Expanding the Concept of Human-Caused Climate

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Policy Statement on Climate Variability and Change
by the American Association of State Climatologists

1. Past climate is a useful guide to the future - Assessing past climate conditions provides a very effective analysis tool to assess societal and environmental vulnerability to future climate, regardless of the extent the future climate is altered by human activity. Our current and future vulnerability, however, will be different than in the past, even if climate were not to change, because society and the environment change as well. Decision makers need assessments of how climate vulnerability has changed.

2. Climate prediction is complex with many uncertainties. The AASC recognizes climate prediction is an extremely difficult undertaking. For time scales of a decade or more, understanding the empirical accuracy of such predictions - called “verification” - is simply impossible, since we have to wait a decade or longer to assess the accuracy of the forecasts.

Available at: http://ccc.atmos.colostate.edu/policystatement.php
Views of Climate Change Science
- Climate change including regional impacts can be skillfully predicted by knowledge of the concentration of well-mixed greenhouse gases.
- Surface temperatures are the most appropriate metric to assess “global warming.”
- The global average temperature provides a useful assessment of climate.
- The surface temperature data has been adequately homogenized in the regional scale using adjustments such as time of observations, instrument changes, and urbanizations.
- Arctic sea-ice cover and Northern Hemisphere snow cover are continuously diminishing in areal coverage.
The atmospheric hydrological cycle is accelerating.
The earth’s atmosphere is warmer today than it was in 1979 when accurate global satellite coverage became available.
The GCM models have skillfully predicted the evolution of the earth’s atmospheric temperature since 1979.
We understand climate change and can introduce policies to prevent our “dangerous intervention in the climate system.”
The IPCC and U.S. National Assessment document a clear scientific understanding of the human disturbance of the climate system.
Norris: Speaking of multilateralism, do you notice, as many have suggested, that there's an increasing unilateralist bent in the United States government?

Blix: Yeah. On big issues like war in Iraq, but in many other issues they simply must be multilateral. There's no other way around. You have the instances like the global warming convention, the Kyoto protocol, when the U.S. went its own way. I regret it. To me the question of the environment is more ominous than that of peace and war. We will have regional conflicts and use of force, but world conflicts I do not believe will happen any longer. But the environment, that is a creeping danger. I'm more worried about global warming than I am of any major military conflict.

Now the Pentagon Tells Bush: Climate Change Will Destroy Us

Secret report warns of rioting and nuclear war; Britain will be 'Siberian' in less than 20 years; Threat to the world is greater than terrorism.

Mark Townsend and Paul Harris in New York
Sunday February 22, 2004
The Observer

Climate change over the next 20 years could result in a global catastrophe costing millions of lives in wars and natural disasters....

http://observer.guardian.co.uk/international/story/0,6903,1153513,00.html
Environmental Doomsday Clock
(Perception of the Crisis Facing Human Survival)

In Developed Regions – Global Warming

In Developing Regions – Deforestation, desertification, loss of biodiversity.
Not Included Climate Forcings, e.g.

- Land-use change as it affects transpiration, physical evaporation and sensible heat fluxes
- Biogeochemical forcing due to increased CO$_2$
- Biochemical forcing due to nitrogen deposition
- Biogeochemical forcing due to changes in the direct/diffuse solar irradiance through aerosols
- Effect of anthropogenic aerosols on precipitation efficiency

These effects alter not only the global radiative fluxes but the regional structure of spatial heating and cooling.
Estimate of actual climate system heat change from the early 1950s-1995 is 0.3 Watts per meter squared (Pielke 2003) based on ocean heat storage changes (Levitus et al. 2000). Figure from Houghton et al. Eds., 2001: Summary for Policymakers: http://www.ipcc.ch
Chapter 1

The Lack of Spatial Representativeness of Surface Temperature


Maximum-minimum temperature sensor (MMTS) installation near Lindon, Colorado.
MMTS installation near John Martin Reservoir, Colorado.
Map of study region, showing all surveyed COOP sites. The USHCN sites are indicated by stars. The following photos are for HCN sites.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Eads, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Holly, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics for the NWS COOP station near Rocky Ford, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively. (CRS-Cotton Region Shelter)
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Trinidad, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Cheyenne Wells, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Lamar, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Wray, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Las Animas, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively.
Fort Morgan site showing images of the cardinal directions from the sensor (from Hanamean et al. 2003)
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GCM Models Have Not Yet Succeeded In Skillfully Predicting 1980-2000 Global Climate

TROPOSPHERIC OBSERVATIONS: GLOBAL TEMPERATURE ANOMALY

UAH MSU (Lower Troposphere Avg.) 0.06°C/decade; p=0.05
RSS MSU (Lower Troposphere Avg.) 0.13°C/decade; p=0.01
NCEP REANALYSES (1000-500mb avg.) 0.10°C/decade; p=0.04
RAWINSONDE (850-300mb Avg.) -0.01°C/decade; p=0.88
CRU SURFACE 0.17°C/decade; p<0.001

T ANOMALY (°C)

YEAR


-0.4 -0.2 0 0.2 0.4 0.6 0.8

Courtesy of Thomas N. Chase, University of Colorado, Boulder.

http://blue.atmos.colostate.edu/publications/pdf/R-224.pdf
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The Lack of Warming in the Arctic Troposphere


http://blue.atmos.colostate.edu/publications/pdf/R-246.pdf
http://www.atmo.arizona.edu/gifs/500mb_t.gif
Reanalysis monthly-averaged area enclosed by indicated isotherm during the period 1950-1998 north of 60°N. (a) -40°C isotherm, (b) -42°C isotherm, and -44°C isotherm.
The Global Spatial Redistribution of Energy by Human-Caused Landscape Change


http://blue.atmos.colostate.edu/publications/pdf/R-258.pdf
Examples of land-use change from (a) 1700, (b) 1900, (c) 1970, and (d) 1990. The human-disturbed landscape includes intensive cropland (red) and marginal cropland used for grazing (pink). Other landscape includes tropical evergreen forest and deciduous forest (dark green), savannah (light green), grassland and steppe (yellow), open shrubland (maroon), temperate deciduous forest (blue), temperate needleleaf evergreen forest (light yellow) and hot desert (orange). Note the expansion of cropland and grazed land between 1700 and 1900. (Reproduced with permission from Klein Goldewijk 2001.)
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$^{-2}$ at the locations where land-use change occurred for (a) January, and (b) July. (Adapted from Chase et al. 2000.)
The ten-year average absolute-value change in surface sensible heat flux in W m$^{-2}$ at the locations where land-use change occurred for (c) January, and (d) July. (Adapted from Chase et al. 2000.)
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.)
The ten-year average absolute-value change in sensible turbulent heat flux in W m$^{-2}$ worldwide as a result of the land-use changes for (c) January, and (d) July. (Adapted from Chase et al. 2000.)
Redistribution of Heat Due to the Human Disturbance of the Earth’s Climate System

<table>
<thead>
<tr>
<th>Only Where Land Use Occurs</th>
<th>July</th>
<th>1.9 Watts m(^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>January</td>
<td>0.7 Watts m(^{-2})</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Teleconnections Included</th>
<th>July</th>
<th>8.9 Watts m(^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>January</td>
<td>9.5 Watts m(^{-2})</td>
</tr>
</tbody>
</table>

Globally-Average Absolute Value of Sensible Heat Plus Latent Heat


Estimate of actual climate system heat change from the early 1950s-1995 is 0.3 Watts per meter squared (Pielke 2003) based on ocean heat storage changes (Levitus et al. 2000). Figure from Houghton et al. Eds., 2001: Summary for Policymakers: http://www.ipcc.ch
“HOT TOWERS”

“As shown in the pioneering study by Riehl and Malkus (1958) and by Riehl and Simpson (1979), 1500-5000 thunderstorms (which they refer to as ‘hot towers’) are the conduit to transport this heat, moisture, and wind energy to higher latitudes. Since thunderstorms occur only in a relatively small percentage of the area of the tropics, a change in their spatial patterns would be expected to have global consequences.”

The Adoption of a More Appropriate Metric to Monitor “Global Warming (or Cooling)”


The heat budget for the earth system can be expressed as

$$\iiint R_N \, dA \, dt = \iiint Q \, dV \, dt + \iiint Q \, dV \, dt$$

\[ t, A_{Earth} \quad t, V_{atmos} \quad t, V_{ocean} \]

+ other heat reservoirs,

where $R_N$ is the global mean nonequilibrium radiative forcing, $A_{Earth}$ is the area of the earth, $Q$ is the heating rate, $V_{atmos}$ is the volume of the atmosphere, and $V_{ocean}$ is the volume of the ocean.
Planetary energy imbalance (heat storage in the upper 3 km of the world ocean) observations expressed in units of watts m$^{-2}$ (adapted from Levitus et al. 2001). (Figure prepared by Alan Robock, Rutgers University, 2001, personal communication.)
Mid-1950s to Mid-1990s

\[ \sim 0.15 \text{ Watts m}^{-2} \quad \text{surface - 300 meters} \]

\[ \sim 0.15 \text{ Watts m}^{-2} \quad 300 \text{ meters} - 3 \text{ km} \]
Figure 5. Interannual variability in heat content integrated over the region from 20°N to 20°N (solid line) and over the entire globe (dashed line). From Willis et al. (2004).

“Perhaps the most important aspect of this work is that it establishes a strong constraint on the performance and veracity of anthropogenically forced climate models. For example, a climate model that reproduces the observed change in global air temperature over the last 50 years, but fails to quantitatively reproduce the observed change in ocean heat content, cannot be correct. The PCM has a relatively low sensitivity (less anthropogenic impact on climate) and captures both the ocean- and air-temperature changes. It seems likely that models with higher sensitivity, those predicting the most drastic anthropogenic climate changes in the future, may have difficulty satisfying the ocean constraint. To our knowledge, the PCM is the only model currently able to do this and still accurately reflect the changes in surface air temperature over the last 50 years. Future studies should take into account the ocean constraint when deciding which future climate summaries are most reliable.”
GLOBAL SURFACE HEAT CHANGES

\[ T \neq \text{Surface Heat} \]

\[ C_pT + Lq = \text{Surface Heat} \]

e.g., At 1000 mb, a decrease of the dewpoint temperature from 24°C to 23°C, corresponds to a change in heat of a temperature decrease of 2.5°C.

This means, for example, the temperature could increase by 1°C, but if the dewpoint temperature decreased by 1°C, there is surface cooling!
Fig. 1: $T_1$ and $T_2$, in °C ($S$ and $H$, in 10, J kg$^{-1}$) for Fort Collins, Colorado (left panels) and the CPER ungrazed site (right panels) are shown for 2002. The top two panels are for maximum daily temperature while the bottom two panels are for minimum daily temperature. The grey lines represent $T_1$ (and $S$) while the black lines represent $T_2$ (and $H$).

The Importance of the Biological Effect of Enhanced CO$_2$


http://blue.atmos.colostate.edu/publications/pdf/R-229.pdf
Modeling domain and natural vegetation distribution. Classes represent: 1-tundra; 2-subalpine; 3-temperate conifer; 4-temperate deciduous; 5-temperate xeromorphic; 6-temperate coniferous xeromorphic; 7-savanna and deciduous; 8-C3 shortgrass 9-C4 tall grass; 10-temperate arid shrub; 11-spring wheat/small grass; 12-small grains; 13-winter wheat; 14-corn; 15-irrigated crop; 16-deciduous forest crop; 17-subtropical mixed forest; and 18-grassland and grain. From Eastman et al. (2001).
Modeling domain and current vegetation distribution. Classes represent:
1-tundra; 2-subalpine; 3-temperate conifer; 4-temperate deciduous; 5-temperate xeromorphic; 6-temperate coniferous xeromorphic; 7-savanna and deciduous; 8-C3 shortgrass 9- C4 tall grass; 10- temperate arid shrub; 11- spring wheat/small grass; 12-small grains; 13-winter wheat; 14-corn; 15-irrigated crop; 16-deciduous forest crop; 17-subtropical mixed forest; and 18-grassland and grain. From Eastman et al. (2001).

Figure 4. RAMS/GEMTM coupled model results — the seasonal domain-averaged (central Great Plains) for 210 days during the growing season, contributions to maximum daily temperature, minimum daily temperature, precipitation, and leaf area index (LAI) due to: f1 = natural vegetation, f2 = 2 × CO₂ radiation, and f3 = 2 × CO₂ biology (adapted from Eastman et al., 2001).

http://blue.atmos.colostate.edu/publications/pdf/R-225.pdf
Figure 6. Schematic of different classes of prediction. The size of the box labeled ‘U’ represents the range of future climate, while the box labeled ‘A’ indicates the relative subset of possible future climate that are estimated using the different classes of prediction. (adapted from Pielke Sr., 2001).
Regional Land-Use Change Effects on Climate in the Winter


Fig. 2. Outer and inner grid configurations for RAMS domain centered on south Florida.
Fig. 1. Number of citrus trees per county and principle areas of winter fresh vegetable production. Figure adapted from Florida Agriculture Facts Directory 2002.
Fig. 2. Observations of minimum temperature from the National Weather Service Cooperative Observer Network on the morning of January 19, 1997.
Fig. 3. U.S. Geological Survey land cover classes for pre-1900s natural conditions (left) and 1993 land use patterns.
Fig. 4. Model simulated 2 meter minimum temperatures on the morning of January 19, 1997 for the pre-1900s scenario (top panel), the 1993 scenario (middle panel), and the difference of the two (1993 minus pre-1900s scenario; bottom panel).
Fig. 5. Time spent below freezing (minutes) for the night prior to the morning of January 19, 1997, for the pre-1900s land cover scenario (top), the 1993 land cover scenario (middle) and the difference of the two (bottom).
Fig. 7. Time series of 2 meter temperature for a model grid point located just south of Lake Okeechobee for the pre-1900s land cover scenario (filled circles) and the 1993 land cover scenario (open circles).
Regional Land-Use Change Effects on Climate in the Summer


http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf
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)
FIG. 4. Accumulated convective rainfall (mm) from the model simulations of July-August 1973 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).
FIG. 5. Same as in Figure 4, except for July-August 1989.
FIG. 6. Same as in Figure 4, except for July-August 1994.
Two-month average of the surface latent heat flux (W m\(^{-2}\)) from the model simulations of July and August 1994 with pre-1900s land cover (top), 1994 land use (middle), and the difference field for the two (bottom; 1994 minus pre-1900s case).
FIG. 13. Two-month average of the daily maximum shelter-level temperature from the model simulations of July-August 1989 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).
FIG. 17. Difference (1993 minus pre-1900s case) of the fields shown in Figure 16.
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Arctic Sea Ice and Northern Hemispheric Snow-Cover Changes


Fig. 1 (left). Observed decrease of NH sea ice extent during the past 25 years. Fig. 2 (right). Observed and modeled variations of annual averages of NH sea ice extent. Observed data for 1901–98 are from Chapman and Walsh (13); Observed data for 1978–98 are from Parkinson et al. (16). The modeled sea ice extents are from the GFDL and Hadley Centre climate model runs forced by observed CO₂ and aerosols. Modeled data for ~250 years are smoothed by polynomials of degree 10 to estimate nonlinear trends caused by a change of external radiative forcing.
Actual snow cover by latitude bands (a) 60-90°N; (b) 50-60°N; (c) 40-50°N; and (d) 30-40°N.
Actual and insolation-weighted values for Arctic sea ice.
Actual and insolation-weighted values with Arctic sea ice and snow (60-90°N) included together.
Actual and insolation-weighted values with Arctic sea ice and snow (60-90°N) included together.
(a) Actual and (b) insolation-weighted monthly Antarctic sea-ice extent for 1980-2002.
Antarctic annual averaged sea-ice extent, 1980-2002, for the cases of no weighting and average daily solar weighting. Plotted are the values minus the 23-year mean, with that quantity divided by the mean.
Northern Hemisphere Sea Ice Area

Data provided by NSIDC: NASA SMMR and SSMI

http://arctic.atmos.uiuc.edu/cryosphere/IMAGES/current.area.jpg
If you were given 100 million dollars to spend on environmental benefits, where would you use that money?

1. CO₂ reduction
2. Potable water
3. AIDS prevention
4. SO₂ reduction
Schematic of the relation of water resource vulnerability to the spectrum of the environmental forcings and feedbacks. The arrows denote nonlinear interactions between and within natural and human forcings.

CONCLUSION

The Earth’s climate system and human disturbance of the climate system is more complicated and multi-dimensional than commonly assumed. This may make skillful prediction of the future climate impossible!

There is a new direction emerging.