Transportation, Climate Change, and Air Quality Practice

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Take Home Message

- **Earth's climate and weather systems are nonlinear**
  - Responses are out of proportion to forcing
  - Understanding adjustments and feedbacks are prerequisite to accurate predictions
- **Human-source GHG emissions are overwhelming "natural" sinks of GHGs**
- **The increase (and unprecedented rate of increase) of atmospheric GHG concentrations are forcing climate and weather system responses that compound the vulnerability of our least resistant resources/populations**

Climate Change & Air Quality Practice

- **Physical Principles/Science**
  - Fundamental physics underlies models
  - GHG Emissions & Concentrations Force Nonlinear Responses
- **Milestones**
  - Key Scientific Questions were Resolved about 1990
  - Scientific Focus since 1990 is Validation & Improving Models
  - Statistical Issues with Model Ensembles largely resolved 2006
- **Fingerprints**
  - Convergence of Evidence gives High Confidence
  - Rejection of Alternate Hypotheses
- **Implications for the Air Quality Discipline**
  - Collaborate to Support Knowledge of Vulnerable Resources
  - Integrate Systems into Life Cycle Emissions Analyses

Physics

… if all we had was a natural record, we would be in a weak position with regard to saying we should do something about carbon dioxide.

But our position is really based on the physics, which says if you add greenhouse gases to the planet, it's going to warm …

Wally Broecker is credited (but disagrees) with coining the term "global warming"

Climate Change: are we on the brink of a pronounced global warming.

Science, 8 August 1975 p. 460

Physics

<u>The Physics</u>

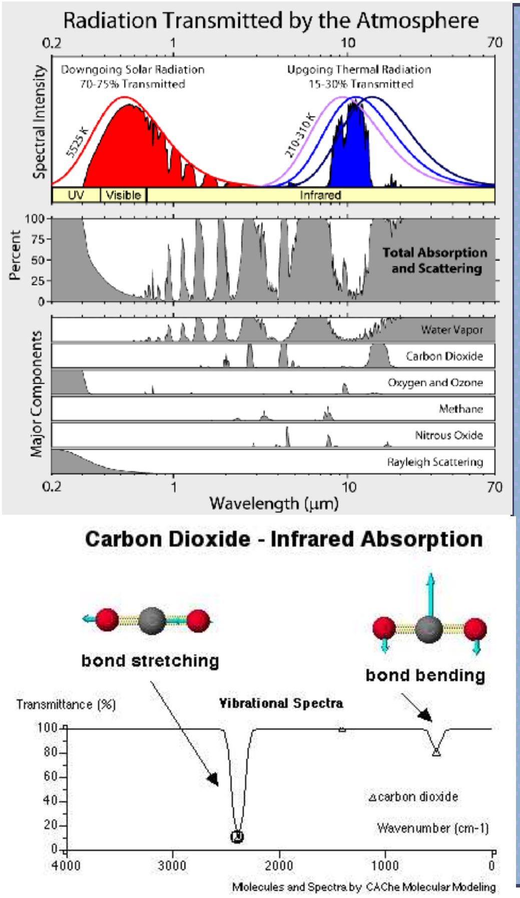
- **The ability of certain trace gases to be …**
  - relatively transparent to incoming visible light from the sun,
  - yet opaque to the energy radiated from the earth

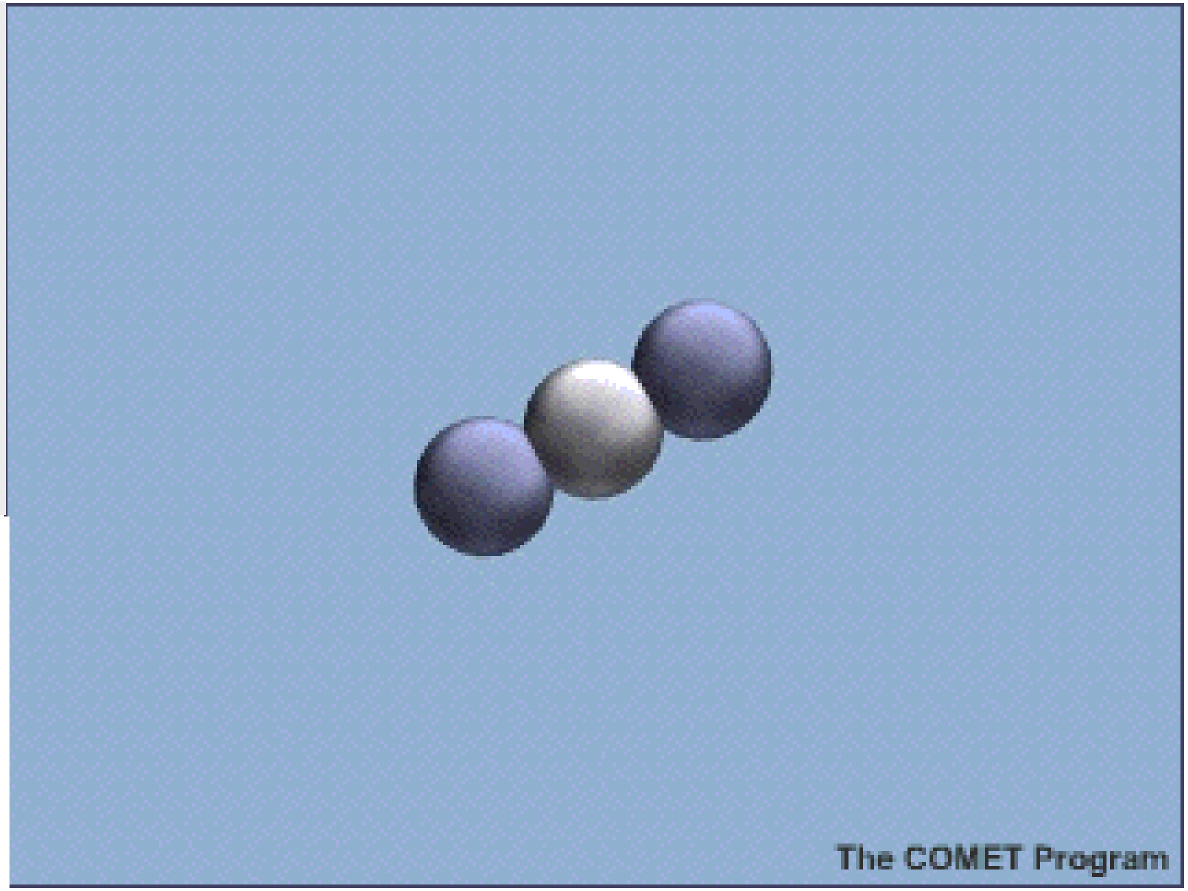
  … is one of the best understood processes in the atmospheric sciences.

- **This phenomenon, the greenhouse effect, makes the earth habitable for life.**

Physics

GHGs absorb IR and
generates extra IR (heat) in atmosphere

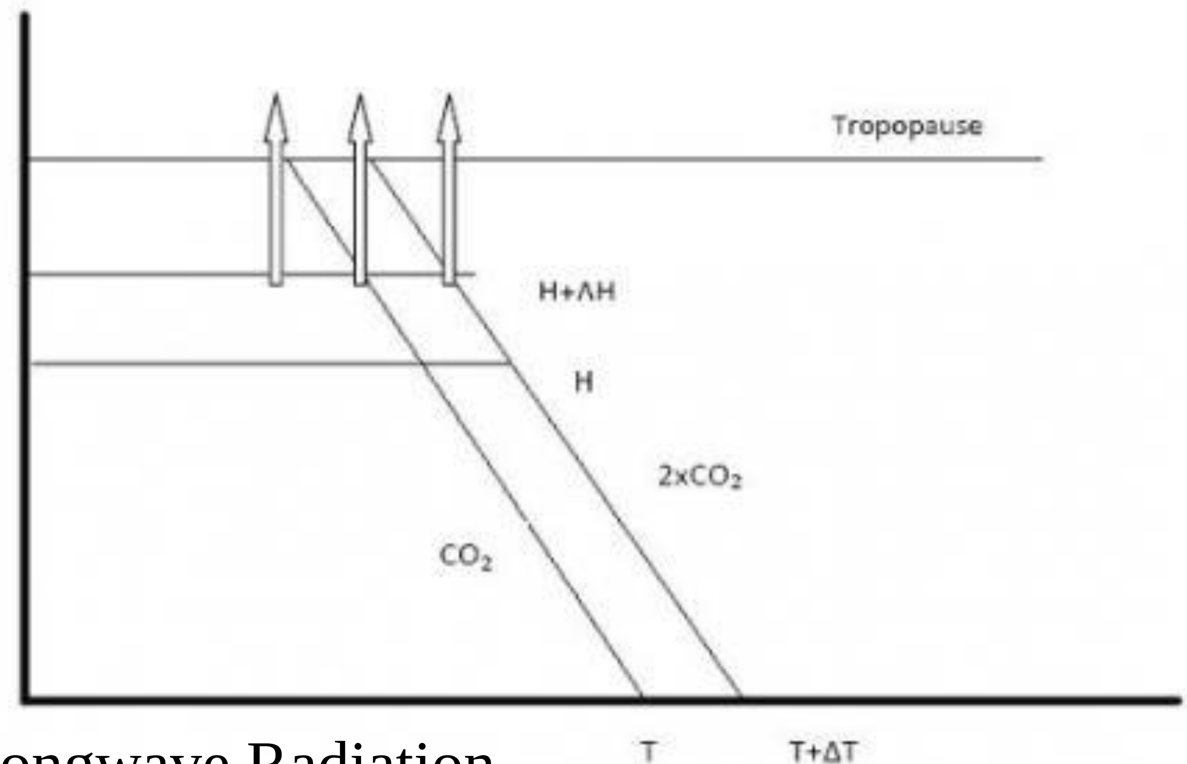




Benchmarks that Aren't

<u>Annual CO_2 in giga-tons</u>

Baseline:	
Plant rot & respire	440
Ocean	330
Human:	
Fossil fuel burning	23
Deforestation	6
Mitigation:	
Extra Ocean uptake	12



<u>Outgoing Longwave Radiation</u>

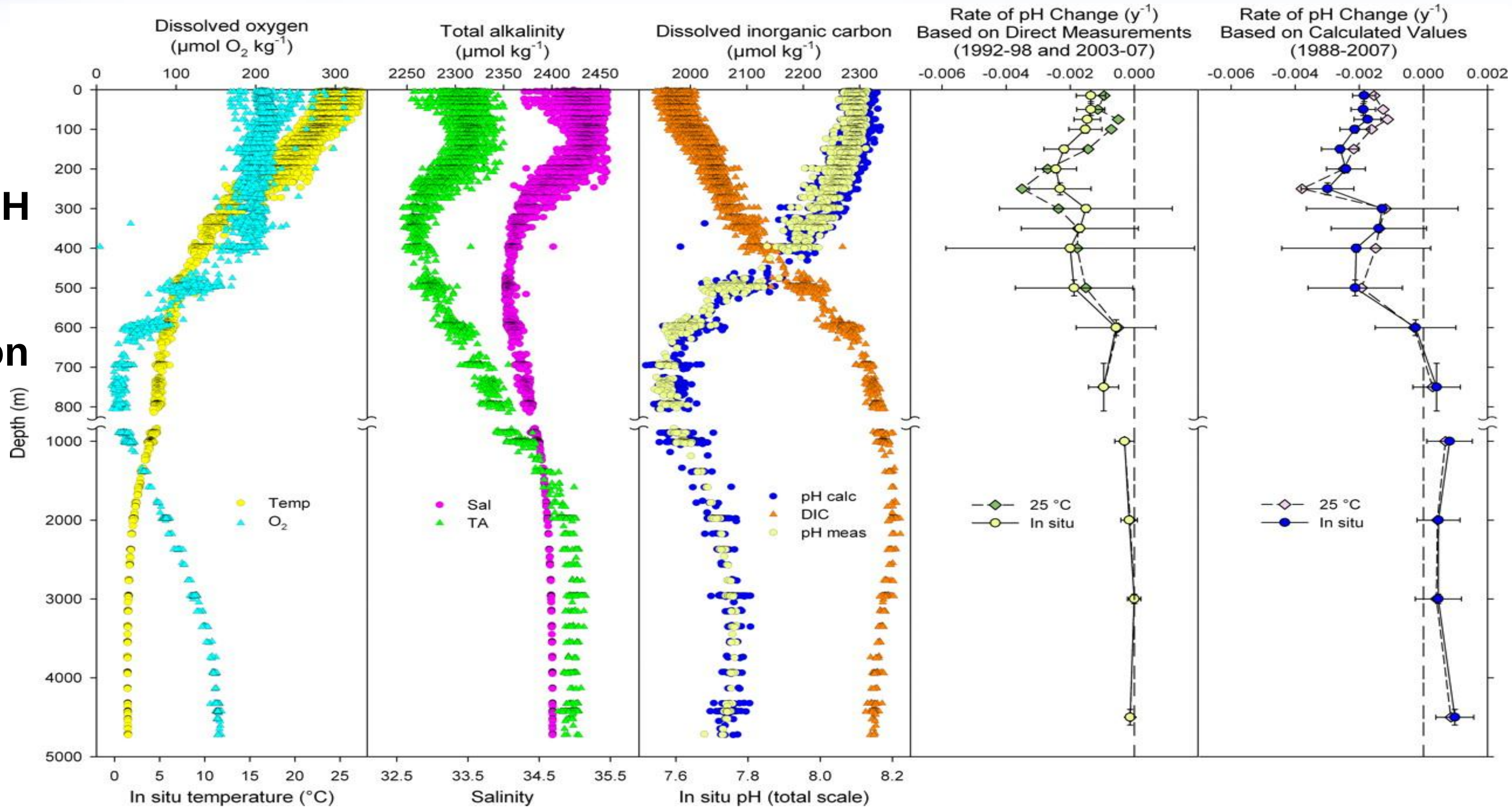
- ORL altitude should correlate with GHG concentrations
- Net temperature increases towards radiative equilibrium
- Confounding – stratospheric water vapor forces troposphere T, etc.

Observations

Depth distribution of seawater pH and more

ALOHA station 1988–2007

Dore J E et al. PNAS 2009; 106:12235-12240



“Ocean Uptake of Fossil Fuel CO_2 is now proceeding at about 1 million metric tons per hour.” Pete Brewer

PNAS

Knowledge Drivers: Observation Platforms & Computers

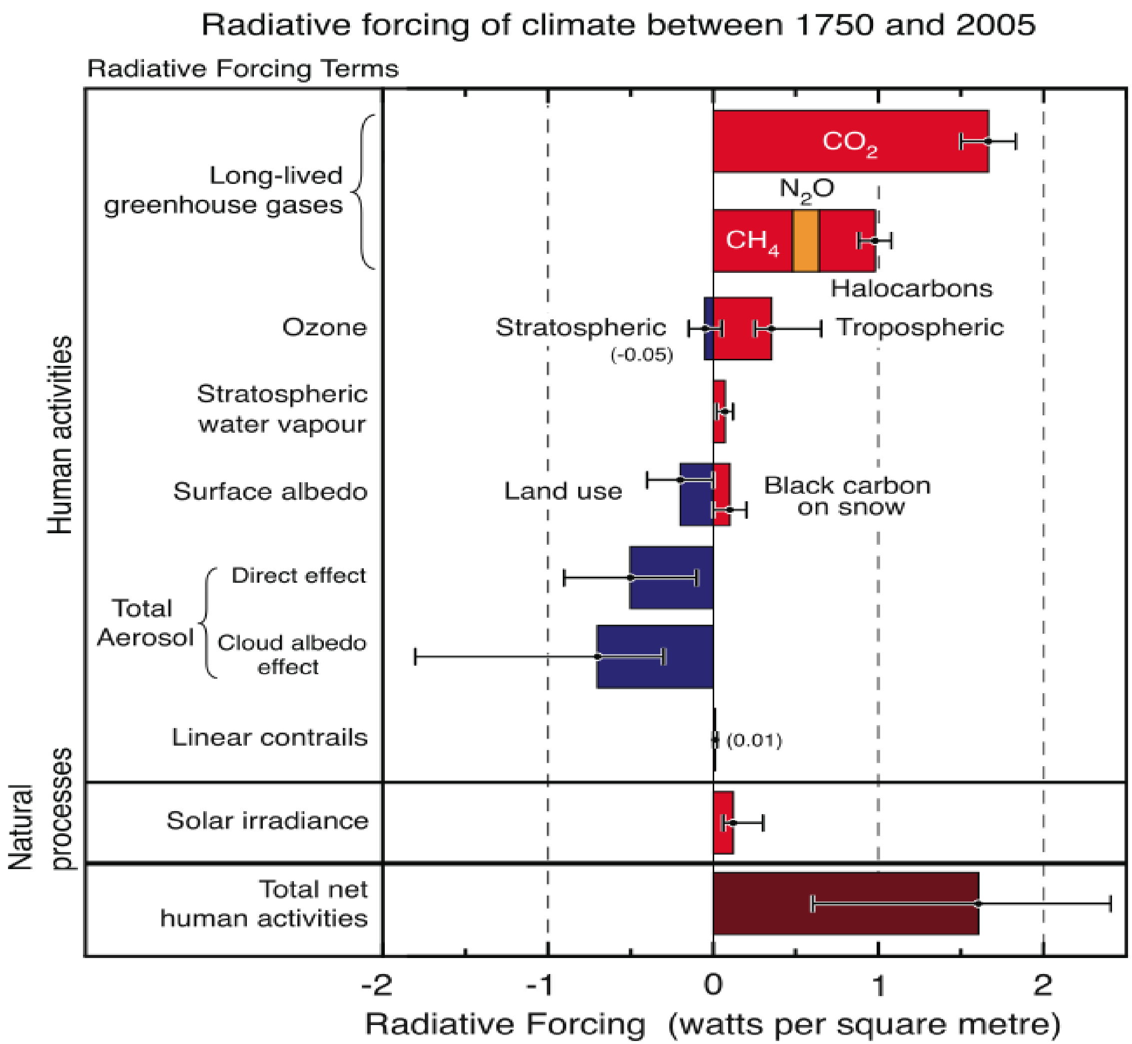
Milestones

- 1840s – 1896 – papers and calculation attempt
- 1950's – Scripps team: Revelle, Keeling, et al
- 1960s – 1970s Which Feedback Dominates?

  (1-d tropo); then SSTs – (3-d + strato)
- 1980's - Nuclear Winter/Fall (Sagan v Schneider)
- 1980/90s - General Circulation Models
- 1994 – Fingerprints (Sandler)
- 2000 – 80% bio trends consistent (2 methods)
- 2009 - EPA endangerment cause/contribute

Fingerprints

Contributions to Radiative Forcing



Convergence of Evidence

Explaining the Rate of Warming

Alternate Hypotheses:

- Fossil Fuels/Industrial Emissions – High Confidence
- Increasing Solar Radiation – rejected (Sandler, 1994)
- Volcanic Activity – rejected (Gerlach, 1991)
- Other Dust (e.g., forest fires) – rejected (Hansen & Lach? 1990)
- Natural Sources/Carbon Cycles - rejected

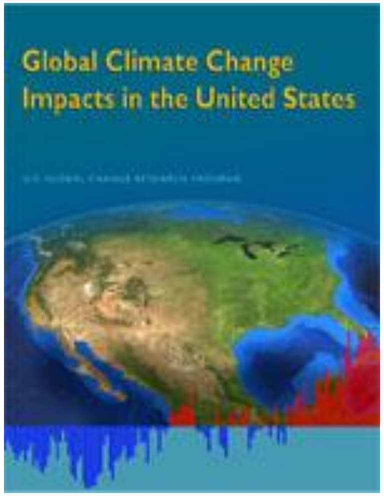
Impacts to Transportation

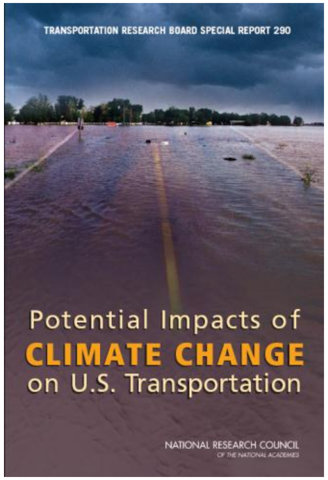
<u>**Impacts on U.S. Transportation**</u>

- **Nonstationarity of extreme weather events complicate investment decisions**

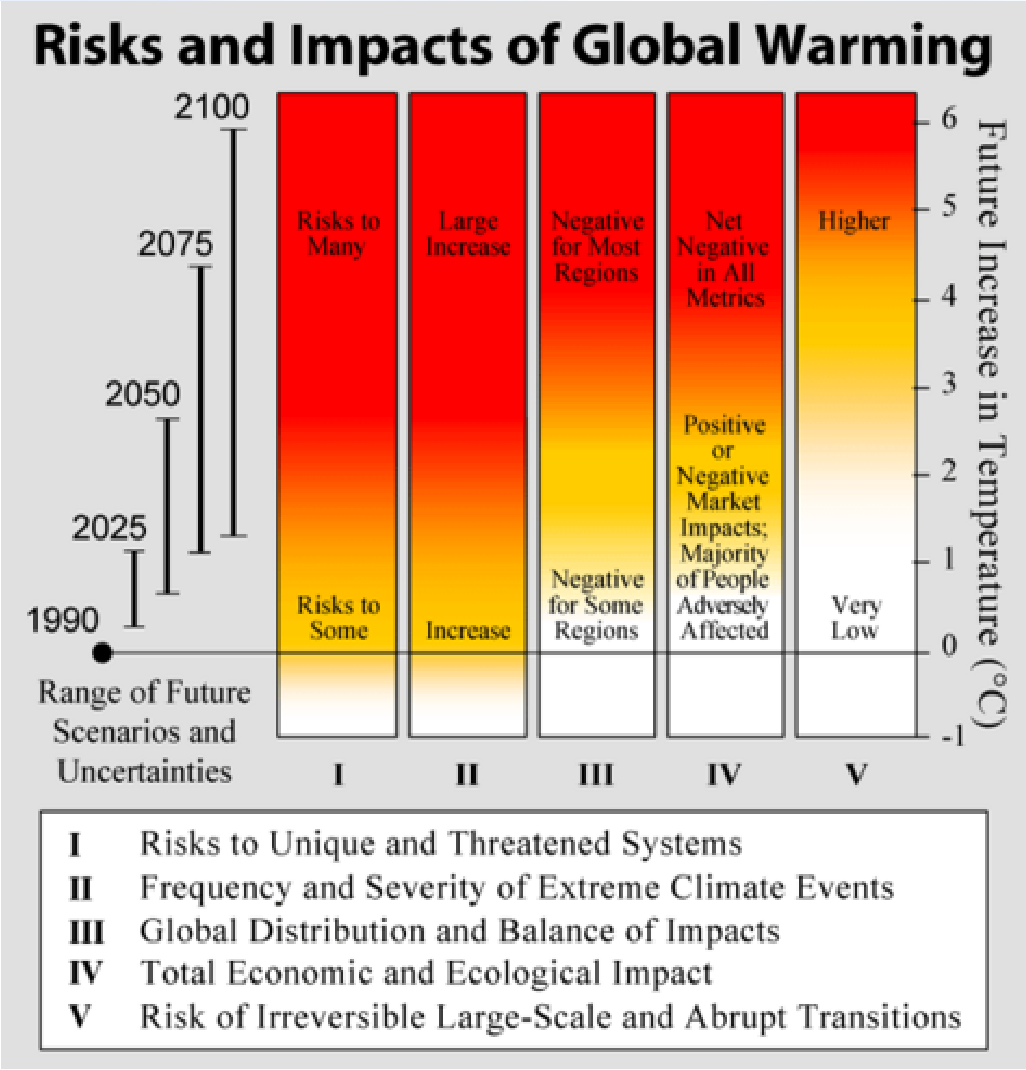
- **Vulnerable resources affect operations - inversion layers & public health, human migrations**

- **Some local and regional opportunities**





Impacts – The Call for Mitigation



Impacts – The Call for Mitigation

- **Impacts of Climate Change:**
  - Are by definition probabilistic and Assumption-based
  - Will vary in time and space (some narrowly “positive”)
  - Are will have synergistic interactions on already stressed resources/communities
- **Overall U.S. infrastructure and economy not imminently threatened with catastrophe**
- **Values are at stake**
  - Discount Rates or Intergenerational Stewardship
  - External Costs and World Views
  - Questions of Justice and Equity (Luck of Birth)

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The Institutional Challenge

Current institutional arrangements … were not organized to address climate change and may not be adequate for the purpose

TRB Report #290

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Addressing climate change requires …

① an examination of
- plausible future scenarios,
- a long-term perspective,

② the capacity to deal with
- uncertain and changing information, and
- responses that may extend beyond jurisdictional boundaries and transportation modal responsibilities.

From TRB Report #290

Climate Change and the Air Quality Practitioner

Systems Thinking

- Start collaborations to understand transportation role in broader system
- f(x) = y
- System behaviors like adjustments and feedbacks
- Characterize thresholds, resilience, and alternate states
- Ask, “How does system respond if we modify the friction associated with travel between A and B?”

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Federal Highway Administration Climate Change Website:

www.fhwa.dot.gov/hep/climate

US DOT Transportation and Climate Change Clearinghouse:

http://climate.dot.gov