs support, encouragement and greater investment. Full Carbon Accounting (FCA)—or full accounting of emissions and removals, including all GHGs—in national GHG inventories is important for advancing the science.
- FCA is a prerequisite for reducing uncertainties in our understanding of the global climate system. From a policy viewpoint, FCA could be encouraged by including it in reporting commitments, but it might be separated from negotiation of reduction targets.
- Future climate agreements will be made more robust, explicitly accounting for the uncertainties associated with emission estimates.

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1. Background: The SPM in a general context

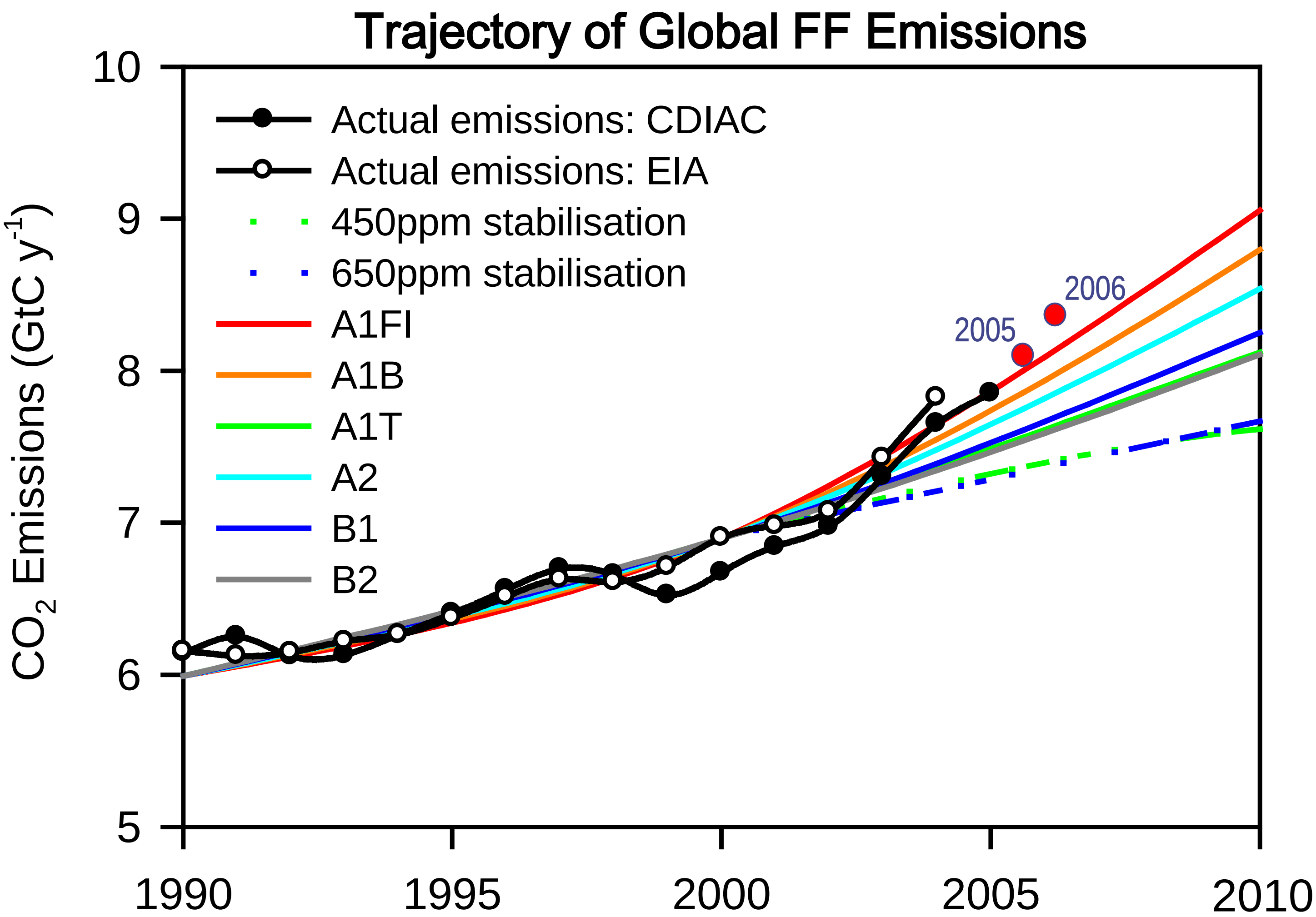
Given that policy/decision-makers prefer unstructured certainty over structured uncertainty, let's ask two simple questions (Q):

Q1. Do we have an uncertainty problem?

Q2. If we do, can we reduce the problem?

The answers are: 'No/Yes' and 'Yes—but uncertainty cannot be eliminated'!

2. Q1: Do we have an uncertainty problem?



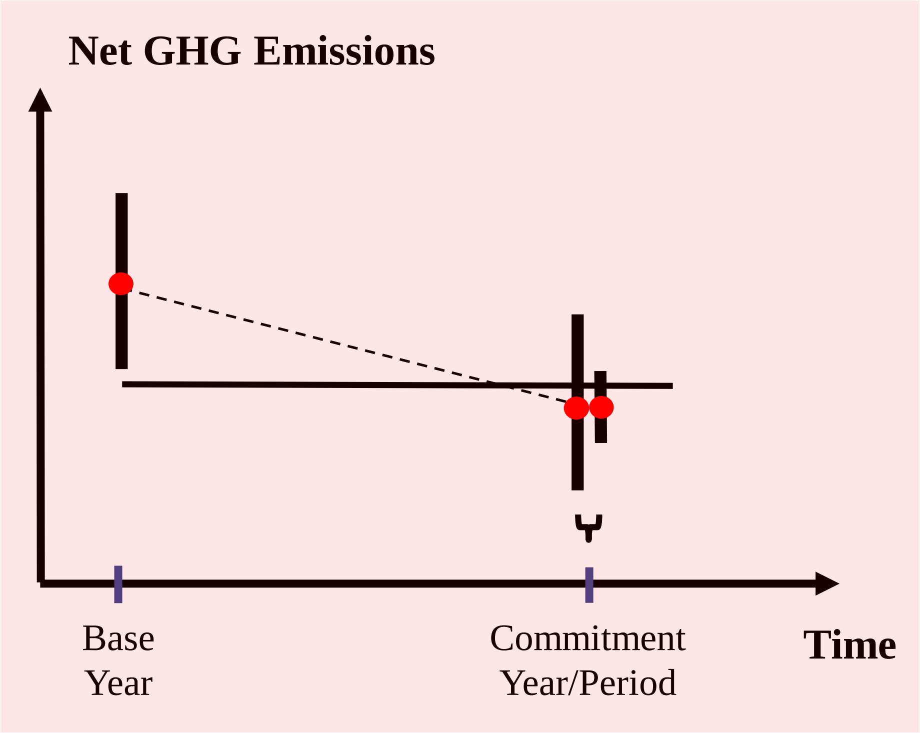
50-year constant growth rates to 2050:

B1 1.1%,
A1B 1.7%,
A2 1.8%
A1FI 2.4%

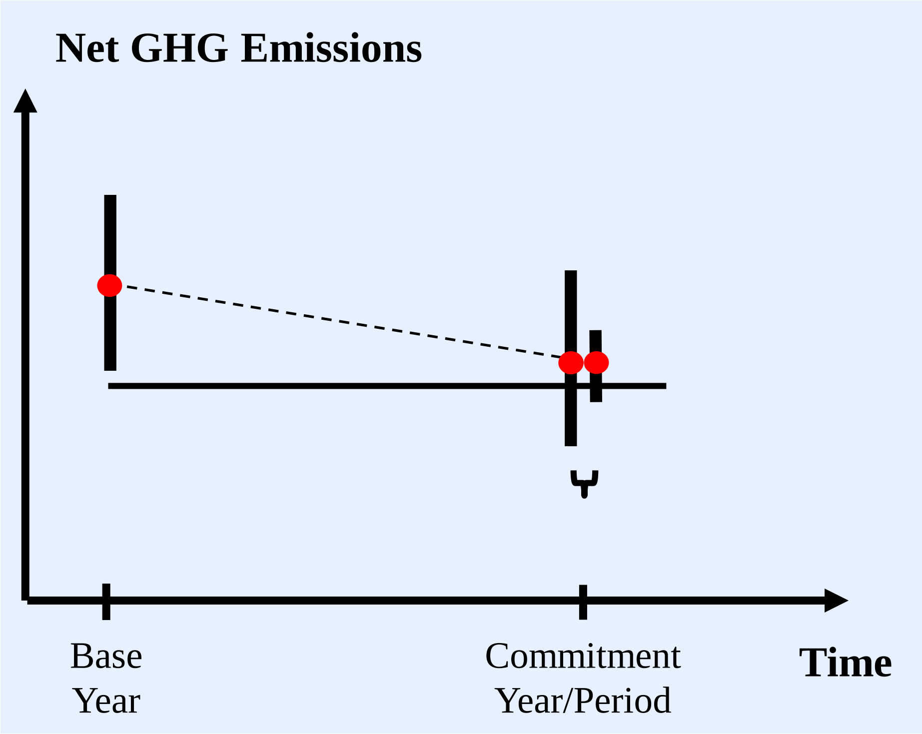
Observed for 2000–2006: 3.3%

Source: Canadell *et al.* (23 Oct 2007); modified

2. Q1: Do we have an uncertainty problem?



Compliance under uncertainty



Uncertainty matters!

Source: Jonas & Nilsson (2007); modified

2. Q1: Interim summary

1) The gigantic task to be tackled: We have not yet managed to swing round our life style and increased use of fossil fuels!

   To recall: 20% of the population in the developed world is responsible for about 80% of the cumulative carbon emissions since 1751. And since a few years, we are back to producing more global wealth by using more carbon intensive energy systems than we did in the past.

2) This task can be tackled by setting binding emission targets. It is at this point in time when uncertainty begins to become important!

3. Q2: Can we reduce the uncertainty problem?

In our answer we consider two perspectives:

→ bottom-up/top-down

→ 'one-by-one versus altogether'

3. To Q2: Bottom-up/top-down (I)

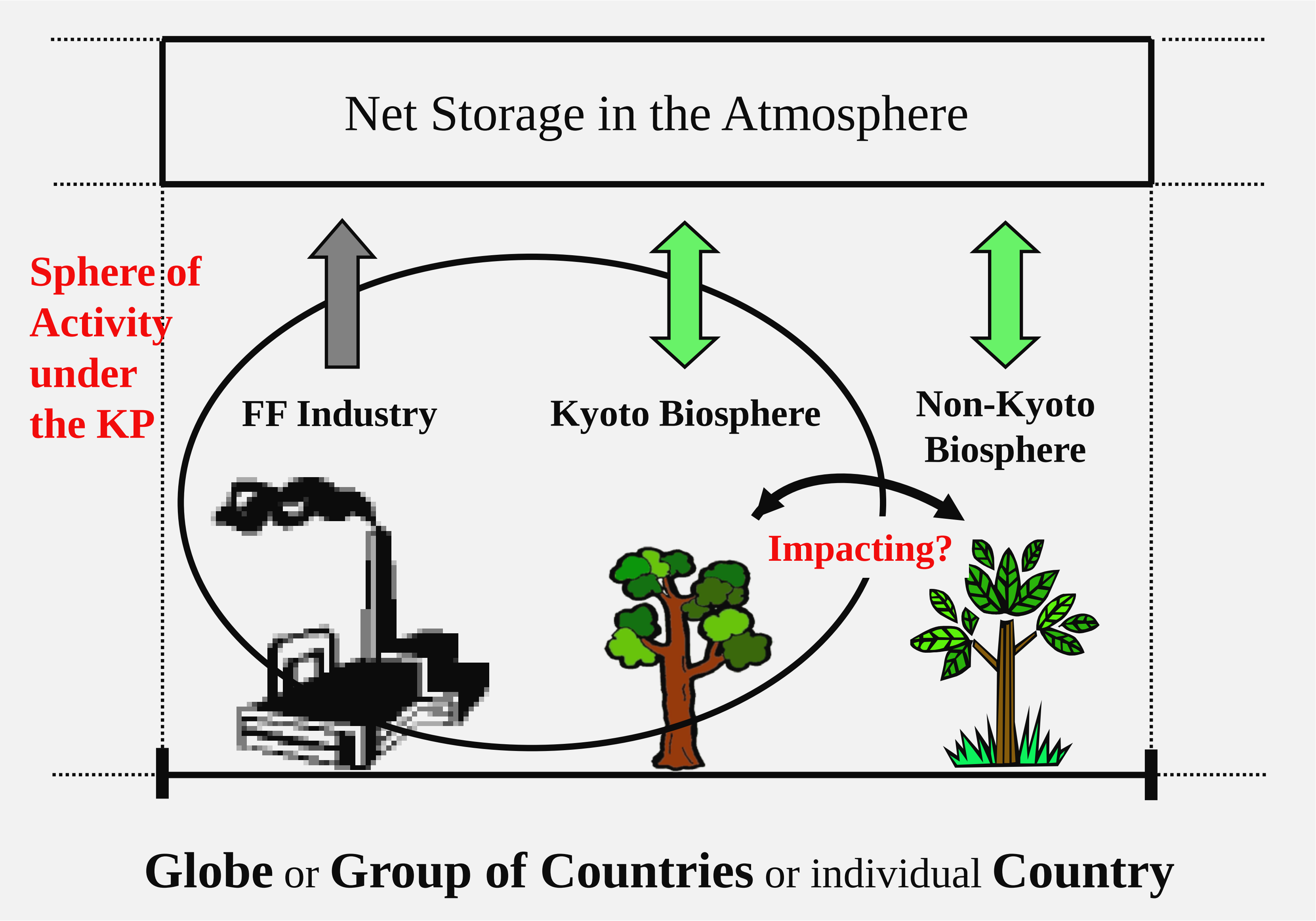
SPM (2007: p. 1):

Full Carbon Accounting (FCA) is a prerequisite for reducing uncertainties in our understanding of the global climate system. From a policy viewpoint, FCA could be encouraged by including it in reporting commitments, but it might be separated from negotiation or reduction targets.

→ basis for accounting

→ verification

3. To Q2: Bu/Td - basis for accounting (II)



Source: Jonas & Nilsson (2007); modified

3. To Q2: Bu/Td – verification (III)

Global CO_2 Budget for the 1990s (Pg C/yr):

	Global					Regional
	Flux	± 1σ	Confidence	Bottom-up	Top-down	Confidence
Atmospheric increase	3.2	± 0.1	High		Measurements (CO_2, $\delta^{13}C$, O_2:N_2, ^{14}C, …)	Acceptable
Emissions (fossil fuel, cement)	6.4	± 0.4	High	Statistics (energy, …)	^{14}C ideal to measure CO_2 from burning fossil fuels	Acceptable – High
Land–atmosphere flux	- 1.4	± 0.7	Low	Statistics (forest, agro, …) + Modeling	$\delta^{13}C$ and O_2:N_2 allow to partition land and ocean uptake (independent uncertainties)	Low (> 100%) Gap between bottom-up and top-down accounting!
Ocean–atmosphere flux	- 1.7	± 0.5	Low	Measurements (ΔpCO_2, ^{13}C, …) + Modeling		Low

Sources: Battle *et al.* (2000); Prentice *et al.* (2001); House *et al.* (2003); Karstens *et al.* (2003); Levin *et al.* (2003); Gregg (2006)

3. To Q2: One-by-one versus altogether (Ia)

SPM (2007: p. 1):

Uncertainty is higher for some aspects of a GHG inventory than for others. … If uncertainty analysis is to play a role in cross-sectoral or international comparison or in trading systems or compliance mechanisms, then approaches to uncertainty analysis need to be robust and standardized across sectors and gases and between countries.

3. To Q2: One-by-one versus altogether (Ib)

SPM (2007: p. 3):

Improving inventories requires one approach: improving emissions trading mechanisms another. Inventories will be improved by *increasing* their scope to include FCA. In contrast, one option for improving emissions trading mechanisms would be to *reduce* their scope.

3. To Q2: One-by-one versus altogether (II)

Class	Relative Uncertainty [%] for 95% CI
1	0 – 5
2	5 – 10
3	10 – 20
4	20 – 40
5	> 40 (40 – 80)

FF CO_2

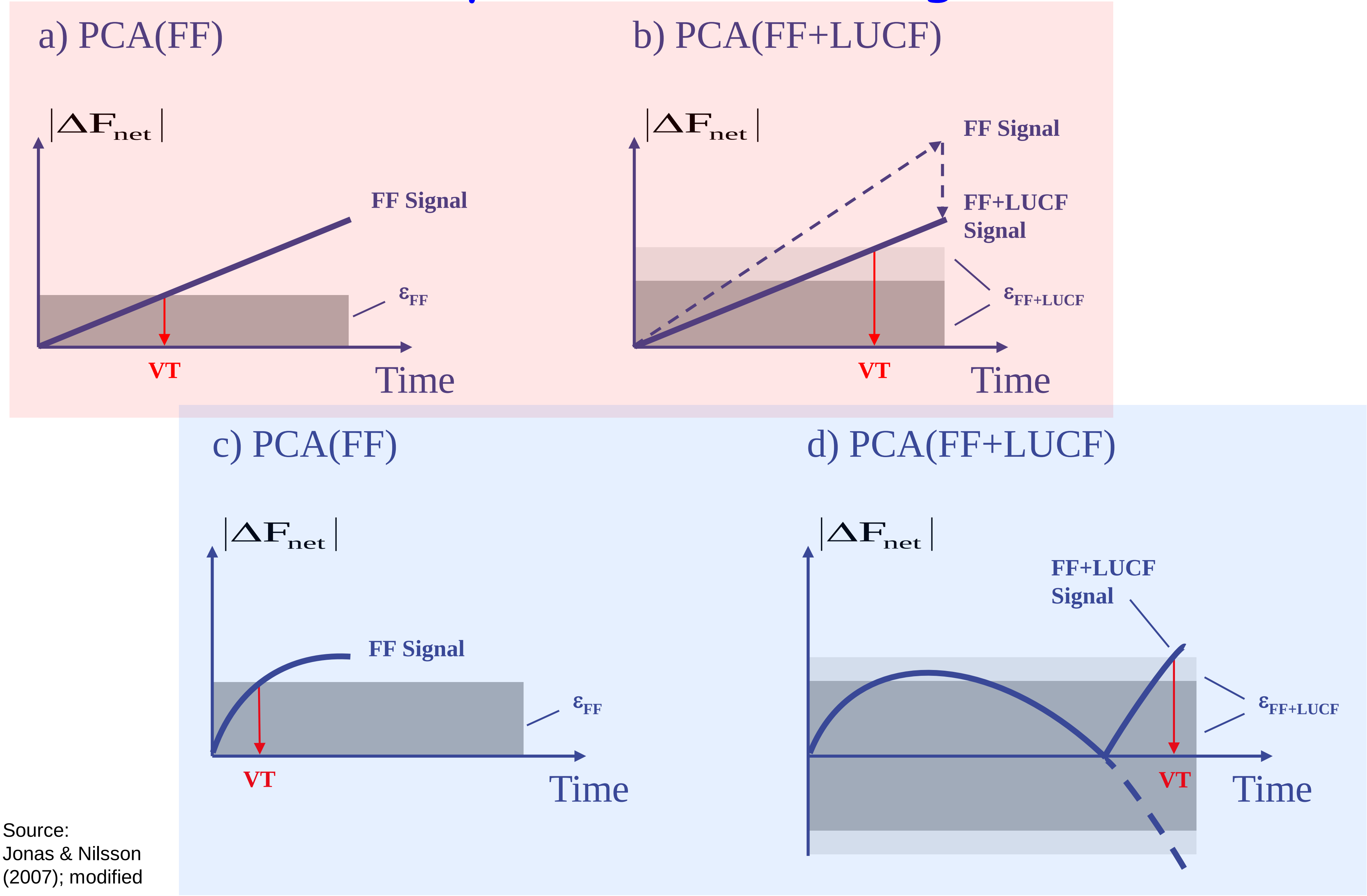
All Kyoto gases

+ LULUCF

net terrestrial

Source: Jonas & Nilsson (2007); modified

3. To Q2: One-by-one versus altogether (III)



Source: Jonas & Nilsson (2007); modified

2. Q2: Interim summary

1) The KP must be expanded to include FCA.
2) Don't split the biosphere which results in compromising verification top-down.
3) Commit to full carbon (GHG) reporting in compliance with strict conservation principles; but set binding reduction targets only for FF related GHGs initially.
4) Don't pool sub-systems and/or GHGs with different relative uncertainties (characterized in terms of classes); treat them individually.

4. Uncertainty analysis techniques (I)

SPM (2007: p. 2):

There is a clear rationale for conducting and improving uncertainty analysis.

First, uncertainty analysis can facilitate the comparison of emissions and emission changes across companies, sectors, or countries …

Second, uncertainty assessment helps to identify the most prudent opportunities for improving the methods for estimating GHG emissions and emission changes.

Third, uncertainties play a role in determining whether or not commitments on GHGs are credibly met. …

4. Uncertainty analysis techniques (II)

1: Critical relative uncertainty (CRU)

2: Verification (detection) time (VT)

3: Undershooting (Und)

4: Undershooting and VT (Und&VT) combined

5: Adjustment of emissions (GSC #1)

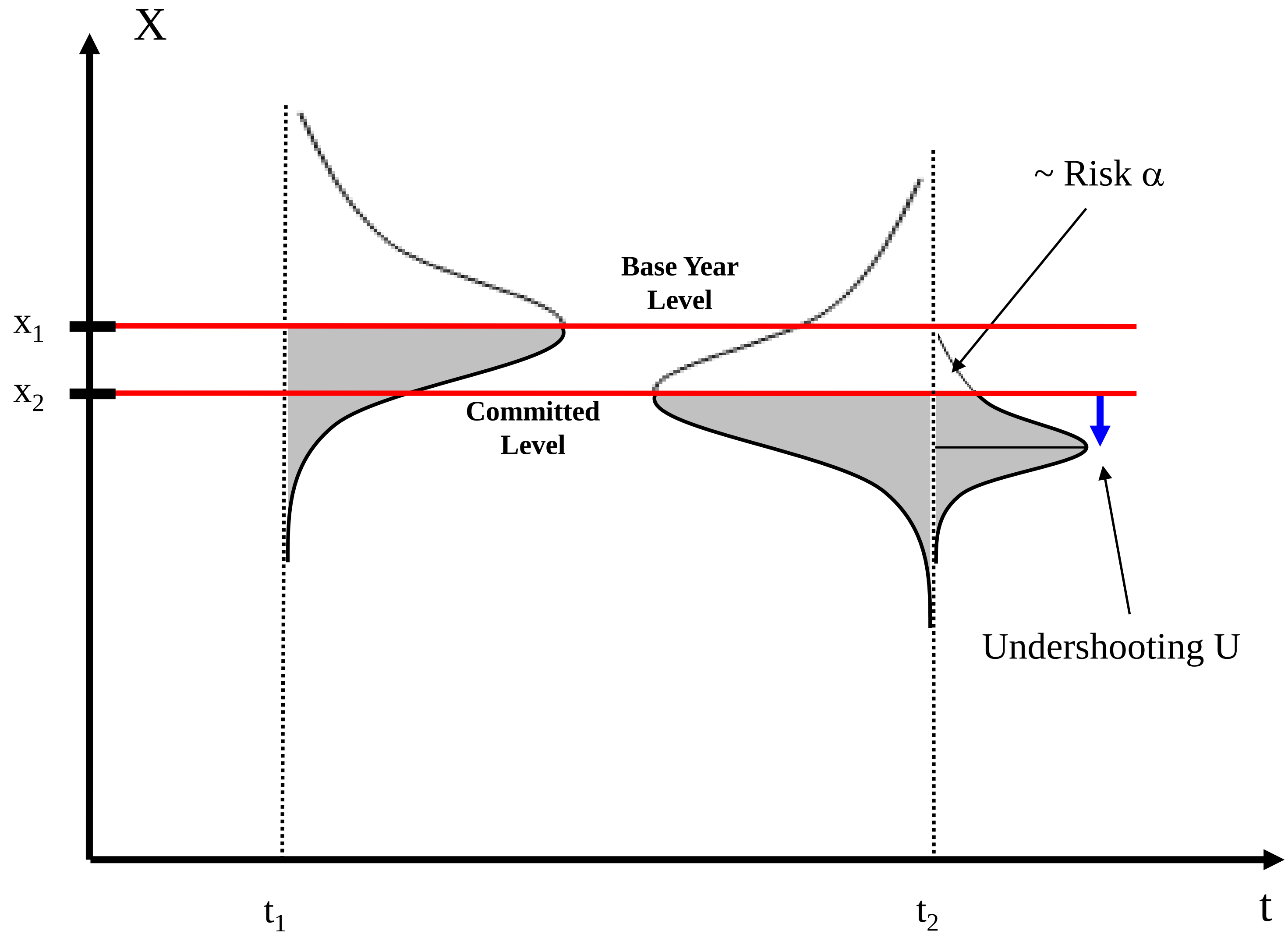
6: Adjustment of emission changes (GSC #2)

4. Uncertainty analysis techniques (III)

Taken into account by the technique	Preparatory SD Technique					
	CRU	VT	Und	Und & VT	GSC #1	GSC #2
Trend uncertainty			✓			✓
Total uncertainty	✓	✓		✓	✓	
Intra-systems view			✓			✓
Intra-systems view but suited to support inter-systems (e.g., top-down) view	✓	✓		✓	✓	
Emissions gradient between t_1 and t_2		✓		✓		
Detectability of emission signals	✓	✓		✓		
Undershooting			✓	✓		
Upward adjustment of reported emissions					✓	✓
Risk with reference to the concept of significance			✓		✓	✓
Risk with reference to the concept of detectability				✓		

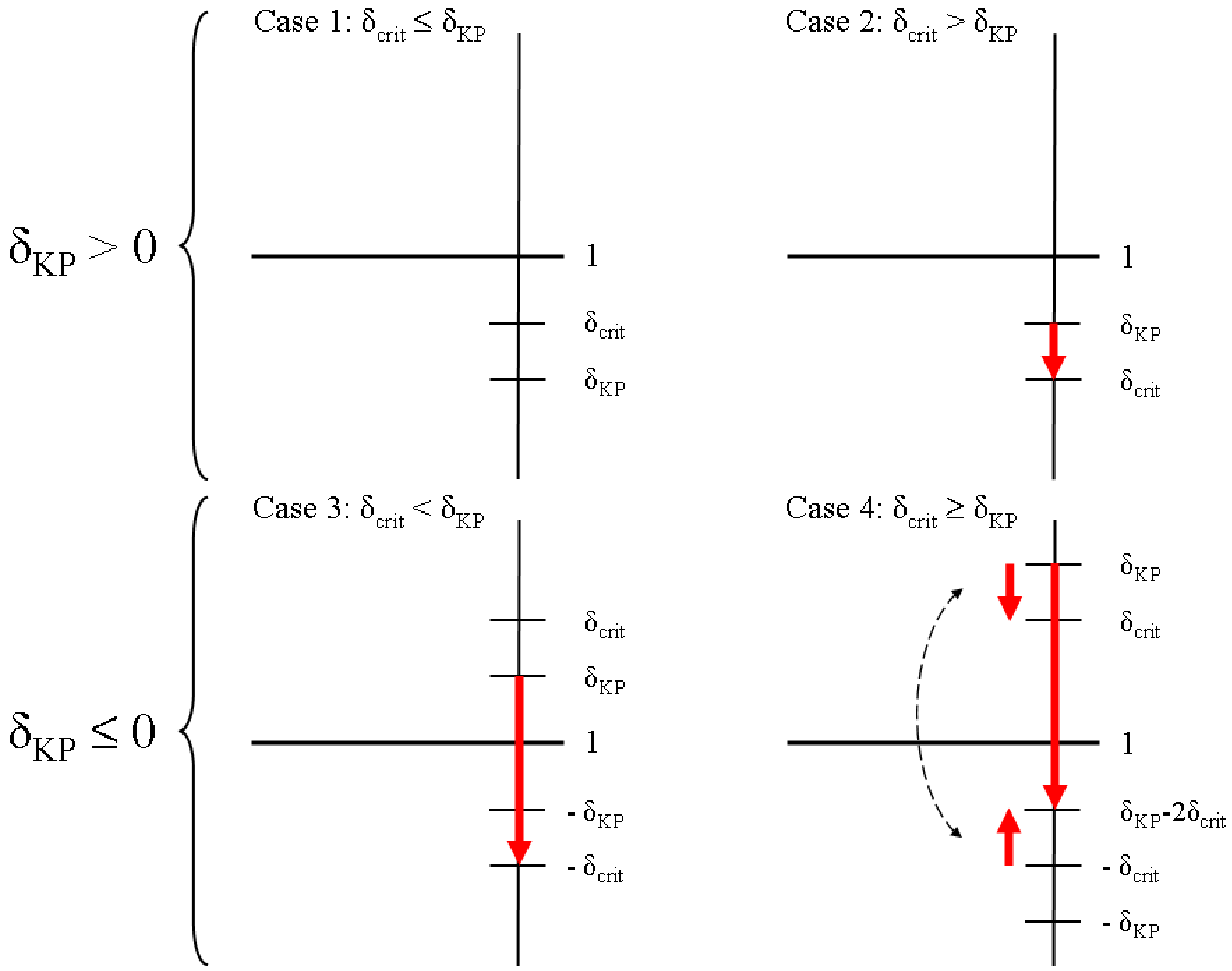
Source: Bun (2007); modified

4. Techniques in Detail: Und (I)



Source: Jonas and Nilsson (2007); modified

4. Techniques in Detail: Und&VT (I)



Source: Hamal (2007)

4. Techniques in Detail: Und (II)

Given	Und and GSC #2 (Reduction)
Kyoto commitment δ_{KP}	Risk $\alpha \downarrow$, Conf. $(1-\alpha) \uparrow$ $\Rightarrow$ Undershooting $\uparrow$, Adjustment $\uparrow$ for any uncertainty ρ
Kyoto commitment δ_{KP}	Unc. $\rho \uparrow$ $\Rightarrow$ Undershooting $\uparrow$, Adjustment $\uparrow$ for any risk α and conf. $(1-\alpha)$
Uncertainty ρ and risk α or confidence $(1-\alpha)$	$\delta_{KP} \downarrow$ $\Rightarrow$ Undershooting $\uparrow$ but modified Kyoto target $\downarrow$; Adjustment $\uparrow$ *) *) Adjustments constant if prior agreement = 0

4. Techniques in Detail: Und&VT (II)

Given	Und&VT and GSC #1
Kyoto commitment δ_{KP}	$\left.\begin{array}{l}\text{Risk } \alpha \downarrow \\ \text{Conf. } (1-\alpha) \uparrow\end{array}\right\} \Rightarrow \left\{\begin{array}{l}\text{Undershooting} \uparrow \\ \text{Adjustment} \uparrow\end{array}\right.$ for any uncertainty ρ
Kyoto commitment δ_{KP}	Unc. $\rho \uparrow \Rightarrow \left\{\begin{array}{l}\text{Undershooting} \uparrow \\ \text{Adjustment} \uparrow\end{array}\right.$ for any risk α and conf. $(1-\alpha)$
Uncertainty ρ and risk α or confidence $(1-\alpha)$	$\delta_{KP} \downarrow \Rightarrow \left\{\begin{array}{l}\text{Und} \uparrow\uparrow \text{ but constant modified Kyoto targets } ^{*)} \\ \text{Adjustment} \uparrow\uparrow \ ^{**)}\end{array}\right.$ *) Except for a-priori detectability **) Adjustments constant if prior agreement = 0

5. Conclusions

- If the post-Kyoto policy process moves toward binding emission reduction targets, uncertainty needs to be considered.
- However, uncertainty analysis has to be carried out in a well-defined framework. Establishing this framework is an obligation that scientists have to meet.
- Still to be accomplished: Preparatory uncertainty analysis techniques exhibit 'peculiarities' that are related to the arbitrary way the KP is designed, not to science! Strategies: 1) Introduce uniform reduction targets under the KP; or 2) set up straightforward rules for introducing differentiated targets (e.g., contraction and convergence).

References

Battle, M., M.L. Bender, P.P. Tans, J.W.C. White, J.T. Ellis, T. Conway and J.R. Francey (2000). Global carbon sinks and their variability inferred from atmospheric O_2 and $\delta^{13}C$. *Science*, **287**, 31 March, 2467–2470.

Bun, A. (2007). The Kyoto Policy Process in Perspective: Long-term Concentration Targets versus Short-term Emission Commitments. Interim Report IR-07-XXX, International Institute for Applied Systems Analysis, Laxenburg, Austria (forthcoming).

Canadell, P., P. Ciais, T. Conway, C. Field, C. Le Quéré, S. Houghton, G. Marland, M. Raupach, E. Buitenhuis and N. Gillett (2007): Recent Carbon Trends and the Global Carbon Budget. Update (as of 23 October) provided by the Global Carbon Budget Team of the Global Carbon Project (http://www.globalcarbonproject.org/). Available at: http://www.globalcarbonproject.org/global/pdf/GCP_CarbonCycleUpdate.pdf.

Hamal, K. (2007). Preparatory Signal Detection for the EU-25 Member States under the EU Burden Sharing—Advanced Monitoring Including Uncertainty (1990–2004). Interim Report IR-07-XXX, International Institute for Applied Systems Analysis, Laxenburg, Austria (forthcoming).

House, J.I., I.C. Prentice, N. Ramankutty, R.A. Houghton and M. Heiman (2003). Reducing apparent uncertainties in estimates of terrestrial CO_2 sources and sinks. *Tellus*, **55B**, 345–363.

Jonas, M., S. Nilsson, R. Bun, V. Dachuk, M. Gusti, J. Horabik, W. Jęda and Z. Nahorski (2004). Preparatory Signal Detection for Annex I Countries under the Kyoto Protocol—A Lesson for the Post-Kyoto Policy Process. Interim Report IR-04-024, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 91. Available at: http://www.iiasa.ac.at/Publications/Documents/IR-04-024.pdf.

Jonas, M. and S. Nilsson (2007). Prior to an Economic Treatment of Emissions and Their Uncertainties under the Kyoto Protocol: Scientific Uncertainties That Must Be Kept in Mind. In: *Accounting for Climate Change: Uncertainty in Greenhouse Gas Inventories—Verification, Compliance, and Trading* [D. Lieberman, M. Jonas, Z.T. Nahorski and S. Nilsson (eds.)]. Springer, Dordrecht, The Netherlands, 75–91. See also: http://www.ibspan.waw.pl/GHGUncert2004/schedule.htm.

Karstens, U., M. Heimann and M.G. Schutz (2003). Regional Modelling of Atmospheric CO and CO_2 Concentrations. In: *CarboEurope Conference "The continental carbon cycle"*. 3rd CarboEurope Conference, 19–21 March, Abstracts, Lisbon, Portugal. Available at: http://www.bgc-jena.mpg.de/public/carboeur/workshop/Poster2/karstens.htm.

Levin, I., B. Kromer, U. Gamnitzer, M. Schmidt and H. Sartorius (2003). Long-term Monitoring of $^{14}CO_2$ in the Atmosphere: Observing Fossil Fuel CO_2 over Europe. In: *CarboEurope Conference "The continental carbon cycle"*. 3rd CarboEurope Conference, 19–21 March, Abstracts, Lisbon, Portugal. Available at: http://www.bgc-jena.mpg.de/public/carboeur/workshop/Poster2/levin.htm.

Prentice, I.C., G.D. Farquar, M.J.R. Fasham, M.L. Goulden, M. Heimann, V.J. Jaramillo, H.S. Kheshgi, C. Le Quéré, R.J. Scholes, D.W.R. Wallace and contributing authors (2001). The Carbon Cycle and Atmospheric Carbon Dioxide. In: *Climate Change 2001. The Scientific Basis* [Houghton, J.T., J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 183–237. Available at: http://www.grida.no/climate/ipcc_tar/.

SPM (2007): Uncertainty in Greenhouse Gas Inventories. IIASA Policy Brief #01, International Institute for Applied Systems Analysis, Laxenburg, Austria, December. Becoming available at: http://www.iiasa.ac.at/Research/FOR/index.html.