# Some Perspectives on Climate Change Science and Policy

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*Questions or comments?*
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# Vision and Overview

GLOBAL CHANGE

**We explore the interplay between our global environment, economy and human activities, and the potential impact of policies intended to stabilize these relationships.**

**We're Supported by an International consortium of 41 major companies, 8 USA Federal Agencies and a Foundation.**

## Our Goals:

- **Discover new interactions among natural and human climate system components**
- **Objectively assess uncertainty in economic and climate projections**
- **Critically and quantitatively analyze environmental management and policy proposals**
- **Understand connections to other science and policy issues (e.g. air pollution)**
- **Verify national emission reports by combining GHG measurements and ES models to estimate**

# Sponsors

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Total (France)
Toyota Motor North America (USA)
Vattenfall (Sweden)
Vetlesen Foundation (USA)

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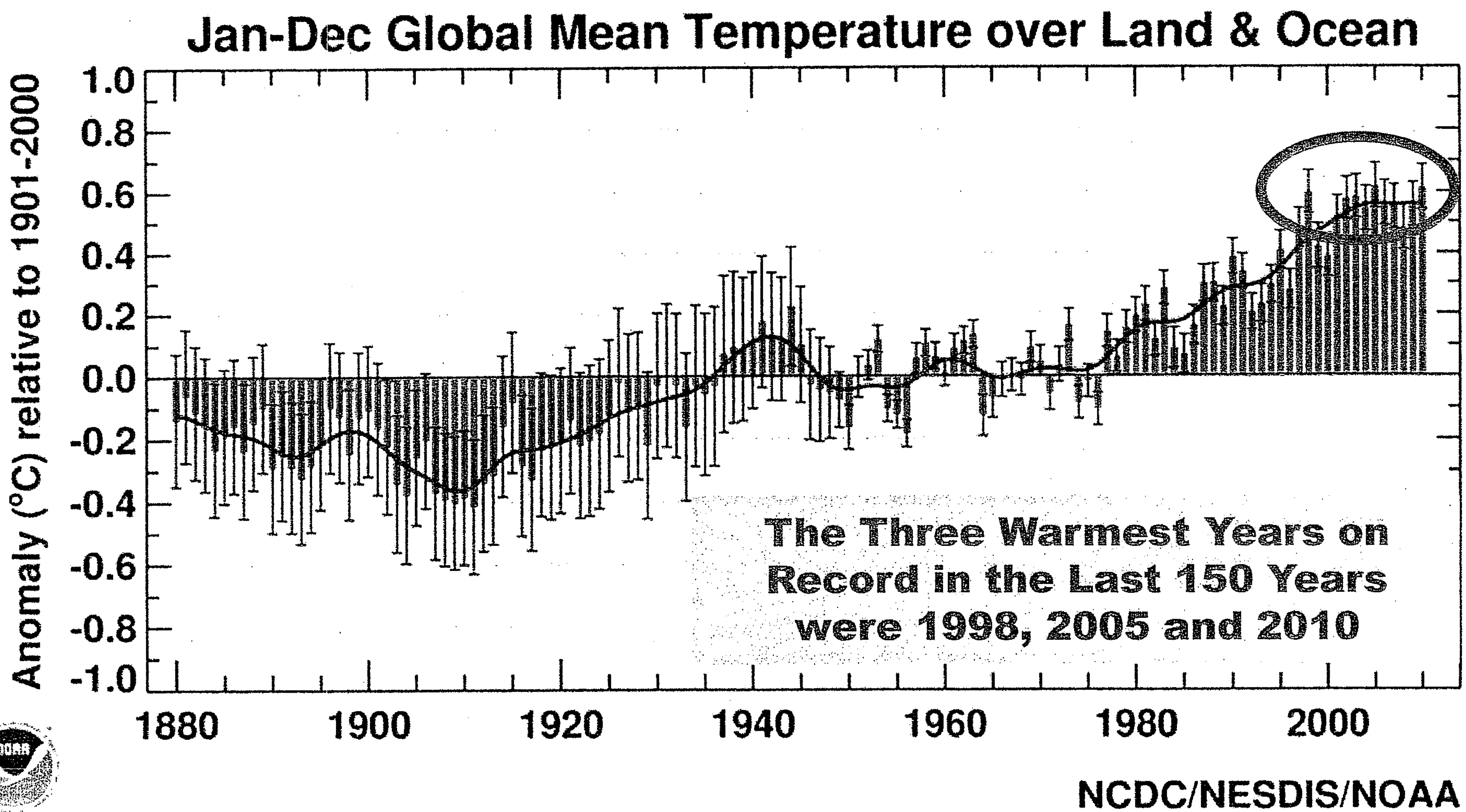
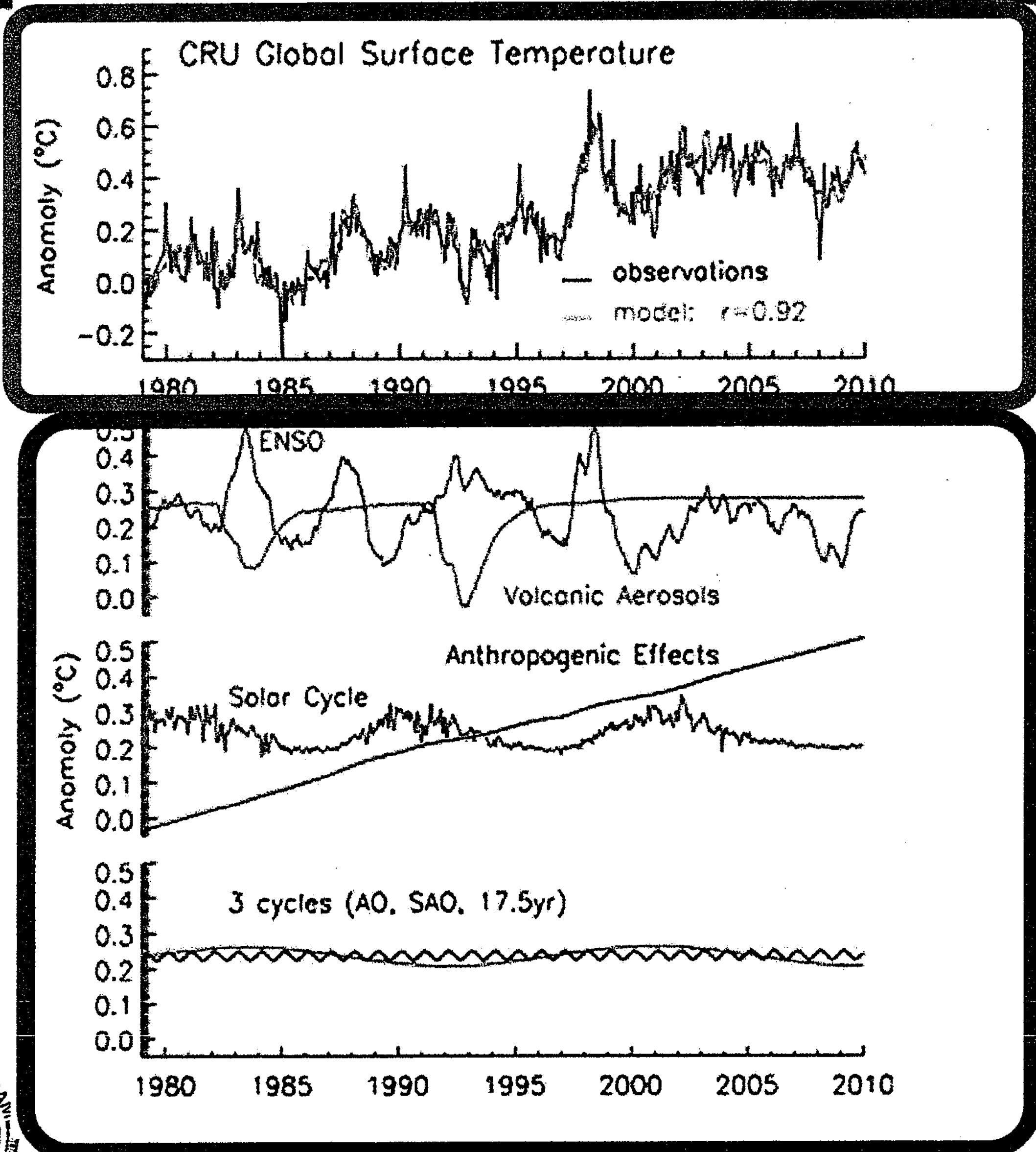
**U.S. National Science Foundation [NSF]**

# How Did Temperatures Evolve Over the past 150 Years?

## Global annual surface air temperature anomaly (relative to 1901-2000 average) as estimated from observations by NOAA-NCDC.



# Attribution: What are the Relative Contributions to Climate Changes of Variability in Natural & Anthropogenic Effects?

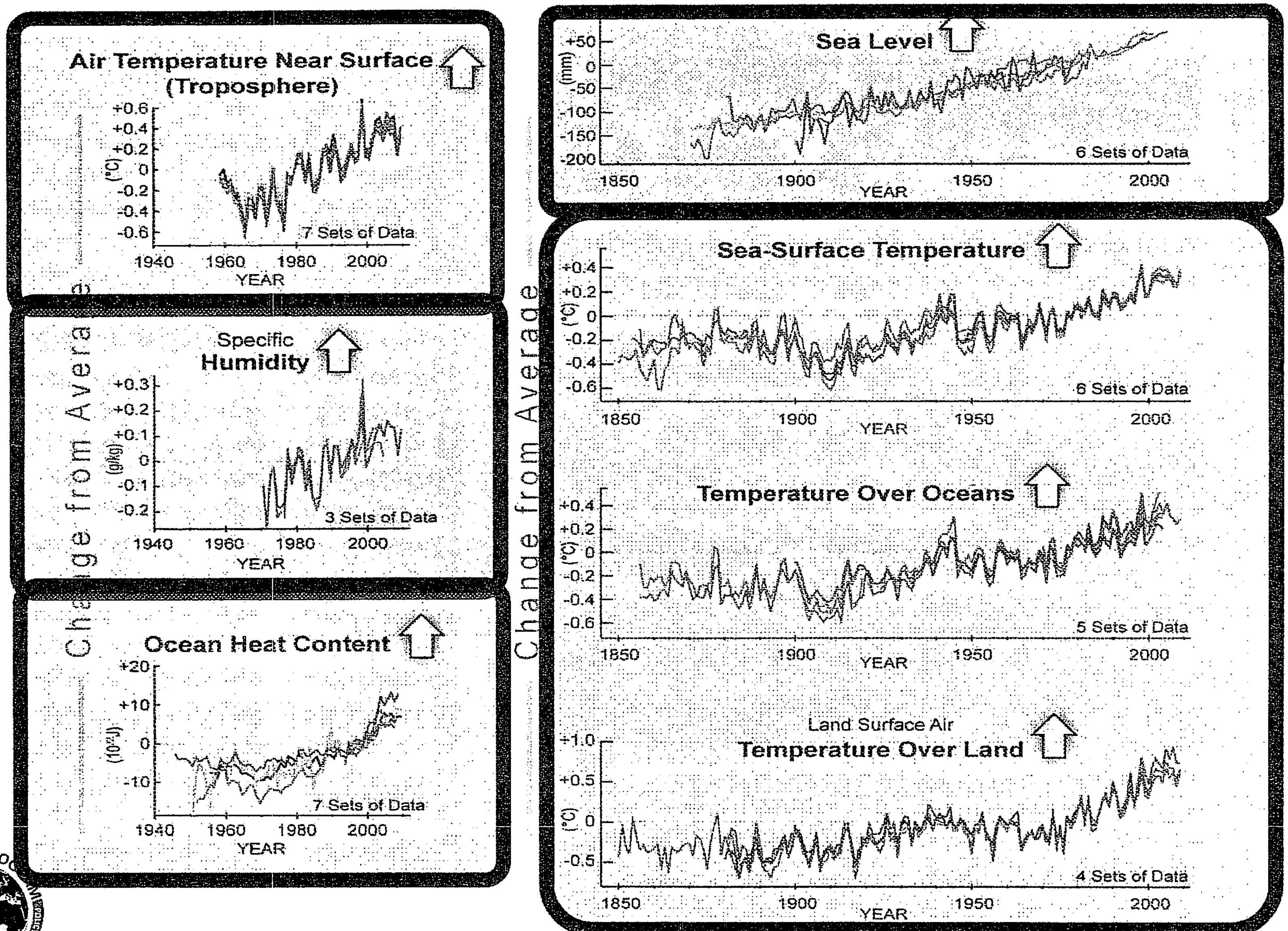



**Compared in the top panel are monthly mean variations in the global temperature of the Earth's surface, from the Climatic Research Unit (CRU, black) and an empirical model (orange, following Lean and Rind [2009]) that combines four primary influences and three minor cycles.**

**These influences & cycles are shown individually in the lower panels. The temperature record has sufficient fidelity that after removing the four primary effects, namely ENSO (purple) at three different lags, volcanic aerosols (blue) at two different lags, solar irradiance (green), and anthropogenic effects (red), minor cycles identifiable as annual (AO, black), semi-annual (SAO, yellow), and 17.5 year oscillations (pink) are evident in the residuals (bottom panel).**

**Ref:Kopp & Lean, GRL, 2011.**

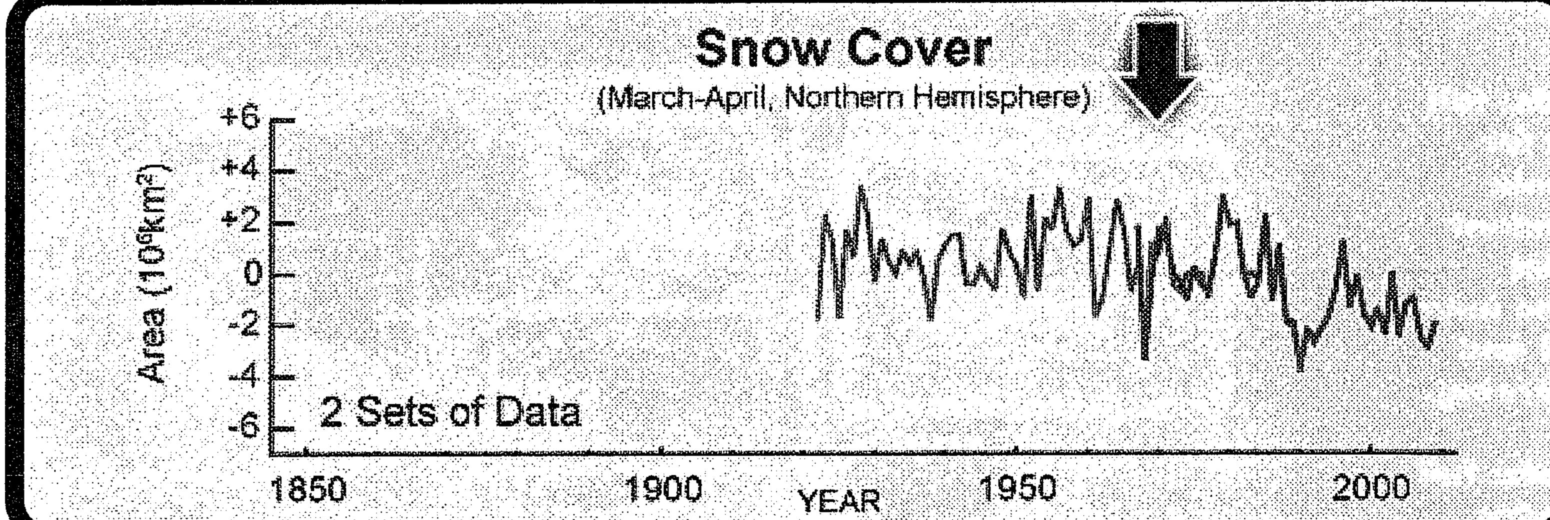
# There are now Multiple Indicators of Warming Global Climate: Indicators with Positive Trends*



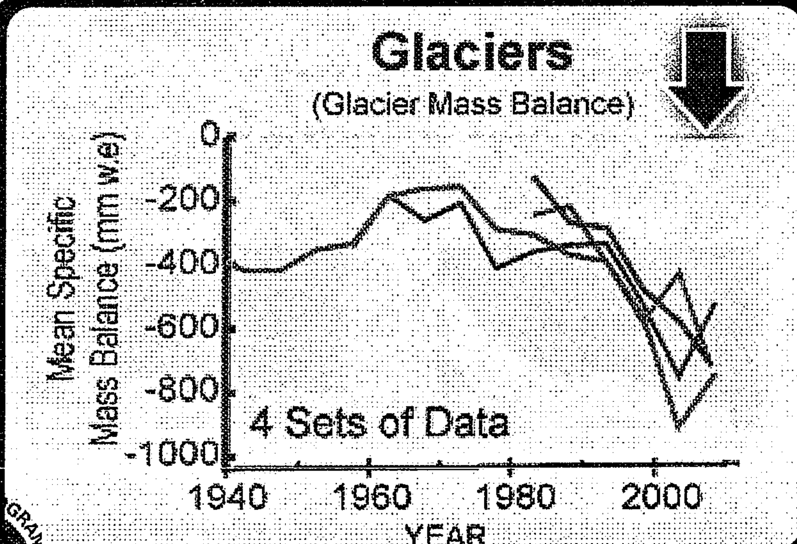

**Courtesy of Tom Karl, Director, National Climate Data Center, NOAA**

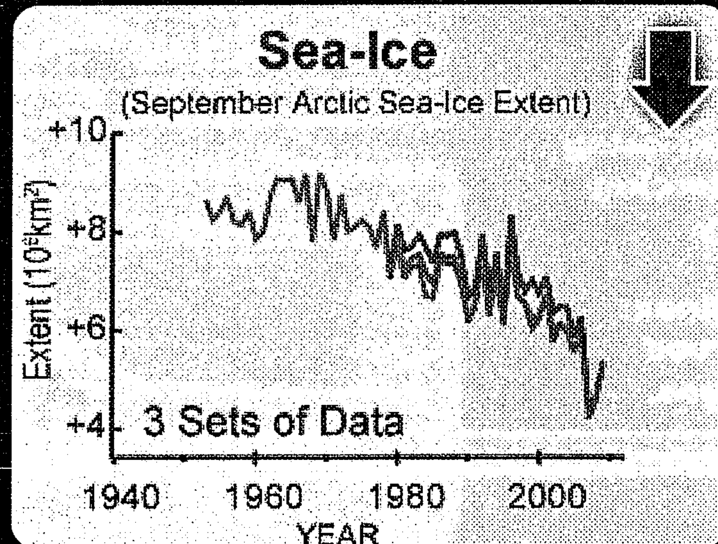
**Arndt, D. S., M. O. Baringer, and M. R. Johnson, Eds., 2010: State of the Climate in 2009. Bull. Amer. Meteor. Soc., 91 (7), S1-S224**

# There are now Multiple Indicators of Warming Global Climate: Indicators with Downward Trends*




Courtesy of Tom Karl, Director, National Climate Data Center, NOAA



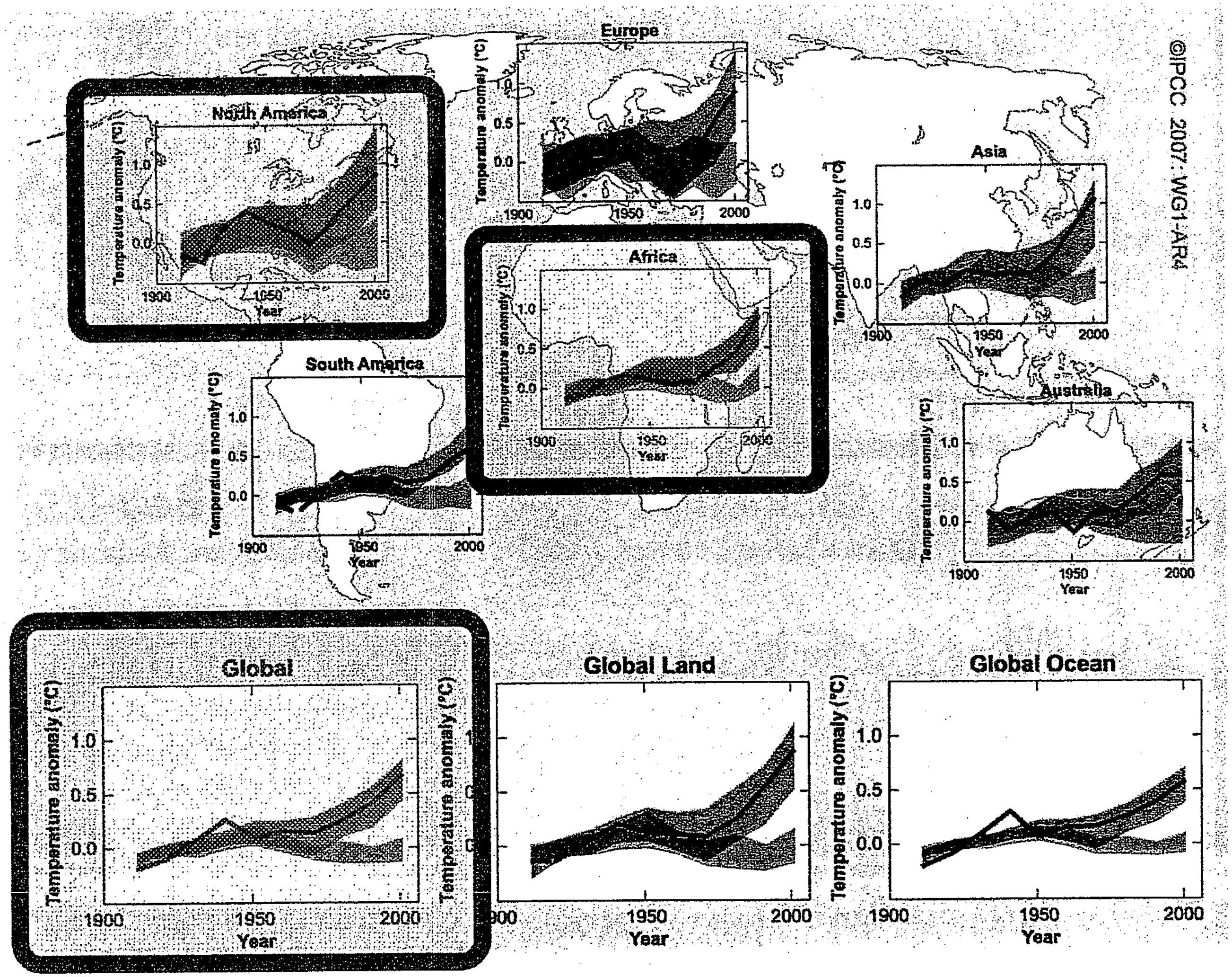

Arndt, D. S., M. O. Baringer, and M. R. Johnson, Eds., 2010: State of the Climate in 2009. Bull. Amer. Meteor. Soc., 91 (7), S1-S224

# Attribution Problem: What are the Relative Roles of Human & Natural Processes in Driving the Observed Global & Continental Temperature Change from 1906 to 2005?

**Red bands: full range for multiple independent model simulations using natural and human forcing.**

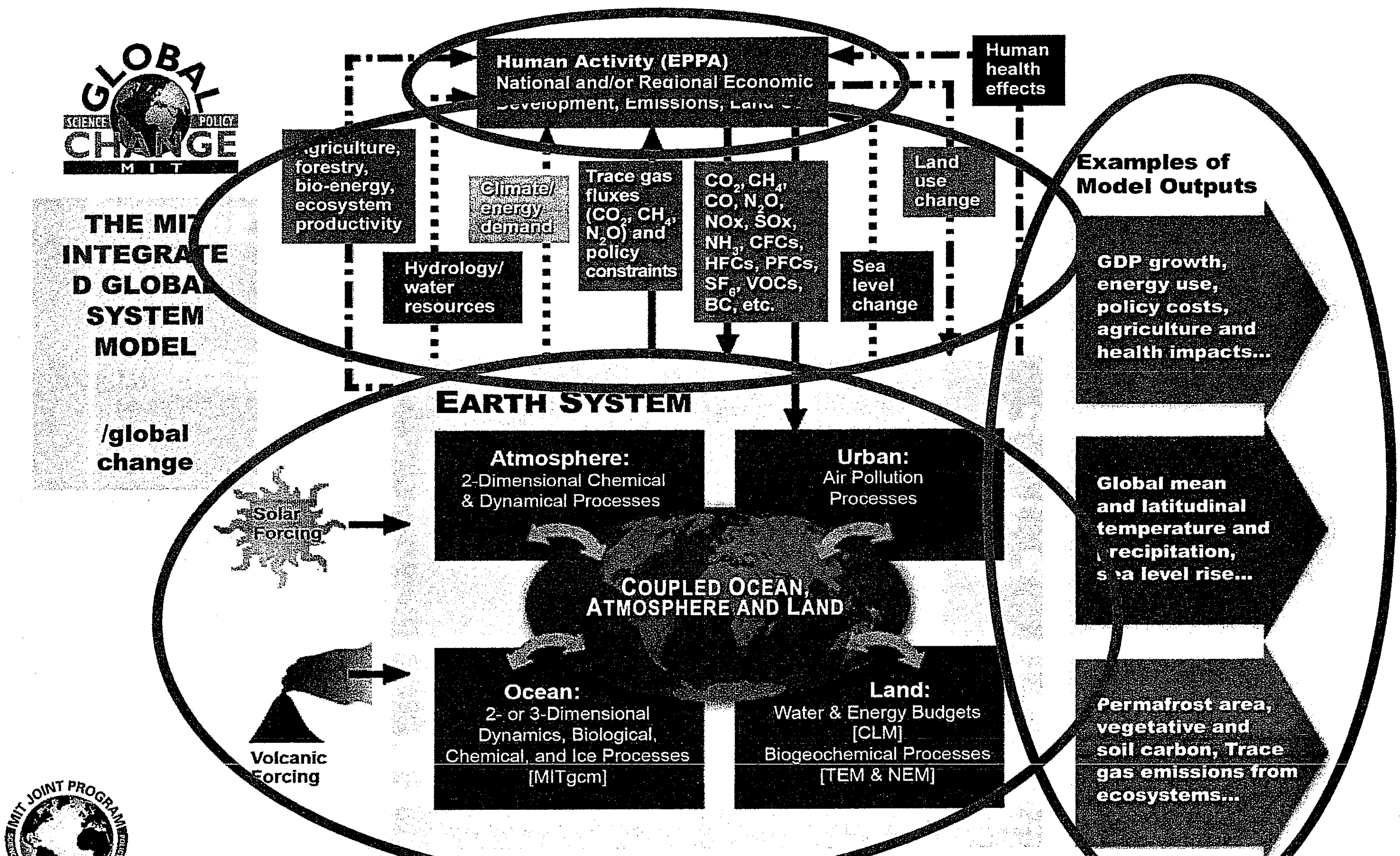
**Blue bands: full range for multiple independent model simulations using natural forcing only.**

**Black lines: observed changes.**




**Ref: D. Fahey, adapted from IPCC 4th Assessment, Summary for Policymakers, Feb. 2, 2007**

# Forecasting Climate Requires Coupling the Uncertain Human and Natural Processes Involved



## What are the Odds of Global Average Surface Air Warming from 1981-2000 to 2091-2100 Exceeding Certain Thresholds for a Range of Policy Scenarios

| | $\Delta T > 2°C$ values in red relative to 1860 or pre-industrial) | $\Delta T > 4°C$ | $\Delta T > 6°C$ |
|---|---|---|---|
| **No Policy at 1400ppm CO2e** | 100% (100%) | 85% | 25% |
| **Stabilize at 900ppm CO2e (L4)** | 100% (100%) | 25% | 0.25% |
| **Stabilize at 790ppm CO2e (L3)** | 97% (100%) | 7% | < 0.25% |
| **Stabilize at 660ppm CO2e (L2)** | 80% (97%) | 0.25% | < 0.25% |
| **Stabilize at 550ppm CO2e (L1)** | 25% (80%) | < 0.25% | < 0.25% |

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**Ref: Sokolov et al, Journal of Climate, 2009; Webster et al, Climatic Change, 2011**

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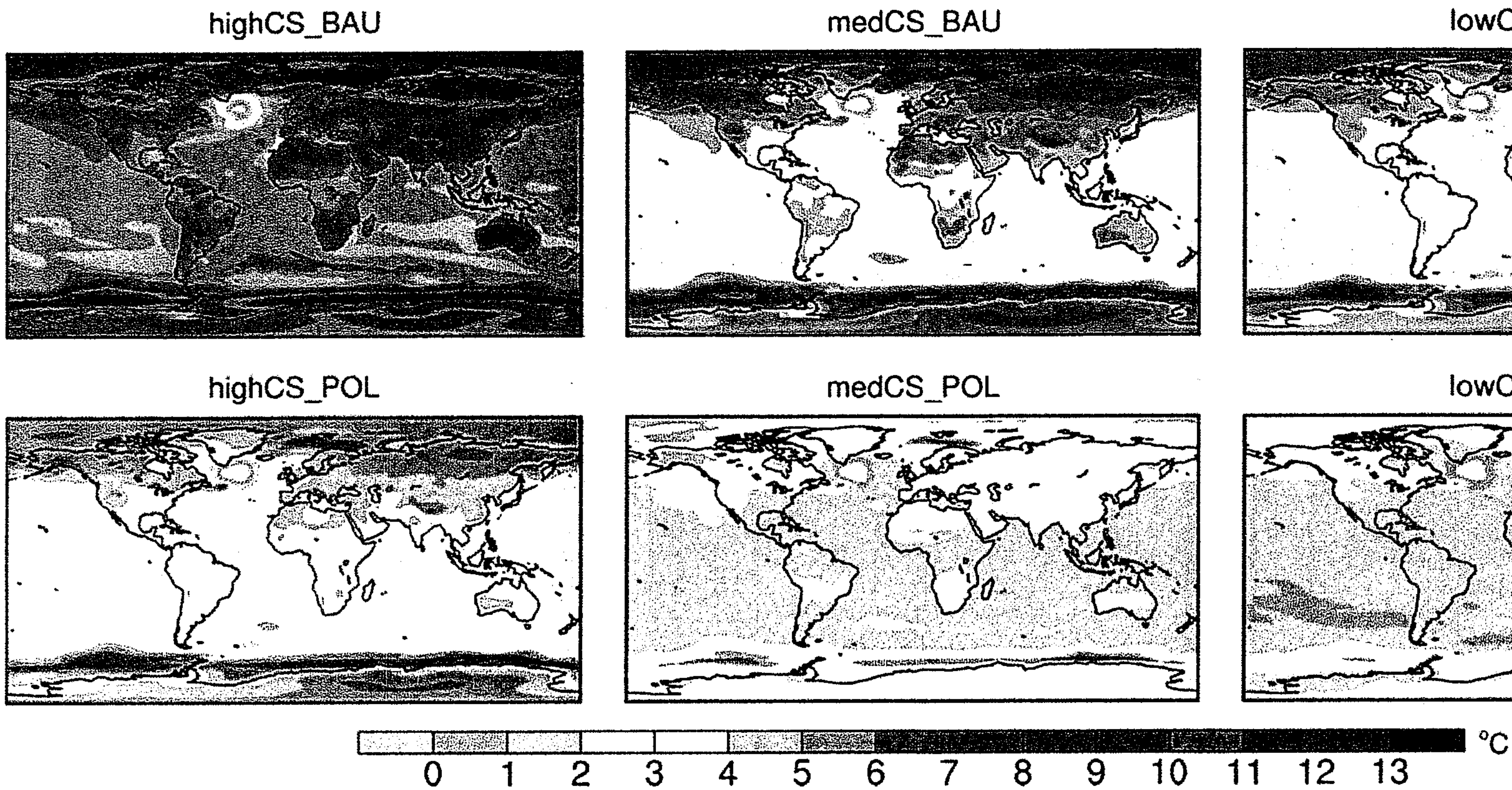
# Range of climate outcomes, one GCM with varied climate sensitivty

## Temperature
## 2080-2099 relative to 1980-1999 (in °C)

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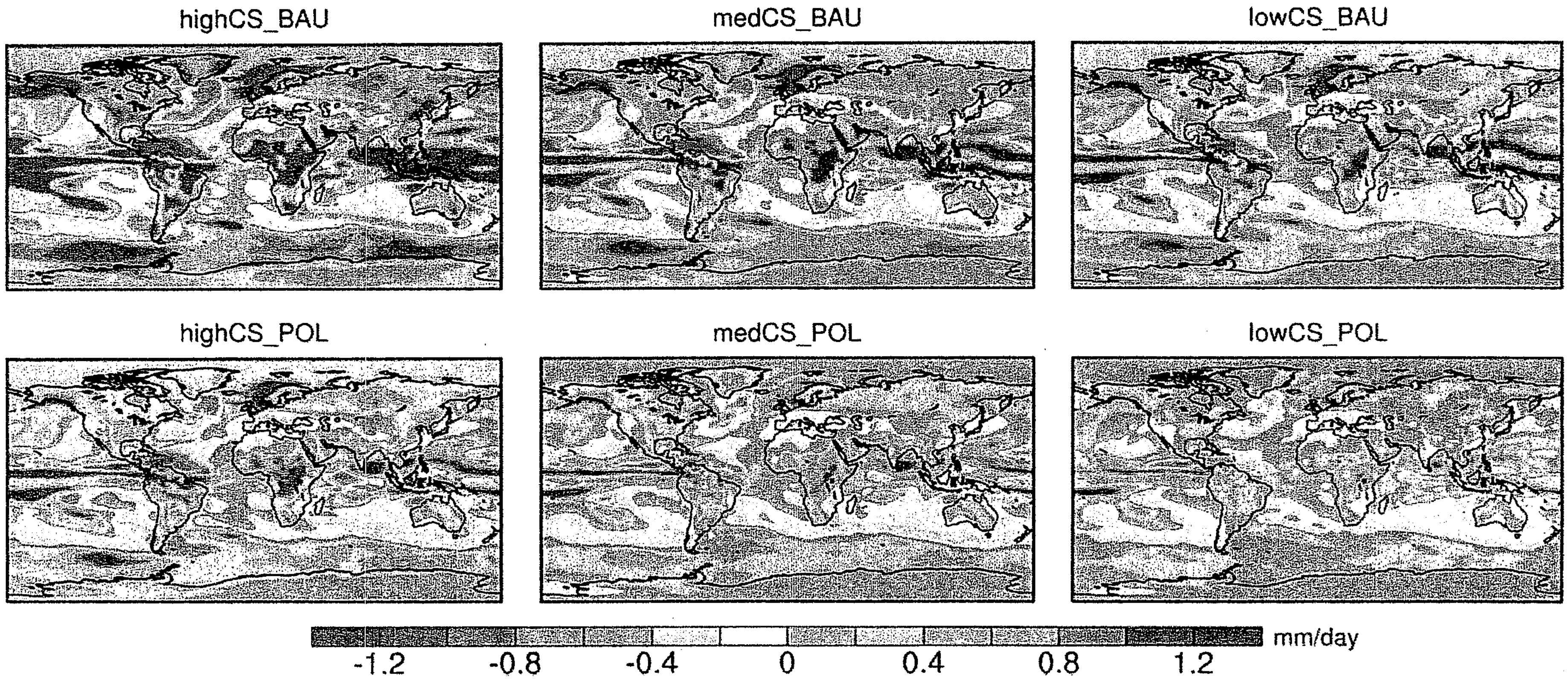
# Climate Simulations

Precipitation

2080-2099 relative to 1980-1999 (in mm/day)

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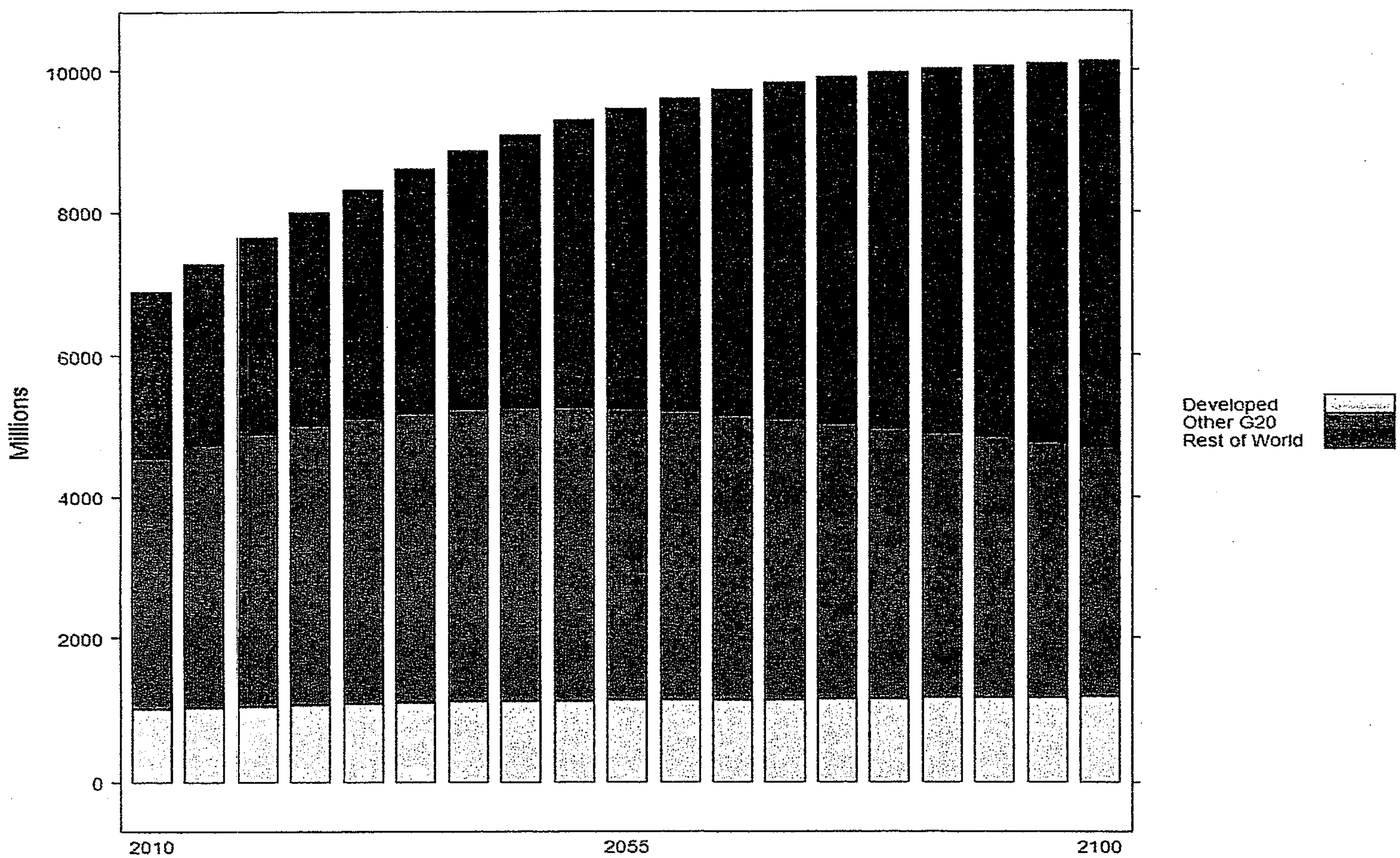
# Where is the world headed?

- Projections of energy mix and impacts on the climate.
- One emission scenario, three climate sensitivity scenarios.
- Reflects Copenhagen/Durban Accord pledges for 2020.
- Keeps 2020 goals afterwards with no additional policy.

# UN Global Population Projections

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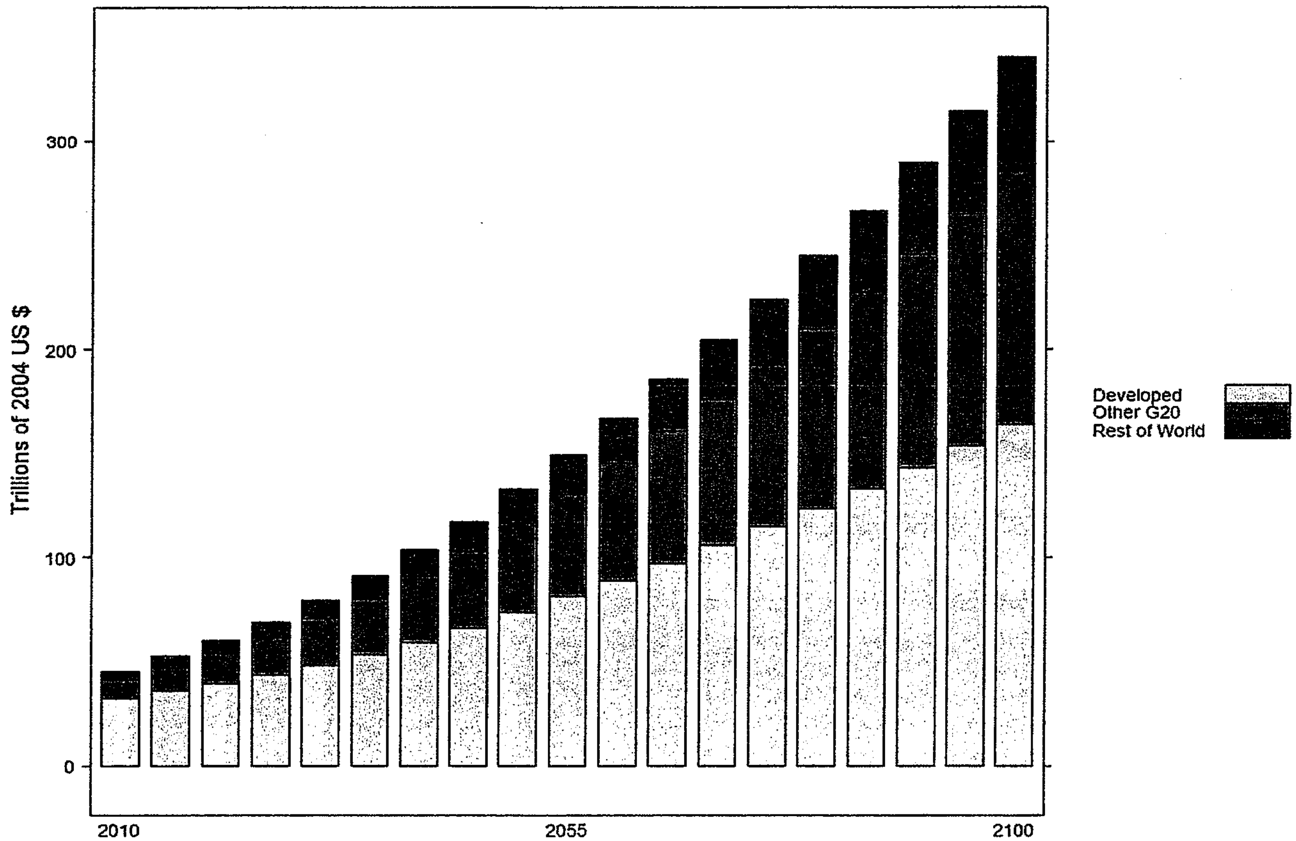
# World GDP

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# Global Energy Use

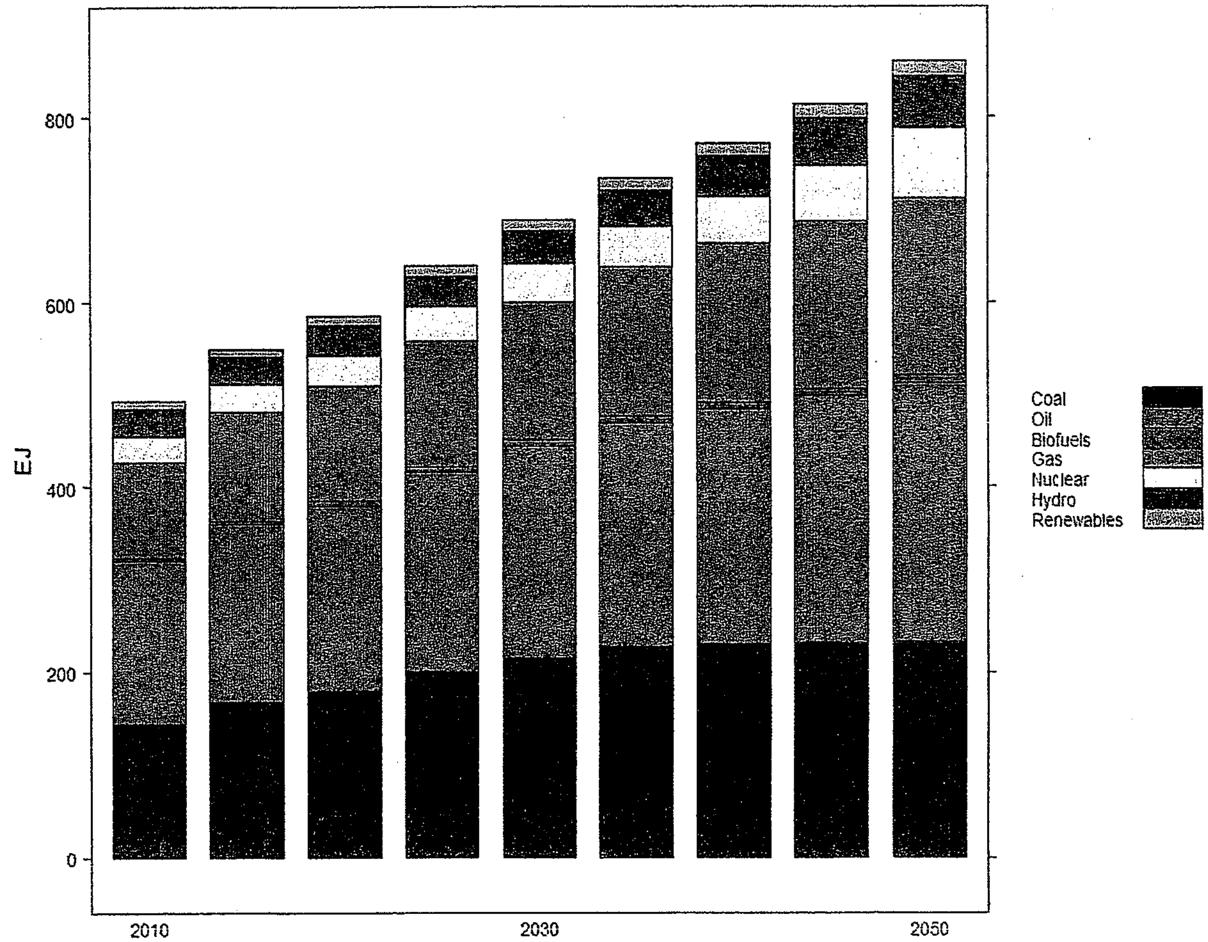
**Coal levels off**

**Larger role of natural gas and oil**

**Renewables increase 2.5 times by 2050**

**We have not forced renewables by RPS or other mandates**

**Some nuclear power growth**

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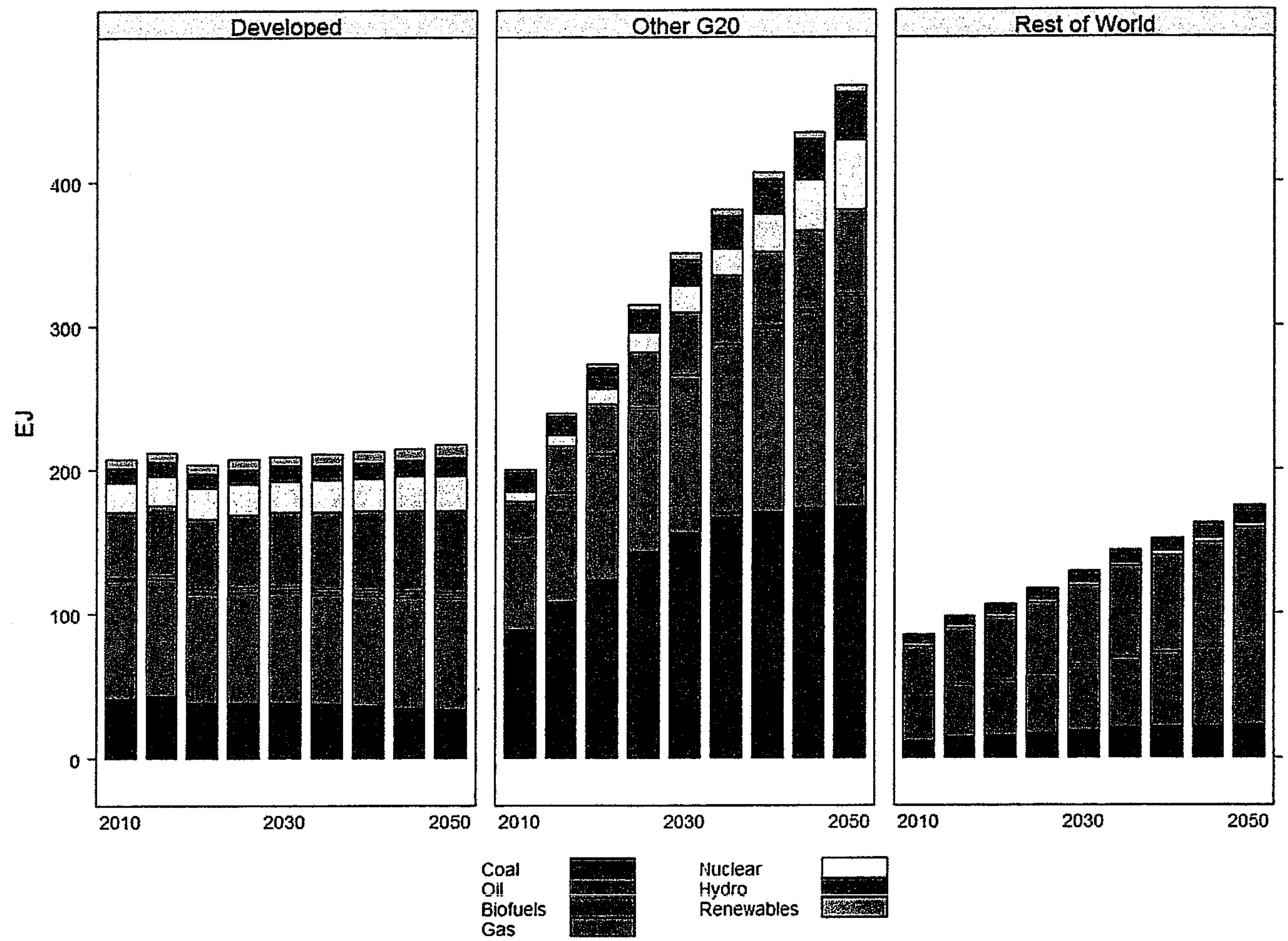
# Energy Use by Major Group

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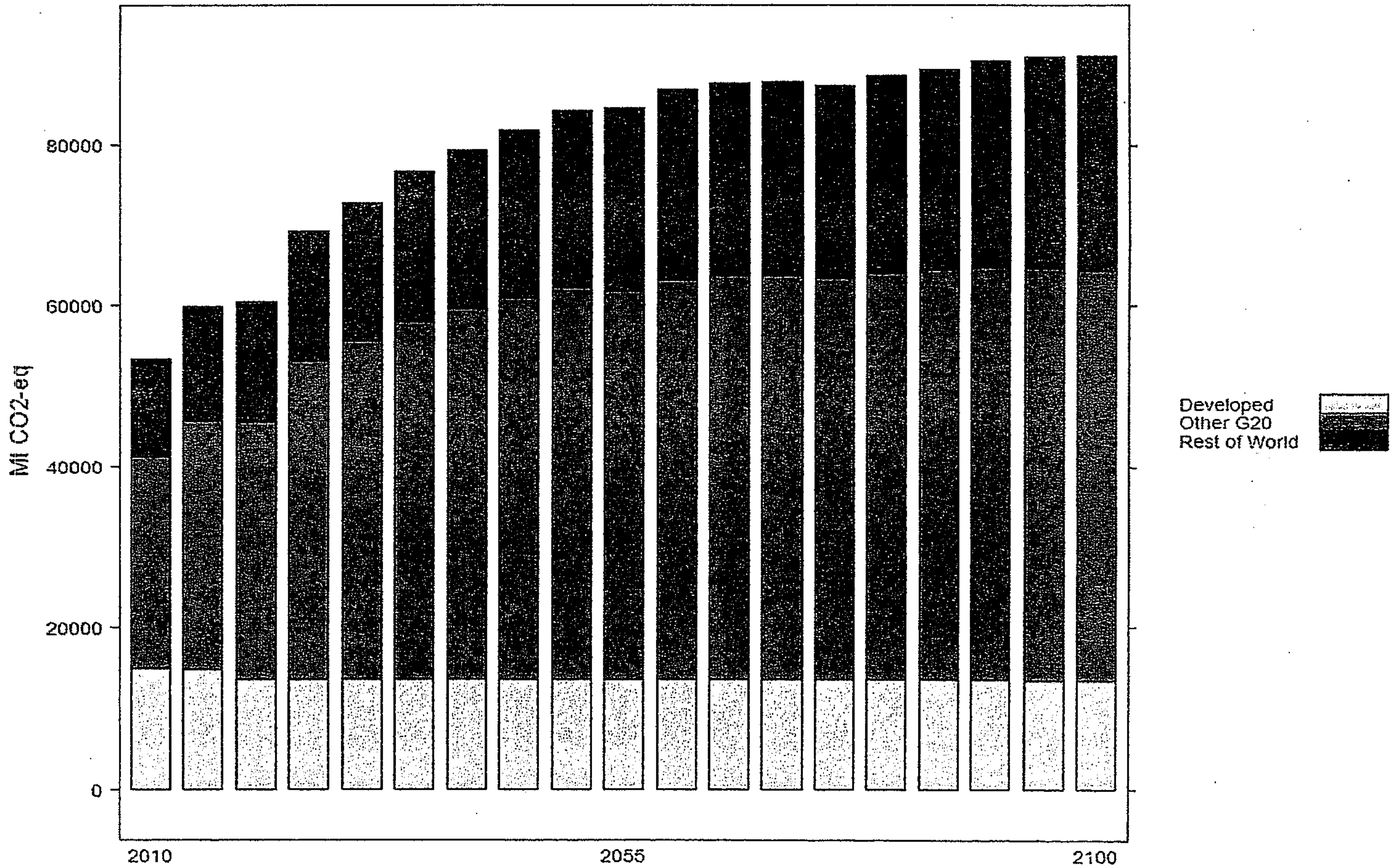
# Fossil $CO_2$ Emissions by Major Group

**Other G20 regions grow even with intensity targets in China and India**

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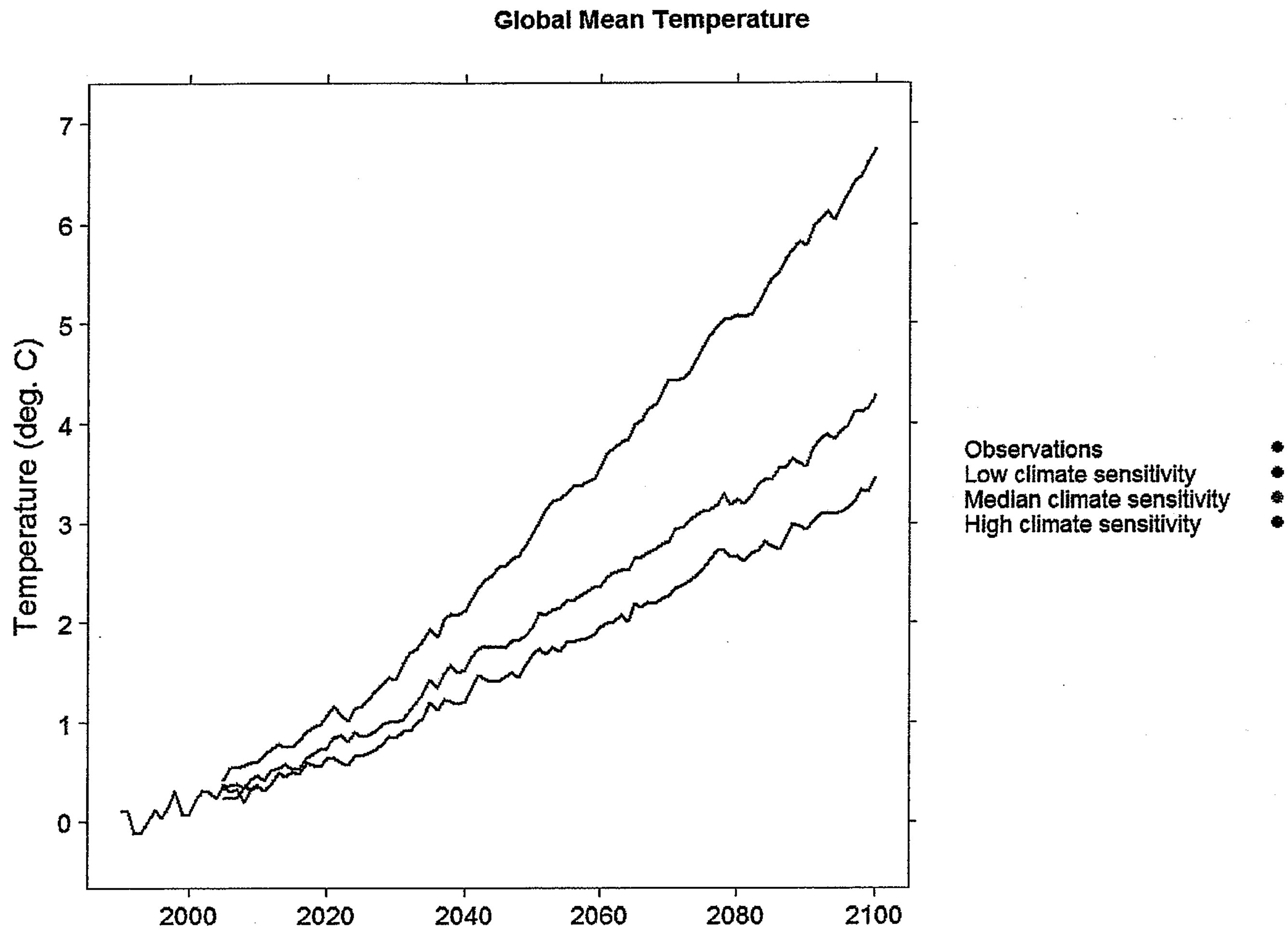
# Temperature Increase

**Global average surface temperature change relative to 2000**

**Black line - observations**



# Risks to Food Production in the World's Breadbaskets

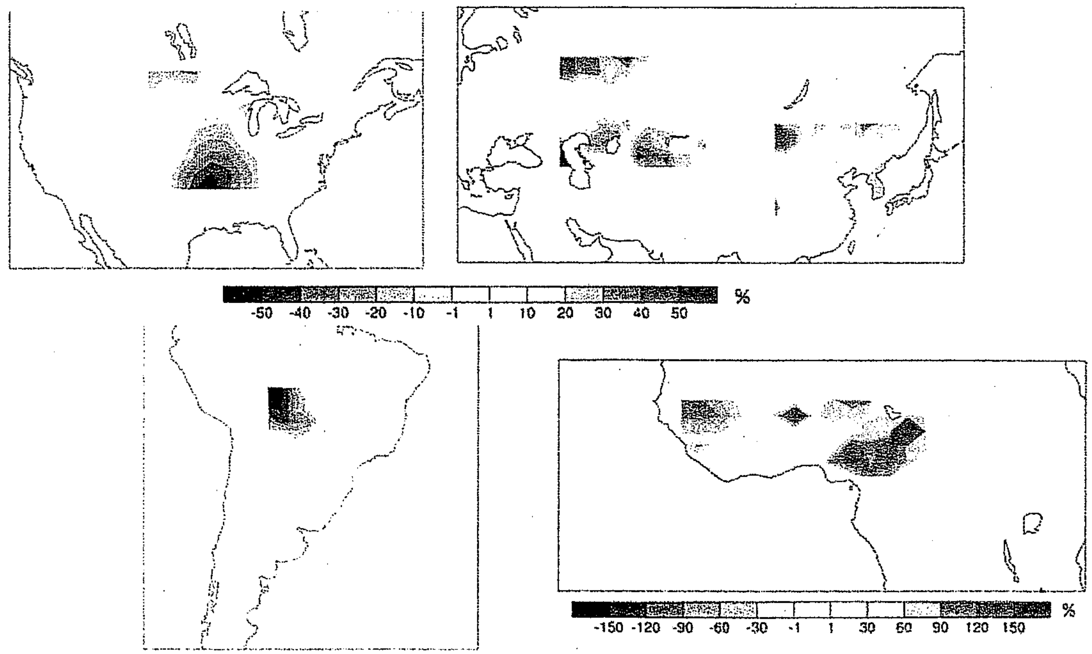
**Objective:** Assess risks to food production in the world's breadbaskets.

**Approach:** Develop a risk-based approach to evaluate changes in crop yields: (1) Identify the world's "breadbaskets" as in Bagley et al (2012)[1] (2) Simulate an ensemble of climate scenarios representing climate and policy uncertainties using the method of Monier et al (2012),[2] and (3) Simulate changes in crop yields for breadbasket regions using a crop model developed for the IGSM in Gueneau et al (2012).[3]

**Impact:** Preliminary results show lower yields toward the equator, and higher yields pole-ward, except in western Africa where the yield gradient goes from west to east. Results also show large increases in variability of yield in North America, with less clear effects on variability in other regions.

Here we show the no-mitigation, high climate sensitivity scenario, with adaptation including adjustments for planting date and crop choice.

**Predicted Change (%) in Potential Yields for each Breadbasket 2080-2099 relative to 1980-1999, high climate sensitivity scenario**




[1]Bagley et al (2012) Effects of land cover change on moisture availability and potential crop yield in the world's breadbaskets, Environmental Research Letters 7

[2]Monier et al (2012) An Integrated Assessment Framework for Uncertainty Studies in Global and Regional Climate Change: The IGSM-CAM, MIT Joint Program Report 223.

[3]Gueneau et al (2012) CLM-AG: An Agriculture Module for the Community Land Model version 3.5, MIT Joint Program Report 229.

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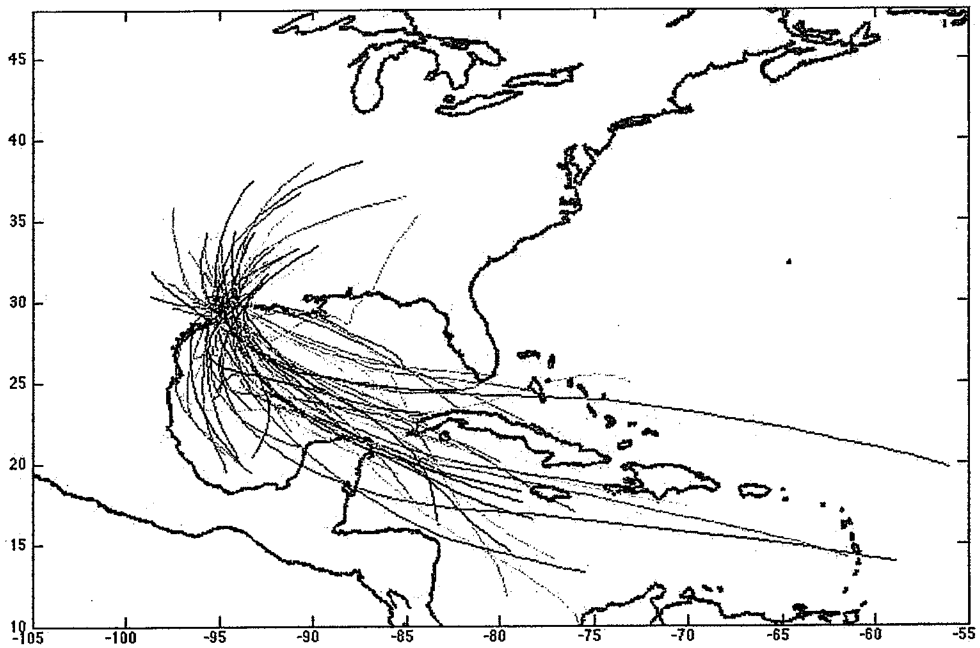
# Risks to Coastal Infrastructure

**Objective:** Evaluate optimal level of coastal protection for energy infrastructure given uncertainty in changes in sea level rise and tropical storms.

**Approach:** The work of Emanuel et al[1,2] is used to develop a model to project tropical storm tracks and intensity for the U.S. Gulf region. Combined with a model of storm surge and estimates of potential sea level rise (Katsman et al., 2011[3]; Nicholls et al., 2010[4]) the analysis projects flood risks to infrastructure. A dynamic programming model of decision-making under uncertainty evaluates optimal levels of protection.

**Results:** Shown here are a sample of 50 simulated hurricane paths that would affect the target location. The approach allows the estimation of the likelihood of storms of varying intensity striking any particular location. With this information, a risk-based assessment of adaptation is possible. The initial application focuses on an existing refinery in the U.S. Gulf.

**50 sample hurricane tracks**

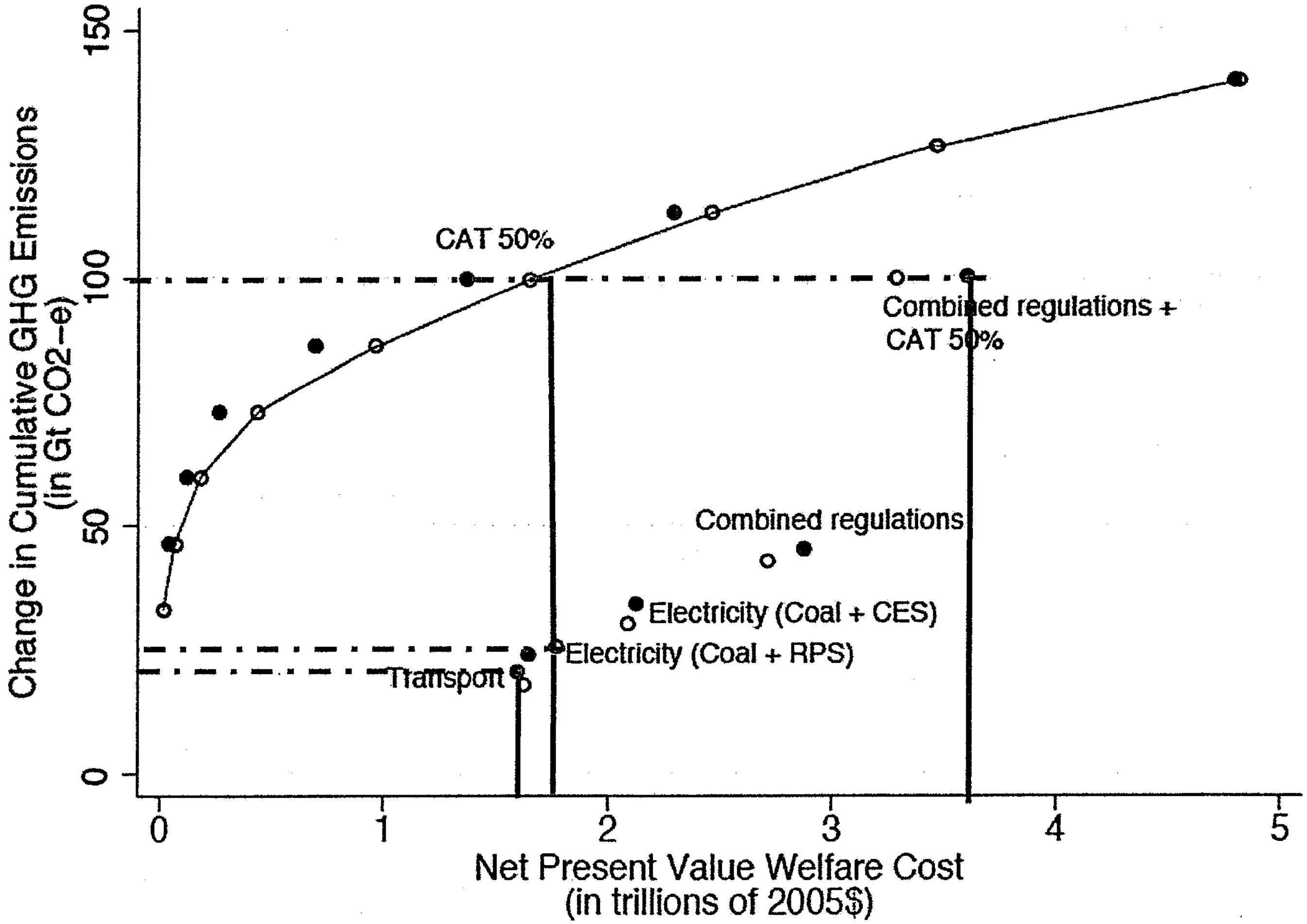



[1]Emanuel, et al, 2006: A statistical deterministic approach to hurricane risk assessment. B. Am. Met. Soc., 87(3): 299–314.
[2]Emanuel, et al., 2008: Hurricanes and global warming. B. of the Am. Met. Society 89: 347–367.
[3]Katsman, et al., 2011: Exploring high-end scenarios for local sea level rise to develop flood protection strategies for a low-lying delta: the Netherlands as an example. Climatic change, 109(3): 617–645.
[4]Nicholls, and Cazenave, 2010: Sea-level rise and its impact on coastal zones. Science, 328(5985): 1517–1520.

# Policy Options

- Cap and Trade
- Carbon tax
- Regulatory approaches;
  - Technology tax incentives (e.g. Investment tax credits)
  - Performance requirements (e.g. CAFE standards)
  - Requirements (e.g. Renewable Portfolio Standards)
  - Best available technology (Appliance standards, building codes)

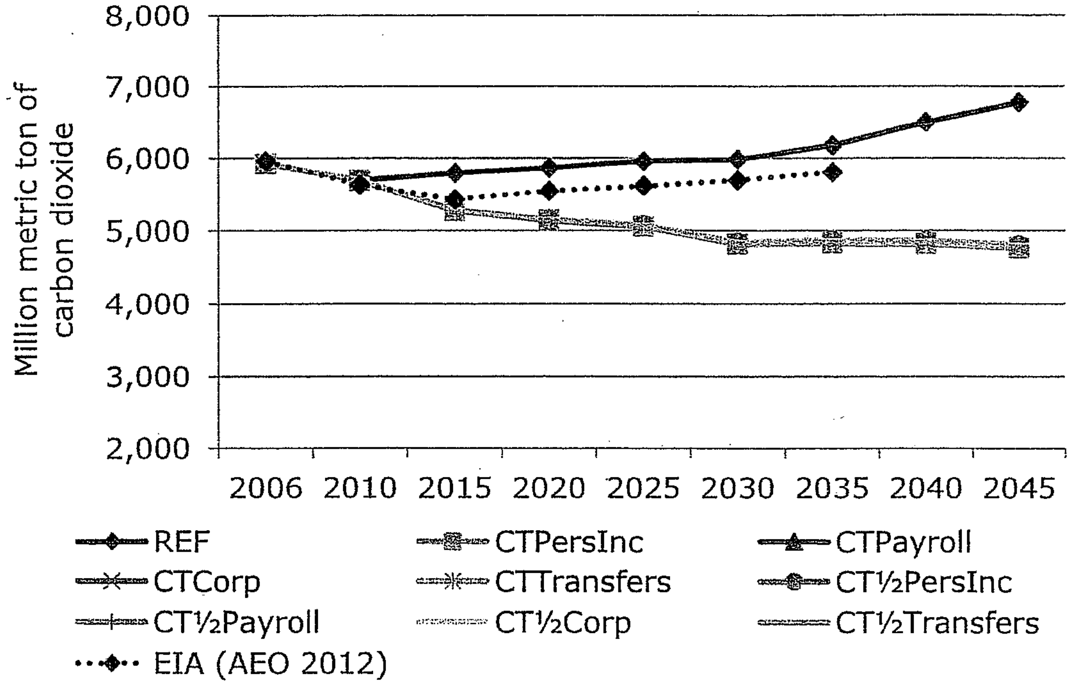
# Many popular policy approaches are inefficient




From: S. Rausch & V. Karplus: Markets versus Regulation: The Efficiency and Distributional Impacts of U.S. Climate Policy Proposals, Energy Economics, forthcoming

# Effects of A Carbon Tax in the US: Different uses of tax revenue

- Carbon tax case: $20/ton starting in 2013, rising at 4% real after CBO analysis of a year ago. [About $85 real in 2050]




- Many different cases of how revenue from the tax is used (defined later)
- Here main point is all lead to almost the same emissions reduction.
- 14% reduction in 2020 from 2006, 20% by 2050

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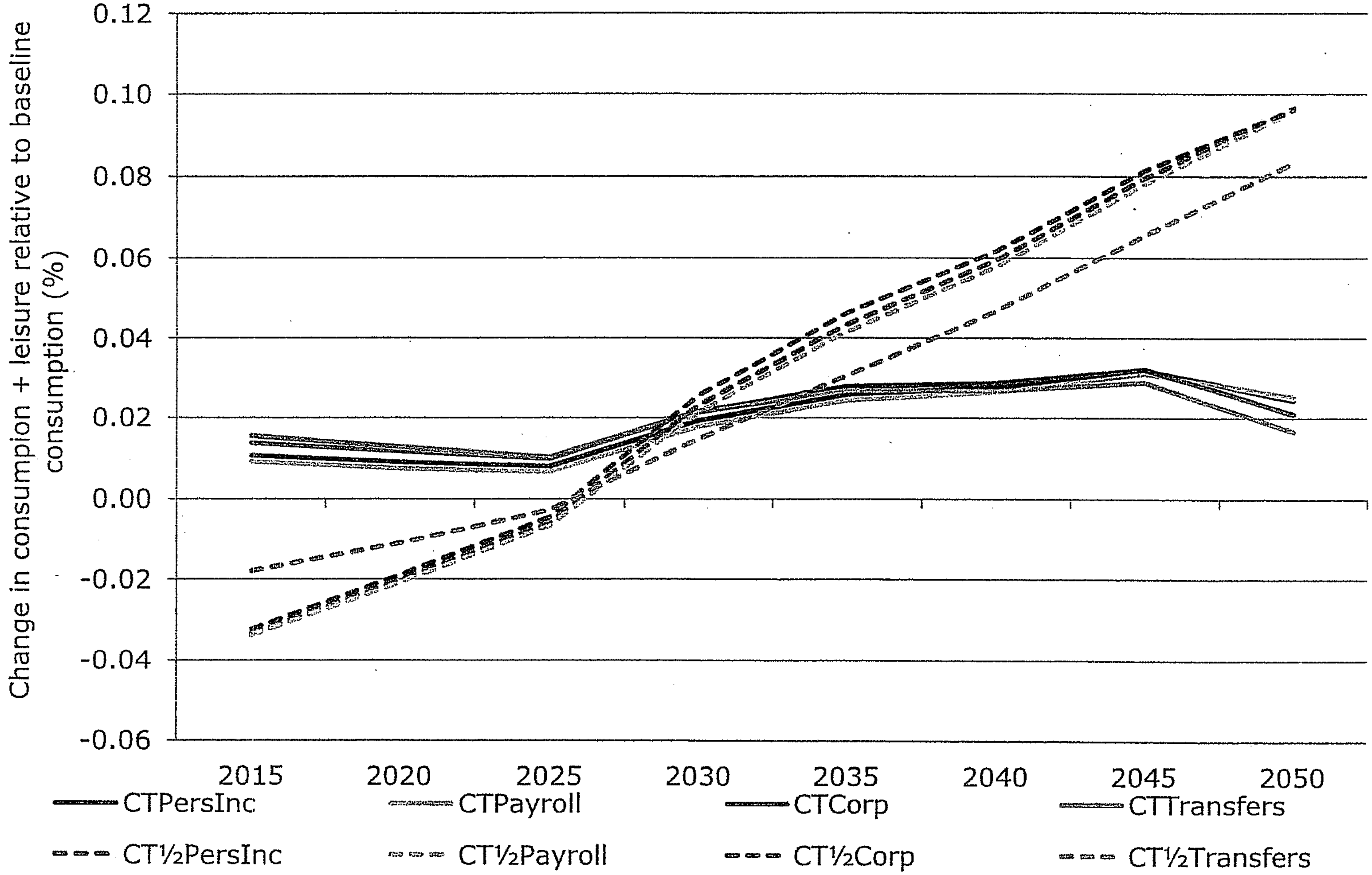
# Scenarios—cutting personal, corporate, or payroll taxes or funding social programs, w or w/o Investment credit

| Name | Scenario |
|---|---|
| Ref | Current law with Bush tax cuts and payroll tax cuts expiring[a] |
| CTPersInc | Carbon tax[b] revenue used to reduce the personal income tax rates |
| CTCorp | Carbon tax revenue used to reduce corporate tax rates |
| CTPayroll | Carbon tax revenue used to reduce payroll taxes |
| CT½PersInc | As in CTPersInc but ½ of revenue diverted to investment |
| CT½Corp | As in CTCorp but ½ of revenue diverted to investment |
| CT½Payroll | As in CTPayroll but ½ of revenue diverted to investment |
| CTTransfers | Carbon tax revenue is used to increase transfer payments |
| CT½Transfers | As in CTTransfers but ½ of the revenue is diverted to investment |

# Key Results—Welfare Effects

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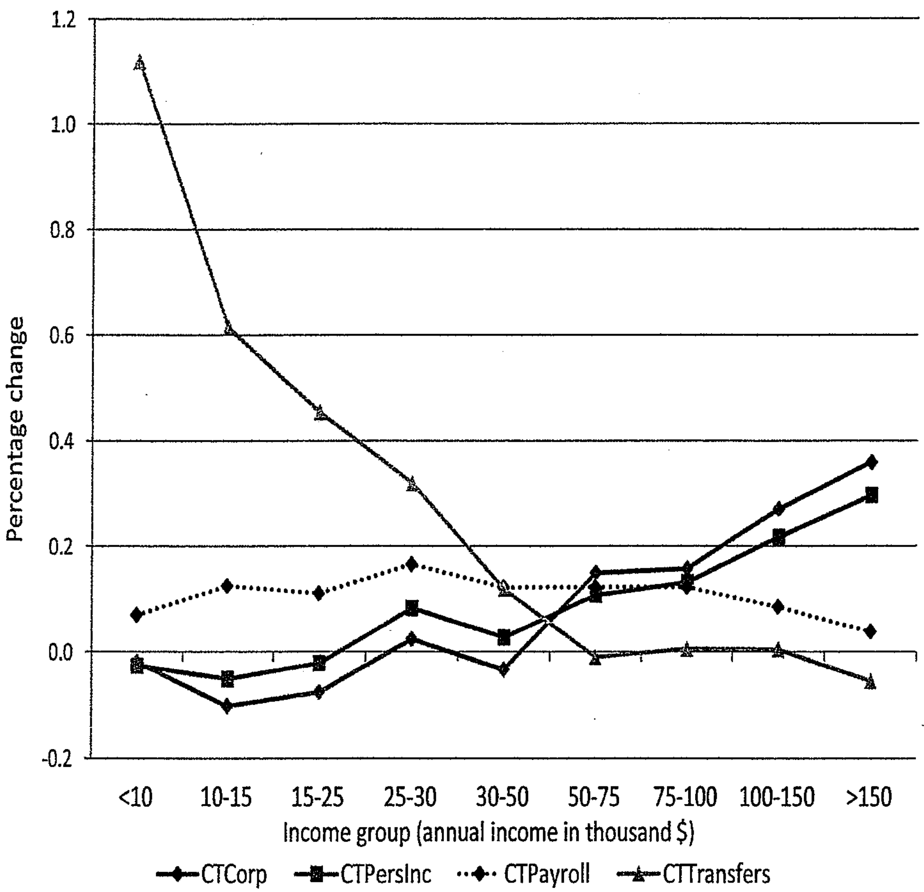
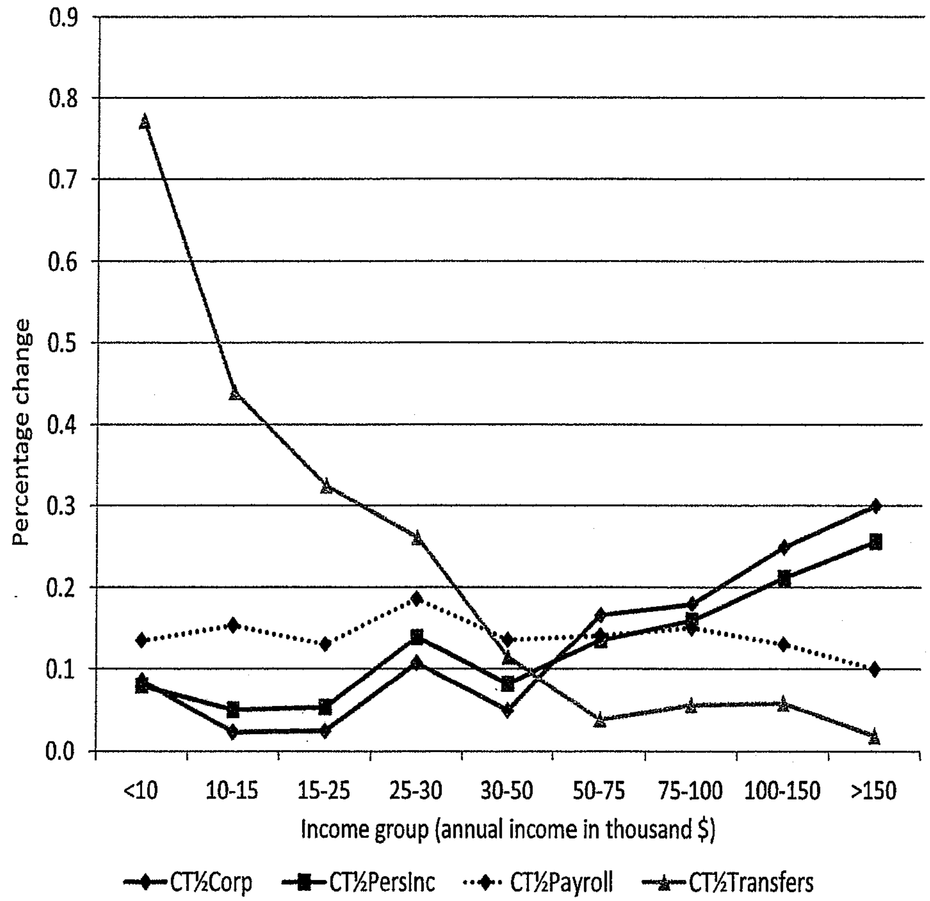
# NPV Distribution effects, w/o ITC left, w/ ITC right



# Some Key Joint Program Studies on These Topics

**Reprint 2012-28.** Schlosser, C.A., X. Gao, K. Strzepek, A. Sokolov, C.E. Forest, S. Awadalla and W. Farmer, online first,

**Reprint 2012-4.** Webster, M.D., A.P. Sokolov, J.M. Reilly, C. Forest, S. Paltsev, C.A. Schlosser, C. Wang, D.W. Kicklighter, M. Sarofim, J.M. Melillo, R.G. Prinn and H.D. Jacoby 112(3-4) 569–583.

**Reprint 2010-14.** Strzepek, K., G. Yohe, J. Neumann and B. Boehlert, 5(044012): 1-9.

**Special Report:** , MIT Joint Program on the Science and Policy of Global Change (March 2012) (13 pages)

**Report 229.** Gueneau, A., C.A. Schlosser, K.M. Strzepek, X. Gao and E. Monier, (September 2012) (28 pages)

**Report 228.** Rausch, S. and J.M. Reilly, (August 2012) (21 pages)

**Report 224.** Lanz, B. and S. Rausch, (July 2012) (51 pages)

**Report 219.** Reilly, J., S. Paltsev, K. Strzepek, N.E. Selin, Y. Cai, K.-M. Nam, E. Monier, S. Dutkiewicz, J. Scott, M. Webster and A. Sokolov, (May 2012) (21 pages)