A Proposed New Metric For Quantifying The Climatic Effects Of Human-Caused Alterations To The Global Water Cycle

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• The most appropriate metric to assess ‘global warming or cooling’ are the changes in heat unit (Joules) stores in accessible components of the earth’s environmental system.

• Humans can produce a net change in the storage and/or a redistribution of where the heat energy is stored.

• Heat units of Joules can be expressed in terms of a heating rate (1.6 X 10^{23} Joules per decade corresponds to an average earth system heating rate of 1.0 Watts m^{-2}).
The Actual Global Heat Change in the Last 50 Years is Relatively Small

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
El Niño has a major effect on weather thousands of kilometers from the tropical Pacific Ocean (Shabbar et al. 1997).

The presence of warm SSTs permit thunderstorms to occur which otherwise would not have occurred.

These thunderstorms export vast amounts of heat, moisture, and kinetic energy to the middle and higher latitudes, which alter the ridge and trough patterns associated with the polar jet stream (Hou 1998).

El Niños have such a major effect on weather due to their large magnitude, long persistence, and spatial coherence (Wu and Newell 1998).

Tropical thunderstorms are referred to as “hot towers” and are the conduit to higher latitudes as part of the Hadley circulations (Riehl and Malkus 1958; Riehl and Simpson 1979).

Most thunderstorms occur over tropical and midlatitude land masses and in the warm season (Lyons 1999; Rosenfeld 2000).

*Therefore, the earth's climate system must also be sensitive to land-use change in those regions where thunderstorms occur.*
El Niño Teleconnection Effect

SURFACE TEMPERATURE DIFFERENCE
El Niño-Natural

Prepared by T.N. Chase, CU, Boulder, CO.

<table>
<thead>
<tr>
<th></th>
<th>January</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Latent Heat Flux</td>
<td>6.1 Watts m⁻²</td>
<td></td>
</tr>
<tr>
<td>Average Sensible Heat Flux</td>
<td>2.4 Watts m⁻²</td>
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Effect of the Spatial Redistribution of Surface Heating (Land-Use Change)

Figure 1. Examples of land-use change from (a) 1700, (b) 1960, (c) 1970 and (d) 1990. The human-disturbed landscape includes intensive cropland (red) and marginal cropland used for grazing (pink). Other landscape includes, for example, tropical evergreen 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). Of particular importance in this paper is the expansion of the cropland and grazed land between 1700 and 1990. (Reproduced with permission from Klein Goldewijk 2001).

Figure 4. Effect of land-use changes on plant-canopy density (potential/actual).
Scale 0.5 latitude x 0.5 longitude.

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>July</th>
<th>1.08 Watts m(^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>January</td>
<td>0.7 Watts m(^{-2})</td>
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<table>
<thead>
<tr>
<th>Teleconnections Included</th>
<th>July</th>
<th>8.90 Watts m(^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>January</td>
<td>9.47 Watts m(^{-2})</td>
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Global redistribution of heat is on the same order as an El Niño.
Spatial Redistribution of Heat is also Associated with a Spatial Redistribution of Water

\[ R_N = Q_G + H + L(E+T) \]
\[ P = E + T + RO + I \]

*New Metric: Changes in \( \delta P; \delta T; \delta RO; \delta I \)*

Alteration in Surface Water Fluxes Associated With Land-Use Change

Alteration of Thermodynamic Profile Associated with Land-Use Change

Figure 6. Radiosonde measurements of (right) temperature and (left) dew point temperature for a dry land area (dashed curve) and an irrigated area (solid curve) in northeast Colorado at 1213 local standard time (LST) on July 28, 1987. Reprinted from Pielke and Zeng [1989] with permission from National Weather Association.

Effect of Land-Use Change on Deep Cumulonimbus Convection

Mean July Convective Available Potential Energy (CAPE) (J kg\(^{-1}\)) from 12 Z Radiosonde Observations

Changes in Mean July CAPE Due to a 1°C Increase in Surface Layer Dewpoint Temperature

Alterations in surface moisture fluxes alter CAPE

Smaller-Scale Spatial Variations in Landscape Change Also Affect the Water Cycle

Figure 11. Accumulated precipitation (millimeters) at 1800 LST in domain (a) 3D0, (b) 3D1, (c) 3D2, (d) 3D3, and (e) 3D4. Contour intervals are 2 mm in 3D0, 1 mm in 3D1, 3D2, and 3D3, and 0.05 mm in 3D4. From Avissar and Liu [1996].

Global Water Cycle Metric

**Absolute Value of Globally-Averaged Change is 1.2 mm/day.**

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

MOISTURE FLUX DIFFERENCE (mm/day)
CURRENT - NATURAL

Absolute Value of Globally-Averaged Change is 0.6 mm/day

Prepared by T.N. Chase, CU, Boulder, CO.
SUMMARY

• Landscape change and vegetation dynamics both result in a significant global redistribution of heat and water within the global climate system.

• This redistribution of heat and water has already had an effect on the global climate system this is at least as large as the IPCC and National Assessment have attributed to the radiative effect of a doubling of carbon dioxide.