Comparison of Preparatory Signal Detection Techniques for Consideration in the (Post-) Kyoto Policy Process

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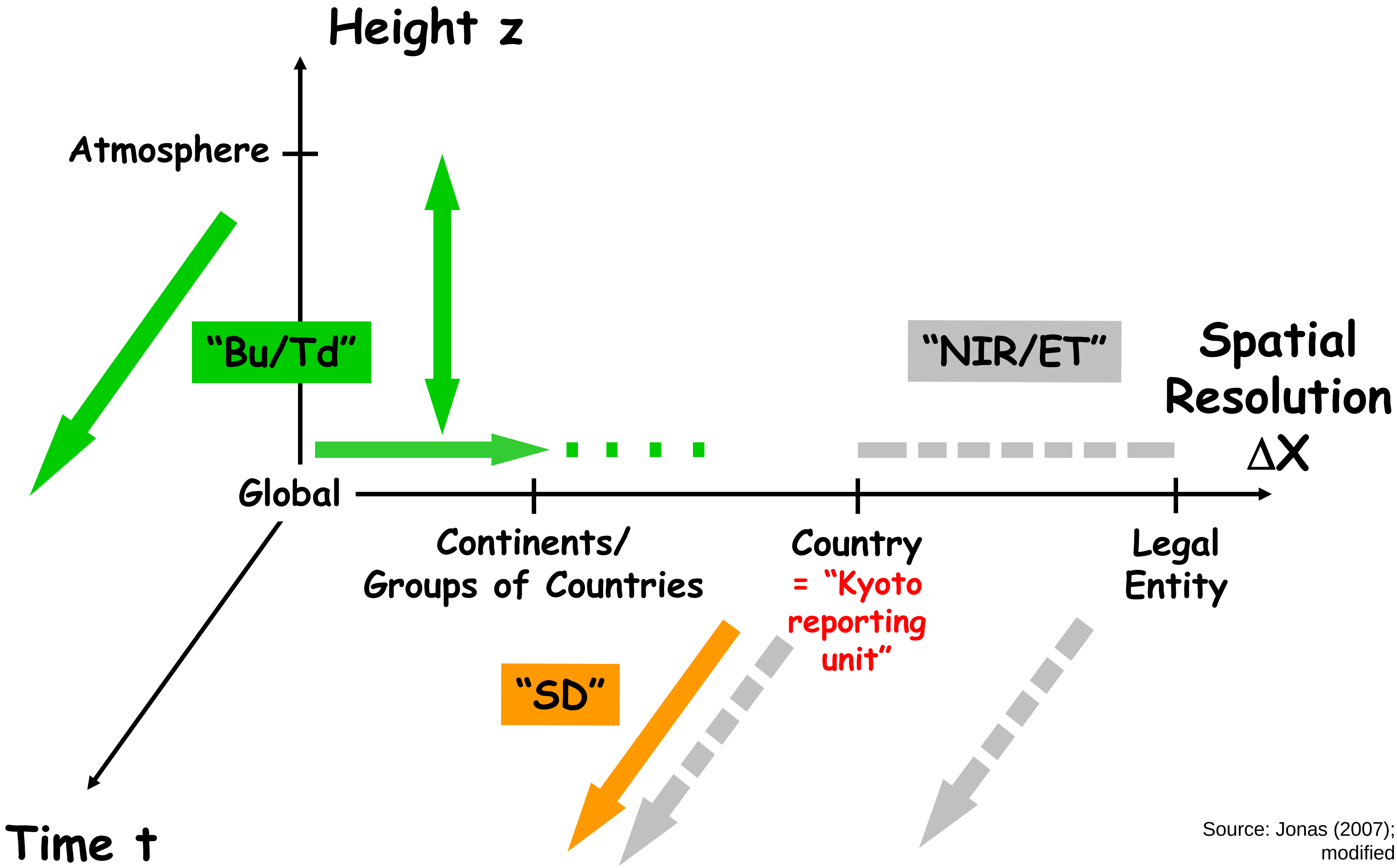
1. Quick Look: Uncertainty across scales (CO_2)



Source: Jonas (2007); modified

1. Quick Look: Uncertainty bottom-up/top-down

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

	Global					Regional
	Flux	$\pm 1\sigma$	Confidence	Bottom-up	Top-down	Confidence
Atmospheric increase	3.2	$\pm$ 0.1	High		Measurements (CO_2, $\delta^{13}C$, $O_2{:}N_2$, ^{14}C, …)	Acceptable
Emissions (fossil fuel, cement)	6.4	$\pm$ 0.4	High	Statistics (energy, …)	^{14}C ideal to measure CO_2 from burning fossil fuels	Acceptable – High
Land–atmosphere flux	- 1.4	$\pm$ 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	$\pm$ 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)

1. Quick Look: Uncertainty bottom-up/top-down

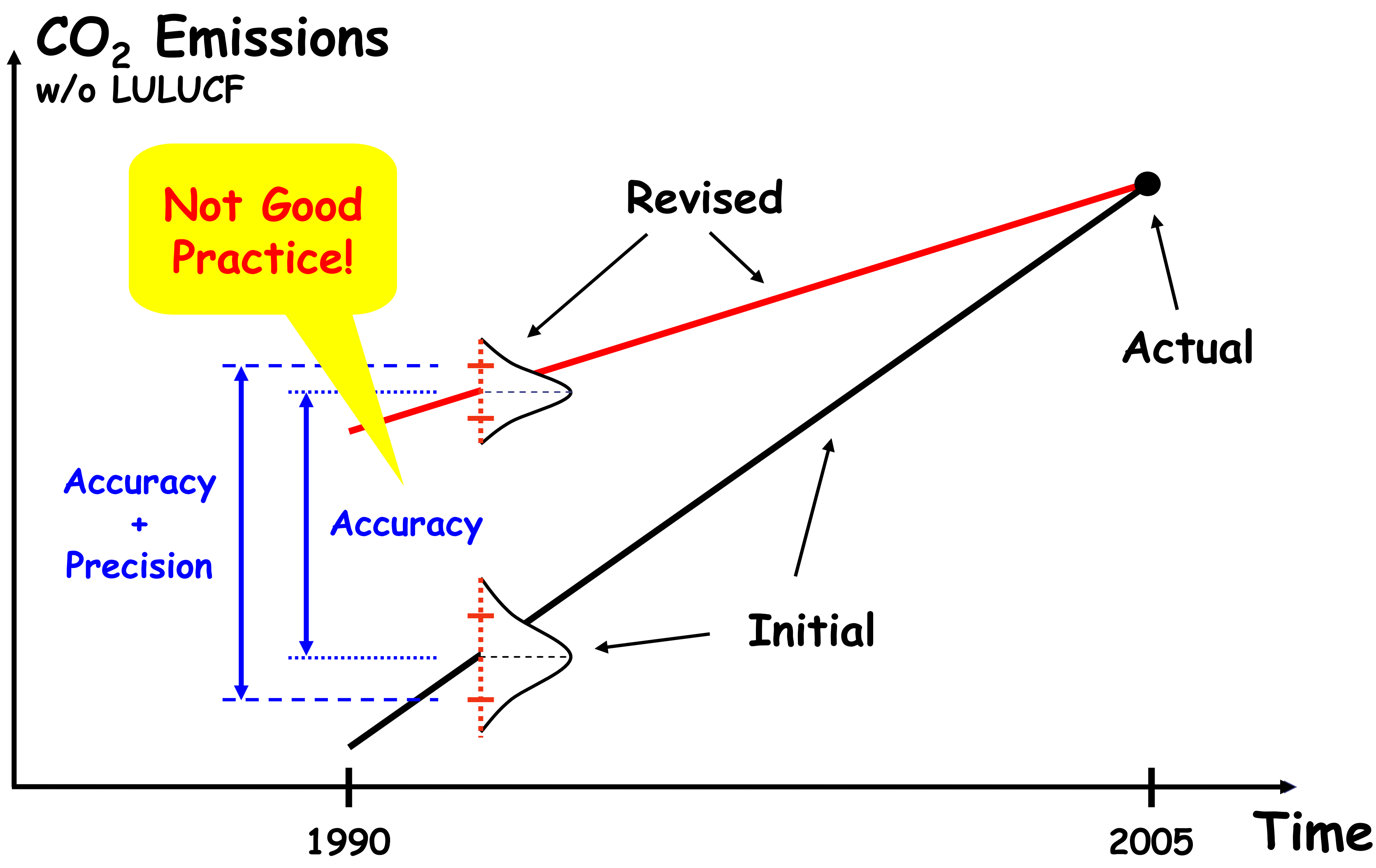
FF Emissions—CO_2:

- Great source strength; uncertainties are believed to be small
- Generally considered perfectly known in inversions
- Under development: ^{14}C (ideal), "^{14}C plus CO"
- Outlook: Rigorous bottom-up/top-down accounting (verification) on a multi-country scale (a matter of years)! Any politically driven (mis-) accounting reported bottom-up can/will be instantaneously corrected!

Net Land and Ocean Uptake—CO_2:

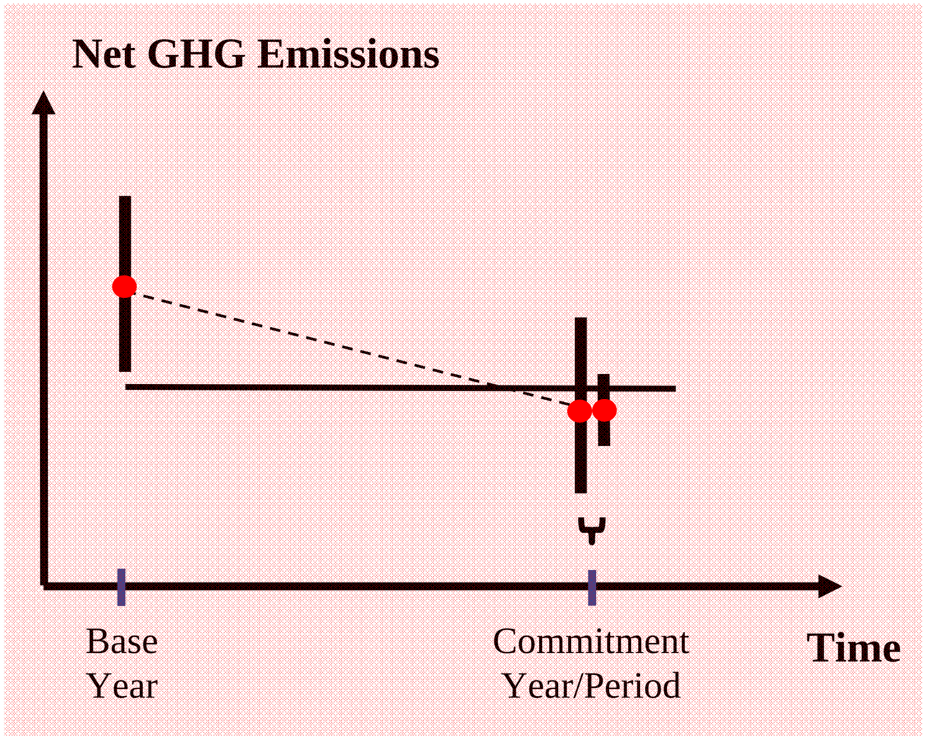
- Small sink strengths, great(er) uncertainties
- Possible: To partition land and ocean uptake
- Challenge: Matching bottom-up/top-down land accounts at continental scales and smaller
- Not possible: To discriminate "Kyoto trees" and "non-Kyoto trees"

1. Quick Look: Current ≤ EU-15 reporting (simplified)

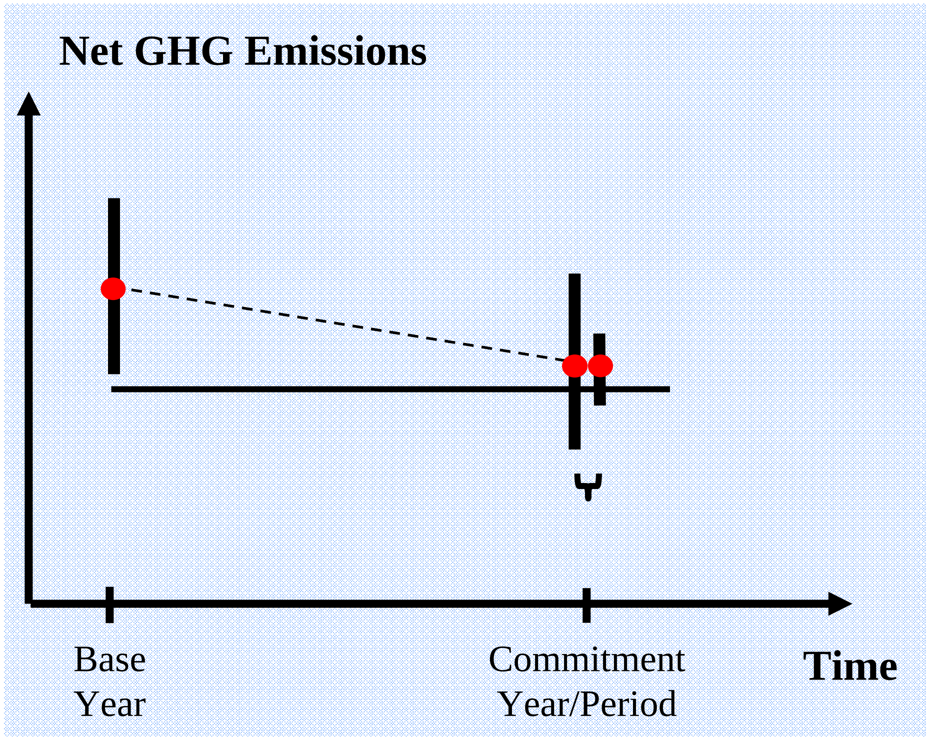


Source: Hamal (2007b); modified

1. Quick Look: Compliance under uncertainty



Irrelevant: Shall uncertainty be considered?
Foreseeable: Scientists will do!



Source: Jonas and Nilsson (2007); modified

2. Key Question

What exactly can scientists say so far about using uncertainty estimates at the national level for compliance purposes using our relative uncertainty knowledge as of today?

… a summary on emissions / emission change "detection" techniques since the 1st Uncertainty Workshop …

3. Agreement: Country grouping

Country Group	Annex I Country	Base Year(s) for CO_2, CH_4, N_2O (for HFCs, PFCs, SF_6)	Commitment Period	KP Commitment %
1a	See note below	1990 (1995)	2008–12	92
1b	BG	1988 (1995)	2008–12	
1c	RO	1989 (1995)	2008–12	
1d	SI	1986 (1995)	2008–12	
2	US	1990 (1995)	2008–12	93
3a	CA, JP	1990 (1995)	2008–12	94
3b	HU	1985–87 (1995)	2008–12	
3c	PL	1988 (1995)	2008–12	
4	HR	1990 (1995)	2008–12	95
5	NZ, RU, UA	1990 (1995)	2008–12	100
6	NO	1990 (1995)	2008–12	101
7	AU	1990 (1995)	2008–12	108
8	IS	1990 (1995)	2008–12	110

Emission Reduction (groups 1a–4)

Emission Limitation (groups 5–8)

1a: AT, BE, CH, CZ, DE, DK, EC, EE, ES, FI, FR, GR, IE, IT, LI, LT, LU, LV, MC, NL, PT SE, SK, UK.

Source: Jonas *et al.* (2004); modified

3. Overview: Techniques (I)

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)

3. Overview: Techniques (II)

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 when an emission signal outstrips total uncertainty	✓	✓				
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

3. Agreement: Relative uncertainty intervals

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

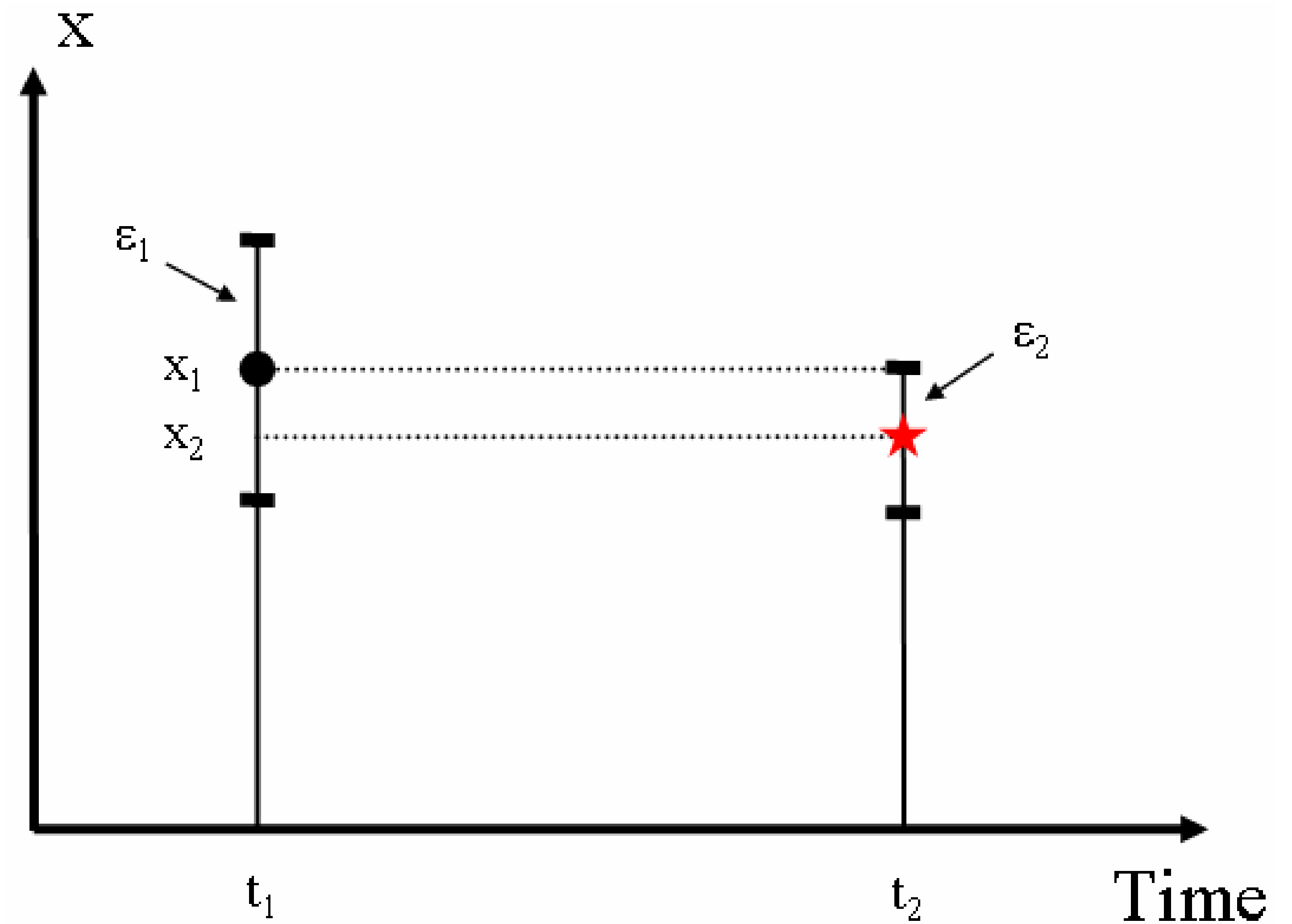
↕ All Kyoto gases

↕ + LULUCF

↓ net terrestrial

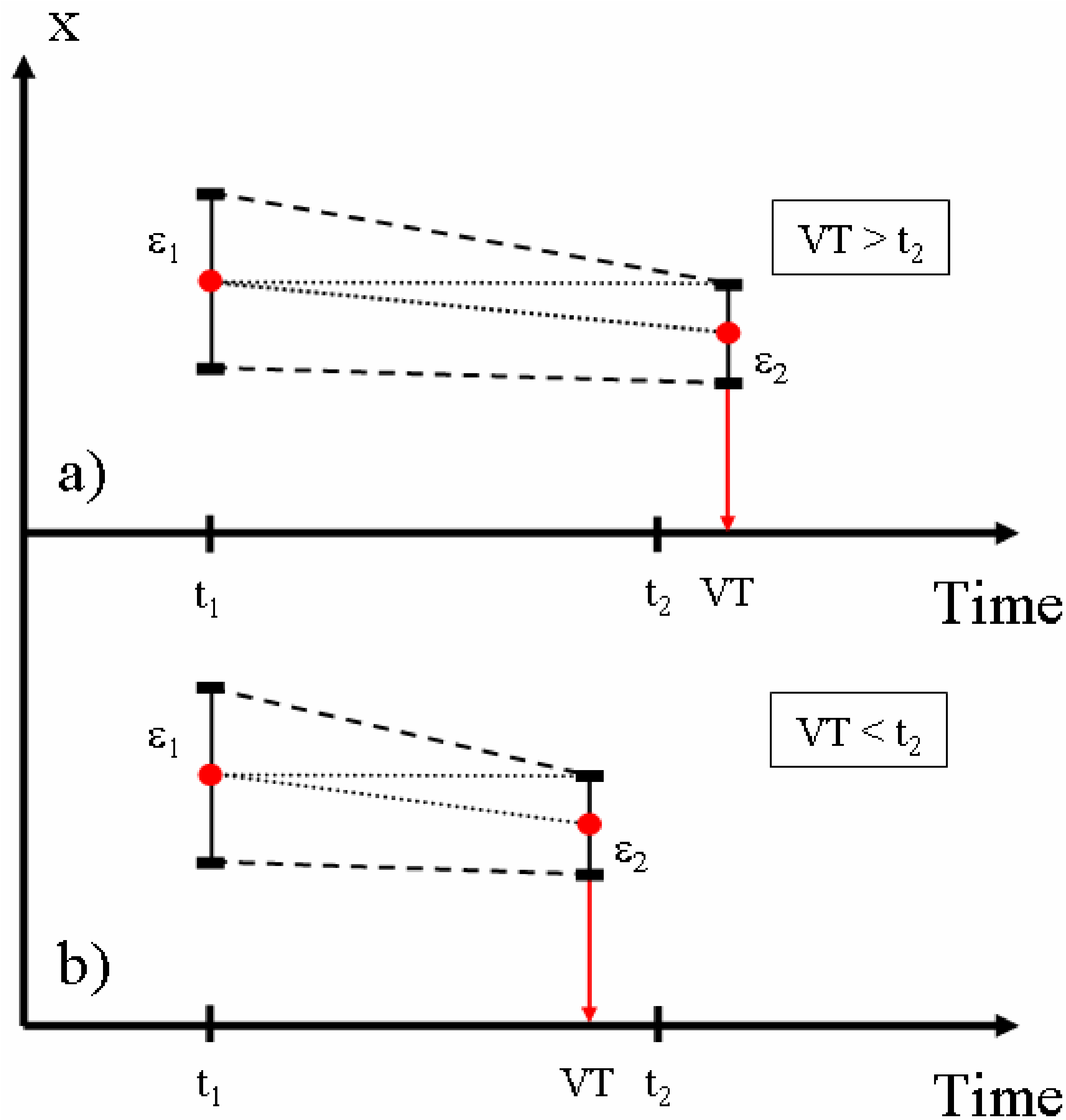
Source: Jonas and Nilsson (2007); modified

4. Techniques in Detail: CRU



Source: Jonas *et al.* (2004); modified

4. Techniques in Detail: VT

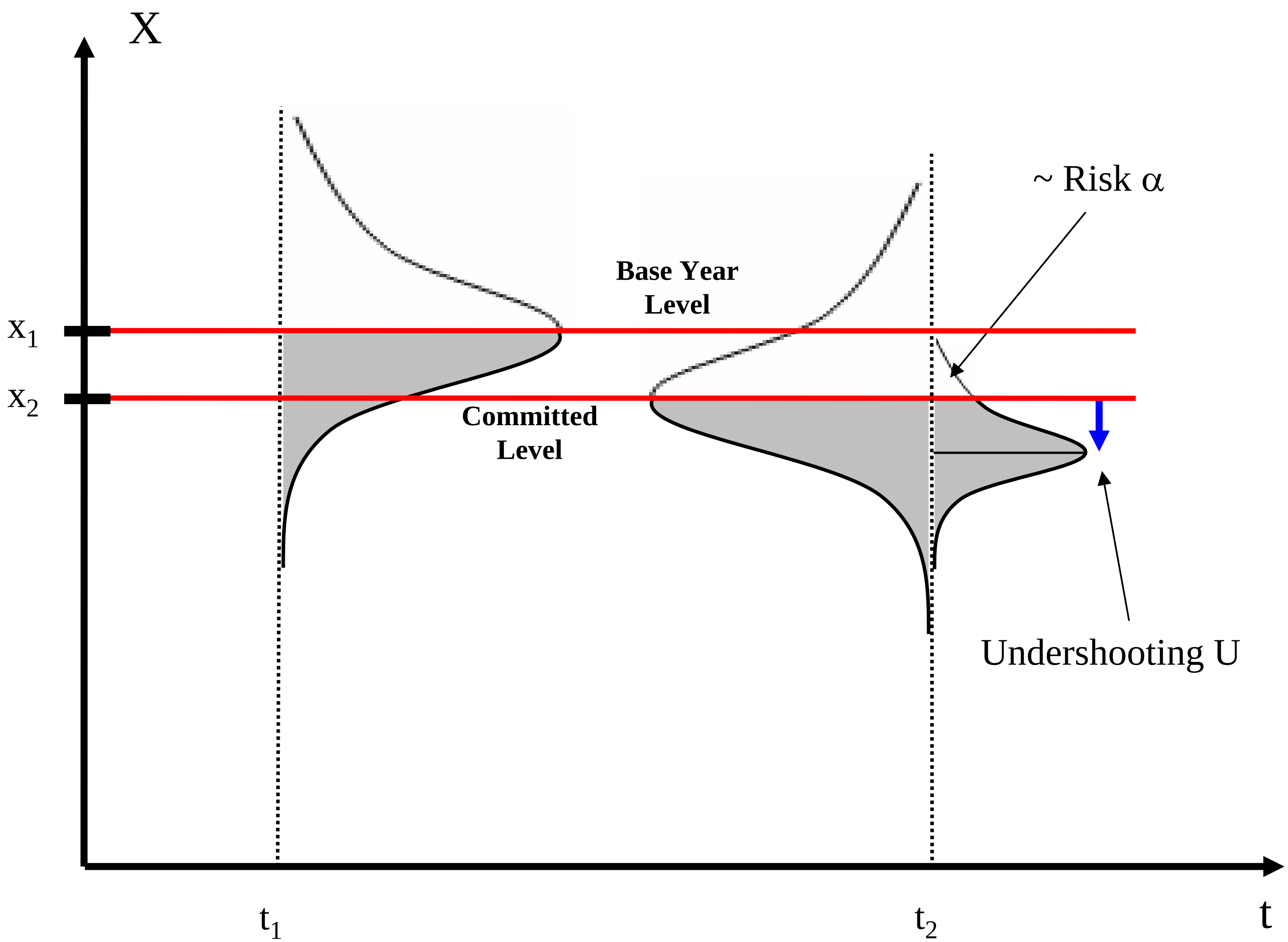


Source: Jonas and Nilsson (2007); modified

4. Techniques in Detail: Und and VT

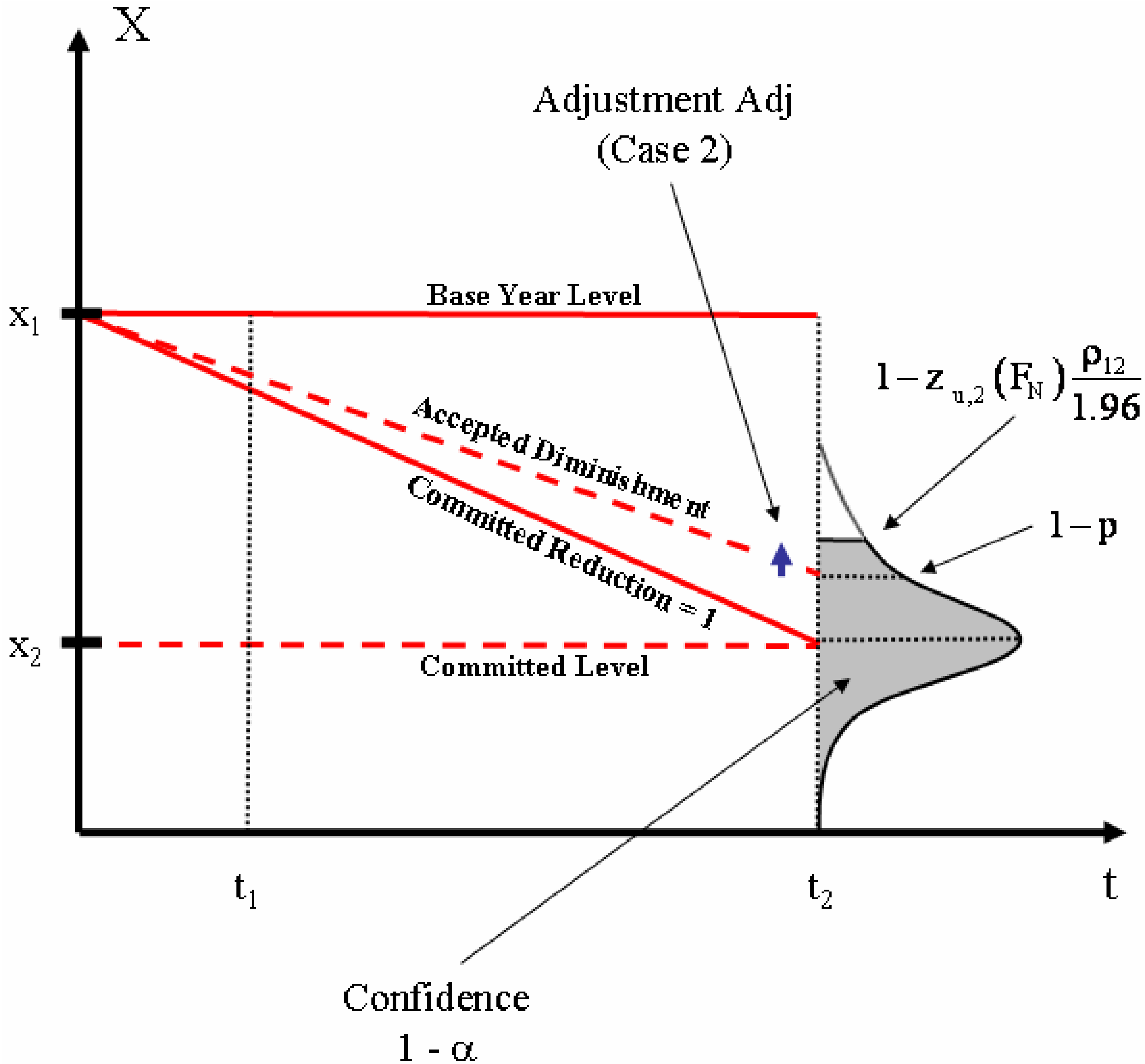
$$|\delta_{KP}| \text{ given} \quad \Rightarrow \quad \begin{cases} \text{CRU} \\ \\ \text{VT} \end{cases} \text{ are nonsymmetrical}$$

4. Techniques in Detail: Und



Source: Jonas and Nilsson (2007); modified

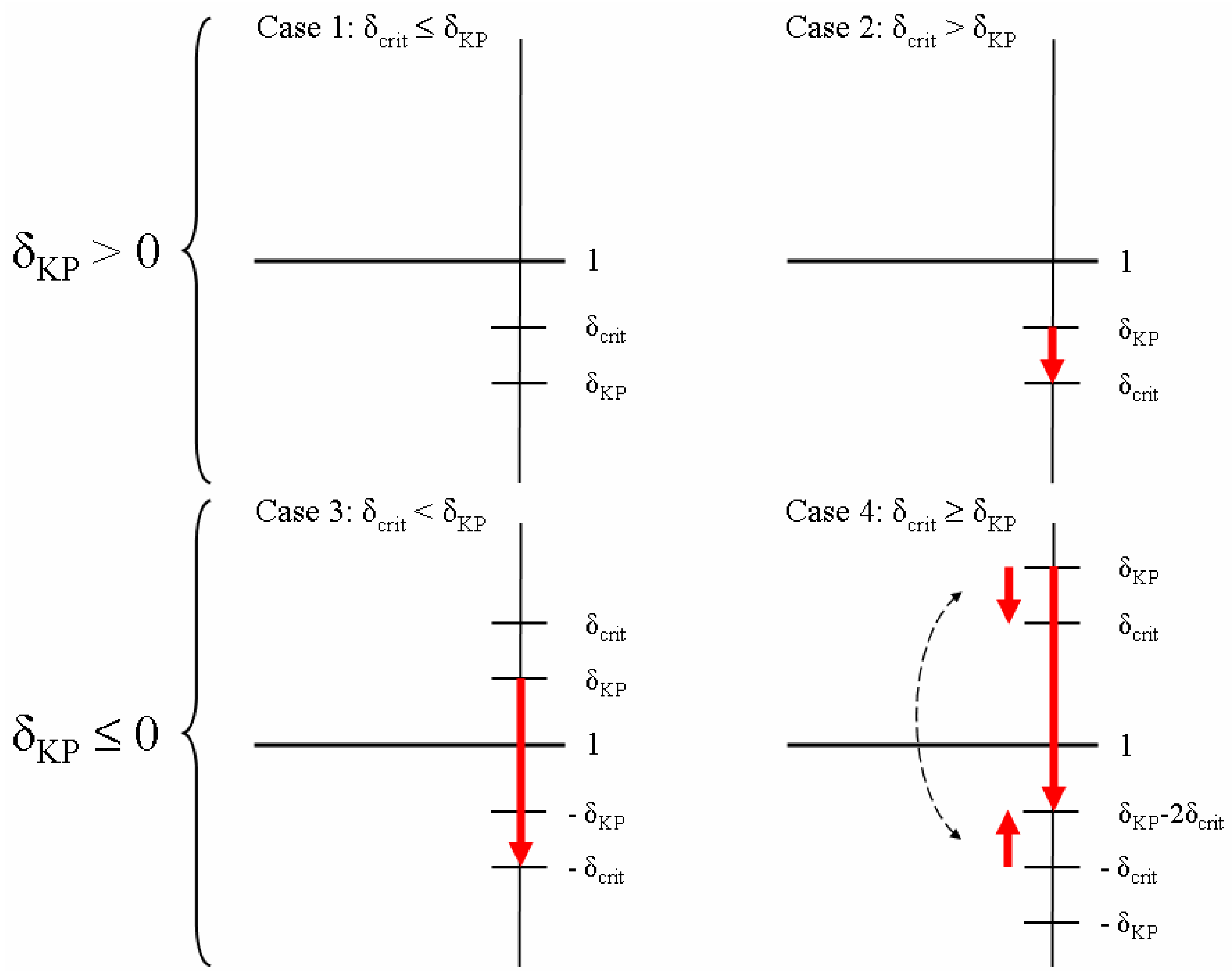
4. Techniques in Detail: GSC #2



4. Techniques in Detail: Und and GSC #2

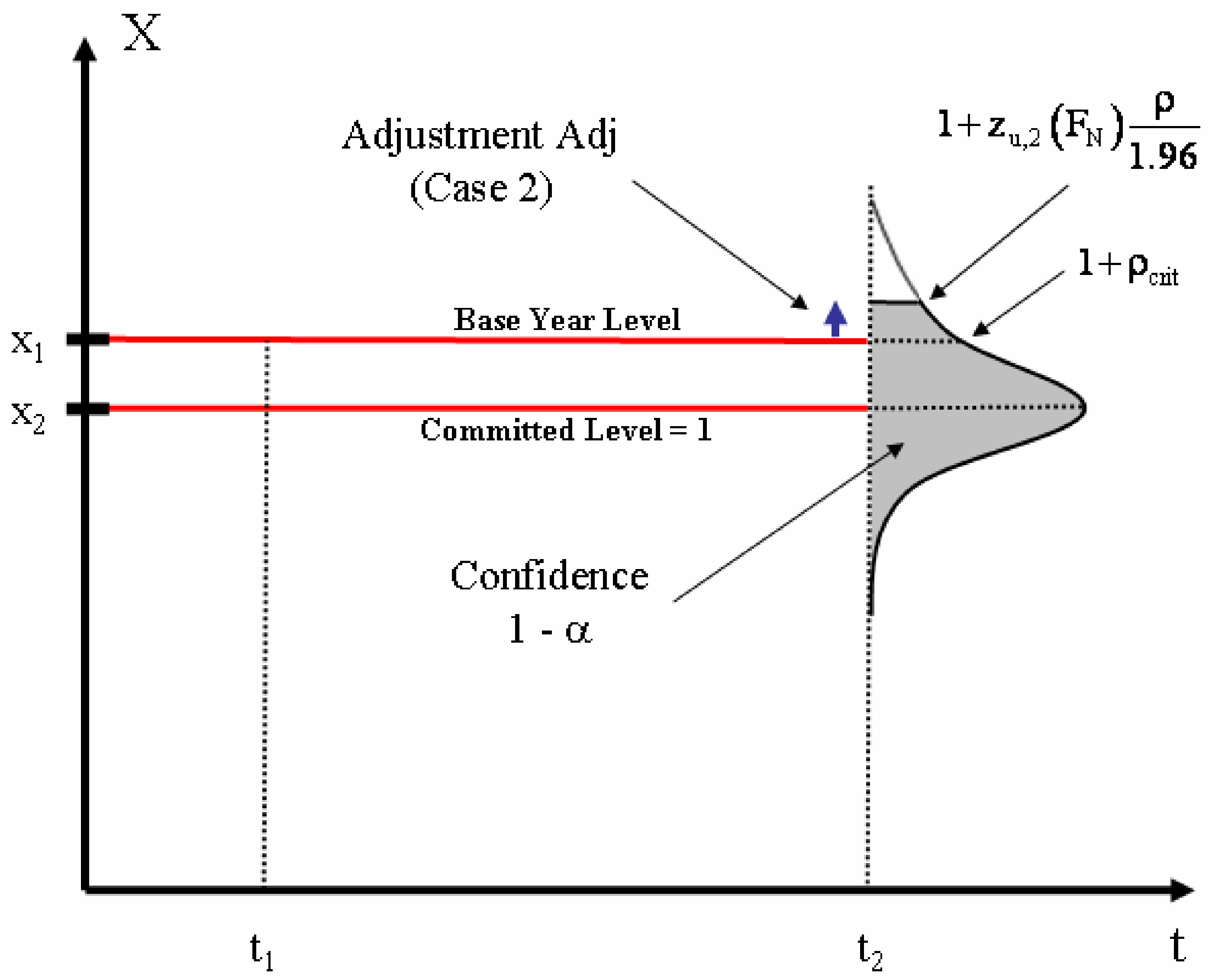
Given	Und and GSC #2 (Reduction)
Kyoto commitment δ_{KP}	Risk α ↓, Conf. $(1-\alpha)$ ↑ $\Rightarrow$ { Undershooting ↑, Adjustment ↑ } for any uncertainty ρ
Kyoto commitment δ_{KP}	Unc. ρ ↑ $\Rightarrow$ { Undershooting ↑, Adjustment ↑ } for any risk α and conf. $(1-\alpha)$
Uncertainty ρ and risk α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

4. Techniques in Detail: Und&VT



Source: Hamal (2007a)

4. Techniques in Detail: GSC #1



4. Techniques in Detail: Und&VT and GSC #1

Given	Und&VT and GSC #1
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 $(1-\alpha)$	$\delta_{KP} \downarrow$ $\Rightarrow$ { Und $\uparrow\uparrow$ but constant modified Kyoto targets *), Adjustment $\uparrow\uparrow$ **) } *) Except for a-priori detectability **) Adjustments constant if prior agreement = 0

5. Conclusions

- Foreseeable: Bu/td verification of FF CO_2, resolving continental scales and smaller, will be in place in the near future. Accounting under the KP will have to cope with this challenge. Strategy: Focus on verifiable emissions (→ separate protocol for the biosphere).

- SD techniques are available to check the quality of compliance (bu or bu/td context). Accounting under the KP will have to cope with this challenge. Strategy: Establish rules for meeting compliance under uncertainty.

- The techniques exhibit 'peculiarities' that are related to the arbitrary way the KP is designed, not to science! Strategies: 1) Introduce uniform reduction under the KP; or 2) set up straightforward rules for introducing differentiated targets (e.g., contraction and convergence).

Thank you for your attention!

UN Climate Change Conference 2007
Bali - Indonesia

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4. Techniques in Detail: CRU

Country Group	KP Commitment δ_{KP} %	CRU ρ_{crit} %
1a–d	**8.0**	**8.7**
2	**7.0**	**7.5**
3a–c	**6.0**	**6.4**
4	**5.0**	**5.3**
--	4.0	4.2
--	3.0	3.1
--	2.0	2.0
--	1.0	1.0
5	**0.0**	**0.0**

Country Group	KP Commitment δ_{KP} %	CRU ρ_{crit} %
8	**-10.0**	**9.1**
--	-9.0	8.3
7	**-8.0**	**7.4**
--	-7.0	6.5
--	-6.0	5.7
--	-5.0	4.8
--	-4.0	3.8
--	-3.0	2.9
--	-2.0	2.0
6	**-1.0**	**1.0**

Source: Jonas *et al.* (2004); modified

4. Techniques in Detail: VT

Country Group	KP Commit. δ_{KP} %	Normalized VTs if countries report with ρ = 2.5 %	7.5 %	15 %	30 %
1a–d	**8.0**	**0.3**	**0.9**	**1.6**	**2.9**
2	**7.0**	**0.3**	**< 1.0**	**1.9**	**3.3**
3a–c	**6.0**	**0.4**	**1.2**	**2.2**	**3.8**
4	**5.0**	**0.5**	**1.4**	**2.6**	**4.6**
--	4.0	0.6	1.7	3.3	5.8
--	3.0	0.8	2.3	4.3	7.7
--	2.0	1.2	3.5	6.5	11.5
--	1.0	2.4	7.0	13.0	23.1
5	**0.0**	**infinite**			

Country Group	KP Commit. δ_{KP} %	Normalized VTs if countries report with ρ = 2.5 %	7.5 %	15 %	30 %
8	**-10.0**	**0.3**	**0.8**	**1.8**	**4.3**
--	-9.0	0.3	0.9	2.0	4.8
7	**-8.0**	**0.3**	**> 1.0**	**2.2**	**5.4**
--	-7.0	0.4	1.2	2.5	6.1
--	-6.0	0.4	1.4	2.9	7.1
--	-5.0	0.5	1.6	3.5	8.6
--	-4.0	0.6	2.0	4.4	10.7
--	-3.0	0.9	2.7	5.9	14.3
--	-2.0	1.3	4.1	8.8	21.4
6	**-1.0**	**2.6**	**8.1**	**17.6**	**42.9**

Source: Jonas *et al.* (2004); modified

4. Techniques in Detail: Und

Country Group	KP Commit. δ_{KP} %	Modified Emission Limitation or Reduction Target δ_{mod} in % for α = 1	ρ = 2.5 %	7.5 %	15 %	30 %
1a–d	8.0	0.0	9.1	11.4	14.7	20.8
		0.1	8.9	10.7	13.4	18.4
		0.3	8.5	9.4	10.7	13.4
		0.5	8.0	8.0	8.0	8.0
2	7.0	0.0	8.2	10.4	13.7	20.0
		0.1	7.9	9.7	12.4	17.5
		0.3	7.5	8.4	9.7	12.4
		0.5	7.0	7.0	7.0	7.0
3a–c	6.0	0.0	7.2	9.5	12.8	19.1
		0.1	6.9	8.8	11.5	16.6
		0.3	6.5	7.4	8.8	11.5
		0.5	6.0	6.0	6.0	6.0
4	5.0	0.0	6.2	8.5	11.9	18.3
		0.1	5.9	7.8	10.5	15.8
		0.3	5.5	6.4	7.8	10.5
		0.5	5.0	5.0	5.0	5.0

Corr ≈ 0.75

Source: Jonas and Nilsson (2007); modified

4. Techniques in Detail: GSC #2

Country Group	KP Commit. δ_{KP} %	CRU δ_{crit} %	Adjustment Factor Adj (absolute) for $1 - \alpha =$ 1	$\rho =$ 2.5 %	7.5 %	15 %	30 %
1a–d	8.0	8.7	1.0				
			0.9	0.999	1.016	1.040	1.089
			0.7	0.995	1.001	1.011	1.031
			0.5	0.991	0.991	0.991	0.991
2	7.0	7.5	1.0				
			0.9	1.001	1.017	1.041	1.090
			0.7	0.996	1.002	1.012	1.032
			0.5	0.993	0.993	0.993	0.993
3a–c	6.0	6.4	1.0				
			0.9	1.002	1.018	1.042	1.091
			0.7	0.997	1.004	1.014	1.034
			0.5	0.994	0.994	0.994	0.994
4	5.0	5.3	1.0				
			0.9	1.003	1.019	1.044	1.092
			0.7	0.998	1.005	1.015	1.035
			0.5	0.995	0.995	0.995	0.995

Corr ≈ 0.75

p = 0.1

4. Techniques in Detail: Und&VT

Country Group	KP Commit. δ_{KP} %	α = 1	Modified Emission Limitation or Reduction Target δ_{mod} in % for ρ = 2.5 %	7.5 %	15 %	30 %
1a–d	8.0	0.0	10.2	14.4	24.4	40.8
		0.1	9.8	13.2	22.4	38.0
		0.3	8.9	10.7	18.0	31.3
		0.5	8.0	8.0	13.0	23.1
2	7.0	0.0	9.3	13.5	24.4	40.8
		0.1	8.8	12.3	22.4	38.0
		0.3	7.9	9.7	18.0	31.3
		0.5	7.0	7.0	13.0	23.1
3a–c	6.0	0.0	8.3	13.5	24.4	40.8
		0.1	7.8	12.2	22.4	38.0
		0.3	6.9	9.7	18.0	31.3
		0.5	6.0	7.0	13.0	23.1
4	5.0	0.0	7.3	13.5	24.4	40.8
		0.1	6.9	12.2	22.4	38.0
		0.3	5.9	9.7	18.0	31.3
		0.5	5.0	7.0	13.0	23.1

Source: Jonas and Nilsson (2007); modified

4. Techniques in Detail: GSC #1

Country Group	KP Commit. δ_{KP} %	CRU δ_{crit} %	Adjustment Factor Adj (absolute) for 1 - α = 1	ρ = 2.5 %	7.5 %	15 %	30 %
1a–d	8.0	8.7	1.0				
			0.9	0.935	0.965	1.010	1.100
			0.7	0.926	0.938	0.957	0.994
			0.5	0.920	0.920	0.920	0.920
2	7.0	7.5	1.0				
			0.9	0.945	0.976	1.021	1.112
			0.7	0.936	0.949	0.967	1.005
			0.5	0.930	0.930	0.930	0.930
3a–c	6.0	6.4	1.0				
			0.9	0.955	0.986	1.032	1.124
			0.7	0.946	0.959	0.978	1.015
			0.5	0.940	0.940	0.940	0.940
4	5.0	5.3	1.0				
			0.9	0.966	0.997	1.043	1.136
			0.7	0.956	0.969	0.988	1.026
			0.5	0.950	0.950	0.950	0.950

$p = \rho_{crit}$

Global Carbon Project (2006)

Significance of CO_2 mitigation options by deployment timescale

	Rapidly Deployable	Not Rapidly Deployable
Minor contributor ≤ 3%	• Biomass co-fire in coal-fired power plants • Cogeneration – small scale distributed • Expanded use of natural gas combined cycle • Hydropower • Wind without storage equal to 10% of electric grid • Niche options: wave and tidal, geothermal, small scale solar • Forest management	• Building-integrated photovoltaics
Major contributor > 3%	• Carbon storage in agricultural soils; no-till cultivation, cover crops • Improved appliance, lighting and motor efficiency • Improved buildings • Improved industrial processes • Improved vehicle efficiency • Non-CO_2 gas abatement from industrial sources including coal mines, land fills, pipelines • Non-CO_2 gas abatement from agriculture including soils, animal industry • Reforestation/land restoration • Stratospheric sulphate aerosol geoengineering	• Biomass to hydrogen or electricity, possibly with carbon capture and sequestration • Biomass to transportation fuel • Cessation of net deforestation • Energy efficient urban and transportation system design • Fossil fuel carbon separation with geologic or ocean storage • Highly efficient coal technologies e.g. Integrated Gasification Combined Cycle (IGCC) • Large scale solar with H_2, long-distance transmission, storage • Next generation nuclear fission • Reduced population growth • Wind with H_2, long-distance transmission, storage • Speculative technologies – direct atmospheric scrubbing, space solar, fusion, exotic geoengineering, bioengineering

After Caldeira et al. 2004, SCOPE 62

Source: GCP (2006): http://www.globalcarbonproject.org/misc/policyBrief.htm