Climate Science: How Earth System Models are reshaping the science policy interface

Alex Ruane

NASA Goddard Institute for Space Studies, New York City
Columbia University Center for Climate Systems Research



Columbia University Alliance Program – EDF Workshop
Italian Academy, Columbia University, New York; October 7th, 2015

Goddard Institute for Space Studies
New York, N.Y.

CENTER FOR CLIMATE SYSTEMS RESEARCH
THE EARTH INSTITUTE AT COLUMBIA UNIVERSITY

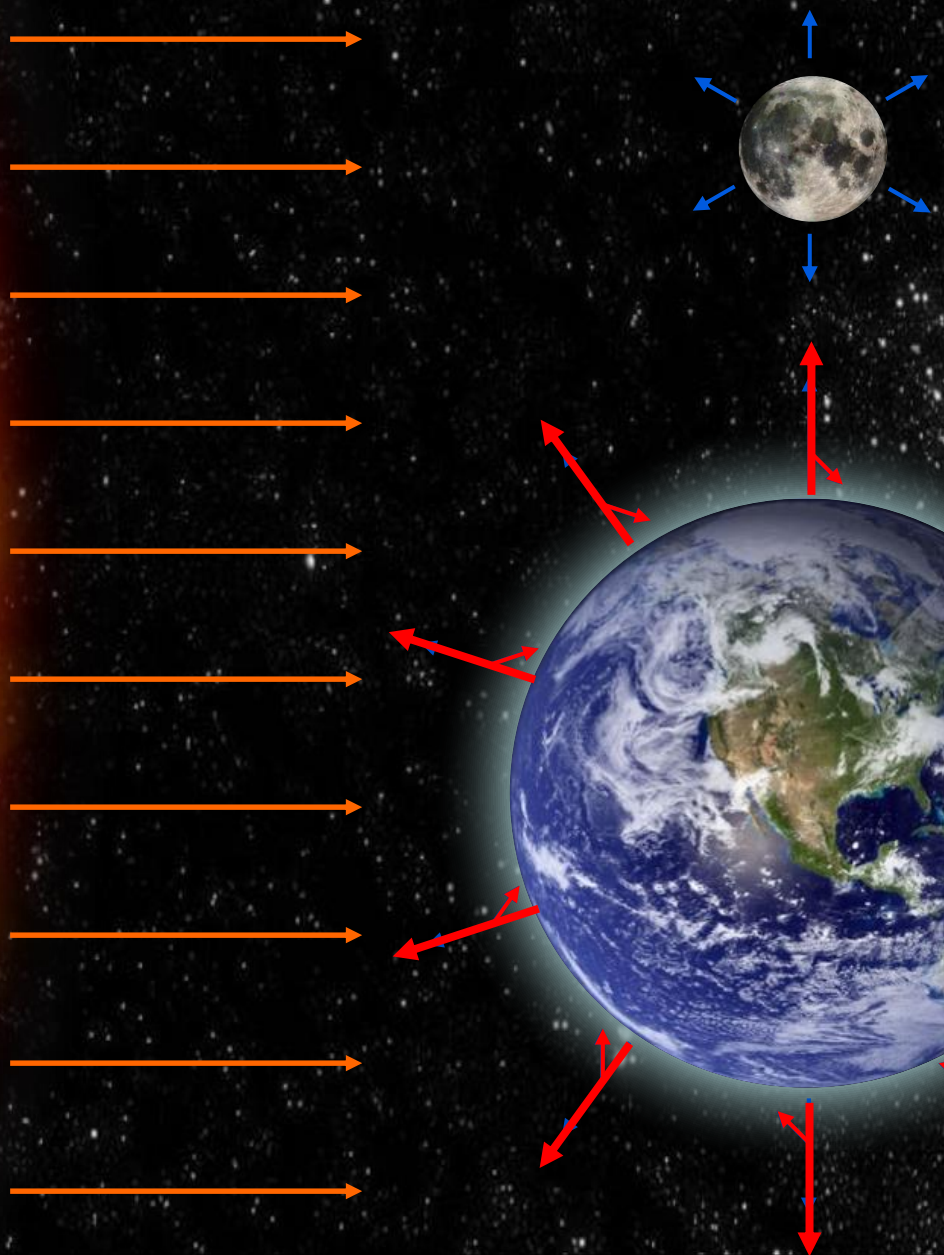
Views expressed are those of the author, and don't necessarily represent those of NASA

Image from NASA/JPL

NASA

NASA

Climate Change - Radiative Basis



Warmer Temperature → More Energy Radiated Away

Moon (no atmosphere)

Energy in = Energy Out

Earth

No Atmosphere

Energy in = Energy Out

Add/thicken Atmosphere

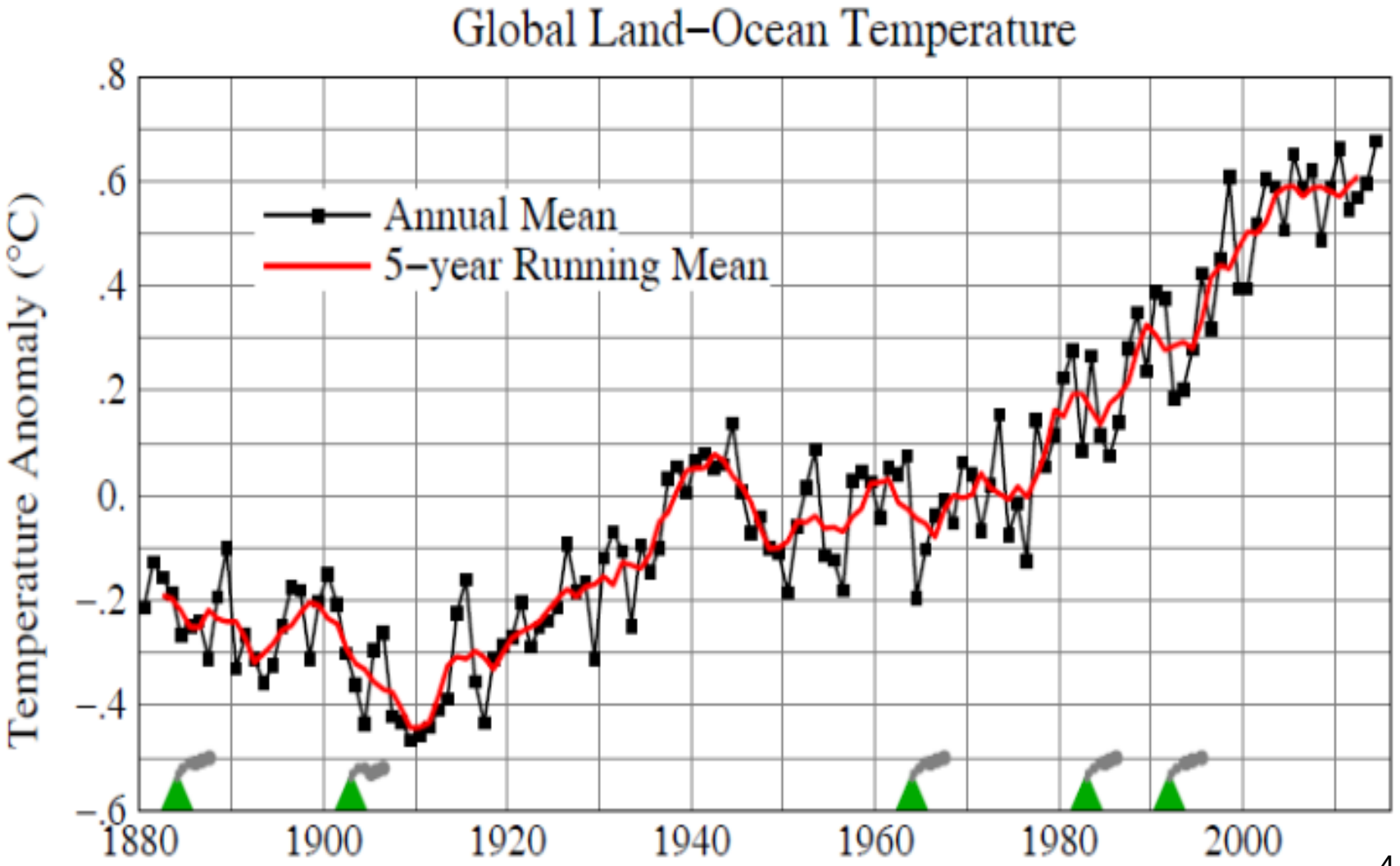
- Same amount of sunlight in
- Some of outgoing energy trapped (imbalance)

Warmer World

- System must warm to get back in balance

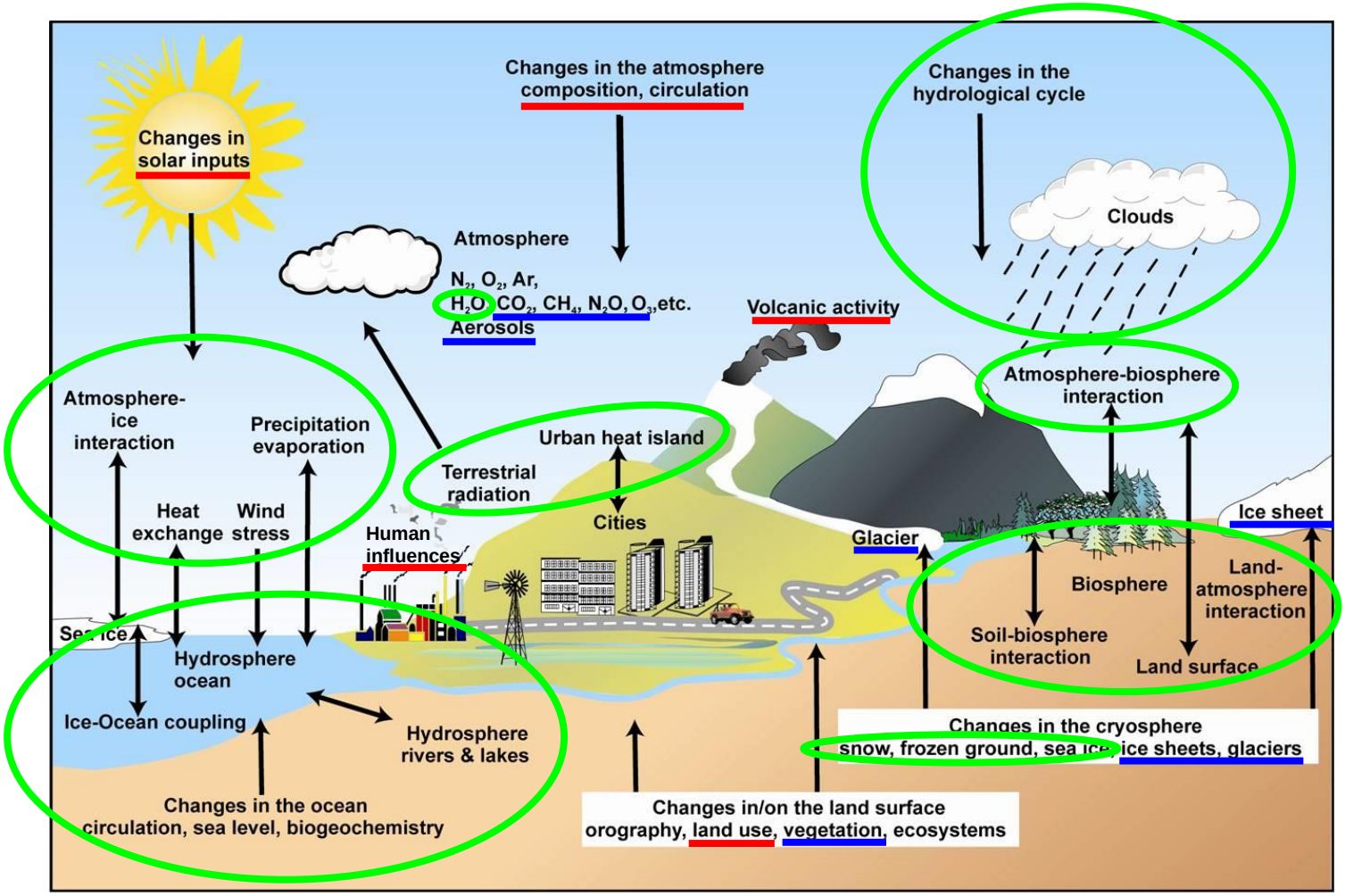
Energy in=energy out

Global temperatures are variable, but warming trend is clear



Hansen et al., 2015

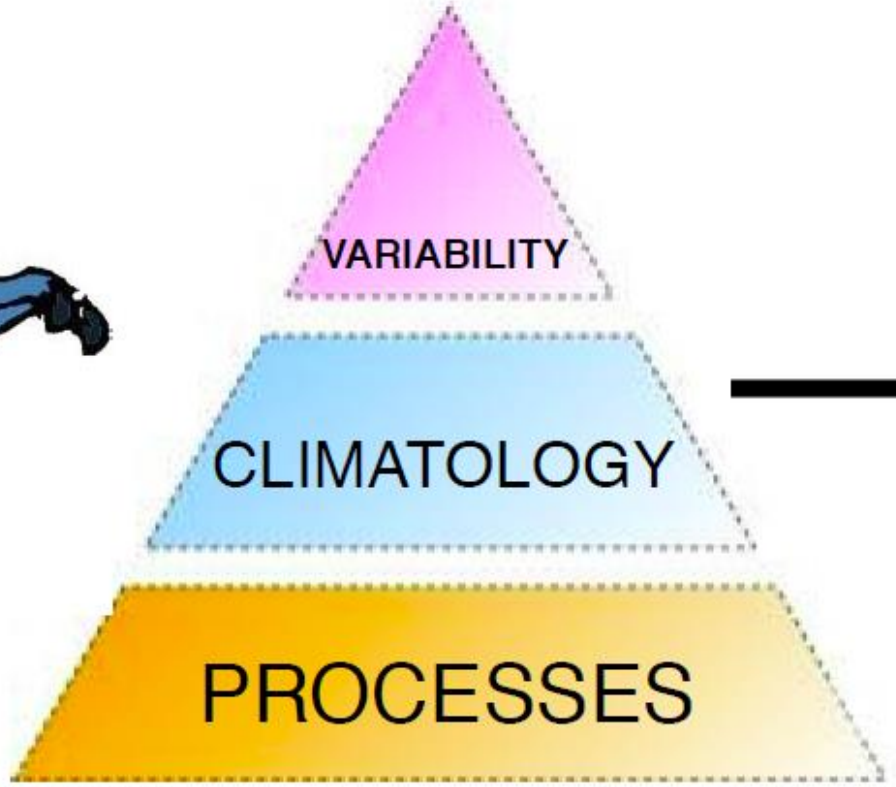
Earth System Models help us understand the Climate System



Forcings GCM Components ESM Components

The Climate Pyramid

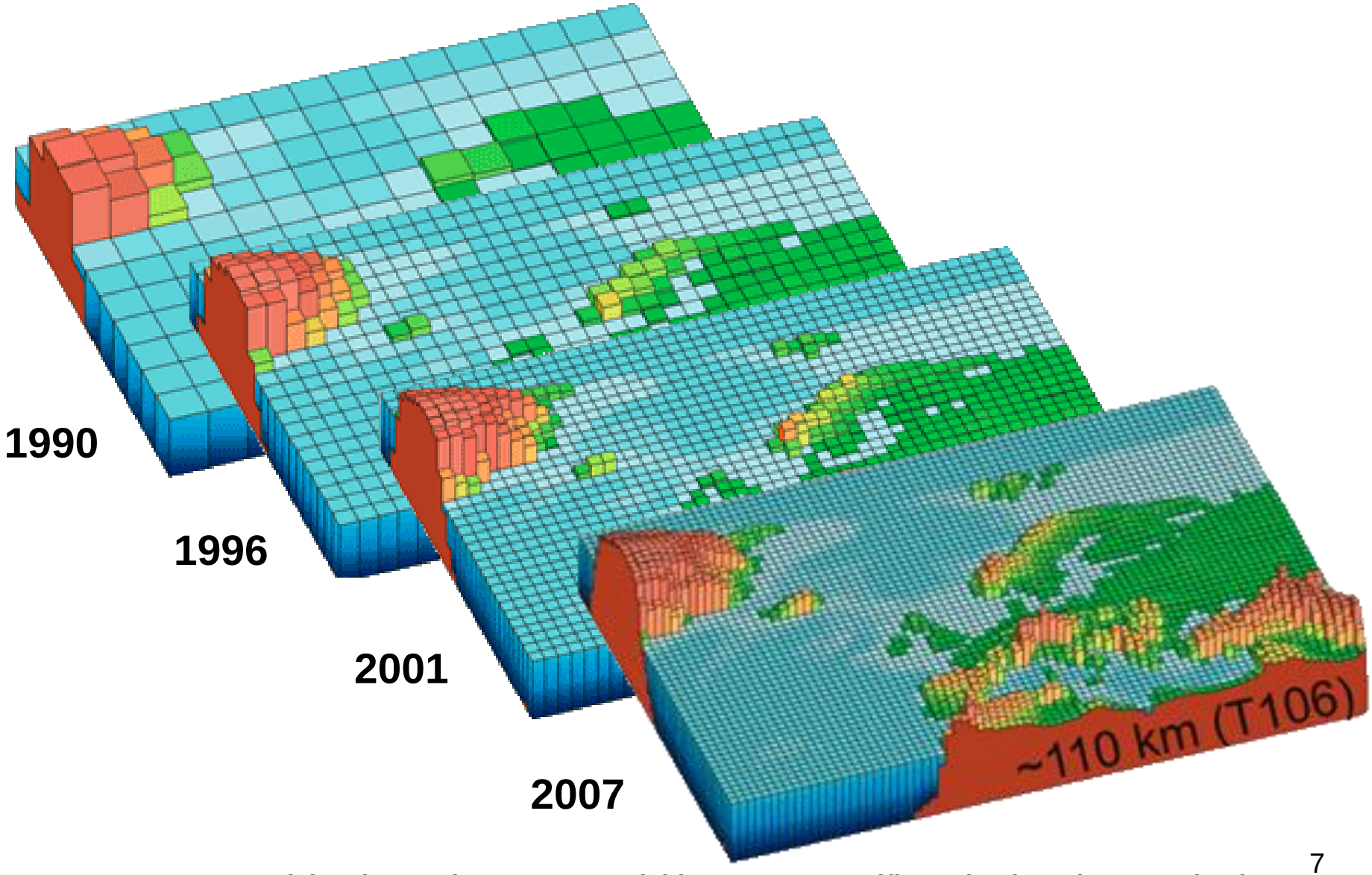
FORCINGS



RESPONSE

Slide courtesy of Gavin Schmidt, NASA GISS

Rising precision/resolution over time

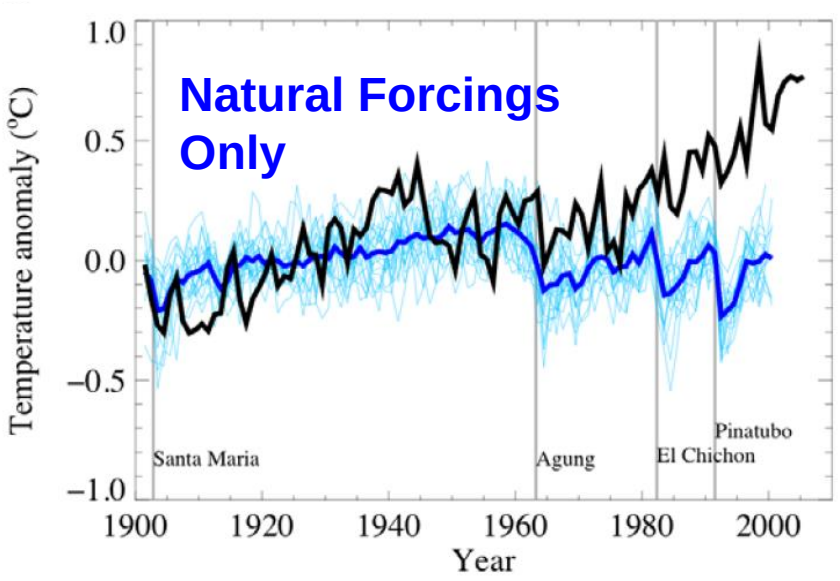


New models + better data + more variables = more specific projections (+uncertainty)

Source: http://www.windows2universe.org/earth/climate/climate_models_CDcourses.html


The Earth Simulator, Japan

Models of Climate Change

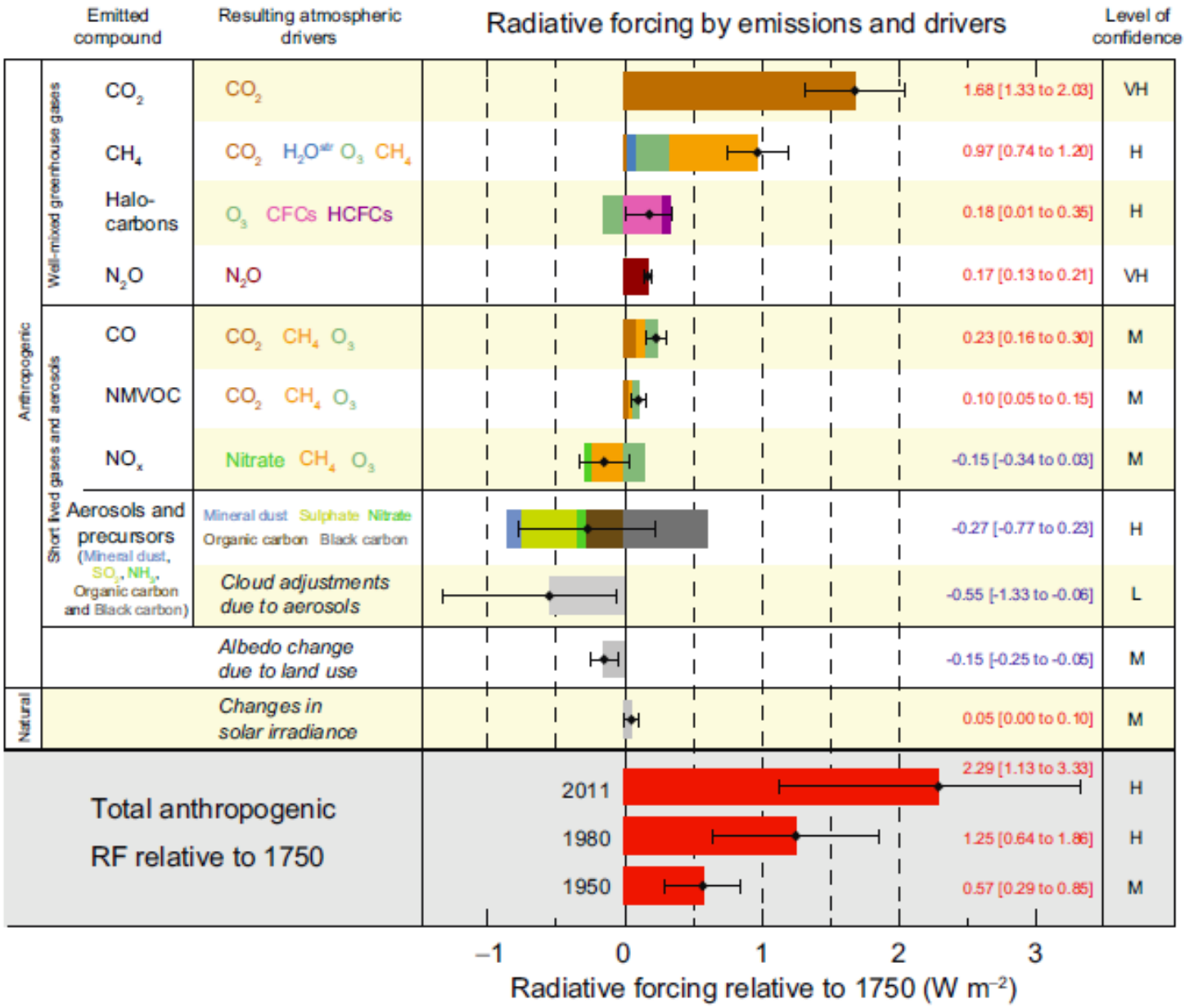


- **Natural:**
  - **Volcanoes**
  - **Natural gas transfers**
  - **Solar cycles**
    - **Sun spots**
    - **Changes in axis and orbits**

– **Man-made:**
  - **Greenhouse gas emissions**
  - **Aerosol emissions**
  - **Land-use changes**

IPCC, 2007

Climate Change – Driving Forcings



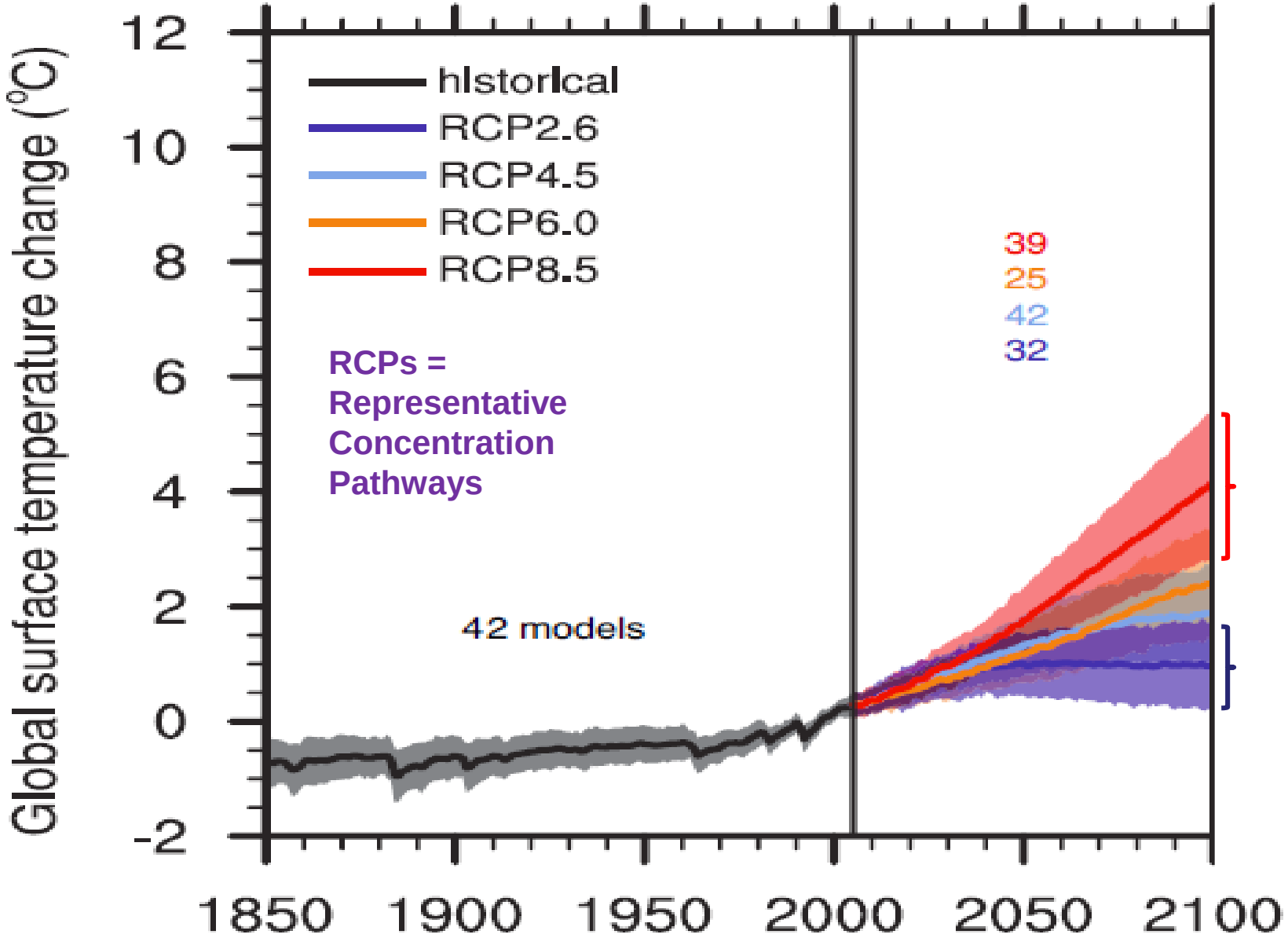
IPCC, 2013

Current research focuses on what happens when the climate system warms

- **Energy has to go somewhere**
  - Atmosphere (upper and lower)
  - Oceans (upper and lower)
  - Ice, land surface, vegetation

- **That energy changes the way that climate behaves**
  - Changes in atmospheric patterns and rainfall
  - Extreme events and sea-level rise
  - Feedbacks

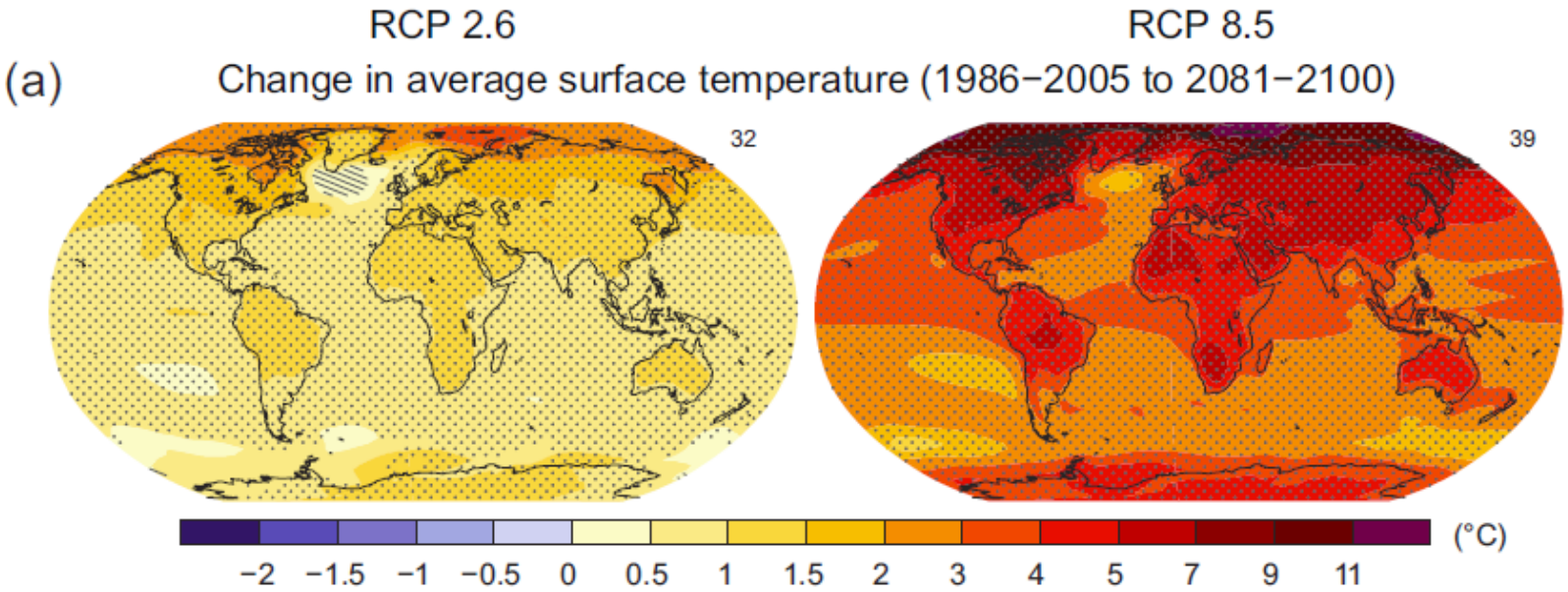
- **Changing climate affects nature and society**
  - Ecosystems and species
  - Agriculture, water resources, infrastructure, health, forests, fisheries, transportation


Global surface temperature change (°C)
12
10
8
6
4
2
0
-2
1850
1900
1950
2000
2050
2100
historical
RCP2.6
RCP4.5
RCP6.0
RCP8.5
39
25
42
32
RCPs = Representative Concentration Pathways
42 models

IPCC, 2013

Earth's climate is warming and changing

We can identify patterns



IPCC, 2013

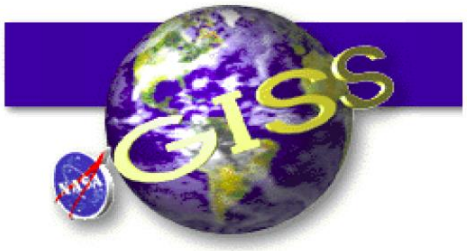
Intergovernmental Panel on Climate Change (IPCC)

- More than 2500 experts from 130 countries
- Long, unpaid process
  - Conducted mostly by authors who were not part of previous IPCC assessments
- Every sentence in the Summary for Policy-Makers is approved unanimously by all participating countries
  - Conservative estimates of change
- This is an unprecedented look at the scientific "consensus"
  - Comes from observations, experiments, theory, and models

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level." -- IPCC, 2007

Earth System Models are for more than just climate change

What are earth system models good for?



Response to single driving factors or causes, e.g.:

- **CH_4 as distinct from CO_2**
- **Impacts of power/transportation**

Simultaneous climate and air quality responses in ESM

- **Requires aerosol/atmospheric chemistry components**

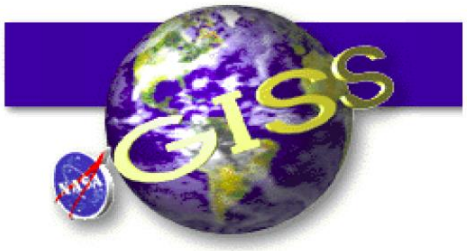
Need for adaptation:

- **In conjunction with local vulnerability assessment**

Impacts of policy choices

Potential impact of "known unknowns"

What are earth system models <u>not particularly</u> good for?



Perfect short- or long-term predictions

- Uncertainty in economic drivers
- Model and data imperfections
- Chaotic nature of internal variability

Solving political issues or ethical quandaries

- Political/ethical calculations are not included in any subroutine

Truly local information

- Models evaluated primarily at larger scales
- Sub-100km information not likely to be reliable any time soon

Recognizing "unknown unknowns"

- E.g., models in 1970 did not know about ozone hole

What does climate change mean for society?

Need to multi-task:

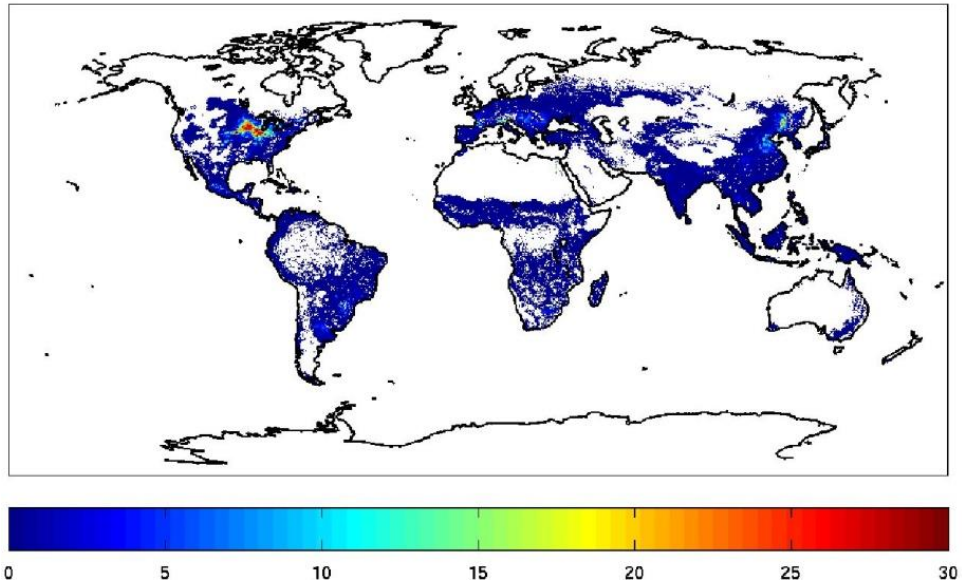
Climate change, economic development, mitigation, and adaptation!

Food harder to grow

The Agricultural Model Intercomparison and Improvement Project (AgMIP)

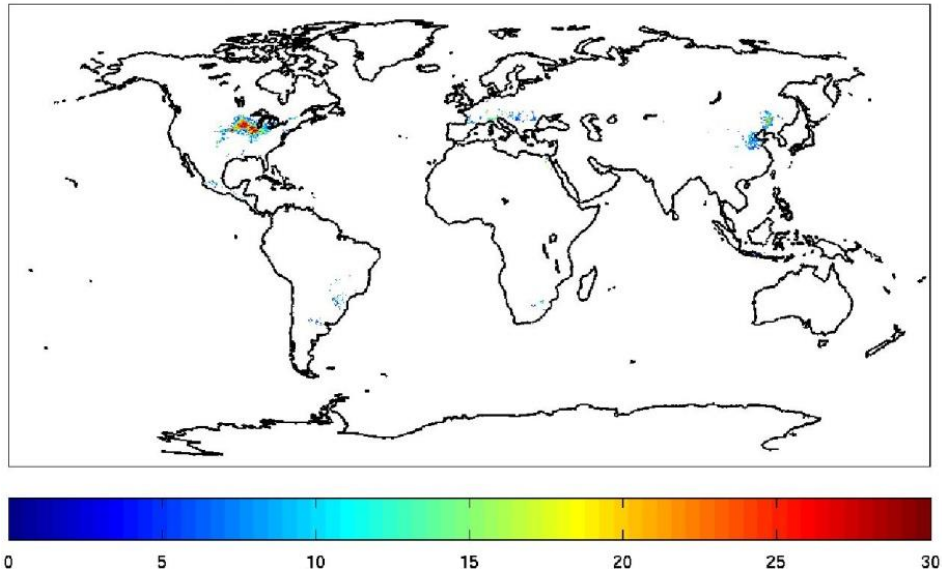
Most of our food comes from a small number of places

All Corn Production (1000s of kg)

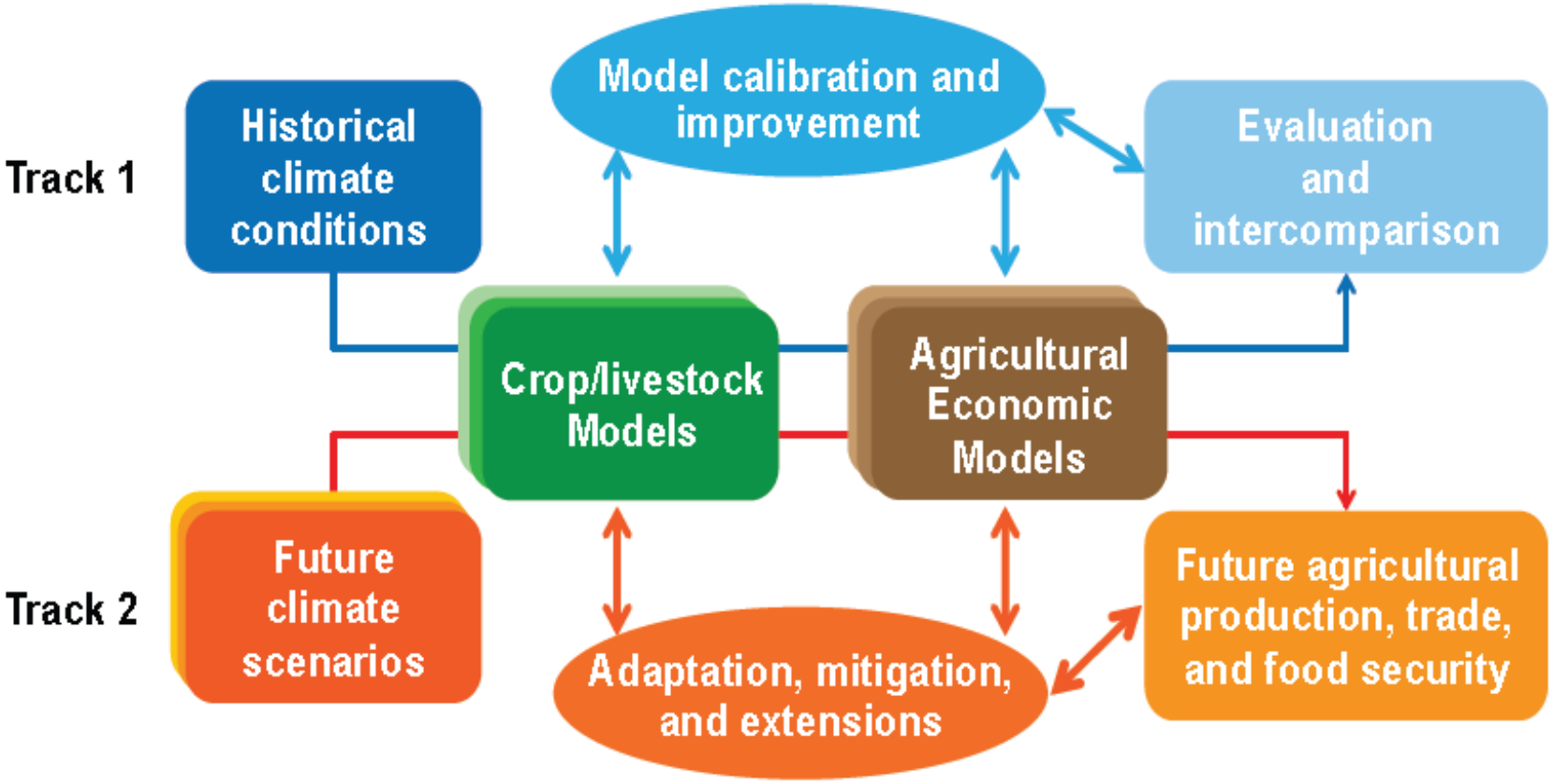


Data from Monfreda et al., 2002

Top Regions Accounting for
90% of World Corn Production



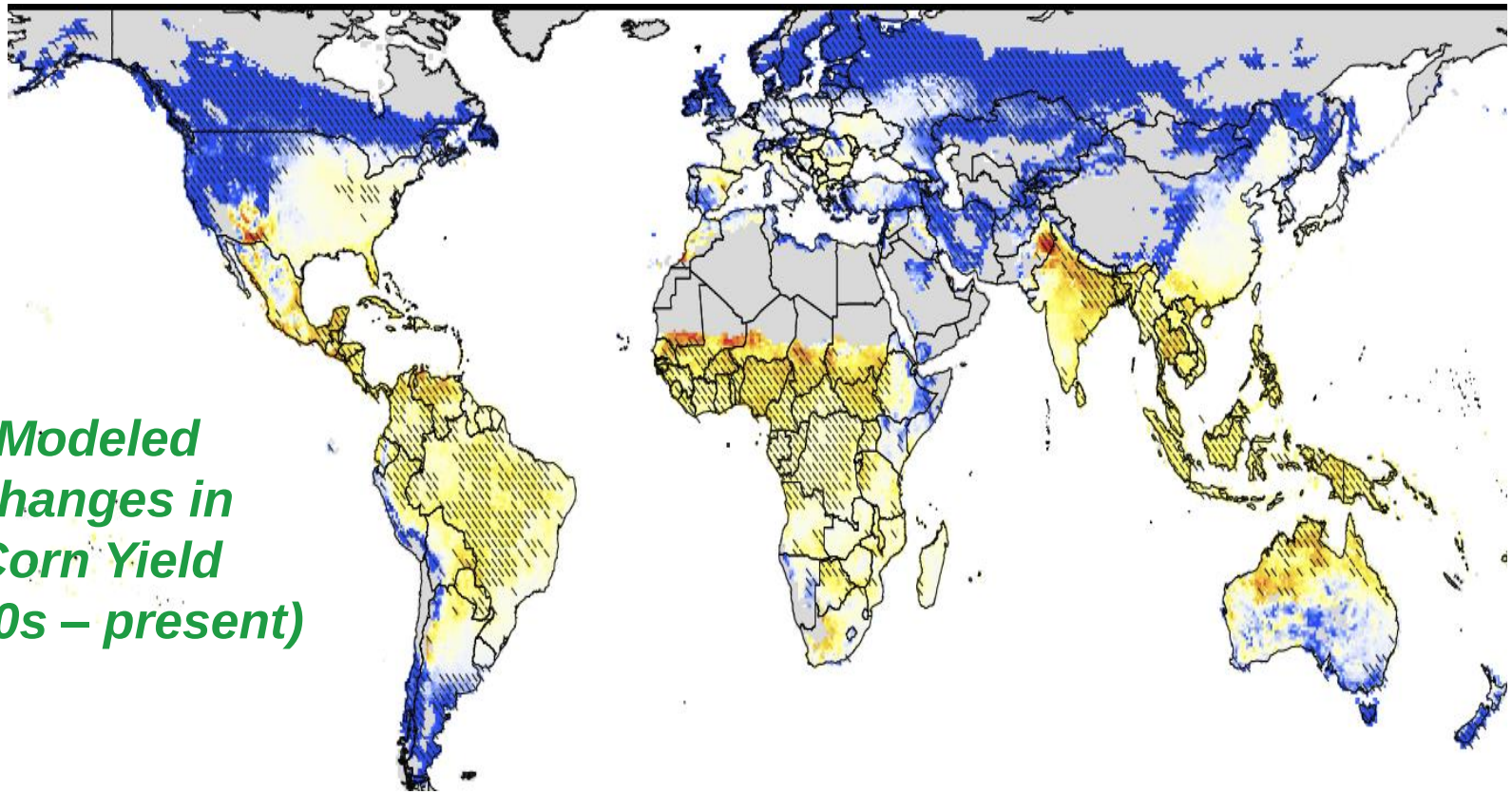
AgMIP Approach Enables *Testing* of Adaptation Strategies



Rosenzweig et al., 2013 AgForMet

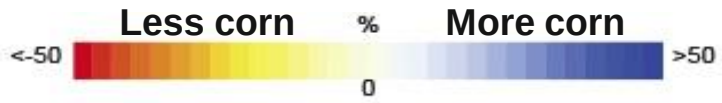
AgMIP The Agricultural Model Intercomparison and Improvement Project

Climate change impacts tropical farmlands first



Modeled Changes in Corn Yield (2080s – present)

Rosenzweig et al., 2013



Melting Ice and Sea-Level Rise

R/V Roger Revelle – South of Australia (March, 2007)

Hurricane Flood Risk for NYC Subways

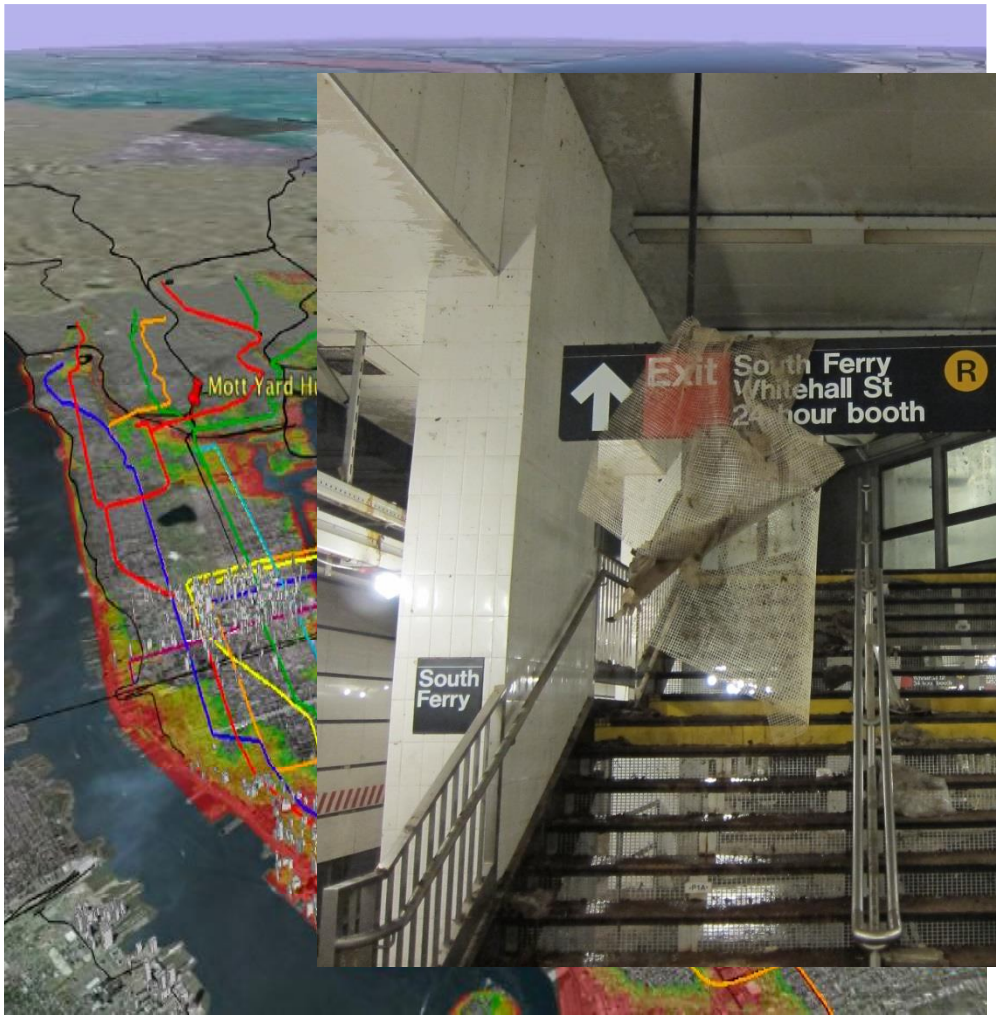
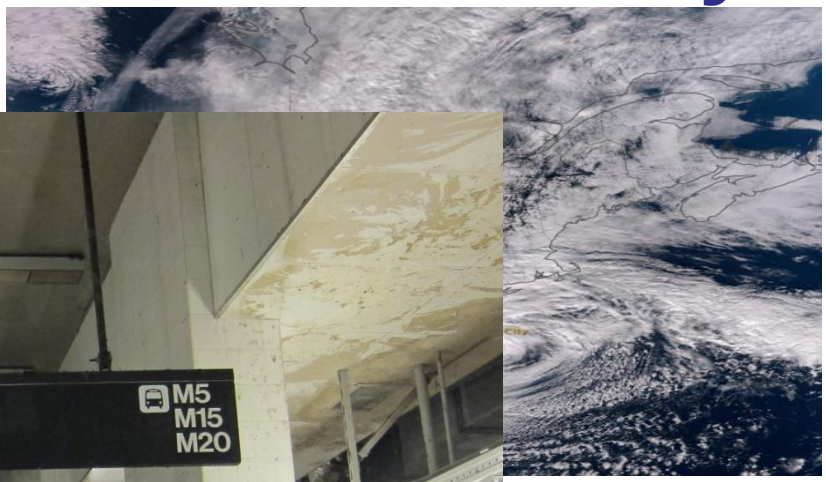
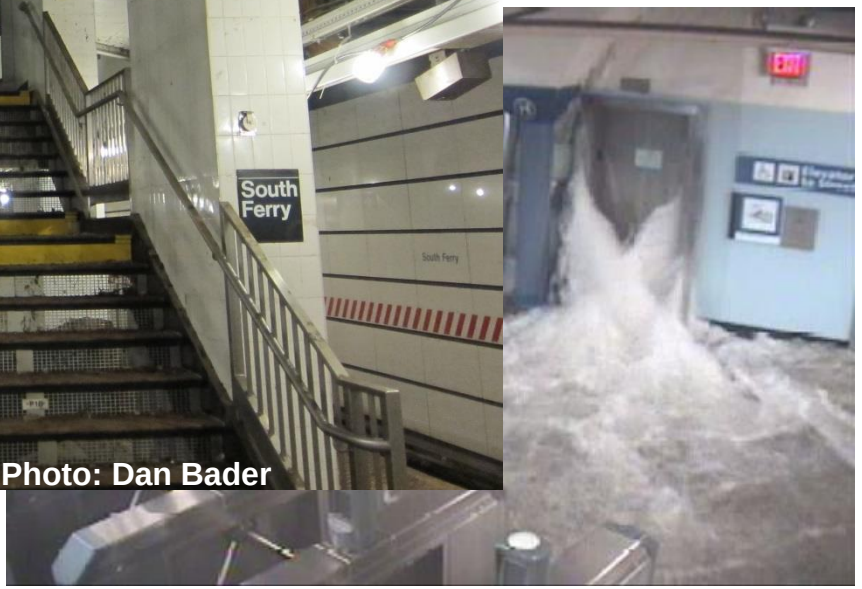


Photo: Dan Bader





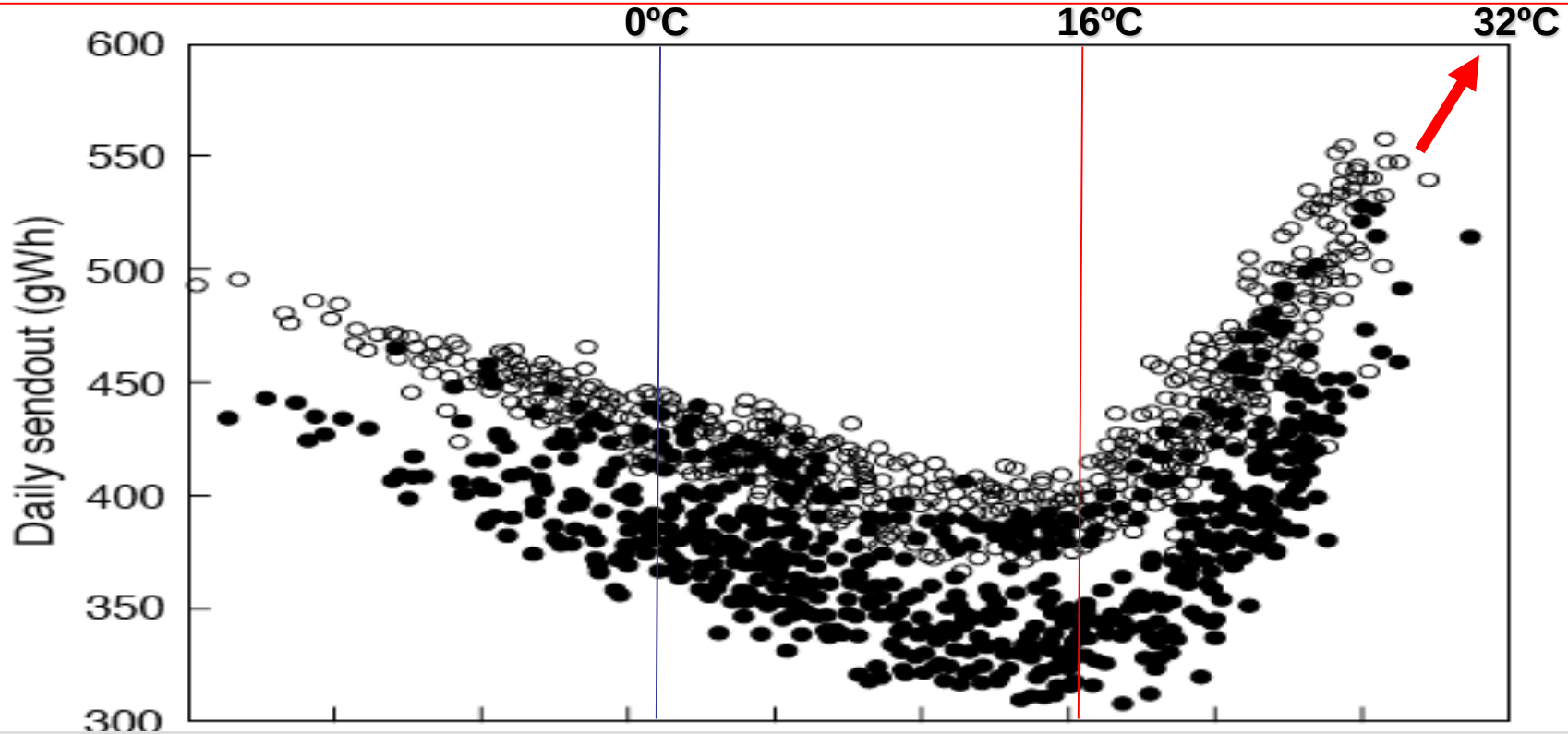
http://www.mta.info/mta/pdf/storm_report_2007.pdf

Worst-track storm surge flood zones for Saffir-Simpson Cat.1 in red, SS2 in brown, SS3 in yellow, and SS4 in green. Shaded lines are subways, black lines are rail sytems.

Lamont-Doherty Earth Observatory, Google Earth, and NYSEMO

Hurricane Sandy, Hoboken, NJ

Impacts: Heat Waves and the Energy and Health Sectors



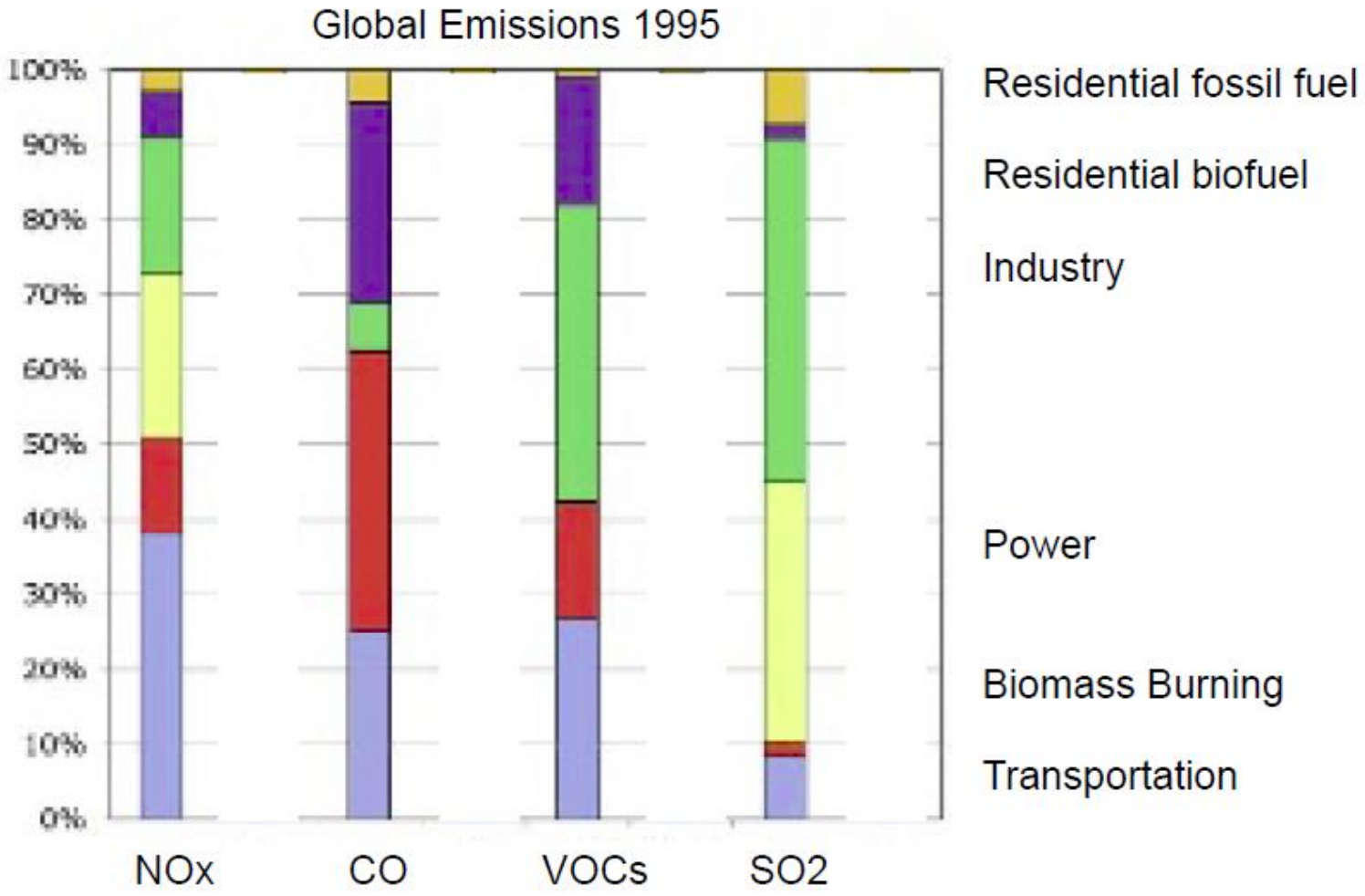
Daily Electric Energy Load (gigawatt-hours) in NY State, vs. Daily-Average Temperature.
Solid Points=1966; Open Points=1997 =>
Peak Load Issues

MEC, 2001

Vulnerable Communities

Earth System Models help us identify the impacts of policy

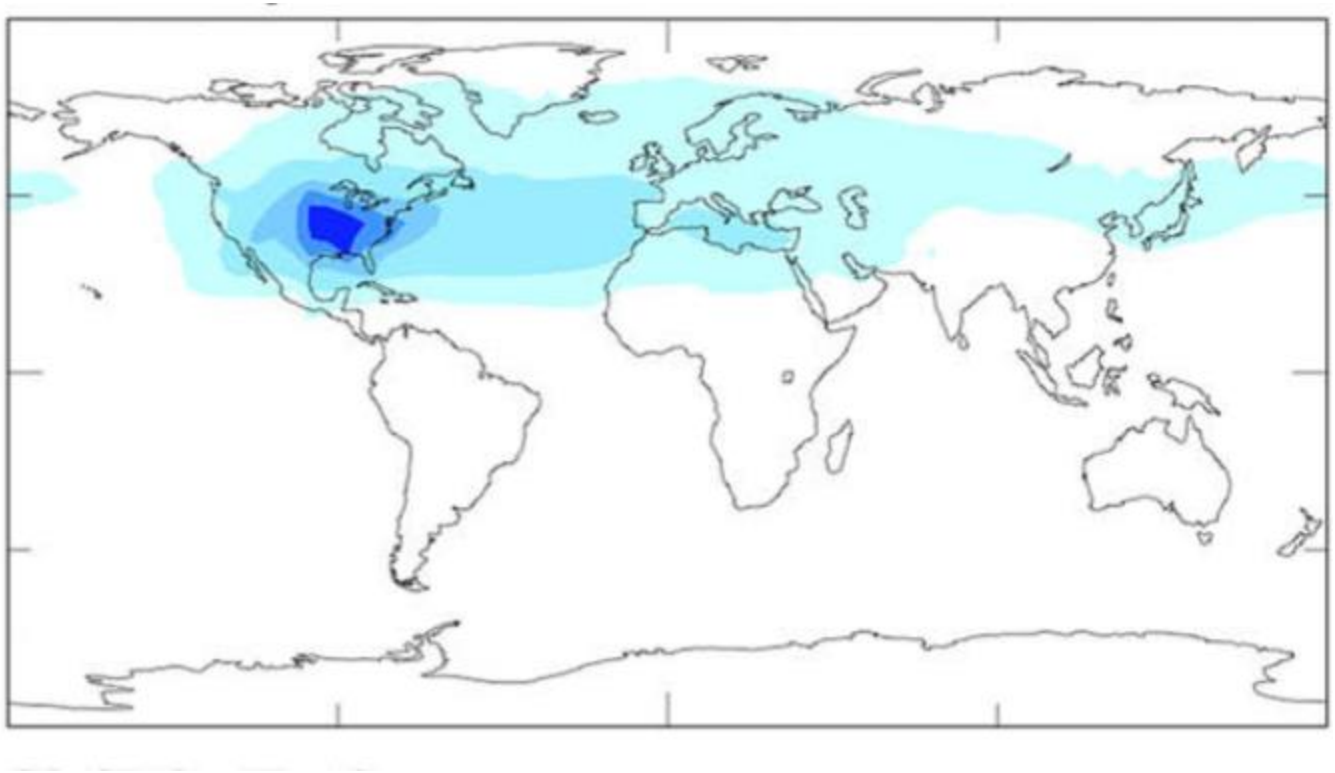
Each emissions source has its own signature of chemicals:



Hypothetical policy scenario: Reduce on-road transportation emissions by 50%, replace with more power generation

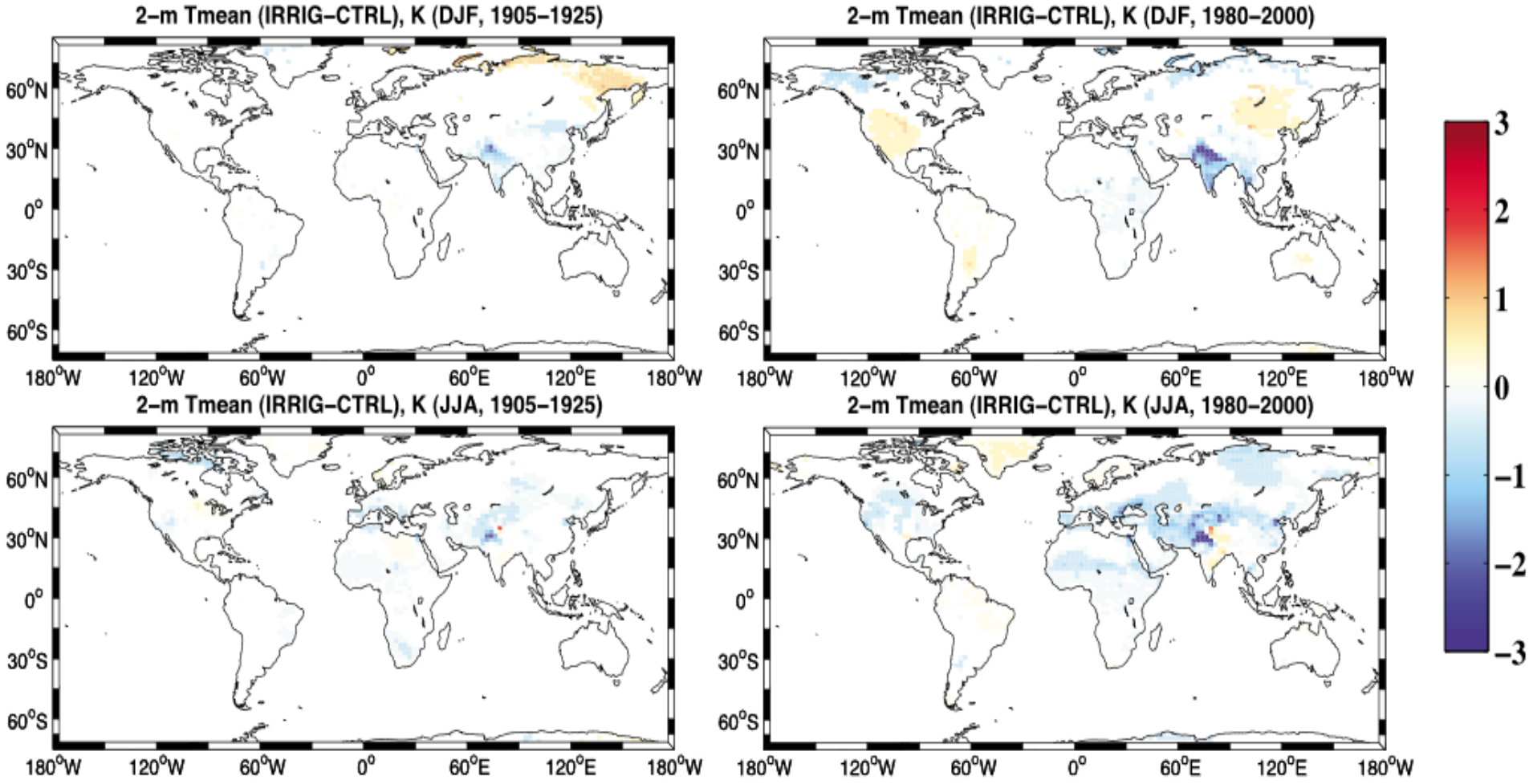
Resulting climate forcing (mW/m^2) from non-CO_2 factors:

(This is for the next 20 years; longer term must factor in CO_2 effects)



Unger et al., 2009; Atmospheric Environment

Effects of irrigation on regional temperature

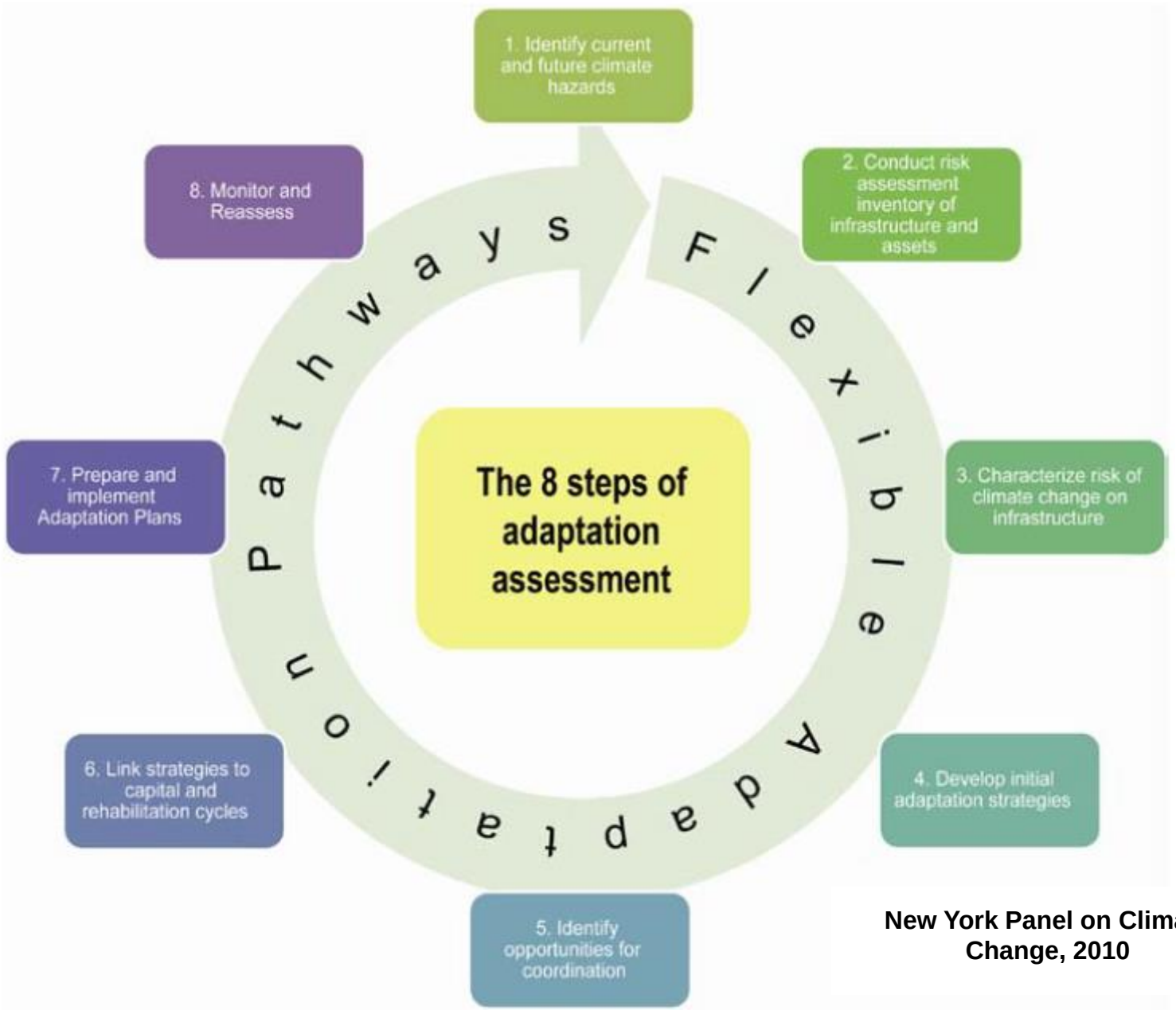


Puma and Cooke, 2010; JGR

Final Thoughts

- We are working to find adaptations and policies for a more resilient future
- Policy-specific science can stay policy neutral


Thanks!



New York Panel on Climate Change, 2010

Cuyahoga River fire, 1969 – Creative Commons Photo