Terrestrial Impacts, Feedbacks & Human Adaptation

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• Where are we headed?
• Impacts of changes that have already occurred
• Impacts of future changes
• Feedbacks from the unmanaged carbon cycle
Terrestrial Impacts, Feedbacks & Human Adaptation

- Paul Kirshen, Tufts University: “Sea level rise and coastal flooding”
- David Lobell, Lawrence Livermore National Laboratory: “Warming and the global harvest”
- Ted Schuur, University of Florida: “Permafrost carbon and climate feedbacks”
North America: Key messages

- A wide range of impacts of climate change are now clearly documented
- Risks from future impacts concentrated on extreme events
- Vulnerable people and activities in almost every region
- Opportunities for improving adaptation

IPCC AR4 WG2, North America
Future risk areas

- Increasing frequency of severe hurricanes
- More frequent and more severe heat waves
- Rising sea level
- Public health challenges
- Decreasing water availability (& quality)
- More frequent and larger wildfires
- Challenges to agriculture and forestry
- International trade and security
Anthropogenic C Emissions: Fossil Fuel

2006 Fossil Fuel: 8.4 Pg C

[Total Anthrop. Emis.: 8.4 + 1.5 = 9.9 Pg]

1990 - 1999: 1.3% y⁻¹

2000 - 2006: 3.3% y⁻¹

Raupach et al. 2007, PNAS; Canadell et al 2007, PNAS
Global Carbon Dioxide Emissions

Carbon emissions (millions of tons/yr)

- **TOTAL**
- Gasuous Fuels
- Liquid Fuels
- Solid Fuels
- Cement Production

Year

1860  1880  1900  1920  1940  1960  1980  2000
Finding the mechanism

$$CO_2 = \left( \frac{CO_2}{GDP} \right) \times \left( \frac{GDP}{P} \right) \times P$$

Carbon intensity of economic activity
Per capita GDP
Population size
Anthropogenic C Emissions: Carbon Intensity of GDP

Factor (relative to 1990)

World

- Emissions
- Population
- Wealth = per capita GDP
- Carbon intensity of GDP

Raupach et al 2007, PNAS
Dramatic contrast - history versus future

Raupach et al. PNAS 2007
Cumul Flux Growth Pop

0%
20%
40%
60%
80%
100%

D3
India
D2
China
FSU D1
Japan
EU
USA

$\text{CO}_2$ emissions

Developing
India
China
Former Soviet
Other developed
Japan
Europe
USA
The diagram shows the CO₂ emissions distribution among different regions. The labels on the diagram indicate the following categories:

- Developing
- India
- China
- Former Soviet
- Other developed
- Japan
- Europe
- USA

The bars are divided into sections representing different percentages, with Cumul, Flux, and Growth categories. The colors correspond to different regions, and the height of each section indicates the percentage of emissions for that category and region.
Cumulative climate-change impacts vs. Time

- Agreements
- Recognition
- Intrinsic goal

"Desired" impacts
Cumulative climate-change impacts

- Technology diffusion
  - Technologies
  - Agreements
  - Recognition
  - Intrinsic goal

Human-system inertia

"Desired" impacts

Land and ocean system inertia

Actual impacts

Time →
• How do we compress the time to keep impacts in the acceptable range?
• How do we minimize the risk of strong amplification by unmanaged processes?
• How do we grow the economy while decreasing CO$_2$ emissions?
• How do we encourage meaningful adaptation?