Human Impacts on Climate: A Broader View than Reported in the 2007 IPCC Report

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Figure SPM.2. Global average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. The range for linear contrails does not include other possible effects of aviation on cloudiness. (2.9, Figure 2.20)
FIGURE SPM-2. Global-average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. Range for linear contrails does not include other possible effects of aviation on cloudiness.
FIGURE 1-4 Conceptual framework for how radiative forcing fits into the climate policy framework. Blue-shaded boxes indicate quantities that have been considered as policy targets in international negotiations and other policy analyses. Radiative forcing (striped box) has not been treated as a policy target in the same explicit way that limiting emissions (e.g., Kyoto Protocol), limiting concentrations (e.g., greenhouse gas stabilization scenarios), and limiting temperature changes and impacts (e.g., environmental scenarios) have. That is, an explicit cap on anthropogenic radiative forcing levels has not been proposed analogous, for example, to the Kyoto Protocol cap on emissions. Note that land-use change has not received much attention as a forcing agent and is not included here, though this report recommends that it should be.
Did The IPCC Adequately Consider All Significant Positive Radiative Forcings?
Estimates of Positive Radiative Forcing
[In Watts per meter squared]

- Methane +0.8
- Short-wave albedo change +0.5
- Tropospheric ozone +0.3
- Aerosol black carbon +0.2
- Black carbon on snow and ice +0.3
- Semi-direct aerosol effect +0.1
- Glaciation effect +0.1
- Solar influences +0.25
- Dust ?

The CO2 contribution to the radiative warming decreases to 30% or less using the IPCC framework given in the 2001 IPCC.
The Narrow Focus of the IPCC Assessment

The IPCC Authors are Climate Skeptics
Politicalization of Climate Science

- The current focus is on carbon dioxide emissions from fossil fuel combustion (the IPCC view).
- Since the climate forcing of CO$_2$ is only one of a diverse set of first order human climate forcings, and global warming is only a subset of climate change (NRC, 2005; IGBP-BAHC, 2004), the current IPCC focus is an ineffective climate policy.
- The current IPCC focus is to use the focus on CO$_2$ to promote changes in energy policy.
- The use of carbon dioxide as the instrument to promote energy policy changes, however, is an inappropriately blunt instrument for this purpose, and can lead to poor energy policy decisions.
The Climate System Is Much More Than Long-term Weather Statistics
Climate Is Not A Boundary Value Problem But An Initial Value Problem
FIGURE 1-1 The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes to the land surface are considered external to the climate system.
INTRODUCTION

FIGURE 1-2 Conceptual framework of climate forcing, response, and feedbacks under present-day climate conditions. Examples of human activities, forcing agents, climate system components, and variables that can be involved in climate response are provided in the lists in each box.

EXPANDING THE RADIATIVE FORCING CONCEPT (NRC 2005 Recommendations)

- Account for the Vertical Structure of Radiative Forcing
- Determine the Importance of Regional Variation in Radiative Forcing
- Determine the Importance of Nonradiative Forcings
- Provide Improved Guidance to the Policy Community
Account for the Vertical Structure of Radiative Forcing

Test and improve the ability of climate models to reproduce the observed vertical structure of forcing for a variety of locations and forcing conditions.
Account for the Vertical Structure of Radiative Forcing

National Research Council Report

PRIORITY RECOMMENDATIONS

Undertake research to characterize the dependence of climate response on the vertical structure of radiative forcing.
Account for the Vertical Structure of Radiative Forcing

National Research Council Report

Priority Recommendations

Report global mean radiative forcing at both the surface and the top of the atmosphere in climate change assessments.
Determine the Importance of Regional Variation in Radiative Forcing

Use climate records to investigate relationships between regional radiative forcing (e.g., land use or aerosol changes) and climate response in the same region, other regions, and globally.
Determine the Importance of Regional Variation in Radiative Forcing

Quantify and compare climate responses from regional radiative forcings in different climate models and on different timescales (e.g., seasonal, interannual), and report results in climate change assessments.
Determine the Importance of Nonradiative Forcings

National Research Council Report

PRIORITY RECOMMENDATIONS

Improve understanding and parameterizations of aerosol-cloud thermodynamic interactions and land-atmosphere interactions in climate models in order to quantify the impacts of these nonradiative forcings on both regional and global scales.
Develop improved land-use and land-cover classifications at high resolution for the past and present, as well as scenarios for the future.
Provide Improved Guidance to the Policy Community

National Research Council Report
PRI OR I TY RECOMMENDATIONS

Encourage policy analysts and integrated assessment modelers to move beyond simple climate models based entirely on global mean TOA radiative forcing and incorporate new global and regional radiative and nonradiative forcing metrics as they become available.
Skillful Multi-decadal Climate Predictions On The Global, Zonally-Averaged And Regional Scales Have Not Been Achieved.
“Tropical Temperature Results (20°S to 20°N)

Although the majority of observational data sets show more warming at the surface than in the troposphere, some observational data sets show the opposite behavior. Almost all model simulations show more warming in the troposphere than at the surface. This difference between models and observations may arise from errors that are common to all models, from errors in the observational data sets, or from a combination of these factors. The second explanation is favored, but the issue is still open.”
Figure 5.4 from Temperature Trends in the Lower Atmosphere - Understanding and Reconciling Differences
The Global-Averaged Surface Temperature Trends Assessment Is An Inadequate Climate Change Metric
One of the objectives of the USHCN, however, as stated in Easterling et al. (1996), "... was to detect temporal changes in regional rather than local climate. Therefore, only stations not influenced to any substantial degree by artificial changes in their local environments were included in the network."

This is the climatological station of record for Odessa, Washington. It is at the residence of a COOP weather observer administered by NOAA. The photo was taken by surfacestations.org volunteer surveyor Bob Meyer. From: http://www.norcalblogs.com/watts/
Fort Morgan site showing images of the cardinal directions from the sensor (from Hanamean et al. 2003)
Tucson, AZ station. From: http://www.norcalblogs.com/watts/
Ocean Heat Content Changes Over Time Provide An Effective Metric To Diagnose The Radiative Imbalance of the Climate System
A Litmus Test For Global Warming

Joules must accumulate in the ocean each year at a more or less monotonic rate of about $10^{22}$ Joules per year.

- 2003 $8 \times 10^{22}$ Joules
- 2004 $9 \times 10^{22}$ Joules
- 2005 $10 \times 10^{22}$ Joules
- 2006 $11 \times 10^{22}$ Joules
- 2007 $12 \times 10^{22}$ Joules
- 2008 $13 \times 10^{22}$ Joules
- 2009 $14 \times 10^{22}$ Joules
- 2010 $15 \times 10^{22}$ Joules
- 2011 $16 \times 10^{22}$ Joules
- 2012 $17 \times 10^{22}$ Joules
Correction to the Lyman et al. paper removes recent cooling but also does not show warming.

Other data also show little if any global warming since 2002. SSTs, tropospheric temperatures [RSS and UAH MSU data]
Figure SPM.2. Global average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. The range for linear contrails does not include other possible effects of aviation on cloudiness. (2.9, Figure 2.20)
2007 IPCC Total Radiative Forcing = 1.72 (0.66 to 2.7) Watts per meter squared

Best Estimate of Total Radiative Imbalance (1993-2005) = 0.33 (0.10 to 0.56) Watts per meter squared

If the IPCC Forcing is accepted as the current forcing, than the net global radiative feedbacks are negative!
Current SST Anomalies

NOAA SST Anomaly (degrees C), 8/6/2007
(white regions indicate sea-ice)

http://www.osdpd.noaa.gov/PSB/EPS/SST/climo.html
Vertical relative weighting functions for each of the channels discussed on this website. The vertical weighting function describes the relative contribution that microwave radiation emitted by a layer in the atmosphere makes to the total intensity measured above the atmosphere by the satellite.

The weighting functions are available on the FTP site at

ftp.ssmi.com/msu/weighting_functions

http://www.remss.com/msu/msu_data_description.html#msu_amsu_trend_map_tlt
Global, monthly time series of brightness temperature anomaly for channel TLS. Channel TLS (Lower Stratosphere) is dominated by stratospheric cooling, punctuated by dramatic warming events caused by the eruptions of El Chichon (1982) and Mt Pinatubo (1991).

http://www.remss.com/msu/msu_data_description.html#msu_decadal_trends
Global, monthly time series of brightness temperature anomaly for Channel TMT (Middle Troposphere), the anomaly time series is dominated by ENSO events and slow tropospheric warming. The three primary El Niños during the past 20 years are clearly evident as peaks in the time series occurring during 1982-83, 1987-88, and 1997-98, with the most recent one being the largest.

http://www.remss.com/msu/msu_data_description.html#msu_decadal_trends
Global, monthly time series of brightness temperature anomaly for Channel TLT (Lower Troposphere), the anomaly time series is dominated by ENSO events and slow tropospheric warming. The three primary El Niños during the past 20 years are clearly evident as peaks in the time series occurring during 1982-83, 1987-88, and 1997-98, with the most recent one being the largest. 

http://www.remss.com/msu/msu_data_description.html#msu_decadal_trends
Northern Hemisphere Anomalies in Extent

http://nsidc.org/data/seaice_index/n_extn.html
Southern Hemisphere Anomalies in Extent

http://nsidc.org/data/seaice_index/s_extn.html
Current Southern Hemisphere Sea Ice Area

recent 365 days shown

http://arctic.atmos.uiuc.edu/cryosphere/IMAGES/current.365.south.jpg
Human-Caused Global Warming Is Just A Subset Of Human-Caused Climate Change
NEW OR UNDER-RECOGNIZED HUMAN CLIMATE FORCINGS

- Biogeochemical Effect of CO₂
- Nitrogen Deposition
- Land-Use/Land-Cover Change
- Glaciation Effect of Aerosols
- Thermodynamic Effect of Aerosols
- Surface Energy Budget Effect
Example of a pyrocumulus cloud (copyright 2001, Axel Thielmann).
Example of industrial emissions from a smokestack

From http://earthobservatory.nasa.gov/Laboratory/Aerosol/Images/anthro_smokestack.jpg
<table>
<thead>
<tr>
<th>Effect</th>
<th>Cloud Type</th>
<th>Description</th>
<th>Sign of TOA Radiative Forcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>First indirect aerosol effect (cloud albedo or Twomey effect)</td>
<td>All clouds</td>
<td>For the same cloud water or ice content, more but smaller cloud particles reflect more solar radiation</td>
<td>Negative</td>
</tr>
<tr>
<td>Second indirect aerosol effect (cloud lifetime or Albrecht effect)</td>
<td>All clouds</td>
<td>Smaller cloud particles decrease the precipitation efficiency, thereby prolonging cloud lifetime</td>
<td>Negative</td>
</tr>
<tr>
<td>Semidirect effect</td>
<td>All clouds</td>
<td>Absorption of solar radiation by soot leads to evaporation of cloud particles</td>
<td>Positive</td>
</tr>
<tr>
<td>Glaciation indirect effect</td>
<td>Mixed-phase clouds</td>
<td>An increase in ice nuclei increases the precipitation efficiency</td>
<td>Positive</td>
</tr>
<tr>
<td>Thermodynamic effect</td>
<td>Mixed-phase clouds</td>
<td>Smaller cloud droplets inhibit freezing, causing supercooled droplets to extend to colder temperatures</td>
<td>Unknown</td>
</tr>
<tr>
<td>Surface energy budget effect</td>
<td>All clouds</td>
<td>The aerosol-induced increase in cloud optical thickness decreases the amount of solar radiation reaching the surface, changing the surface energy budget</td>
<td>Negative</td>
</tr>
</tbody>
</table>

Effect of Land-Use Change on Deep Cumulonimbus Convection
Land-Use Intensity: 1850 vs 1920
Reconstructed Historical Land-Use Intensity
Showing Fractional Areas

Top: Remaining Old-Growth and Pre-settlement Vegetation (a) 1850 and (b) 1920

Middle: Disturbed/Semi-natural Vegetation/Village  
(c) 1850 and (d) 1920

Bottom: Mixed Agriculture 
(e) 1850 and (f) 1920

Source: Steyaert and Knox (in review)
Albedo: 1650, 1850, 1920, 1992

Historical Patterns of Broadband Solar Albedo:

(a) 1650
(b) 1850
(c) 1920
(d) 1992

Source: Steyaert and Knox (in review)
Surface Roughness Length:
1650, 1850, 1920, 1992

Historical Patterns of Surface Roughness Length (cm):
(a) 1650
(b) 1850
(c) 1920
(d) 1992

Source: Steyaert and Knox (in review)
REGIONAL LAND-USE CHANGE EFFECTS ON CLIMATE IN FLORIDA IN THE SUMMER
FIG. 25. Regional average time series of accumulated convective rainfall (cm) from 1924 to 2000, with corresponding trend based on linear regression of all July-August amounts. The vertical bars overlain on the raw time series indicate the value of the standard error of the July-August regional mean.

FIG. 26. Same as in Figure 25, except for daily (a) maximum and (b) minimum shelter-level temperature (°C)
Global Land-Use Change Effects On Climate
Vegetation classifications for (a) natural vegetation and (b) current vegetation in regions where current and natural vegetation differ (i.e., anthropogenically disturbed regions in the current case).

The ten-year average absolute-value change in surface latent turbulent heat flux in W m$^{-2}$ worldwide as a result of the land-use changes for (a) January, and (b) July. (Adapted from Chase et al. 2000.)


http://climatesci.colorado.edu/publications/pdf/R-258.pdf
Redistribution of Heat Due to the Human Disturbance of the Earth’s Climate System

<table>
<thead>
<tr>
<th>Only Where Land Use Occurred</th>
<th>Globally-Averaged Absolute Value of Sensible Heat Plus Latent Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>July</td>
</tr>
<tr>
<td>Teleconnections Included</td>
<td>July</td>
</tr>
</tbody>
</table>

Global redistribution of heat is on the same order as an El Niño.
Absolute Value of Globally-Averaged Change is 1.2 mm/day.

Prepared by T.N. Chase, CU, Boulder, CO.
Global Water Cycle Metric

Absolute Value of Globally-Averaged Change is 0.6 mm/day
Prepared by T.N. Chase, CU, Boulder, CO.
DJF temperature differences due to land-cover change in each of the scenarios. Values were calculated by subtracting the greenhouse gas–only forcing scenarios from a simulation including land-cover and greenhouse gas forcings. Feddema et al. 2005: The importance of land-cover change in simulating future climates, Science 310
Changes in the annual average diurnal temperature range due to land-cover change in each of the scenarios. Values were calculated by subtracting the greenhouse gas–only forcing scenarios from a simulation including land-cover and greenhouse gas forcings. Shaded grid cells are significant at the 0.05 confidence level. Feddema et al. 2005
WHAT IS THE IMPORTANCE OF MORE HETEROGENEOUS CLIMATE FORCINGS RELATIVE TO MORE HOMOGENEOUS CLIMATE FORCING SUCH AS THE RADIATIVE FORCING OF CO$_2$?
AN EXAMPLE FOR AEROSOL CLIMATE FORCING
Human-Caused Climate Change is Just a Subset of Human-Caused Environmental Change
I) Land Clearing / Degradation

massive changes to Earth’s land

~40% of land converted to agriculture

~18 million km\(^2\) in crops
~30 million km\(^2\) in pastures, rangeland

today, ~40% of global photosynthesis now in human hands

Lesson #1

- **fact:** agricultural areas have expanded
  - in past 40 years, area increased by ~12%

- **fact:** agricultural intensification has been far larger
  - in past 40 years, irrigated land increased by ~70%
  - fertilizer use increased ~700%
  - dramatic loss of cropping diversity

- **current approaches are inadequate**
  - global data products & models basically ignore this

- **need to focus on land use practices and agricultural management**
Lesson #2

- fact: forest area has declined
- fact: fate of deforested lands is also changing
  - shortening fallow cycles
  - more permanent clearings
- current approaches are inadequate
  - global data products & models basically ignore this
- need to focus on fates of deforestation

Lesson #3

- key point: *land use practices are changing quickly; much more than changing land cover*

- massive shifts in the coming years...
  - increasing *biofuels* (maize, sugarcane, oil palm, ...)
  - increasing demands for *animal feed*
  - increasing participation in *global markets*

- *throw all of our old assumptions about land use / land cover change out the window...*
Points on Greenhouse Gases

**wow!** global land use & agriculture, taken together, contribute more greenhouse gases than any single societal activity

- more than global transportation...
- more than global electricity...
- more than global heating...
- more than global manufacturing...

altogether, agriculture and deforestation appear to contribute *at least 1/3* of all GHG forcing.
Points on Greenhouse Gases

- CO₂ from land use is important...
  - but only about half the story

- the other half...
  - CH₄ from rice paddies, livestock
  - N₂O from agricultural lands

- and that doesn’t consider...
  - fires: O₃, black carbon, aerosols
  - biogenic VOCs: O₃
  - linked chemistry of O₃, CH₄

Lesson #1

- agriculture & land use release **more greenhouse gases** than any other single human activity

- extends far **beyond CO₂**
  - other greenhouse gases, especially CH₄, O₃, N₂O
  - also aerosols, black carbon

- effects on **physical climate** also large
  - regional in scale, but still important
  - often get “washed out” in outdated climate metrics of radiative forcing and global mean temperature

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Lesson #2

- Changes in land use / land cover have many other, direct impacts on human societies

Direct effects...
- Agricultural production (food, feed and fuels)
- Water quantity and water quality
- Vector-borne disease
- Etc...

Bottom Line

Global Change is Much More Than CO₂ and Global Warming
Current Focus on CO$_2$ / Climate Connection is Very Short Sighted
Need More Comprehensive Framework to Exploring Changes in Earth System
WE NEED A NEW PERSPECTIVE ON THE ROLE OF ENVIRONMENTAL VARIABILITY AND CHANGE ON SOCIETY AND THE ENVIRONMENT

A FOCUS ON VULNERABILITY
Prediction: Science, Decision Making and the Future of Nature
Edited by Daniel Sarewitz, Roger A. Pielke, Jr., and Radford Byerly, Jr., 2000: Island Press, Washington, DC, 400 pp
April 1 snowpack percent of average for the state of Colorado for years 1968 through 2007.
Resource Specific Impact Level with Respect to Water Resources - June 2004

Resource Specific Impact Level
Examples from Larimer County

- **Negligible**
- **Minor**
- **Moderate**
- **Major**
- **Exceptional**

*Impacted Groups*
- Anheuser-Busch
- Fort Collins Municipal Water
- Grant Family Farms
- Dryland Ranching
If you were given 100 million Dollars to spend on environmental benefits in Arizona, where would you use that money?

1. subsidies for solar and wind power
2. subsidies for coal liquidification and pollution extraction
3. purchasing greenbelts (public parks)
4. more mass transit
WHERE SHOULD THIS MONEY COME FROM?

1. higher gas taxes
2. mileage driven tax
3. lottery
4. luxury tax on large private vehicles
5. higher income taxes
6. square foot tax on residences
CONCLUSIONS
The needed focus for the study of climate change and variability is on the regional and local scales. Global and zonally-averaged climate metrics would only be important to the extent that they provide useful information on these space scales.
Global warming is not equivalent to climate change. Significant, societally important climate change, due to both natural- and human- climate forcings, can occur without any global warming or cooling.
The spatial pattern of ocean heat content change is the appropriate metric to assess climate system heat changes including global warming and cooling.
Global and zonally-averaged surface temperature trend assessments, besides having major difficulties in terms of how this metric is diagnosed and analyzed, do not provide significant information on climate change and variability on the regional and local scales.
In terms of climate change and variability on the regional and local scale, the IPCC Reports, the CCSP Report on surface and tropospheric temperature trends, and the U.S. National Assessment have overstated the role of the radiative effect of the anthropogenic increase of CO$_2$ relative to the role of the diversity of other human climate forcing on global warming, and more generally, on climate variability and change.
Global and regional climate models have not demonstrated skill at predicting climate change and variability on multi-decadal time scales.
Attempts to significantly influence regional and local-scale climate based on controlling CO$_2$ emissions alone is an inadequate policy for this purpose.
A vulnerability paradigm, focused on regional and local societal and environmental resources of importance, is a more inclusive, useful, and scientifically robust framework to interact with policymakers, than is the focus on global multi-decadal climate predictions which are downcaled to the regional and local scales. The vulnerability paradigm permits the evaluation of the entire spectrum of risks associated with different social and environmental threats, including climate variability and change.
Humans are significantly altering the global climate, but in a variety of diverse ways beyond the radiative effect of carbon dioxide. The IPCC assessments have been too conservative in recognizing the importance of these human climate forcings as they alter regional and global climate. These assessments have also not communicated the inability of the models to accurately forecast the spread of possibilities of future climate. The forecasts, therefore, do not provide any skill in quantifying the impact of different mitigation strategies on the actual climate response that would occur.
The Current IPCC Focus is to Promote Energy Policy Changes, Not to Provide an Effective Climate Policy.

Policymakers Need To Be Informed Of This Very Important Distinction.

We Need To Separate Climate Policy From Energy Policy.