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Another Inconvenient Truth: A Carbon-Intensive South Faces Environmental Disaster, No Matter What the North Does

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Abstract

This paper critically examines a view of global warming that is common among developing countries (the South) and many in the development community: Developed countries (the North) caused climate change, the North should address the problem by dramatically reducing its own carbon emissions, and the South should be left free to develop along a carbon-intensive path until it is much richer. Our results indicate that this view cannot withstand empirical scrutiny and is, in fact, dangerous for the South itself. The South's cumulative carbon emissions are already large enough to jeopardize climatic stability and its own future growth, regardless of Northern emissions. By implication, a fossil-fueled South will undermine its own development long before it reaches Northern income levels. Sustainable development will therefore require a dramatic shift toward clean energy in the South, beginning immediately, as well as rapid reduction of Northern emissions.

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1. Introduction

The world community now views global warming as a major threat, with particularly dire implications for developing countries (IPCC, 2007). A common Southern view of this problem was expressed in a recent Security Council address by India's UN Ambassador, who *"… told the developed nations that the main responsibility for taking action to lessen the threat of climate change rests with them …, while efforts to impose greenhouse gas commitments on developing nations would 'simply adversely impact' their prospects of growth."*[1] Although this view commands near-universal support in the South, it remains largely an article of faith. If the South begins aggressive mitigation now, will it actually damage its own growth prospects? Or will such mitigation improve those prospects by significantly reducing the impact of global warming on the South itself?

A lot hinges on these questions, so an empirical test of the conventional wisdom seems warranted. In this paper, we attempt to provide an unambiguous answer by isolating the Southern experience for analysis. Using newly-available emissions data for the period 1850 to 2005, we re-estimate and verify a standard carbon-cycle model that relates cumulative carbon dioxide emissions to the atmospheric concentration of CO_2. We calculate separate historical emissions paths for the North and South, and extend them into the near future using the most recent scenarios from the Intergovernmental Panel on Climate Change (IPCC). Applying the carbon-cycle model to the two regional emissions paths, we compute separate paths of atmospheric CO_2 concentration

[1] Press Trust of India/Factiva, April 20, 2007. In fact, the Ambassador was paraphrasing the original "understandings" in the Kyoto Protocol: (1) The largest share of historical and current global emissions of greenhouse gases has originated in the North; (2) Per capita emissions in the South are still relatively low; (3) The share of global emissions originating in the South will grow to meet its social and development needs.

attributable to the North and South. Then we compare the Southern concentration path to the global path that has provoked alarm about global warming.

This experiment enables us to test the view, implicit in the Indian Ambassador's statement, that the isolated Southern concentration path lags so far behind the global path that the South can defer worrying about its own emissions until it is much richer. Does the evidence support this view? If the answer is yes, then the South should indeed defer costly mitigation and a double burden should fall on the North: It should reduce emissions rapidly and compensate any mitigation undertaken by the South. If the answer is no, on the other hand, the converse is true: Southern emissions are, by themselves, sufficient to damage Southern growth prospects. In this case, the South's interest dictates immediate action to reduce its own emissions, whatever the North has done or will choose to do in the future.

The remainder of the paper is organized as follows. Section 2 introduces and empirically verifies the IPCC's Bern carbon-cycle model, using new emissions data for 1850-2005 and atmospheric CO_2 concentration data for 1744-2007. Section 3 calculates historical emissions paths for the North and South, and extends them using an IPCC scenario that assumes rapid development in the South with no targeted mitigation of carbon emissions. In Section 4, we apply the Bern model to regional emissions, generate separate atmospheric concentration paths for the North and South, and compare the Southern path to the historical global path. Section 5 summarizes our findings and concludes the paper.

2. Global Emissions and the Atmospheric CO_2 Concentration, 1850-2005

The atmospheric concentration of CO_2 is determined by the pre-industrial concentration, plus cumulative emissions from human activity, minus terrestrial and marine re-absorption of emitted carbon. From an online database maintained by the World Resources Institute (WRI), we draw estimates of annual CO_2 emissions from combustion of solid, liquid and gaseous fuels, cement manufacturing, and gas flaring. The WRI data cover the period 1850-2002 for 185 countries.[2] For CO_2 emissions from land-use change, we draw on newly-released regional data from Houghton (2007) for the period 1850-2005. Combining the WRI and Houghton databases, we calculate cumulative anthropogenic CO_2 in the atmosphere using an approximation to the standard Bern carbon-cycle model (Siegenthaler and Joos, 1992; Shaffer and Sarmiento, 1995):[3]

$$(1)\quad \rho_C(T) = K_C \sum_{t_0}^{T} E_C(t) \left[f_0 + \sum_{S=1}^{n} f_S \cdot e^{\left[-\frac{T-t}{\tau_S}\right]} \right]$$

T	=	Observation year for atmospheric CO_2 concentration
ρ	=	Atmospheric concentration of CO_2 in year T
K_C	=	A physical constant[4]
E_C	=	Anthropogenic carbon emitted in year t
τ_S	=	Exponential time decay factor for carbon sink S
f_0	=	Constant fraction
f_S	=	Fractional weight associated with exponential time decay factor S

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[2] WRI uses CO_2-equivalent values computed from emissions of elemental carbon. The database accounts for emissions from combustion of solid, liquid, and gaseous fuels since 1900, the manufacture of cement since 1928, and gas flaring since 1980. The data are available online at http://earthtrends.wri.org/searchable_db/index.php?theme=3, with detailed descriptions of assumptions and sources.

[3] For a more detailed exposition of the Bern model, see http://unfccc.int/resource/brazil/carbon.html. Both the WRI and Houghton data have non-zero anthropogenic emissions in the first observation year, 1850, implying an earlier year for zero emissions. This is also implied by an increase in the atmospheric CO_2 concentration from 276.8 ppm in 1744 (the first observation year in the WRI database) to 288.2 ppm in 1854 Accordingly, we set the zero year for emissions at 1744 and interpolate to 1850 for WRI and Houghton emissions from the North and South separately. Calculation of cumulative emissions in equation (1) therefore uses 1744 as the base year.

[4] Approximately 0.47 ppm (parts per million volume)/GtC (gigaton of carbon) in the scientific literature. We verify this empirically using the regressions reported in Table 1.

The Bern model accounts for the intertemporal distribution of emissions among three reservoirs: the atmosphere, ocean and land biosphere. After a ton of anthropogenic carbon is emitted, it begins a long re-absorption process that the model captures with fractionally-weighted exponential decay factors corresponding to known absorption rates in different carbon sinks.[5] We apply this model year-by-year to build our time series of anthropogenic CO_2 remaining in the atmosphere. Figure 1 illustrates an application of the model to one ton of carbon emitted in 1850. Decay is relatively rapid during the first forty years, with about 40% remaining in the atmosphere in 1890. However, rapid decline in the re-absorption rate leaves 25% of the original ton in the atmosphere in 2010.

We use atmospheric CO_2 concentration measurements for the period 1744-2007 to verify that K_C (equation 1) for our dataset is close to the value used in standard applications of the Bern model. We combine observations from the Siple Ice Core (1744-1953 (Neftel, et al., 1994)) and the Mauna Loa Observatory, Hawaii (1959-2007 (Keeling, et al., 2007)). Figure 2 displays the time path of the CO_2 concentration since 1744.

Figure 3 displays the relationship between the atmospheric CO_2 concentration and our estimate of cumulative atmospheric CO_2 using the Bern model. The scatter shows an extremely close relationship between the two variables, which is confirmed by the strong regression results in Table 1. Since we are interested in comparing our estimate of K_C with the value cited in the literature (.47 ppm/Gt carbon), we convert cumulative CO_2 to cumulative carbon using the standard conversion factor.[6] The results in column (1) span the period 1744-2002, with gaps for early-period concentration data that are indicated in

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[5] The Bern model incorporates three carbon sinks, using the following parameters for equation (1): E_C 280, K_C 0.47, f_0 0.152, f_1 0.253, f_2 0.279, f_3 0.316, τ_1 171.0 years, τ_2 18.0 years, τ_3 2.57 years.

[6] 1 ton carbon = 3.664 tons CO_2

Figure 3. Regression statistics are extremely robust, with an R^2 of .998 and huge t-statistics for the estimated parameters. Columns (2) – (3) report equally-robust regression fits for the period 1959-2002, which has no data gaps. All three regressions – two using OLS, one using the Prais-Winsten first-order autocorrelation correction (AR1) -- yield equivalent results: Since 1744, the atmospheric CO_2 concentration has risen .46-.48 ppm per incremental gigaton (one billion tons) of emitted carbon, from a pre-industrial concentration of about 277 ppm. These results are very close to the scientific parameters used in standard applications of the Bern model, and our estimates may differ slightly because we are using the most recent data. For the period 1744-2002, cumulating anthropogenic carbon raised the atmospheric CO_2 concentration by 36% (from 277 to 376 ppm).[7]

3. Emissions in the South and North

We separate countries into the North and South, using regional identifiers in Houghton's dataset and the IPCC's most recent projection scenarios.[8] The North comprises Europe (including Turkey), the Former Soviet Union (FSU), North America, Japan, Australia and New Zealand. The South comprises Asia (excluding Japan and the FSU), Africa, the Middle East, Latin America, the Caribbean and the Pacific islands.

Figure 4 displays cumulative atmospheric CO_2 in the two regions, separated into components from WRI (fossil fuels, cement, flaring – principally fossil fuels) and Houghton (land-use change). All series have been computed from annual emissions, using our parameter estimates for the Bern model in column (1), Table 1. As Table 2

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[7] As of June 2007, rising cumulative emissions have increased the atmospheric CO_2 concentration to 387 ppm. It has not been possible to extend the estimation exercise to 2007, because WRI's data on emissions from fuels, cement and gas flaring terminate in 2002.

[8] Both datasets use regional aggregates rather than countries.

shows, the North has dominated cumulative emissions from fossil fuel combustion. In 2000, cumulative atmospheric CO_2 measures from fossil fuel emissions in the North and South were 372 and 115 Gt (gigatons), respectively. For land-use change, the converse has been true: Extensive deforestation in the South raised its cumulative CO_2 contribution to 180 Gt by 2000, while reforestation in the North led to carbon re-absorption and a decline from a peak in the early 1960's to 58 Gt by 2000 . For fossil fuels and land-use change combined, cumulative CO_2 from the South in 2000 was almost 70% of cumulative CO_2 from the North: 295 Gt vs 430 Gt.

To project conditions in the near future, we compute annual CO_2 emissions for the North and South from the IPCC's A1F1 scenario (IPCC, 2001). This scenario reflects the current aspirations of many developing countries: rapid economic growth in a globalizing economy, low population growth, the rapid introduction of more efficient technologies, and an energy path, unconstrained by carbon emissions reductions, that is consistent with the current development strategies of countries with abundant domestic fossil fuel resources.[9] The IPCC scenario projects from the historical data in our database, so it dovetails with our South/North historical series in 2002, the final observation year. Figure 5a displays annual emissions for the South and North, which are already diverging toward Southern dominance in 2007. By 2025, only 18 years from now, the South's annual emissions are around 32 Gt -- 32% higher than emissions from the North (21 Gt). We use the Bern model to calculate cumulative atmospheric CO_2

[9] We have performed the same exercise using the IPCC's A2 scenario, with results that are effectively identical for CO_2 emissions. Scenario A2 also features continued reliance on fossil energy resources but differs in other respects from A1F1: a more heterogeneous world economy, with more local self-reliance and preservation of local identities; non-convergent fertility patterns and high population growth; regionally-oriented economic development with per capita economic growth and technological change that are more fragmented and slower than in scenario A1F1.

from the two regions. Figure 5b displays the result: By 2025, cumulative CO_2 from the South is 91% of the North's (555 Gt vs 609 Gt), and the South takes the lead in about five more years.

4. Atmospheric Effects of Cumulative Emissions From the South Alone

With separate cumulative emissions series for the North and South, we can use the regression results in column (1), Table 1 to compute the atmospheric CO_2 concentrations that are attributable to each region.[10] In the Southern case, for example, the result is the pre-industrial CO_2 concentration, plus the increment that has been produced by cumulative emissions from the South alone. We believe that the model-based prediction for the South is extremely robust, for three reasons: Our regression results match the standard Bern model; they provide an excellent fit to the historical data (R^2 of .998, huge t-statistics); and, equally important, our predication for the South lies well within the range of the historical data used to fit the model. Southern cumulative CO_2 in 2025 remains lower than maximum global CO_2 in the regression sample (1744 – 2002).

Figure 6 provides an illuminating comparison between the historical global CO_2 concentration and the projected concentration attributable to the South alone. The South's isolated concentration in 2025 matches the measured global concentration in 1986 (350 ppm). By 1986, serious scientific concern about the greenhouse effect had already generated the crisis atmosphere that catalyzed the UN Conference on

[10] We recognize that this attribution does not account for Southern emissions from activities that export to the North. Neither, however, does it account for Northern emissions from activities that export to the South. The balance is far from clear, and additional research on this problem would be useful.

Environment and Development in 1992.[11] Figure 7 reveals the implication of the South's continued rapid development on the IPCC A1F1 track for the remainder of the century. *Here we should emphasize that Figure 7 displays the consequences of Southern development alone, with no historical or future contribution from the North.* By 2040, the South surpasses the current global concentration; by 2060, it surpasses the 450 ppm threshold that the IPCC associates with large, irreversible impacts on developing countries (IPCC, 2007). By the end of the century, the atmospheric concentration is nearing 600 ppm and the South has long since passed the extreme-danger threshold. It is important to bear in mind that these figures are, if anything, conservative. They do not include possible carbon cycle feedback effects – such as increased soil carbon respiration or diminished ocean absorption – as the Earth warms and the oceans acidify. Such processes would result in concentrations of atmospheric CO_2 even higher than reported here. The clear implication is that emissions from the South alone are more than enough to catalyze a climate crisis for the South.

5. Summary and Conclusions

In this paper we have mobilized the best available information for an empirical assessment of a common view in the South (and the North): Global warming is the responsibility of the North, the North should solve it, and the South should be left alone to develop. We have tested these propositions by isolating the Southern experience for analysis. Our results are sobering. Under a business as usual scenario, *cumulative*

[11] Our estimate is conservative, because the actual global CO_2 concentration in 2007 (387 ppm) is significantly higher than the concentration of 382 predicted by our regression model (and the standard Bern model). This divergence implies one of two things: Either CO2 emissions since 2002 have grown faster than anticipated by the IPCC, or ocean and terrestrial CO_2 re-absorption rates have declined. By implication, the South will probably pass benchmark years earlier than projected in Figures 5-7. For further discussion of the recent divergence between actual and projected atmospheric concentrations, see Canadell, et al. (2007).

emissions from the South will probably exceed those from the North soon after 2025. By that time, the atmospheric CO_2 concentration attributable to the South alone will match the global concentration that provoked a crisis and the UN Conference on Environment and Development in 1992. And things will get steadily worse for the South as the 21st century progresses.

Our results reveal the dangerous fallacy in the notion that the South can utilize carbon-intensive growth to dramatically increase incomes – a kind of last-minute, fossil-fueled development push – before the onset of catastrophic climate change. The IPCC A1F1 scenario provides a useful illustration in this context, because it describes precisely such a development path: an economic boom in the South fueled by the continued use of cheap, carbon-based energy, coupled with slow population growth. In this scenario the South achieves rapid short-run development, but on a carbon-intensive path that virtually assures the crossing of critical climate thresholds, *even if there had never been any emissions from the North*. To reinforce the implication, it's worthwhile to pursue the counterfactual a bit further: By the 2030's, the scientists in an isolated South would observe unequivocal global warming, widespread glacial and polar melting, and a rising sea level. Out of necessity and self-interest, the South's governments would then replicate the recent global experience by convening to plan for a carbon-free future.

Unfortunately things are even more precarious for the South in the real world, which also confronts the North's legacy of fossil-fueled growth. If global emissions continue unabated, the resulting increases in temperatures and sea level, greater storm intensity, reduced agricultural productivity, and dwindling freshwater supplies will likely undermine the South's development long before it arrives at Northern income levels.

But from the perspective of the South's own self-interest, focusing exclusively on the Northern sources of this problem is a dangerous distraction. As our results indicate, the South's own emissions have already moved it near the brink of rapid global warming. Cumulative emissions from the North have primarily served to shift fundamental and unavoidable Southern decisions about mitigation a few years closer to the present.

This conclusion is sufficiently startling that the mind gropes for an alternative to such injustice. Why should the South have fallen into this trap, when the North has somehow managed to avoid it? On reflection, the answer is obvious. The South's population is over four times greater than the North's, so it has been trapped by the sheer scale of its emissions at a much earlier stage of development. The South finds itself weighed down by a mass of humanity, as well as the energy technologies and fuels of an earlier age. The question is not *if* the South will commit to emissions reductions – under any scenario it eventually must for its own sake – but whether it will do so in time, and how the costs of the transition are to be shared.

We conclude that the conventional wisdom is dangerously misguided. The South cannot relegate mitigation to the North until it achieves prosperity. In fact, cumulative emissions from a carbon-intensive South have already reached levels that are dangerous for the South itself. They are more than sufficient to create a global climate crisis, even if the North eliminates all of its emissions immediately. So we face another inconvenient truth: A carbon-intensive South faces environmental disaster, no matter what the North does. For its own sake, the South must recognize this hard truth, accept the necessity of serious, costly mitigation, and immediately embark on a low-carbon development path.

The North must clearly do the same, while recognizing that its own survival requires an immediate, large-scale commitment to assisting emissions reductions in the South.

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Table 1: Atmospheric CO_2 Concentration vs. Cumulative Atmospheric CO_2, 1744-2002

Dependent Variable: Atmospheric CO2 Concentration (ppm)

	(1)	(2)	(3)
Period	1744-2002	1959-2002	1959-2002
Estimation Method	OLS[a]	OLS[a]	Prais-Winsten[b]
Cumulative Carbon (Gt)	0.461 (152.99)**	0.477 (132.33)**	0.478 (65.31)**
Constant	279.628 (692.48)**	277.087 (503.39)**	277.121 (257.69)**
Observations	67	44	44
R-squared	.998	.998	.999

[a] Robust t statistics in parentheses
[b] Iterative AR1
* Significant at 5%; ** significant at 1%

Table 2: Cumulative Atmospheric CO_2 From the North and South, 1850-2000

	Cumulative Atmospheric CO_2 (Gt)					
	South			North		
Year	Land Use Change	Fossil Fuels	Total	Land Use Change	Fossil Fuels	Total
1850	19.38	0.00	19.38	25.68	4.83	30.52
1875	24.31	0.00	24.32	40.13	10.09	50.22
1900	33.93	0.14	34.08	54.05	25.83	79.88
1925	54.37	1.62	55.99	61.42	61.61	123.03
1950	82.07	5.32	87.39	62.33	106.51	168.83
1975	127.57	28.34	155.92	65.34	221.54	286.87
2000	180.17	115.13	295.30	58.29	371.73	430.02

Figure 1: One Ton of Carbon Emitted in 1850 – Fraction Remaining Airborne by Year

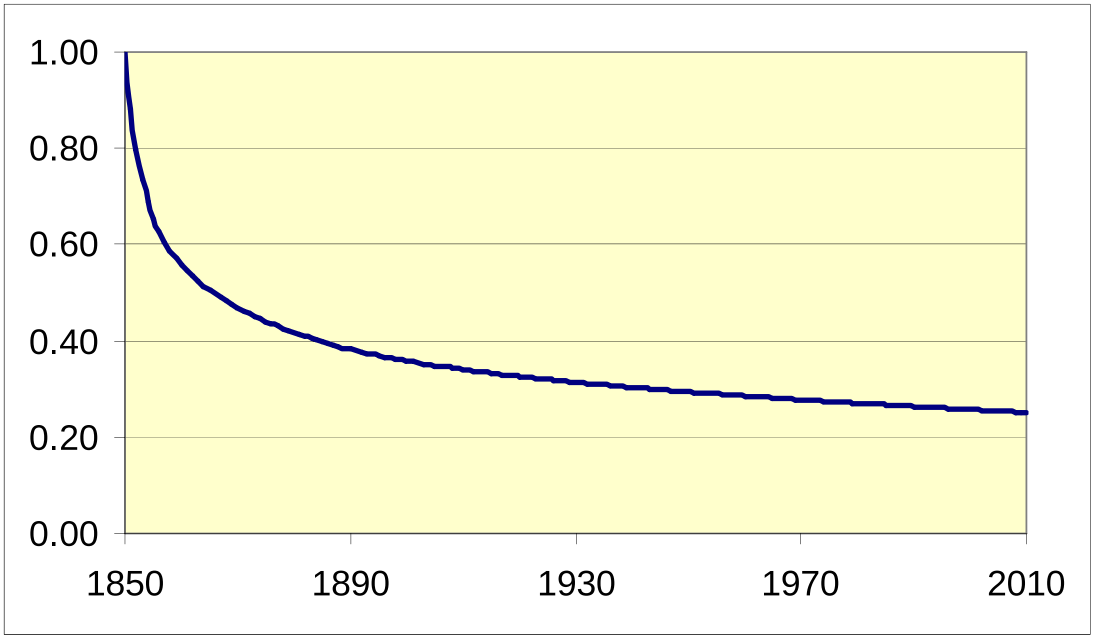

Figure 2: Atmospheric CO_2 Concentration (ppm), 1744 - 2007

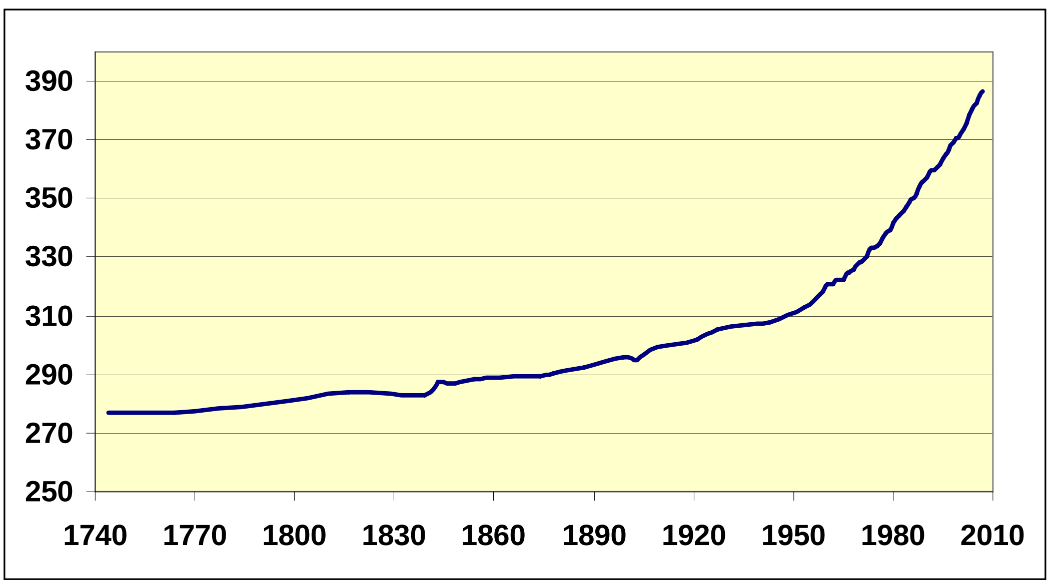

Figure 3: Atmospheric CO_2 Concentration vs. Cumulative Emissions, 1744-2002

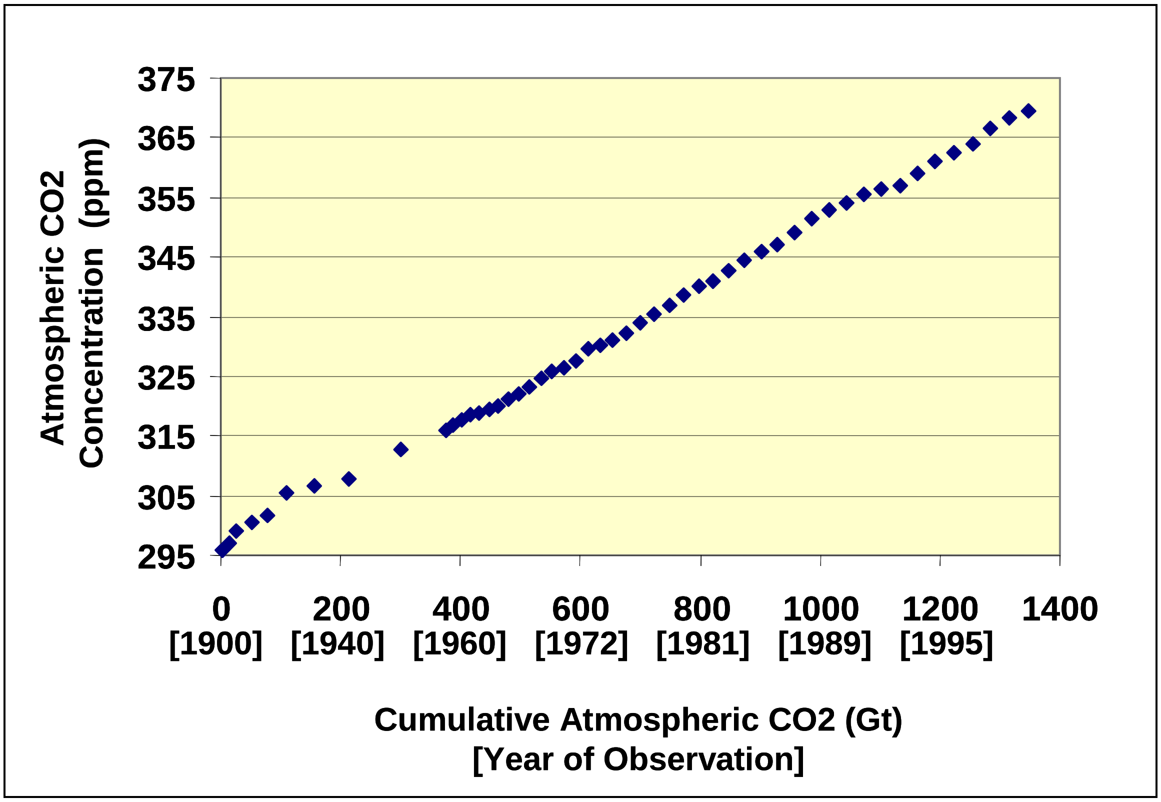

Figure 4: Cumulative CO_2 Contributions by Region, 1850-2005

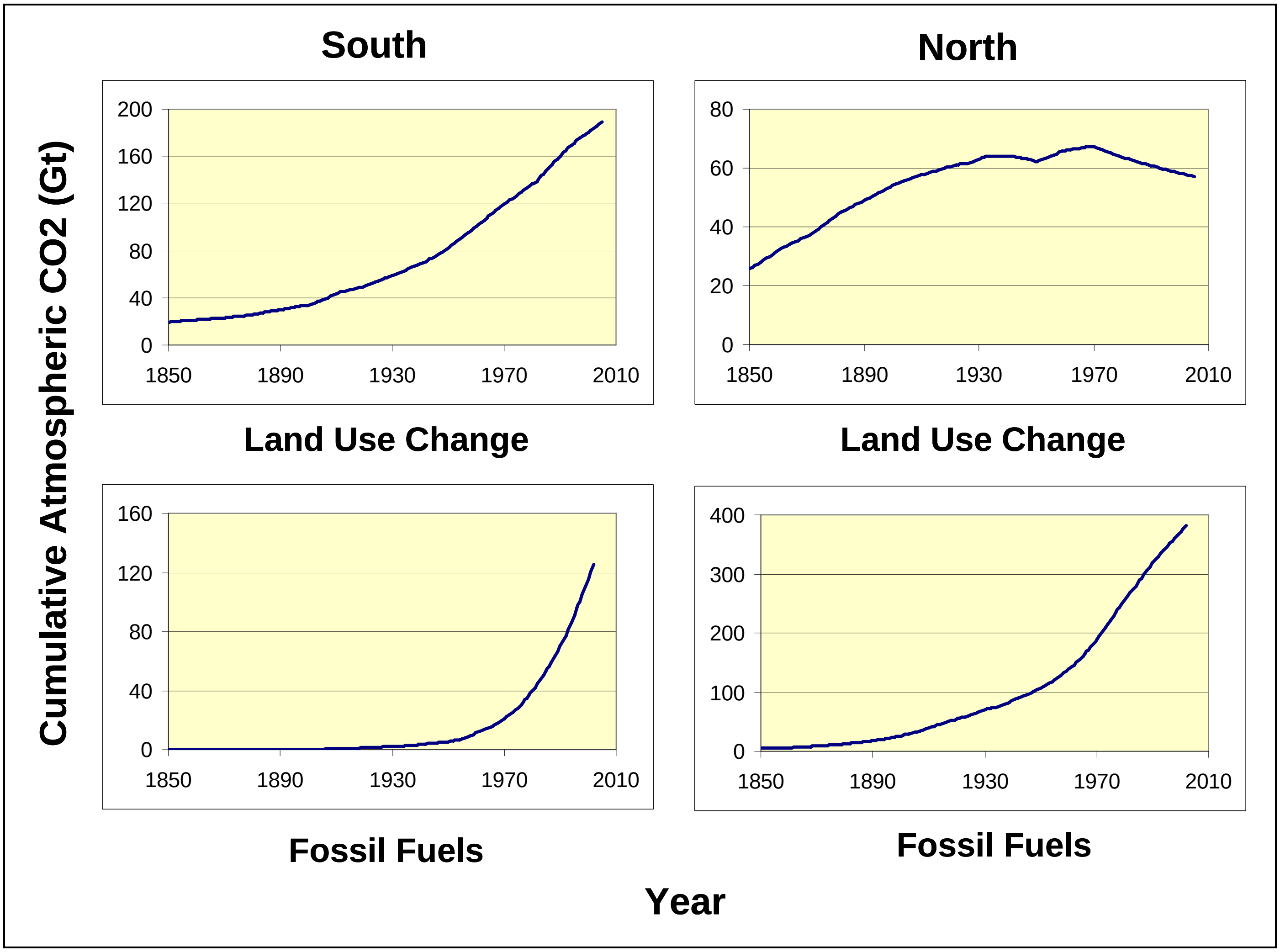

Figure 5a: Annual CO_2 Emissions from the South and North

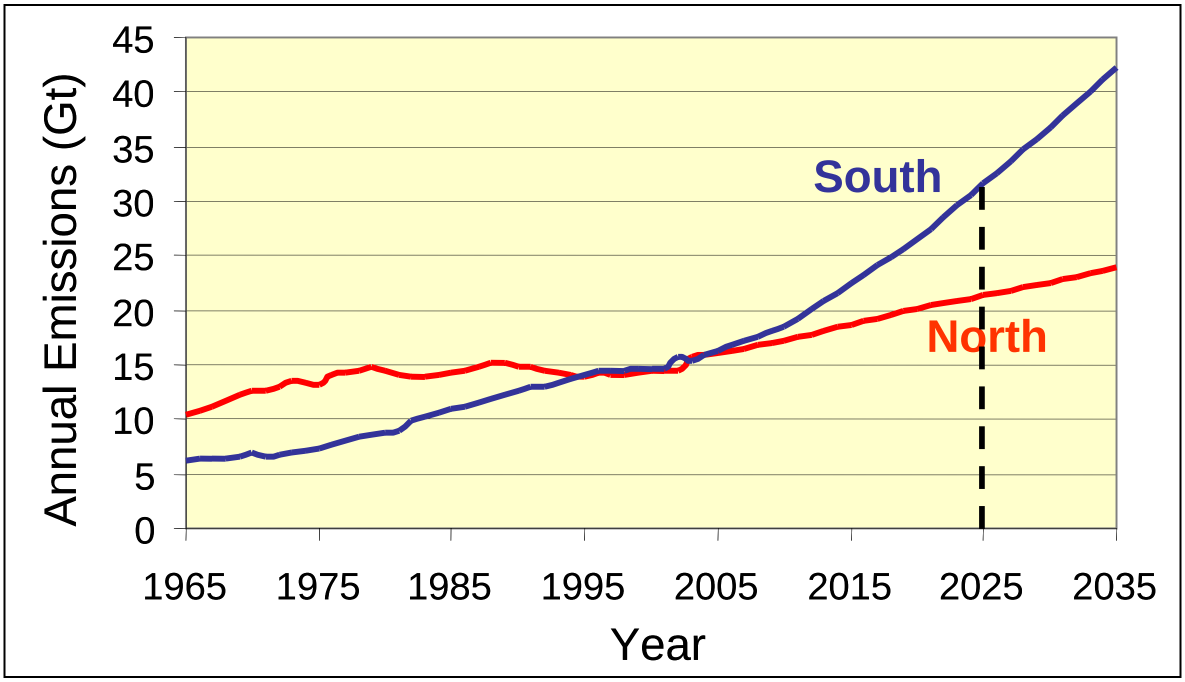

Figure 5b: Cumulative Atmospheric CO_2 from the South and North

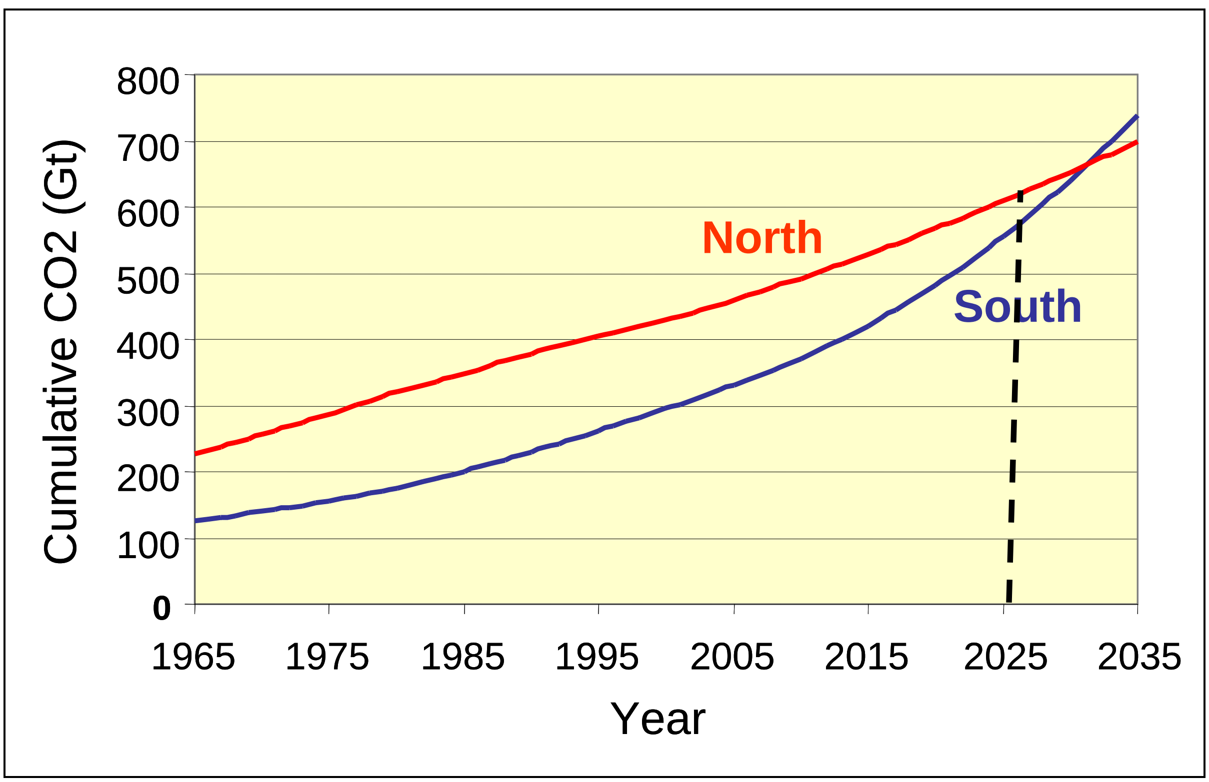

Figure 6: Comparative Atmospheric CO_2 Concentration Paths: Global vs. Isolated South (IPCC A1F1 Scenario)

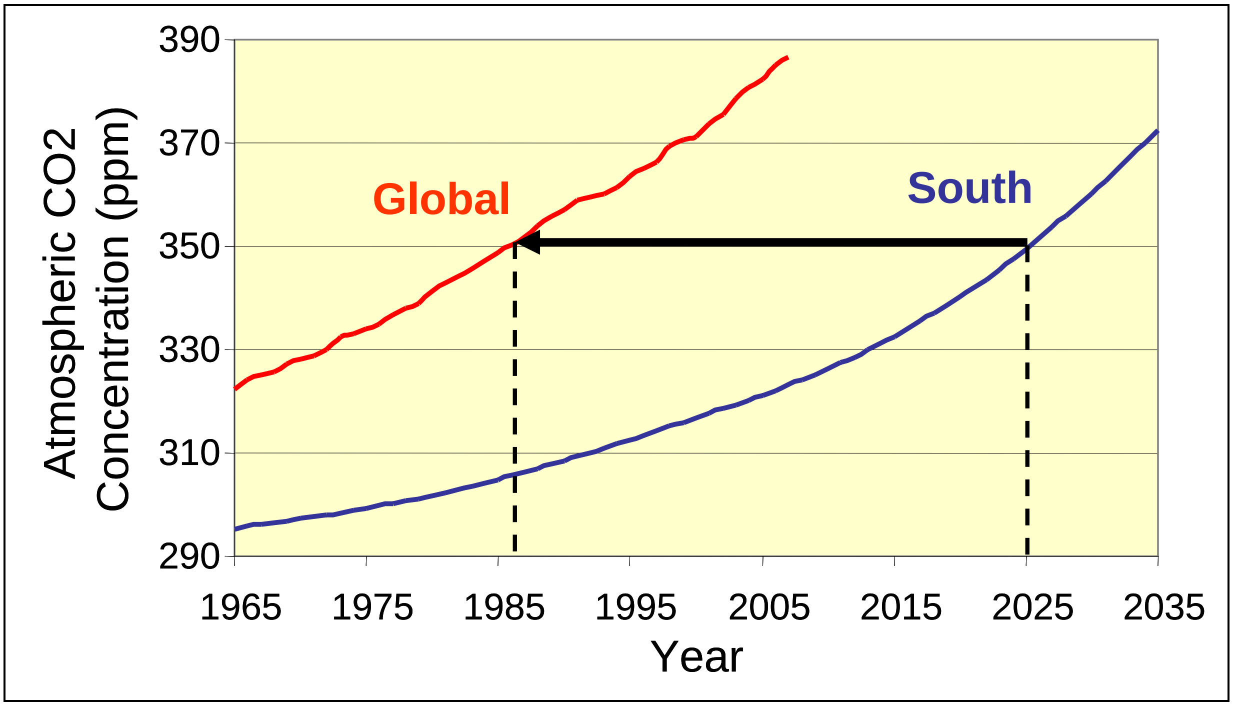

Figure 7: Atmospheric CO_2 Concentration Path: Isolated South (IPCC A1F1 Scenario)