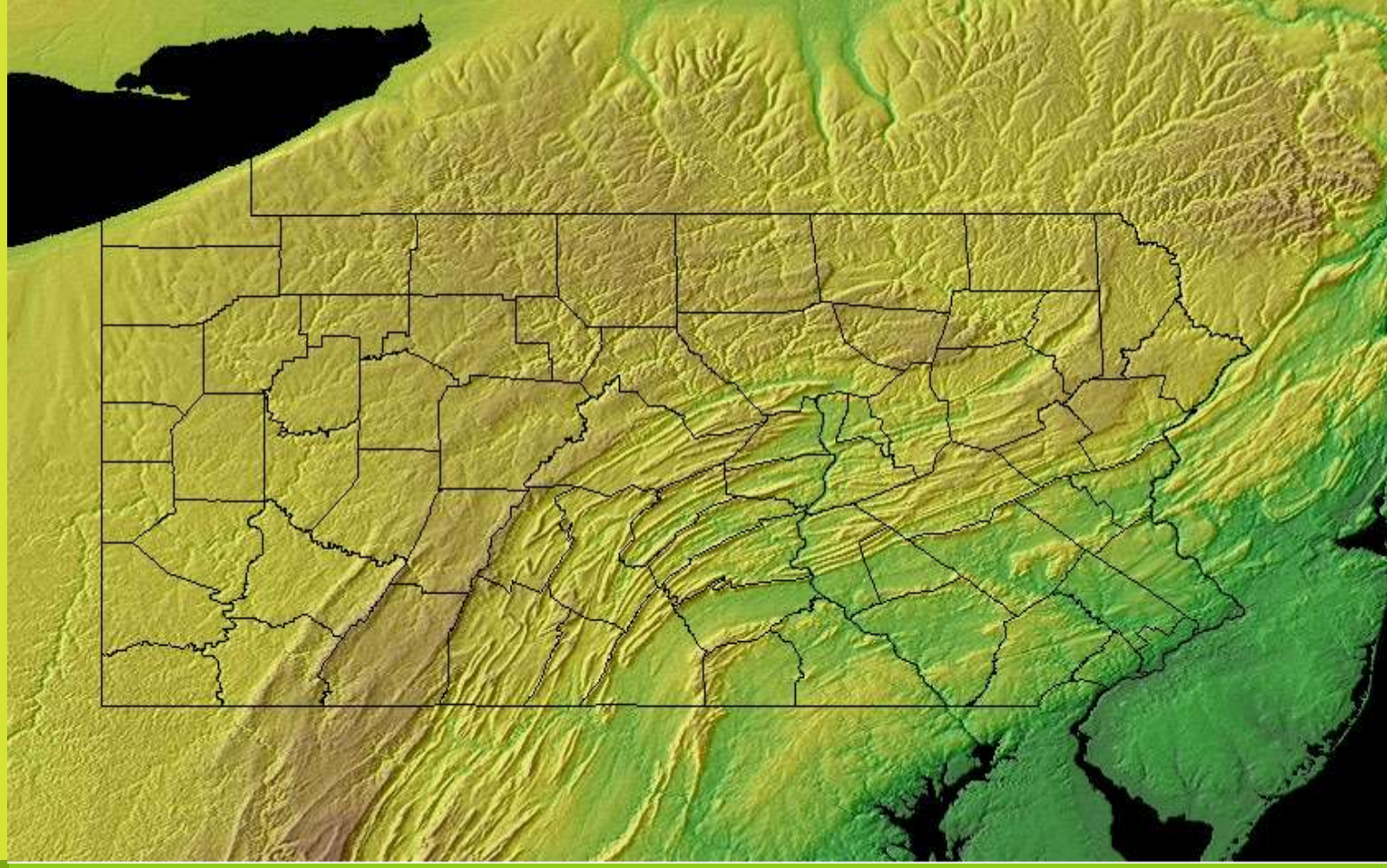


PENNSYLVANIA CLIMATE IMPACTS ASSESSMENT PREVIEW

REPORT COMPONENTS

- Executive Summary
- Methodology
- PA 21st Century Climate Futures
- Impacts of climate change by sector
  - Water, Agriculture, Forests, Ecosystems, Fisheries, Wildlife, Human Health, Recreation and Tourism, Energy, Insurance, General Economy
- Mitigation opportunities and barriers
- Information Needs

METHODOLOGY

- Based on existing data and research:
  - Research and assessments that are specifically applicable to PA
  - Research and assessments that can be used to make inferences about PA
  - Some new data analysis
- Impact assessments take into account:
  - Adaptation
  - Multiple pathways of causation and feedbacks between sectors
  - Non-climate-driven economic, demographic, and other sources of change
  - Uncertainty

UNCERTAINTY

- Uncertainty is pervasive in regional climate impact assessment
- Multiple sources
  - Future climate
    - Global emissions paths
    - Global climate response
    - Regional climate response
  - Global and regional social, economic, biogeophysical responses
  - The future without climate change

EXPRESSING UNCERTAINTY

- Virtually certain >99%;
- Extremely likely >95%;
- Very likely >90%;
- Likely >66%;
- And so on…
- Disclaimer: Additional word smithing is needed in this presentation and the draft report to accurately reflect confidence

PA CLIMATE FUTURES

Projections based on:

Global Circulation Model Averages

Plausible Emissions Scenarios

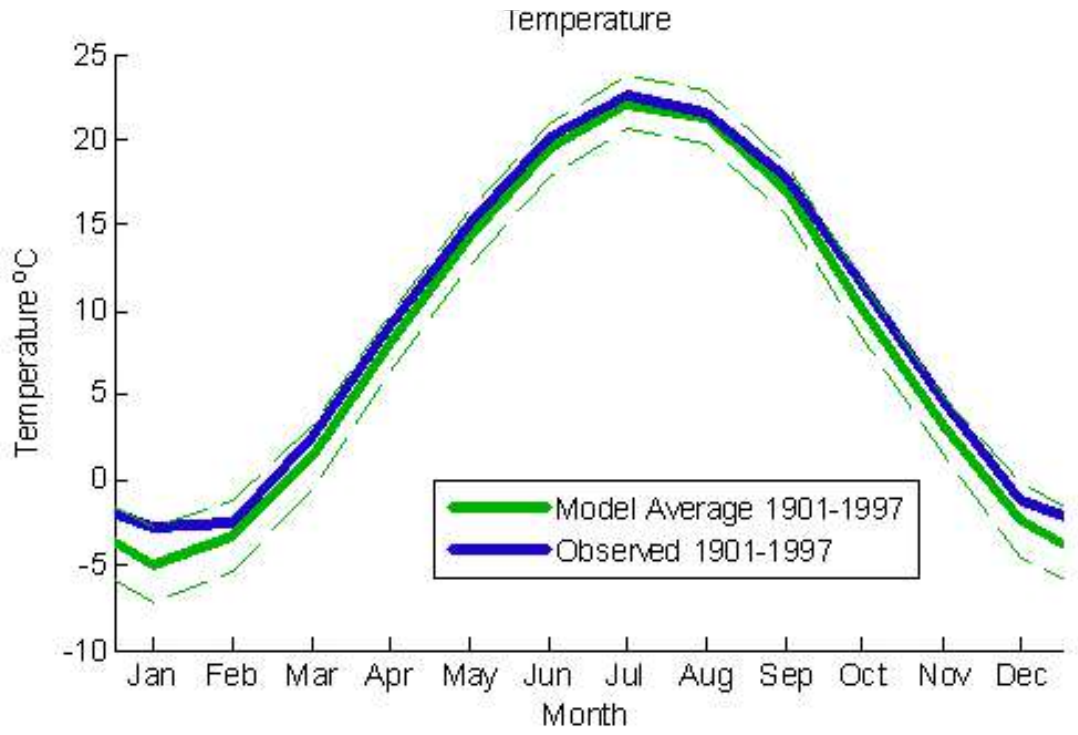
GCM MODEL ACCURACY

- GCM projections were evaluated for PA using observational data sets of temperature and precipitation for the 20th century to the present.
- A 21 GCM average does better in backcasting PA's 20^{th} century climate than individual GCMs or subsets of GCMs
- The 21 model average accuracy is better for temperature than precipitation

TEMPERATURE

Annual cycle of observed (blue) and modeled (green) Pennsylvania-averaged mean temperature.

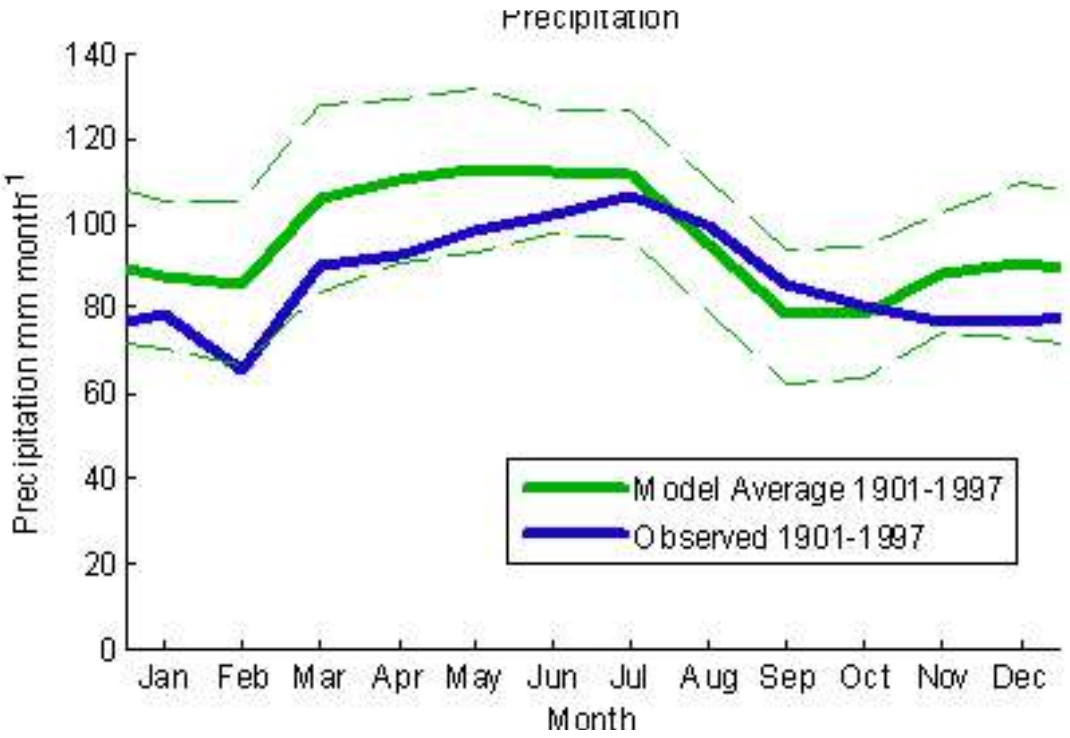
(Dashed lines represent +/- 1 standard deviation)



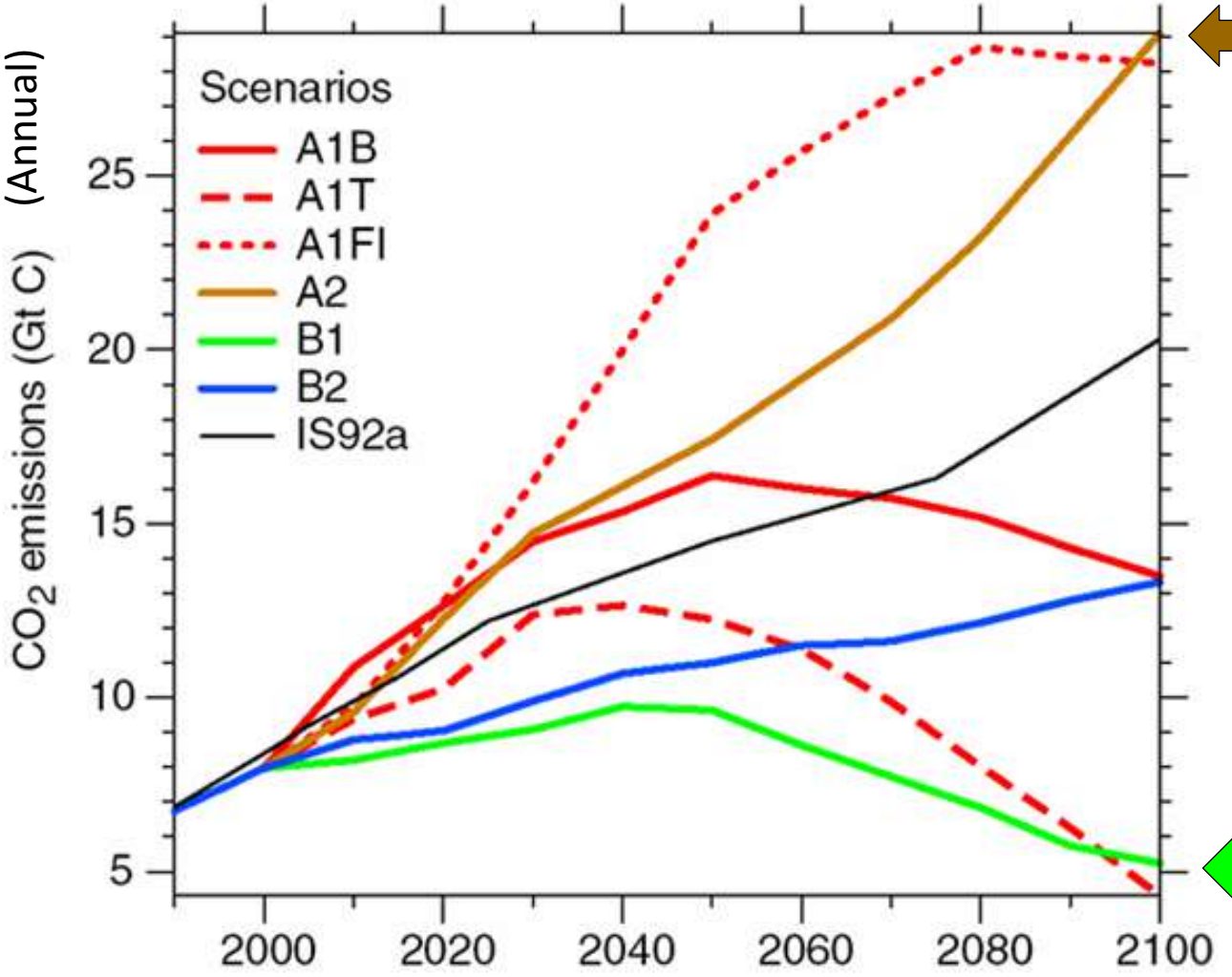
PRECIPITATION

Annual cycle of observed (blue) and modeled (green) Pennsylvania-averaged mean precipitation.

(Dashed lines represent +/- 1 standard deviation)



2 PLAUSIBLE FUTURE EMISSIONS SCENARIOS



Higher emissions A2 scenario

Lower emissions B1 scenario

CLIMATE PROJECTIONS

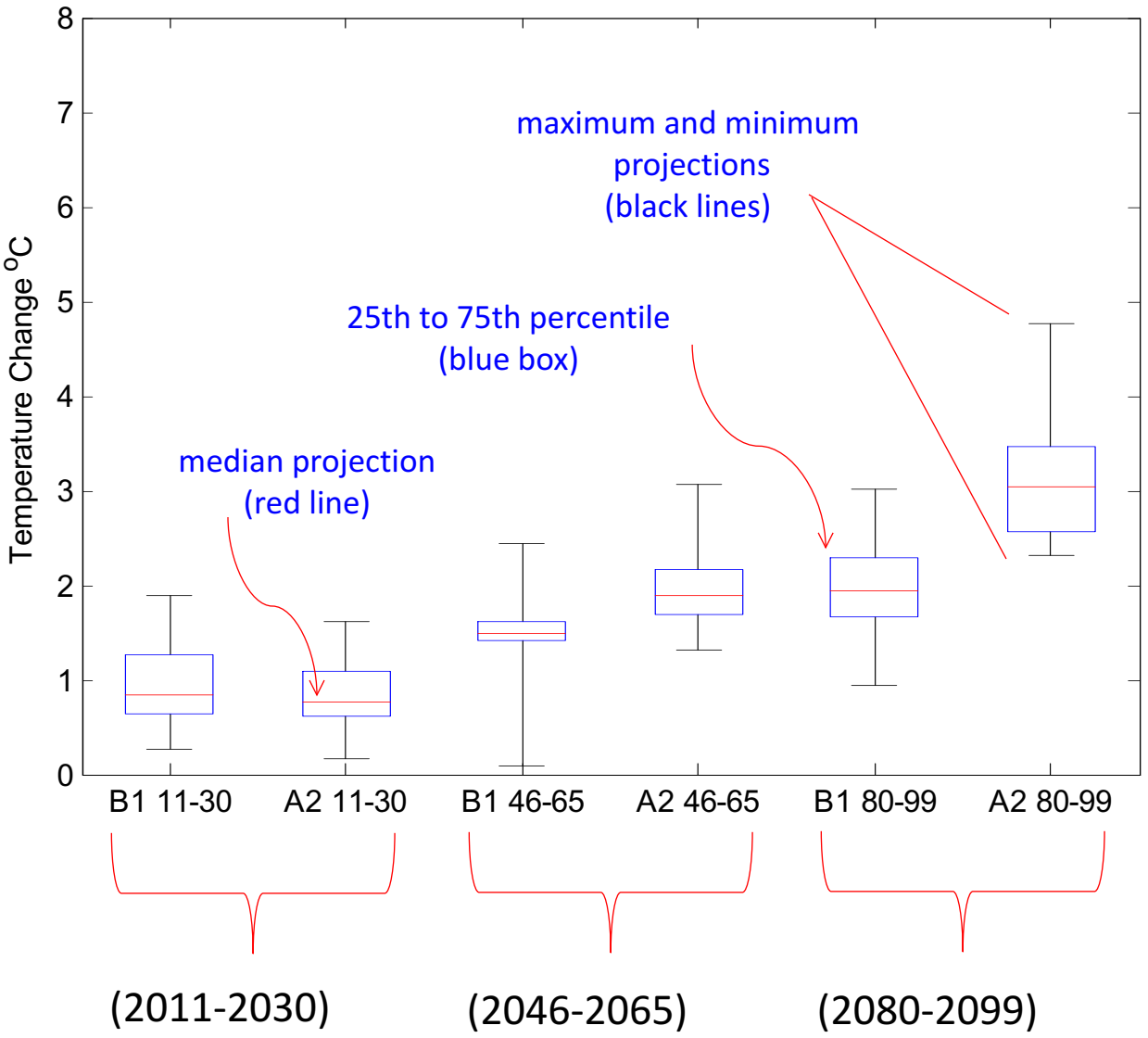
GLOBAL WARMING

- All GCM models predict global warming will occur during 2035-2045, regardless of the path of global emissions.
- Global emissions choices made today will have little effect until after 2045.
- Adaptation is important.

PA WARMING IS VIRTUALLY CERTAIN

- The extent after mid century will depend on the global emissions path.
- Mean summer temperatures in Pennsylvania projected to increase on the order of 2-2.5ºC during 2046-2065 and 2.5-4.5ºC during 2080-2099, depending on the climate scenario.
- Mean winter temperatures protected to increase somewhat less around 1.5-2ºC during 2046-2065 and 2-3ºC during 2080-2099.

Mean winter temperatures increasing somewhat less around 1.5-2ºC during 2046-2065 and 2-3ºC during 2080-2099.



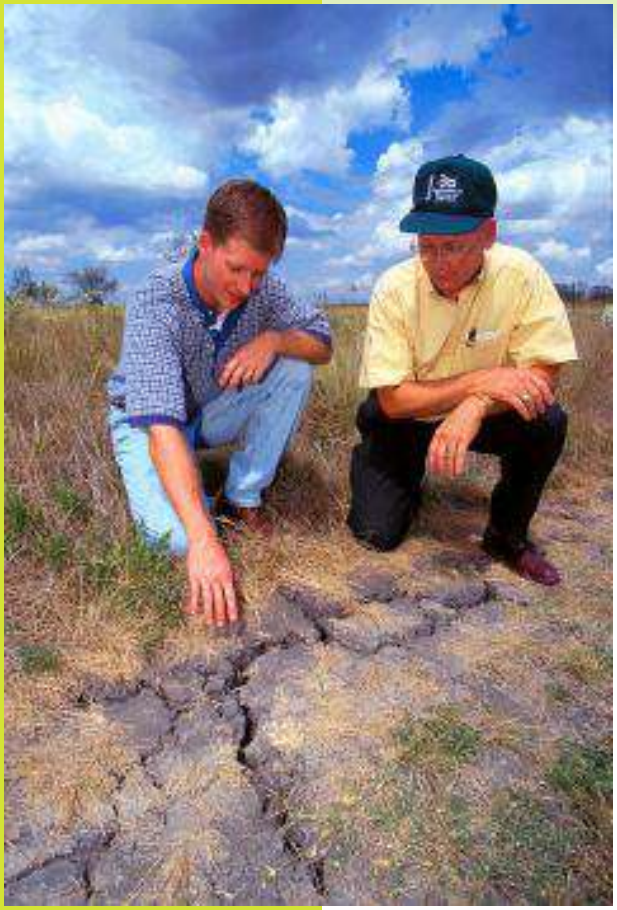
METEOROLOGICAL EXTREMES

- Pennsylvania's meteorological climate is projected to become more extreme in the future.
  - Longer dry periods;
  - Increased intensity but reduced frequency of tropical and extratropical systems;
  - Greater intensity of precipitation.

PA WILL LIKELY GET WETTER

- The extent after mid century will depend on the global emissions path.
- The average summer precipitation increase across all models is on the order of 0-5% during 2046-2065 and a little greater than that during 2080-2099.
- Winter precipitation is projected to increase more than summer precipitation. (~5-10% during 2046-2065 and 10-15% during 2080-2099).

DROUGHT



- Annual maximum number of consecutive dry days (an indicator of drought) will likely increase.
- Current simulated number is about 14 days.
- Projected to rise 1-2 days during 2046-2065 and 1-4 days during 2080-2099 (depending on the climate scenario).

PRECIPITATION INTENSITY

- Three indicators of precipitation intensity also projected to increase:
  - Number of days in a year with precipitation exceeding 10 mm;
  - Annual maximum 5-day precipitation total; and
  - Fraction of annual precipitation that arrives in daily events that exceed the historical 95th percentile.

LAND COVER AND WATER RESOURCES WILL CHANGE

FOREST LAND COVER

- Species composition will shift as the ranges of key Pennsylvania tree species shift northward .
- Trees stressed by the changing climate will become increasingly susceptible to disturbances such as fire, insects, and diseases .

WATER RESOURCES

- **Floods:** Potential decrease of rain on snow events (good news), but more summer floods and higher flow variability.
- **Stream temperature:** Increase in stream temperature for most streams likely. Streams with high groundwater inflow less affected.
- **Snow pack:** Substantial decrease in snow cover extent and duration.
- **Runoff:** Overall increase, but mainly due to higher winter runoff. Decrease in summer runoff due to higher temperatures.

WATER RESOURCES

- **Groundwater:** Potential increase in recharge due to reduced frozen soil and higher winter precipitation.
- **Soil moisture:** Decrease in summer and fall soil moisture. Increased frequency of short and medium term soil moisture droughts.
- **Water quality:** Flashier runoff, urbanization and increasing water temperatures might negatively impact water quality.

ECOSYSTEMS WILL BE INCREASINGLY STRESSED

- Wetlands and headwater streams in Pennsylvania are already compromised in their ability to provide ecosystem services
- Climate change will increase stresses on aquatic ecosystems
- Impacts will be difficult to detect because of the continuation of other stressors such as development and invasive species.

IN HUMAN SOCIETY THERE WILL BE WINNERS AND LOSERS

- Losers:
  - Snow based recreation
  - People at risk from exposure to pollens, ozone, heat
  - Municipal rate payers in the Delaware Estuary (Salinity)
  - Some farmers
  - People living in flood plains.

…AND WINNERS

- Winners:
  - Some farmers
  - People at risk from cold related health stresses
  - People who like to be outdoors when it is not cold
  - Fisherman who prefer a longer season or warm water species.

AND SOME RELATIVELY UNAFFECTED

NEW RESEARCH IS NEEDED TO FULLY UNDERSTAND IMPACTS

- Climate downscaling;
- Reduce emission scenario uncertainty;
- Macro and sectoral modeling studies;
- Storm risk assessment;
- Hydrologic conditions at a small watershed scale;
- Ability of already impacted systems to accommodate climate change;
- Determinants of flood risks;
- Health-climate-environment relationships.

ADAPTATION WILL HELP

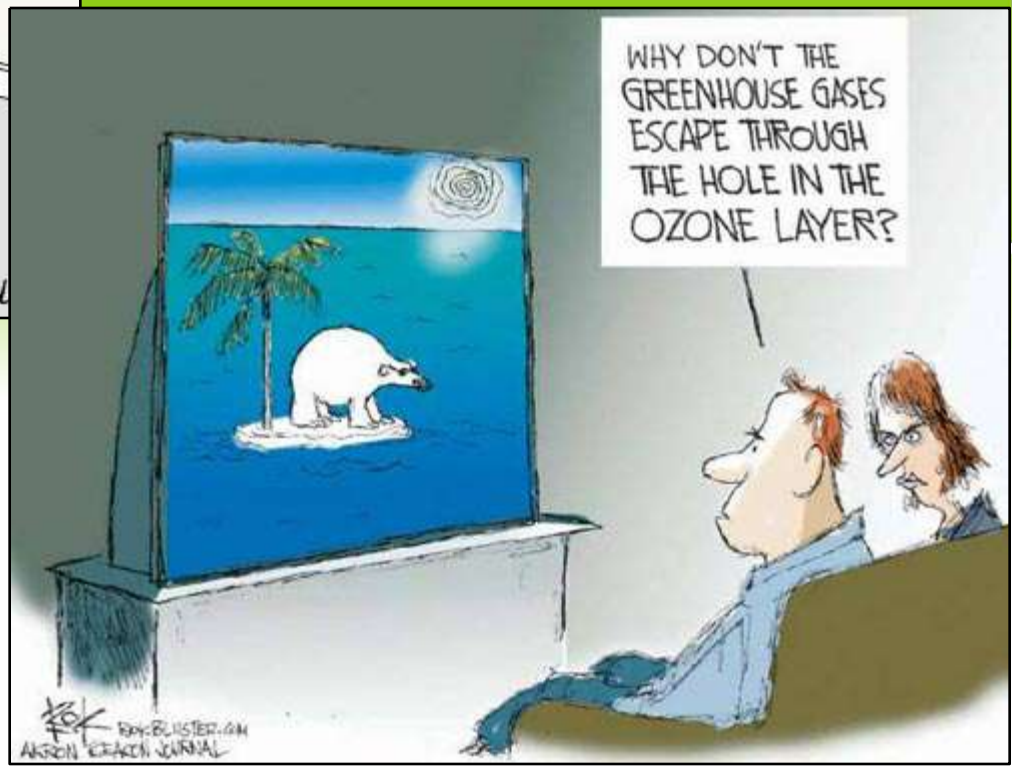
- Farmers - new crops and practices
- Insurance companies – reprice risks and develop new products
- Fishermen – switch from cold to warm water species, fish more
- Foresters – new species, biomass energy
- Skiers – indoor skiing
- New cooling requirements - green buildings

PROACTIVE STATE AND LOCAL ADAPTATION POLICY IS NEEDED

- Ag cultivars and practices;
- Forest management practices – cultivated forests with facilitated regeneration;
- Land use planning;
- Restoration of aquatic ecosystems such as streams and wetlands wherever possible; and
- Expansion of public outdoor recreation facilities


THIS IS THE SOLUTION WE'VE DEVISED FOR DEALING WITH THE FLOODING CAUSED BY CLIMATE CHANGE.

QUESTIONS?


WHY DON'T THE GREENHOUSE GASES ESCAPE THROUGH THE HOLE IN THE OZONE LAYER?

PROJECT TEAM

DAVID ABLER

PhD, Economics, University of Chicago, 1987

Professor of Agricultural, Environmental & Regional Economics and Demography at Penn State University

Research Areas

- Economic modeling
- Climate impacts
- Trade

Relevant Experience

- Led agricultural component of Mid-Atlantic Regional Assessment of Climate Change and Consortium for Atlantic Regional Assessment
- Member of the National Agriculture Assessment Group for the U.S. Global Change Research Program

SETH BLUMSACK

PhD, Engineering and Public Policy, Carnegie Mellon University, 2006

Assistant Professor, Department of Energy and Mineral Engineering

Research Areas

- The Electric Power Industry
- Energy and Environmental Policy
- Complex Networks and Systems
- Deregulation in Network Industries
- Infrastructure Investment and Management

Relevant Experience

-Leading a project to develop a greenhouse-gas inventory for Pennsylvania's electric generation sector.

-Contributing author of a Pew Foundation report on the electric power industry and climate change.

-Multiple articles discussing the impact of greenhouse-gas regulation on regional electricity markets, and on low-carbon electricity and transportation technologies.

ROBERT CRANE

PhD, University of Colorado, 1981

Professor of Geography

Director, Alliance for Earth Science, Engineering and Development in Africa

Research Areas

- Regional Climate Change
- Climate Change and Adaptation in Sub-Saharan Africa
- Climate Downscaling

Relevant Experience

- Mid-Atlantic Regional Assessment
- Consortium for Atlantic Regional Assessment
- Assessments of Impacts and Adaptations to Climate Change (AIACC): A global initiative developed in collaboration with the UNEP/WMO Intergovernmental Panel on Climate Change (IPCC) and funded by the Global Environment Facility to advance scientific understanding of climate change vulnerabilities and adaptation options in developing countries

MARC MCDILL

PhD, Forest Economics, Virginia Tech, 1989

Associate Professor of Forest Management,
School of Forest Resources

Research Areas

- Forest resources modeling and assessment
- Forest management planning and economics
- Forest growth and yield modeling
- Wood supply
- Operations research

Relevant Experience

- Assessment of carbon sequestration rates in northeastern and northcentral forests.

-Assessment of harvesting costs and economic and environmental impacts of woody biomass harvests

-Assessment of wood supplies for emerging forest biomass-based industries

RAYMOND NAJJAR

PhD, Princeton University Princeton, NJ 1990

Associate Professor of Oceanography in the Department of Meteorology at Penn State

Research Areas

- Mid-Atlantic climate change
- Impact of climate change on coastal areas
- Biogeochemistry of nutrients and dissolved gases in the ocean

Relevant Experience

-Evaluated climate models for the Mid Atlantic and Upper Atlantic Regional Assessments

-Continuing research on impacts of climate change on coastal regions, and energy use

RICHARD READY

PhD, University of Wisconsin, 1988

Associate Professor of Agricultural and Environmental Economics, Department of Agricultural Economics and Rural Sociology

Research Areas

- Nonmarket Valuation of Environmental Quality
- Outdoor Recreation
- Environmental Health
- Land Use Change and Impacts

Relevant Experience

- Mid-Atlantic Regional Assessment – Cape May, NJ Case Study
- Consortium for Atlantic Regional Assessment – Interactions of Climate and Land Use
- Coauthor of chapter on options to affect the carbon cycle in the First State of the Carbon Cycle Report (SOCCR), U.S. Climate Change Science Program

JIM SHORTLE

PhD, Economics, Iowa State University, 1981

Distinguished Professor of Agricultural and Environmental Economics, Director, Environment and Natural Resources Institute

Research Areas

- Incentive design for ecosystem services
- Integrated assessment of climate change
- Public policies for agriculture and the environment

Relevant Experience

- Assessment of agricultural, human health, water, and ecosystem impacts of climate change for the Mid-Atlantic Regional Assessment of Climate Change and Consortium for Atlantic Regional Assessment
- Member of National Technical Advisory Committee of the National Initiative on Global Environmental Change

THORSTEN WAGENER

PhD, Imperial College London, 2002

Assistant Professor of Hydrology in the Department of Civil and Environmental Engineering

Research Areas

- Analysis and modeling of hydrologic systems
- Uncertainty and sensitivity analysis
- Hydrologic impacts of environmental change
- Scenario analysis

Climate Assessment Experience

- Ongoing research on how climate (and other environmental) change will impact main hydrologic variables, and thus water storages and availability (currently funded by NSF Hydrology Program)
- Investigating the implications of these impacts on energy production (power plants – currently funded by Department of Energy) and aquatic ecosystems (currently funded by NSF Education Program) in Pennsylvania.
-Recently finished a project on climate change impacts on the hydrology of the Olifants Basin in South Africa (funded by the Clare Luce Booth Foundation).

DENICE WARDROP

BS Systems Engineering, U of Virginia
MS Environmental Sciences, UVA
PhD Ecology Penn State

Senior Research Associate

Research Areas

- Human Disturbance and its effects on aquatic ecosystems
- Response patterns of ecosystems to stress
- Condition assessment of wetlands and headwater streams
- Quantification of ecosystem services

Climate Assessment Experience

Ongoing research into the effects of climate change on the production of ecosystem services in wetlands and headwater streams (EPA-STAR)

Condition assessment of mid-Atlantic wetlands (EPA ORD)

Denitrification, carbon storage, and flood storage in Pennsylvania and Ohio wetlands (EPA-STAR)

Invasion by exotic species in coastal wetlands