CLIMATE FORCINGS, FEEDBACKS, AND TELECONNECTIONS IN THE LAND SURFACE-VEGETATION-WATER COMPONENTS OF THE CLIMATE SYSTEM: CONSEQUENCES AND AN ALTERNATE PARADIGM TO CLIMATE PREDICTION

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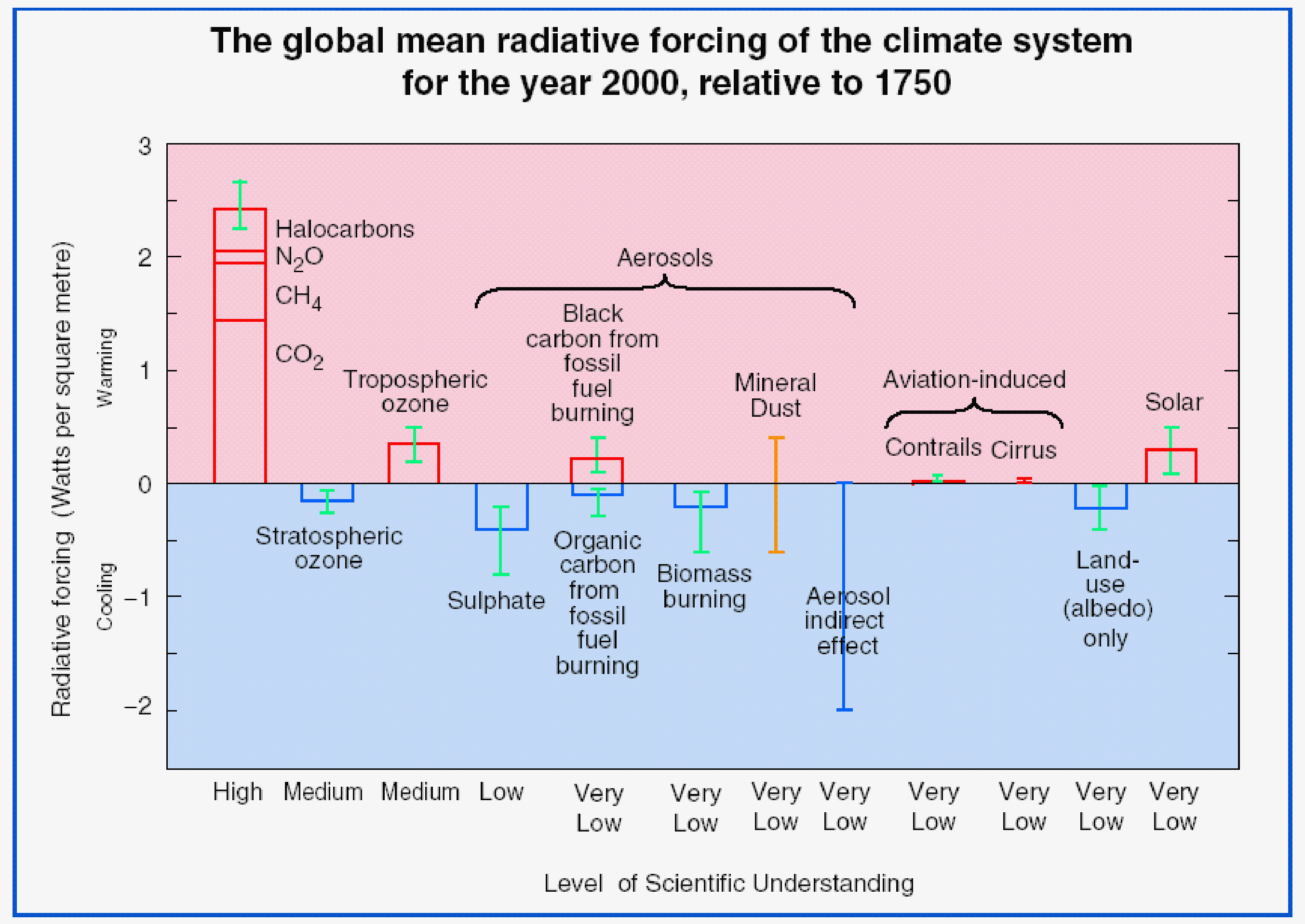
IPCC Perspective



Estimated radiative forcings since preindustrial times for the Earth and Troposphere system (TOA) radiative forcing with adjusted stratospheric temperatures). The height of the rectangular bar denotes a central or best estimate of the forcing, while each vertical line is an estimate of the uncertainty range associated with the forcing guided by the spread in the published record and physical understanding, and with no statistical connotation. Each forcing agent is associated with a level of scientific understanding, which is based on an assessment of the nature of assumptions involved, the uncertainties prevailing about the processes that govern the forcing, and the resulting confidence in the numerical values of the estimate. On the vertical axis, the direction of expected surface temperature change due to each radiative forcing is indicated by the labels "warming" and "cooling." From: IPCC 2001: Summary for Policymakers. A Report of the Working Group 1 of the Intergovernmental Panel on Climate Change.
http://www.ipcc.ch/pub/spm22-01.pdf

NRC 2005 Perspective

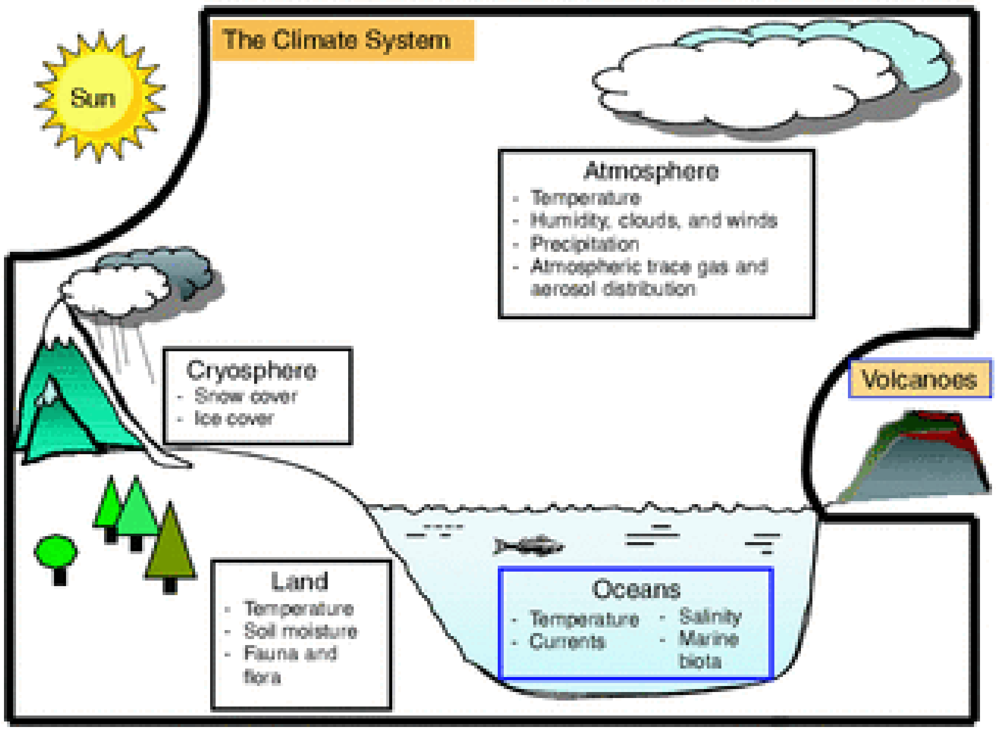


FIGURE 1-1 The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes to the land surface are considered external to the climate system.

From: National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp.
http://www.nap.edu/catalog/11175.html

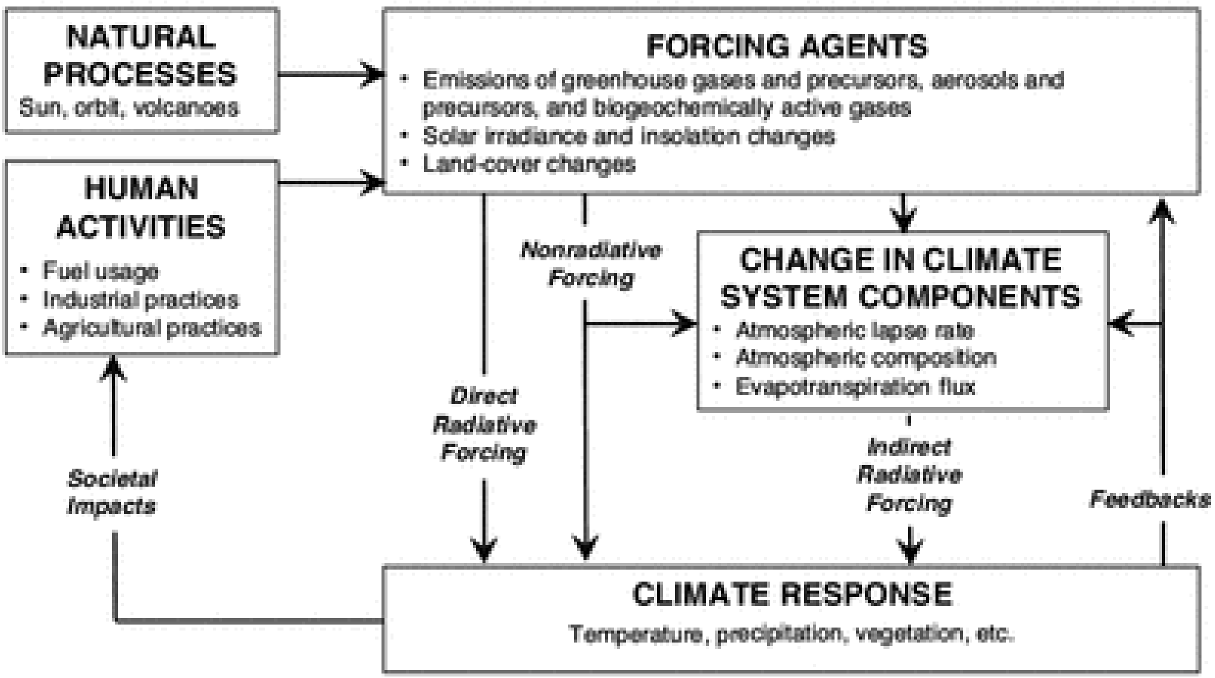


FIGURE 1-2 Conceptual framework of climate forcing, response, and feedbacks under present-day climate conditions. Examples of human activities, forcing agents, climate system components, and variables that can be involved in climate response are provided in the lists in each box.

From: National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp.
http://www.nap.edu/catalog/11175.html

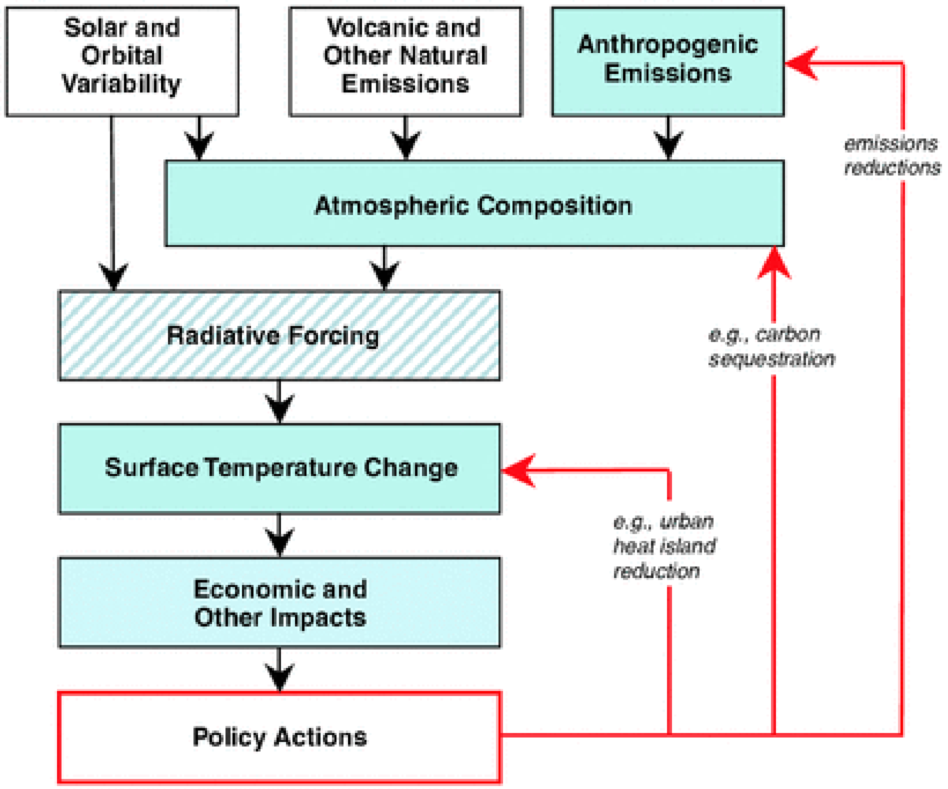


FIGURE 1-4 Conceptual framework for how radiative forcing fits into the climate policy framework. Blue-shaded boxes indicate quantities that have been considered as policy targets in international negotiations and other policy analyses. Radiative forcing (striped box) has not been treated as a policy 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.

From: National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp.
http://www.nap.edu/catalog/11175.html

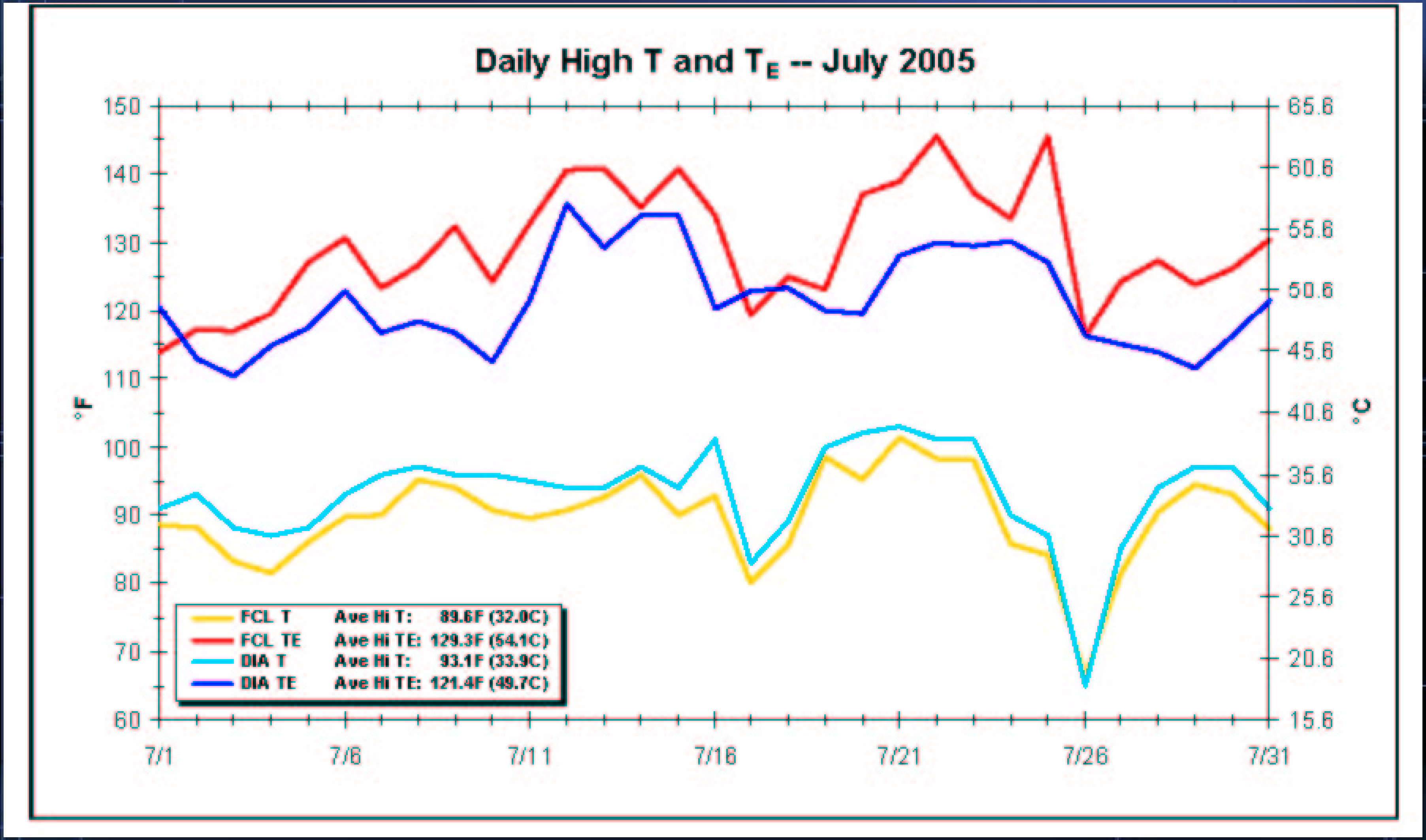
Missing Land - Atmosphere Surface Data Issues

- Moist Enthalpy
- Microclimate Exposure
- Vertical Lapse Rate Trends
- Uncertainty in the Homogenization Adjustments

Moist enthalpy provides a proper measure of surface air heat content, which is not provided by air temperature alone.

$$T_E = H/C_p$$

$$H = C_p\,T + L\,q$$



Hourly data from automated weather stations at Fort Collins and DIA are used to pick and calculate the highest air temperature and effective temperature for each day in July 2005. The average high air temperature is higher at DIA, while the average high effective temperature is higher at Fort Collins. From Pielke, R.A. Sr., K. Wolter, O. Bliss, N. Doesken, and B. McNoldy, 2005: July 2005 heat wave: How unusual was it. National Weather Digest, submitted.

http://blue.atmos.colostate.edu/publications/pdf/R-313.pdf

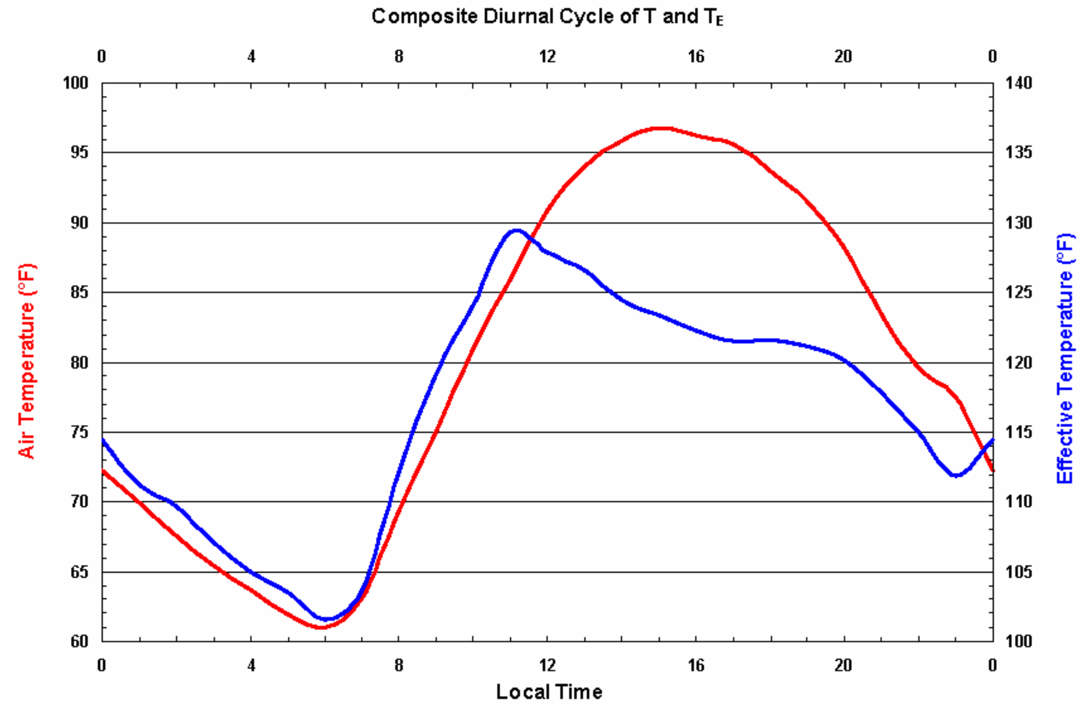


Figure 10. A daily composite of air temperature (red line) and effective temperature (blue line). The composite is created by averaging hourly data during the five days with highest air temperature in each of the three years considered in this section – fifteen days total. This shows the pattern of heating and cooling on the station's extreme hottest days. Note how the effective temperature peaks approximately four hours before the air temperature peaks. Typically, the hottest days are characterized by exceptionally low relative humidity in the late afternoon, which explains the premature drop in effective temperature.

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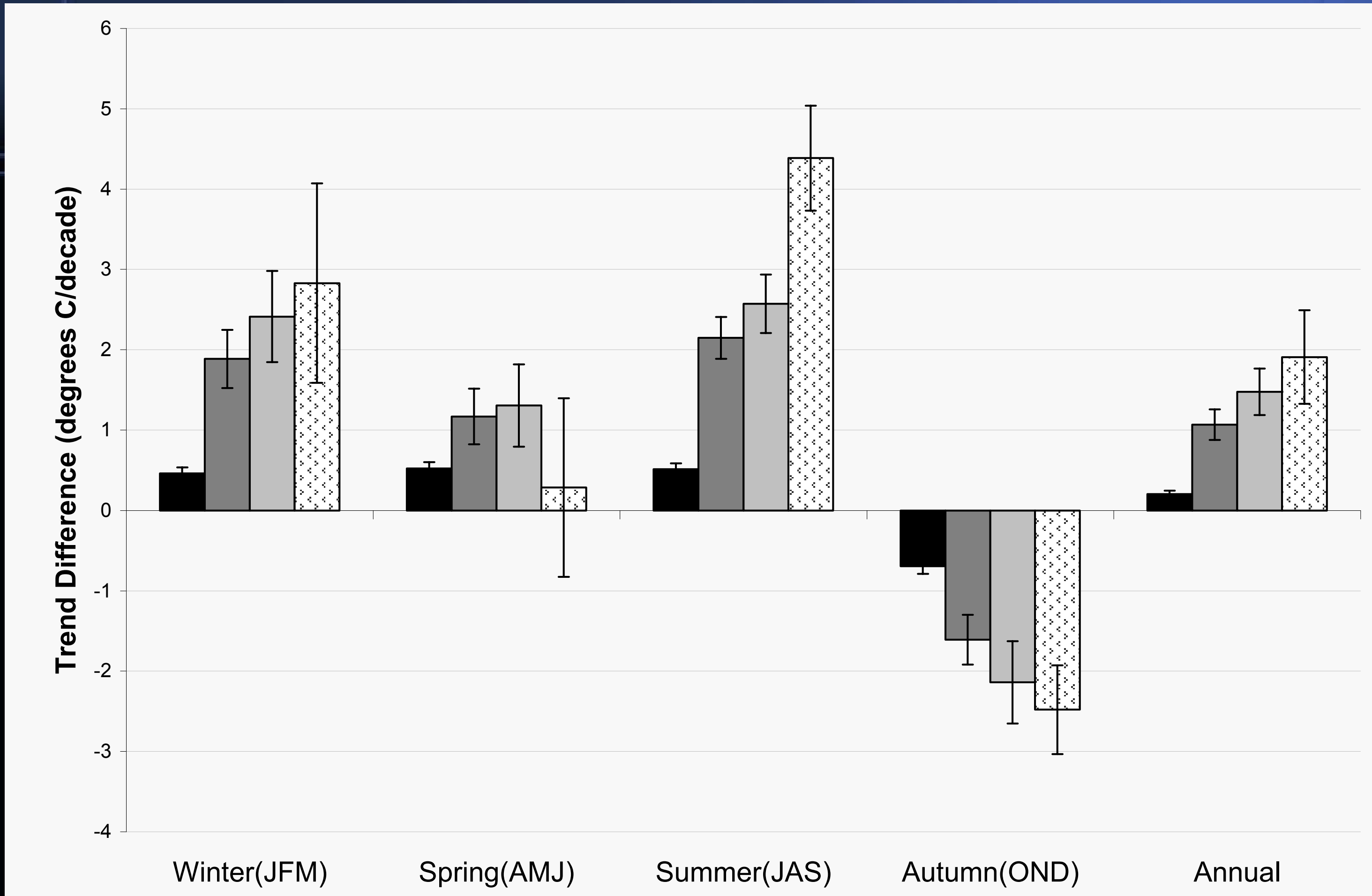

Figure 2. Seasonally-averaged 1982-1997 differences between *T*E trends and *T* trends for all individual trends (black bars), individual trends that are at least 90% significant (dark gray bars), individual trends that are at least 95% significant (light gray bars), and individual trends that are at least 99% significant (stippled bars). Error bars indicate standard errors. For each computation, each station is weighted equally. From Davey, C.A., R.A. Pielke Sr., and K.P. Gallo, 2005: Differences between near-surface equivalent temperature and temperature trends for the eastern United States - Equivalent temperature as an alternative measure of heat content. Global and Planetary Change, accepted.

http://blue.atmos.colostate.edu/publications/pdf/R-268.pdf

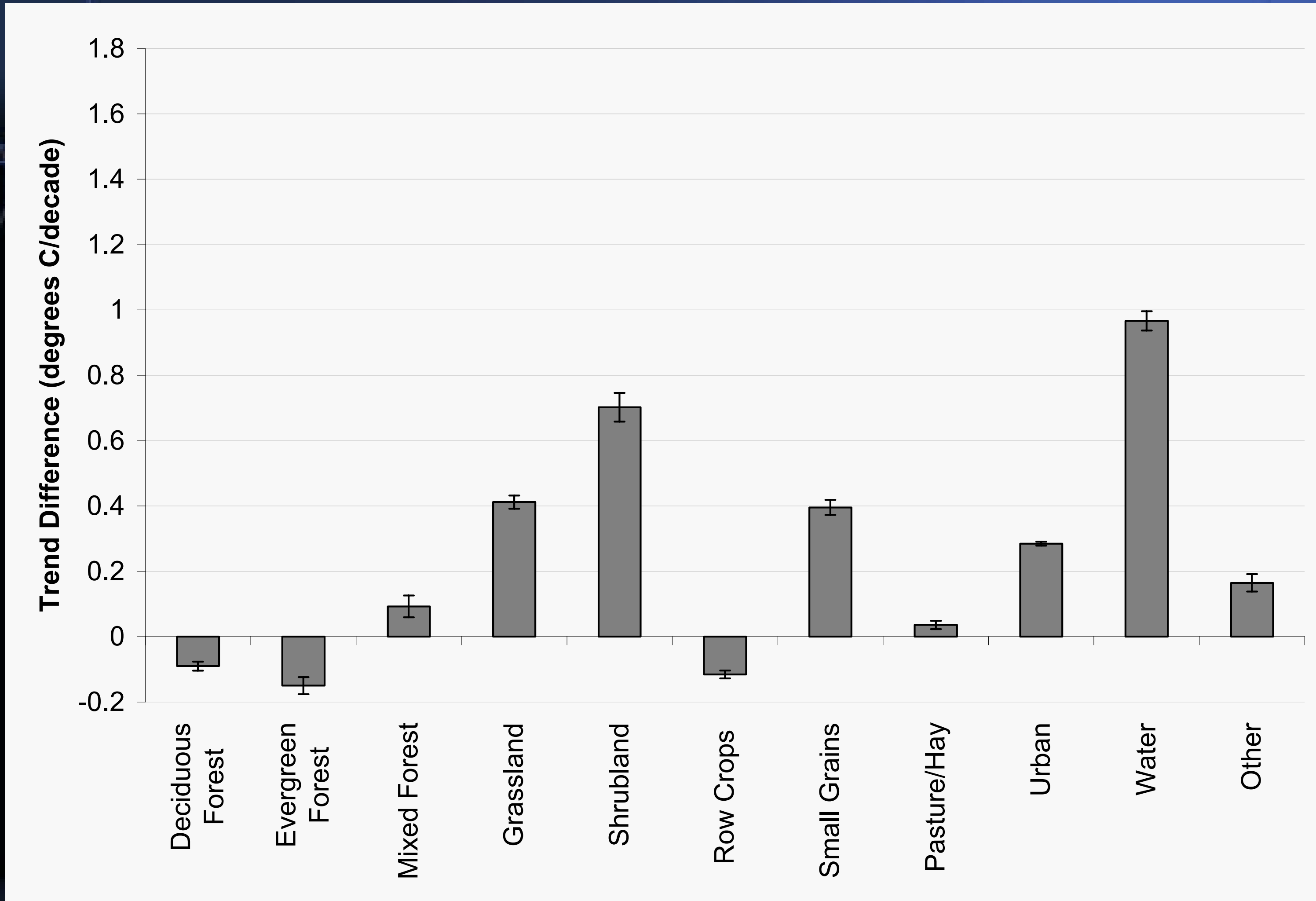

Figure 3. Annually-averaged differences between *T*E and *T* trends for 1982-1997, as a function of the land-cover classes listed in Table 2. Error bars indicate standard errors. All individual trends are considered.

From Davey, C.A., R.A. Pielke Sr., and K.P. Gallo, 2005: Differences between near-surface equivalent temperature and temperature trends for the eastern United States - Equivalent temperature as an alternative measure of heat content. Global and Planetary Change, accepted.

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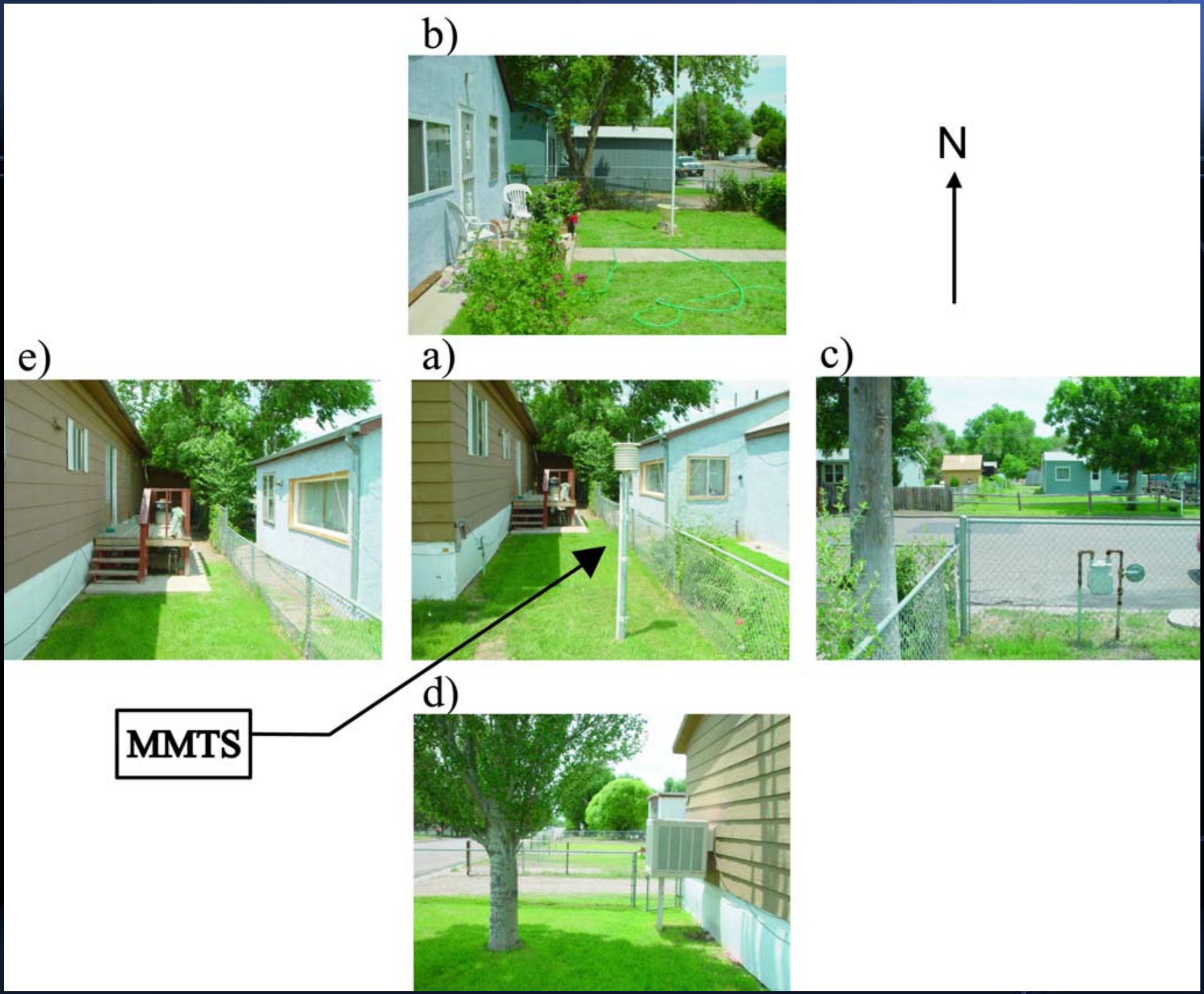
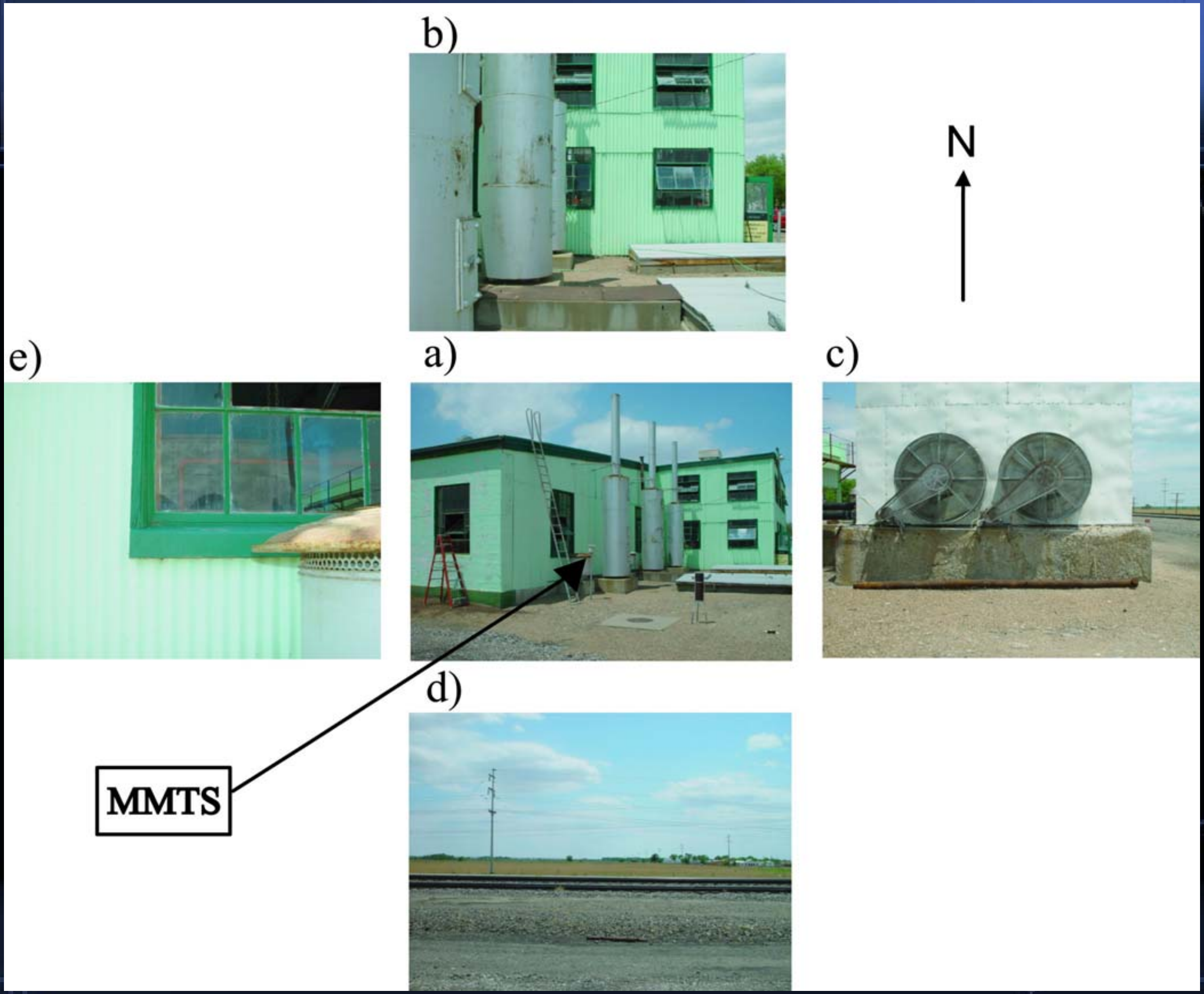


Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Lamar, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively. From Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate exposures of surface-based weather stations - implications for the assessment of long-term temperature trends. Bull. Amer. Meteor. Soc., 4, 497–504. http://blue.atmos.colostate.edu/publications/pdf/R-274.pdf



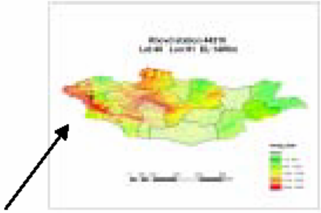
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Las Animas, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively. From Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate exposures of surface-based weather stations - implications for the assessment of long-term temperature trends. Bull. Amer. Meteor. Soc., 4, 497–504.

http://blue.atmos.colostate.edu/publications/pdf/R-274.pdf

From **Exposure Characteristics of the Mongolian Weather Stations,** By Khishigbayar Jamiyansharav, Dr. Dennis Ojima and Dr. Roger A. Pielke Sr

<u>GCON sites in residential area.</u> The Khovd station in Khovd province is located in the middle of a residential area surrounded by concrete walls (about 1.5m high) from south, west, and north side at about 10-30m distances. Walls were built in 1982 by the military army, which located in southeast side of the station. Household fence were built in 1999 inside the wall in the northeastern corner at about 30m distance. The meteorological station's office building, built in 1983, was on the east side at about 100m distance. There were mountains to the north, south side at about 6-7 km, and to the west at about 8-10km.

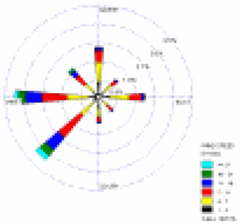
b.



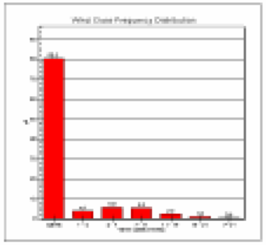
e.

a.

c.



d.



The sensor exposure characteristics of Khovd station in Khovd province of Mongolia, 44218. 48N 91E.Altitude: 1411m.. A meteorological station's office building is in the east side at about 100m distance.

a. Station sensors
b. Illustration of exposures viewed looking North
c. Illustration of exposures viewed looking East
d. Illustration of exposures viewed looking West
e. Illustration of exposures viewed looking South

Most Warming Has Been Reported Over Higher Latitude Land at Night

As reported at http://www.ucsusa.org/global_warming/science/early-warning-signs-of-global-warming-heat-waves.html

"Most of the recent warming has been in winter over the high mid-latitudes of the Northern Hemisphere continents, between 40 and 70°N (Nicholls et al. 1996).

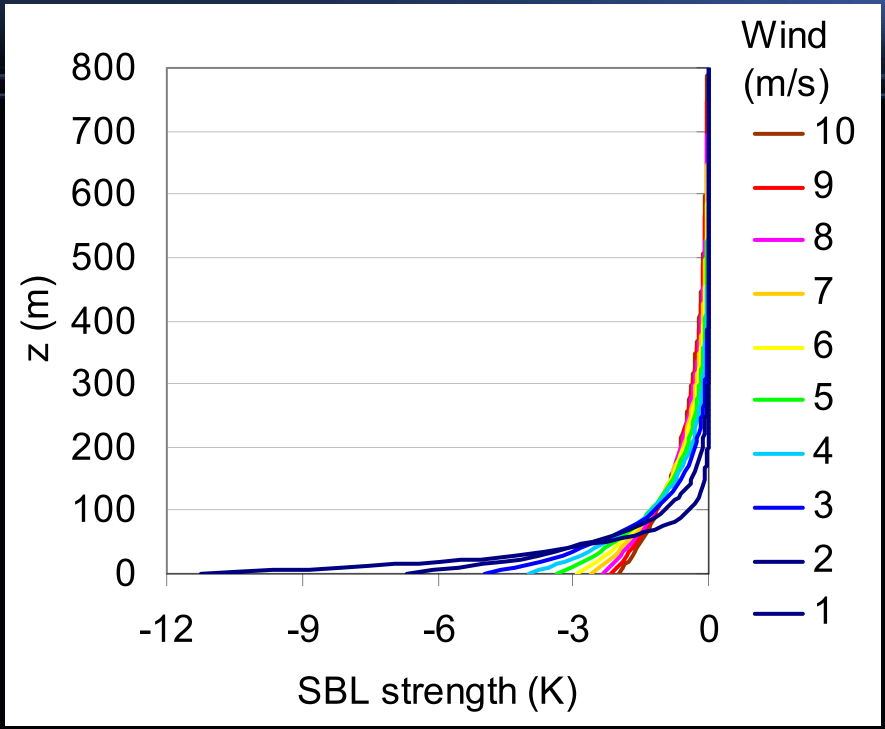


Figure 1. (SBL strength) profile in different wind conditions for cases of -10 W m-2 constant cooling rate over night.

Pielke Sr., R.A., and T. Matsui, 2005
http://blue.atmos.colostate.edu/publications/pdf/R-302.pdf

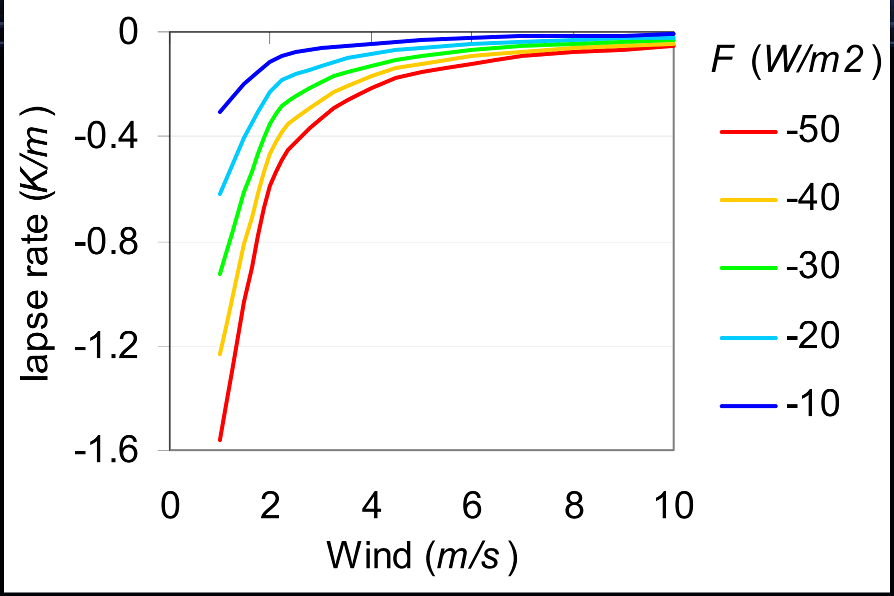


Figure 2: Lapse rate of potential temperature profile for the lowest 0~10 m for different wind conditions and five different values of the flux divergence.

http://blue.atmos.colostate.edu/publications/pdf/R-302.pdf

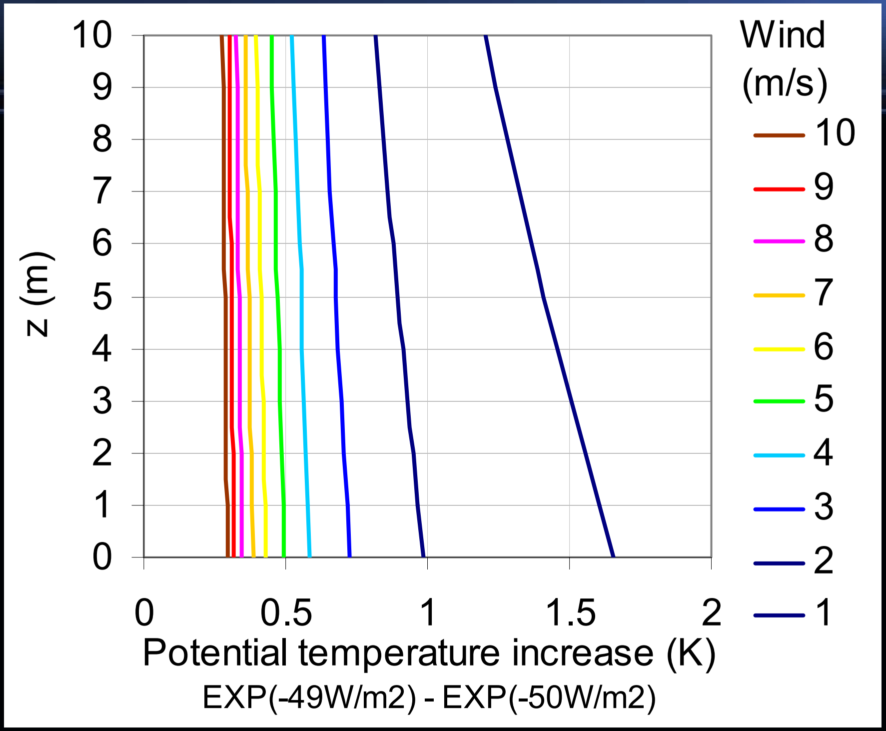


Figure 3: Potential temperature increase at different levels from the experiment with -49 W m-2 cooling to the experiment with -50 W m^{-2} cooling.

http://blue.atmos.colostate.edu/publications/pdf/R-302.pdf

Our Research Has Raised Several Issues On The Robustness Of The Global Surface Temperature Trend Analyses

The first overarching question, of course, is what is meant by the "global average surface temperature"? The 2005 National Research Council Report (see page 19 and page 21) provides a definition as

"According to the radiative-convective equilibrium concept, the equation for determining global average surface temperature of the planet is

$$dH/dt = f - T'/\lambda \qquad (1\text{–}1)$$

where H...is the heat content of the land-ocean-atmosphere system ... Equation (1-1) describes the change in the heat content where f is the radiative forcing at the tropopause, T' is the change in surface temperature in response to a change in heat content, and ? is the climate feedback parameter (Schneider and Dickinson, 1974), also known as the climate sensitivity parameter, which denotes the rate at which the climate system returns the added forcing to space as infrared radiation or as reflected
solar radiation (by changes in clouds, ice and snow, etc.)."

Thus T is the "global average surface temperature." However, where is this temperature and its change with time, T', diagnosed?"

Question: What is the level at which this temperature is monitored? Is T' height invariant near the surface, if the lowest levels of the atmosphere are used to compute T'?

Using the Near-Surface Air Temperature Changes as the Climate Metric to Assess T' Raises the Research Questions Listed Below

We have shown that the Parker Nature study entitled "Large-scale warming is not urban" has serious issues on its conclusions, as well as demonstrated that an unrecognized until now warm bias occurs in nighttime minimum temperatures (see Pielke Sr., R.A., and T. Matsui, 2005: Should light wind and windy nights have the same temperature trends at individual levels even if the boundary layer averaged heat content change is the same?")

Question: What is the magnitude of this warm bias in the analyses of the global surface temperature trends?

There are photographed major problems with the microclimate exposure of a subset of surface observation sites (see Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate exposures of surface-based weather stations - implications for the assessment of long-term temperature trends.

Question: What photographic documentation is available for the global network of surface temperature sites used to construct the long-term global surface temperature analyses?

We have shown that surface air water vapor changes over time must be accounted for in the assessment of long-term surface air temperature trends (see Pielke Sr., R.A., C. Davey, and J. Morgan, 2004: Assessing "global warming" with surface heat content" and Davey,C.A., R.A. Pielke Sr., and K.P. Gallo, 2005: Differences between near-surface equivalent temperature and temperature trends for the eastern United States - Equivalent temperature as an alternative measure of heat content."

Question: What are the quantitative trends in surface absolute humidity for the sites used to construct the global surface temperature trends, and what is the uncertainty that is introduced if this information is not available?

Our research has raised issues with the robustness of the adjustments that are used to "homogenize" surface temperature data. This includes adjustments made due to the time of observation, a change of instrument, the change in location, and from urbanization. Pielke Sr., R.A., T. Stohlgren, L. Schell, W. Parton, N. Doesken, K. Redmond, J. Moeny, T. McKee, and T.G.F. Kittel, 2002: Problems in evaluating regional and local trends in temperature: An example from eastern Colorado"

Question: What are the quantitative uncertainties introduced from each step of the homogenization adjustment? Do they vary geographically?

As discussed in the weblog of December 16, 2005 the raw surface temperature data from which global surface temperature trend analyses are derived are essentially the same. The best estimate we have seen is that 90-95% of the raw data is the same. That the four analyses produce similar trends should come as no surprise.

Question: What is the degree of overlap in the data sets that are used to construct the global average surface temperature trend analyses? To frame this question another way, what raw surface temperature data is used in each analysis that is not used in the other analyses?

Regional Effects of Landscape Change

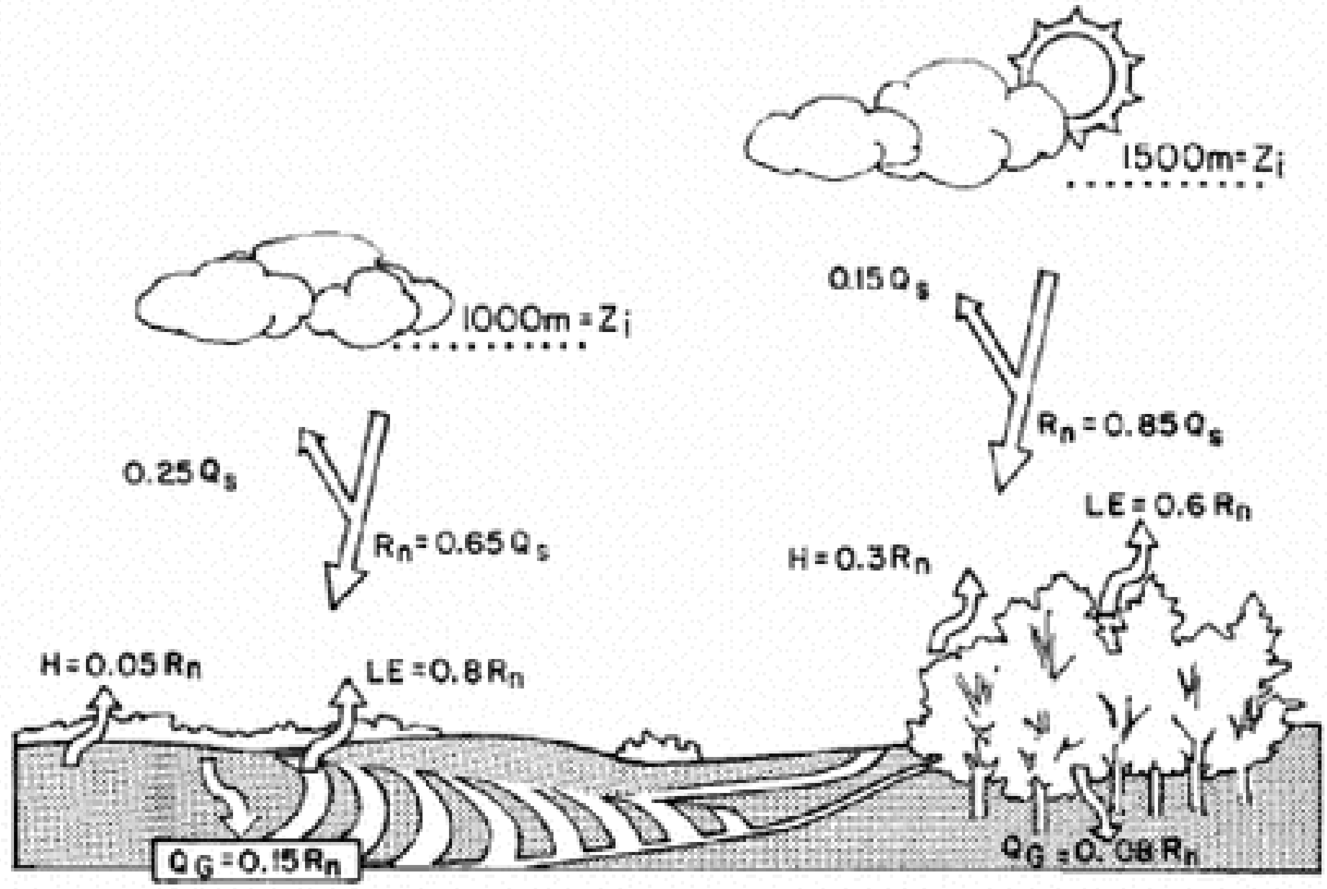


FIGURE 2-4 Schematic, based on observations in southwest France, of the influence on the surface energy budget of land-use change from forest to cropland. SOURCE: Kabat et al. (2004).

From: National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp.
http://www.nap.edu/catalog/11175.html

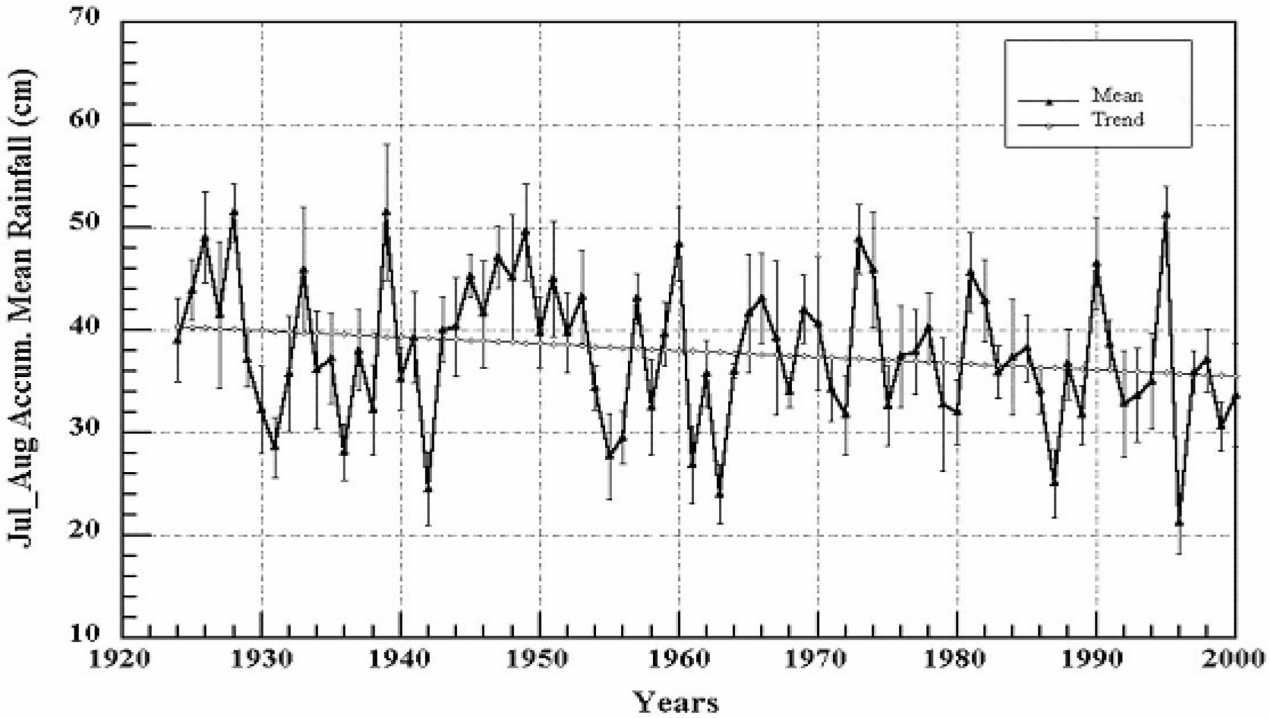


FIG. 25. Regional average time series of accumulated convective rainfall (cm) from 1924 to 2000, with corresponding trend based on linear regression of all July-August amounts. The vertical bars overlain on the raw time series indicate the value of the standard error of the July-August regional mean.

From: Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. *Mon. Wea Rev*., 132, 28-52.

http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf

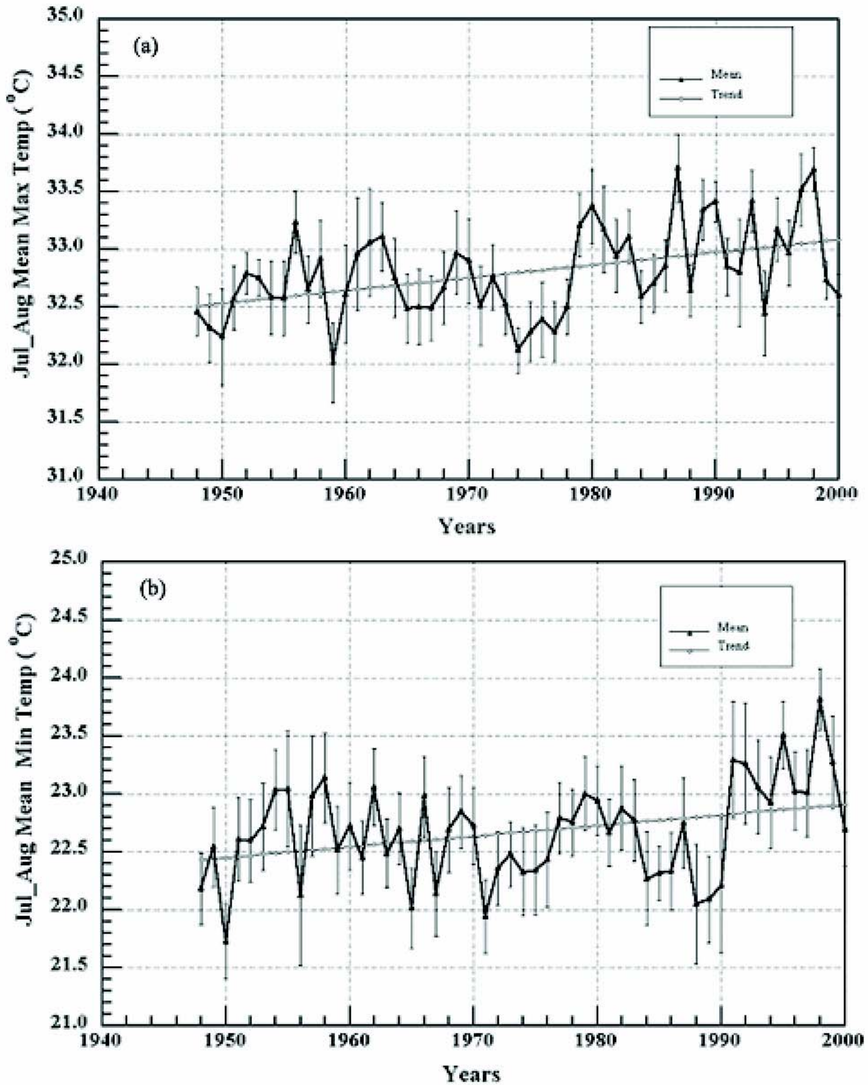
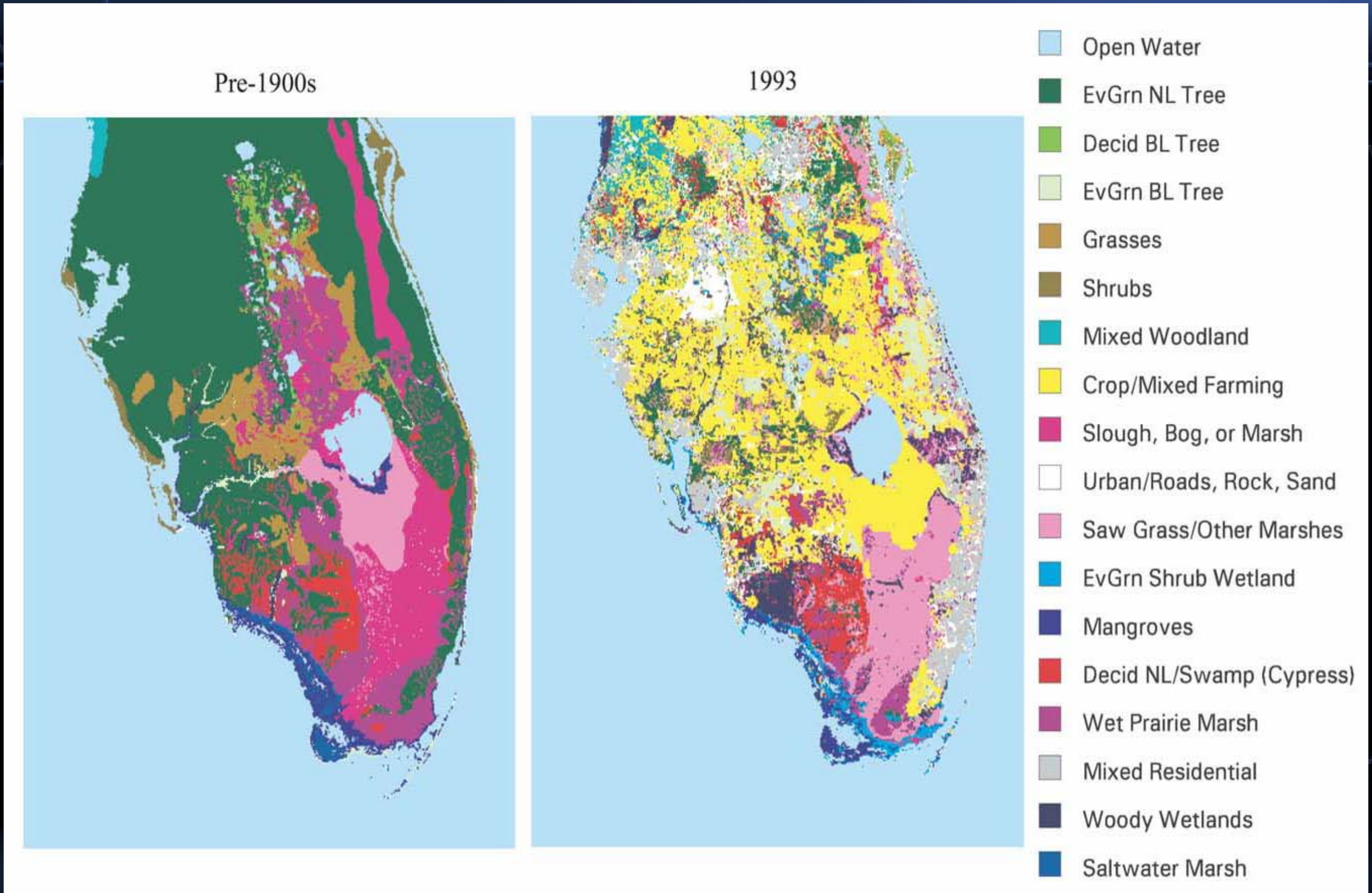


FIG. 26. Same as in Figure 25, except for daily (a) maximum and (b) minimum shelter-level temperature (°C)

From: Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. *Mon. Wea Rev.*, 132, 28-52.
http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf



U.S. Geological Survey land-cover classes for pre-1900's natural conditions (left) and 1993 land-use patterns (right).

From Marshall, C.H., Pielke Sr. R.A., Steyaert, L.T., 2003. Crop freezes and land-use change in Florida. Nature, 426, 29-30.

http://blue.atmos.colostate.edu/publications/pdf/R-277.pdf

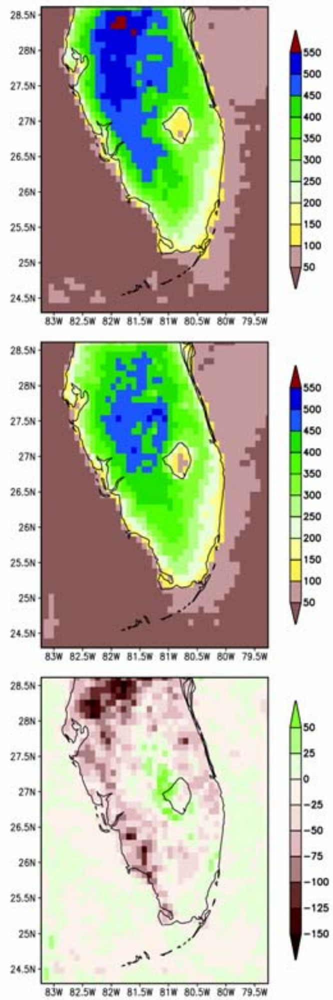


FIG. 4. Accumulated convective rainfall (mm) from the model simulations of July-August 1973 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).

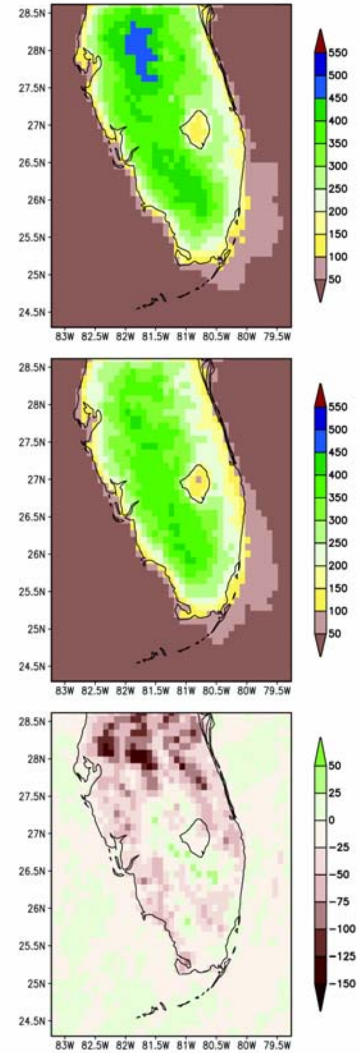


FIG. 5. Same as in Figure 4, except for July-August 1989.

From: Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. *Mon. Wea Rev.*, 132, 28-52.
http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf

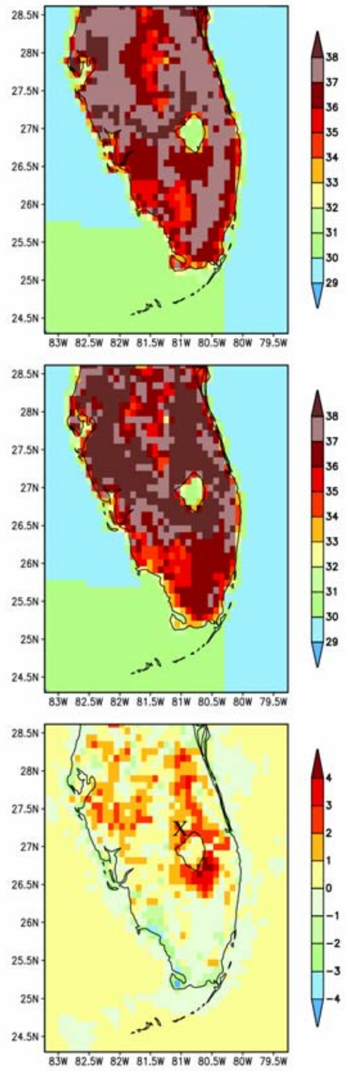


FIG. 13. Two-month average of the daily maximum shelter-level temperature from the model simulations of July-August 1989 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).

From: Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. *Mon. Wea Rev.*, 132, 28-52.
http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf

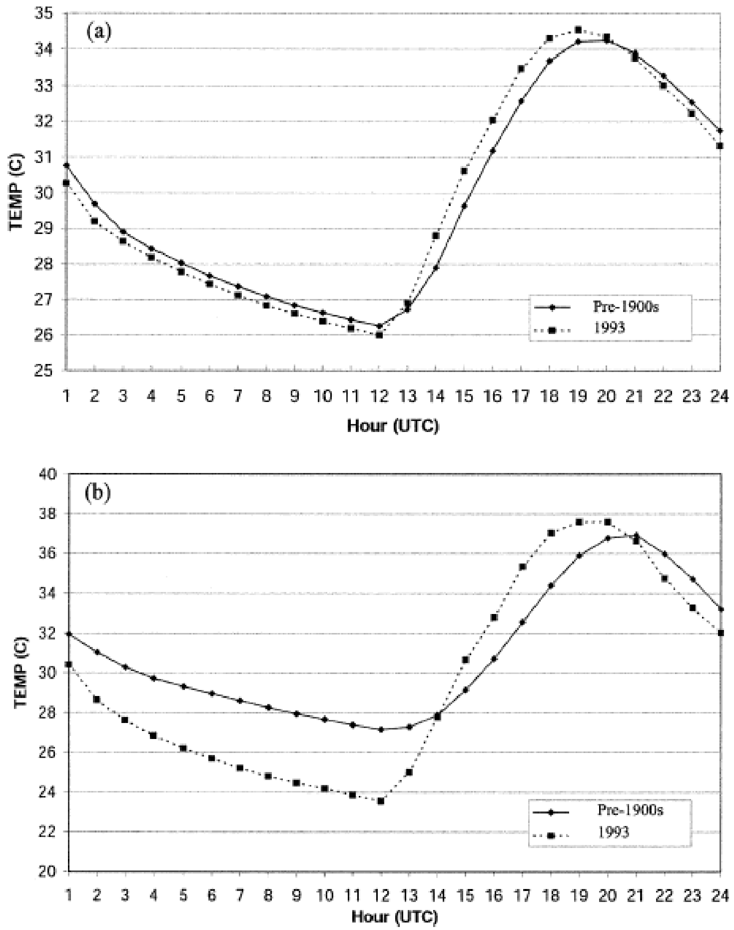


FIG. 15. Two-month average of the diurnal cycle of shelter-level temperature from the model simulations for Jul–Aug 1989 (a) averaged over all land grid points in the domain and (b) for a grid point in the Kissimmee River valley that is indicated by the "X" in Figs. 13 and 14.

From: Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. *Mon. Wea Rev*., 132, 28-52.
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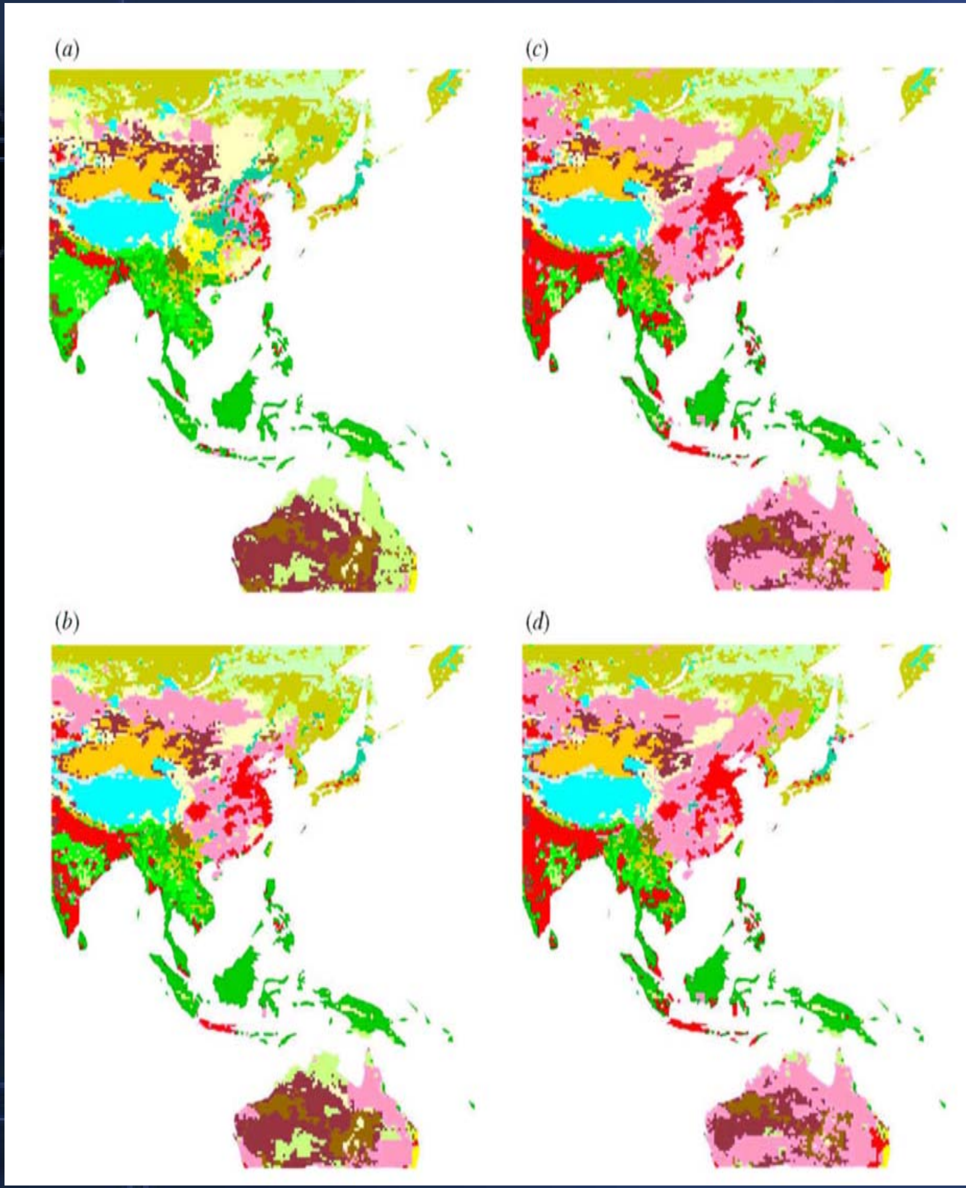
Global Effects of Landscape Change



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.)

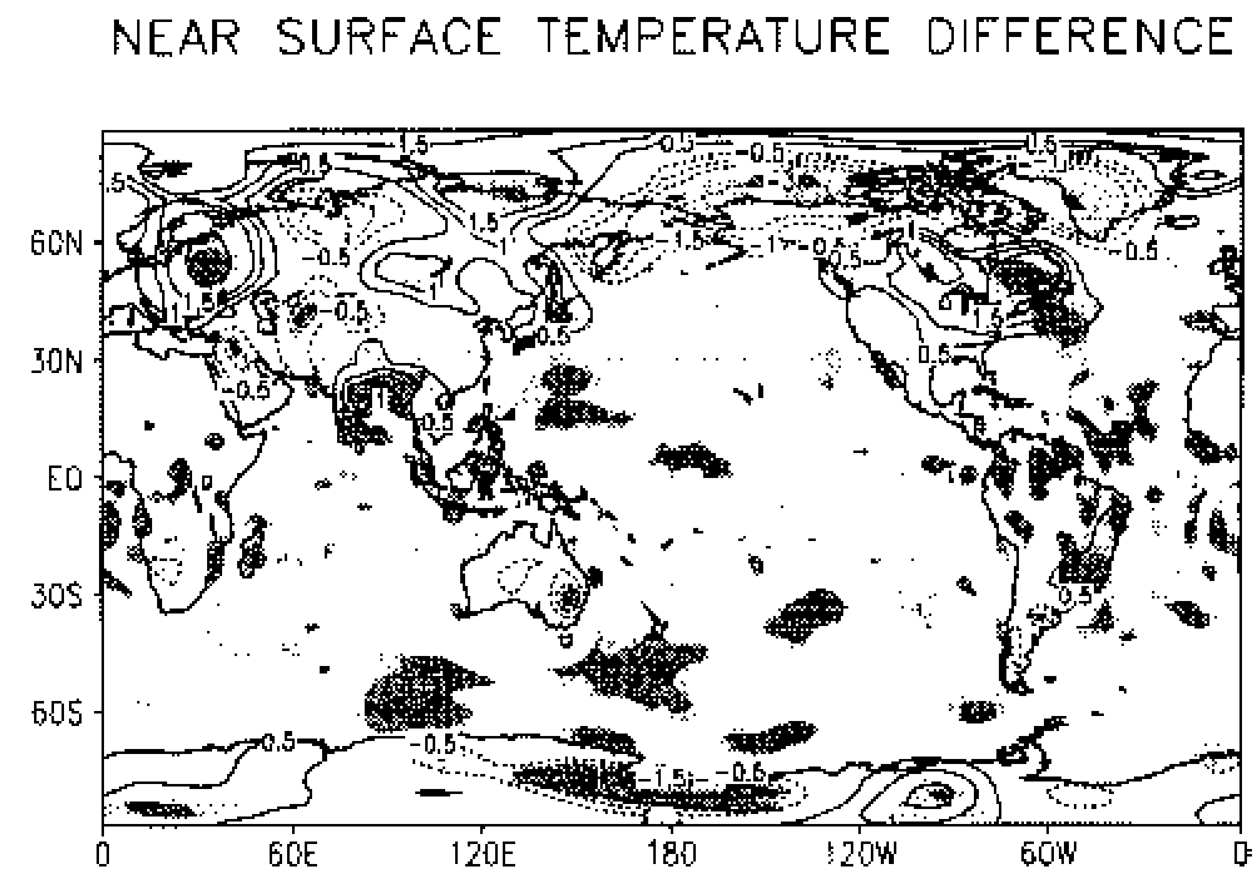
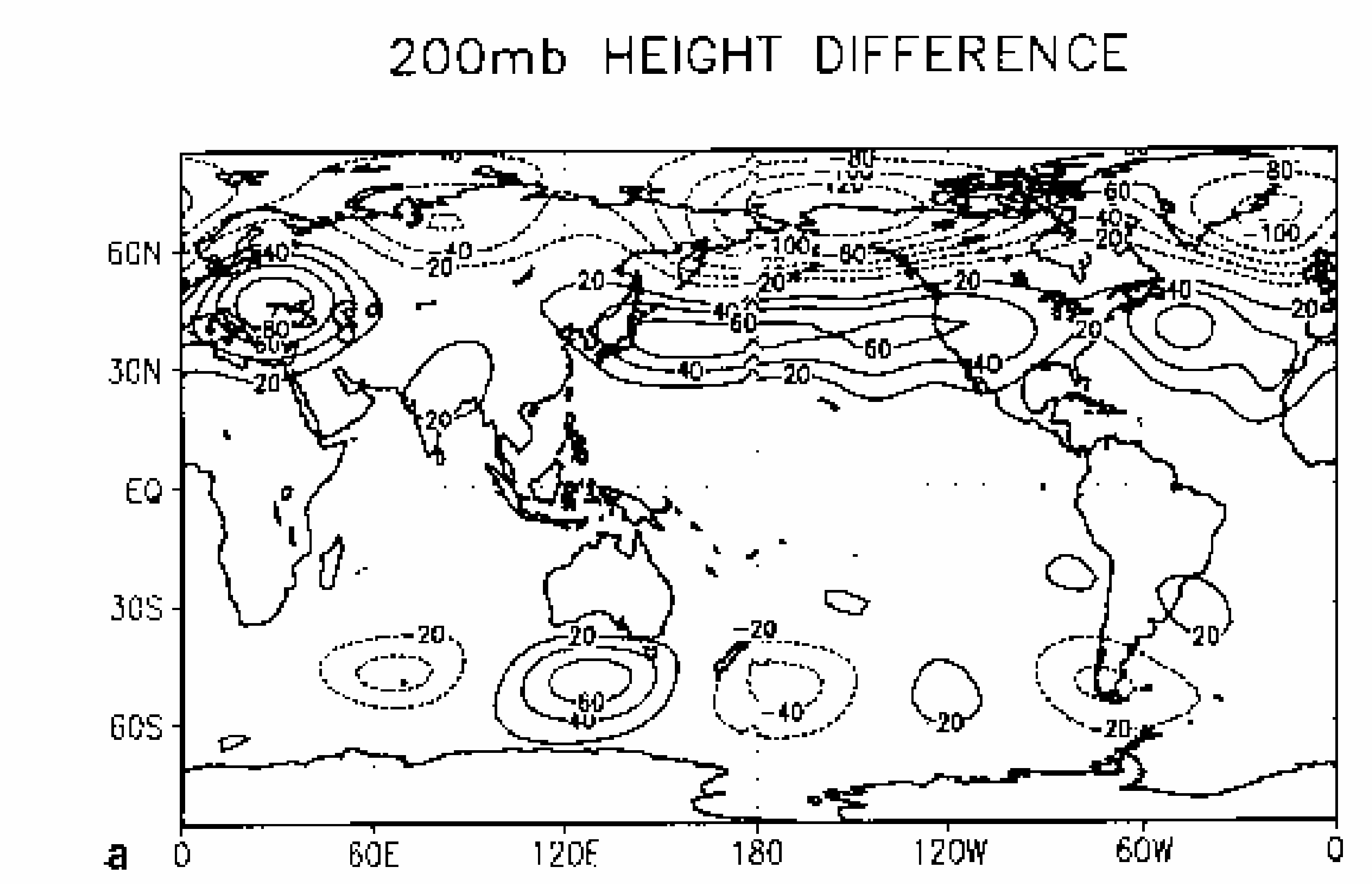


Fig. 11 Difference in near-surface air temperature (current-natural) using a 9-point spatial filter for easier visibility. Contours at 0.5, 1.0, 1.5, and 3.0 °C. *Shaded regions* as in Fig. 3

From: Chase, T.N., R.A. Pielke, T.G.F. Kittel, R.R. Nemani, and S.W. Running, 2000: Simulated impacts of historical land cover changes on global climate in northern winter. Climate Dynamics, 16, 93-105.

http://blue.atmos.colostate.edu/publications/pdf/R-214.pdf



The 200 hPa (current-natural) height difference. Contours at 20 m. From: Chase, T.N., R.A. Pielke, T.G.F. Kittel, R.R. Nemani, and S.W. Running, 2000: Simulated impacts of historical land cover changes on global climate in northern winter. Climate Dynamics, 16, 93-105.

http://blue.atmos.colostate.edu/publications/pdf/R-214.pdf

Why Should Landscape Effects, Which Cover Only a Fraction of the Earth’s Surface, Have Global Circulation Effects?

Global Climate Effects occur with ENSOs for the Following Reasons:

1. Large Magnitude
2. Long Persistence
3. Spatial Coherence

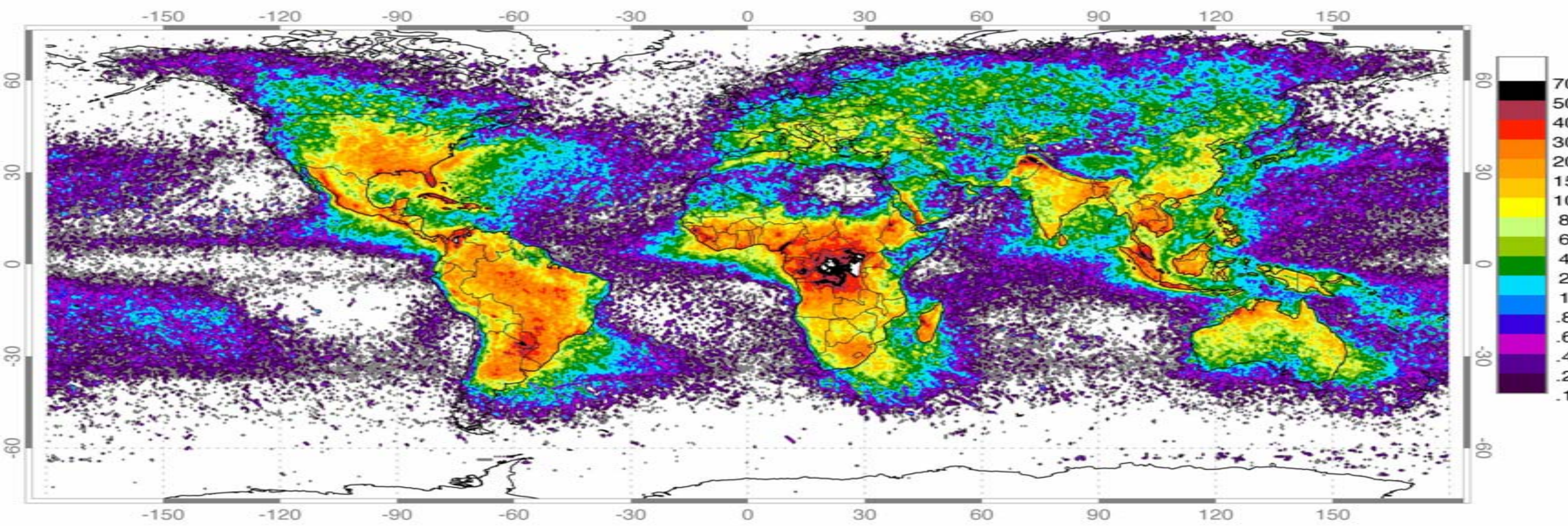
Wu, Z. - X., and Newell, R. E. 1998 Influence of sea surface temperature of air temperature in the tropic. *Climate Dynamics* 14, 275-290.

"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."

From Pielke Sr., R.A., 2001: Influence of the spatial distribution of vegetation and soils on the prediction of cumulus convective rainfall. Rev. Geophys., 39,151-177.

http://blue.atmos.colostate.edu/publications/pdf/R-231.pdf



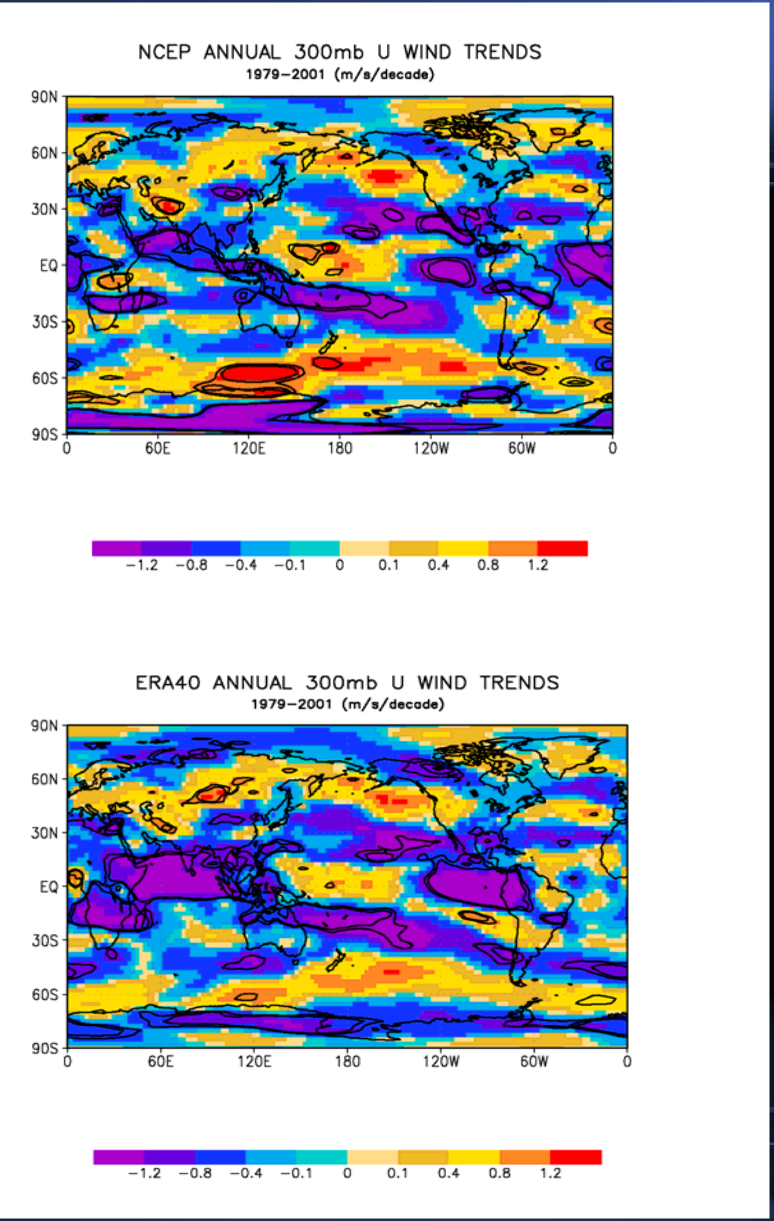
High Resolution Full Climatology Annual Flash Rate

Global distribution of lightning April 1995-February 2003 from the combined observations of the NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments

Most thunderstorms (about 10 to 1) occur over land.

From: http://thunder.nsstc.nasa.gov/images/HRFC_AnnualFlashRate_cap.jpg

The Regional Alteration in Tropospheric Diabatic Heating has a Greater Influence on the Climate System than a Change in the Globally-Averaged Surface and Tropospheric Temperatures



(a) and (b) show recent trends in annual, 300 mb winds from the NCEP/NCAR and ECMWF40 Reanalyses respectively. Significant trends at the 90 and 95% levels are thickly contoured. Figure courtesy of Dr. Tom. Chase.

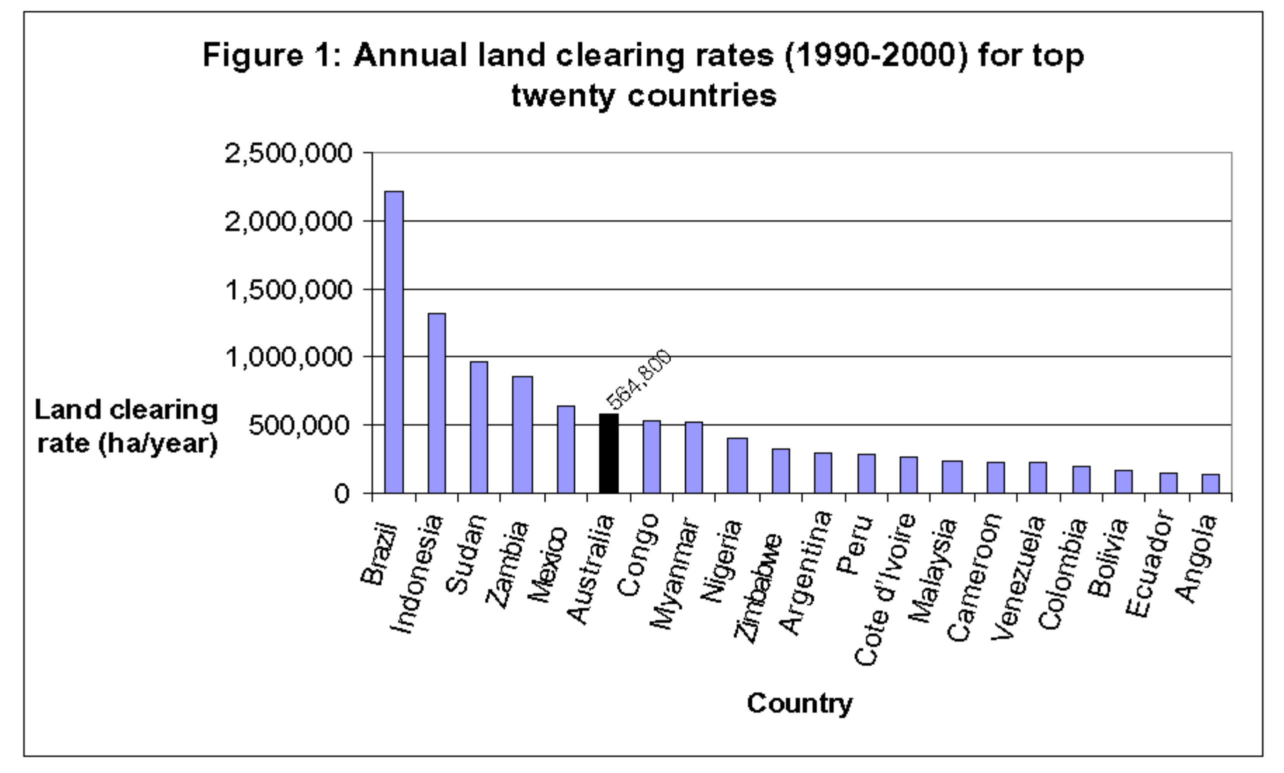
Quantitative Assessment of the Relative Importance of the Regional Alteration in Tropospheric Diabatic Heating due to Different Climate Forcings

From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of aerosol radiative forcing: introducing the concept of normalized gradient of radiative forcing. Geophys. Res. Letts., submitted.

We define the *Normalized Gradient of Radiative Forcing* (*NGoRF*), as a fraction of the present global heterogeneous insolation attributed to human activity……Although the GHGs have a larger forcing as measured in terms of a global-mean TOA value, the aerosol direct and indirect effects have much greater *NGoRF* values. Thus, they have a greater potential to modulate atmospheric circulations and consequently regional climate. Together with the current global mean TOA radiative forcing, the *Normalized Gradient of Radiative Forcing* (*NGoRF*) should be considered in any assessments of the climate impact of anthropogenic activity.
http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

We Should, Therefore, Expect Global Climate Effects With Landscape Changes!

Landscape Change Continues at a Rapid Pace



International annual land clearing rates for 1990-2000. (From Australia Conversation Foundation, 2001. Australian Land Clearing, A Global Perspective: Latest Facts & Figures.)

What is the Importance to Climate of Heterogeneous Spatial Trends in Tropospheric Temperatures?

The 2005 National Research Council report concluded that:

"regional variations in radiative forcing may have important regional and global climate implications that are not resolved by the concept of global mean radiative forcing."

And furthermore:

"Regional diabatic heating can cause atmospheric teleconnections that influence regional climate thousands of kilometers away from the point of forcing."

This regional diabatic heating produces temperature increases or decreases in the layer-averaged regional troposphere. This necessarily alters the regional pressure fields and thus the wind pattern. This pressure and wind pattern then affects the pressure and wind patterns at large distances from the region of the forcing which we refer to as teleconnections.

The Metric of Assessing Climate Change Using a Global Surface Temperature Trend Should be Replaced By A Metric that Assesses Atmosphere and Ocean Circulation Variability and Change

This Requires Spatial Analyses

Skillful multidecadal climate forecasts have not been demonstrated

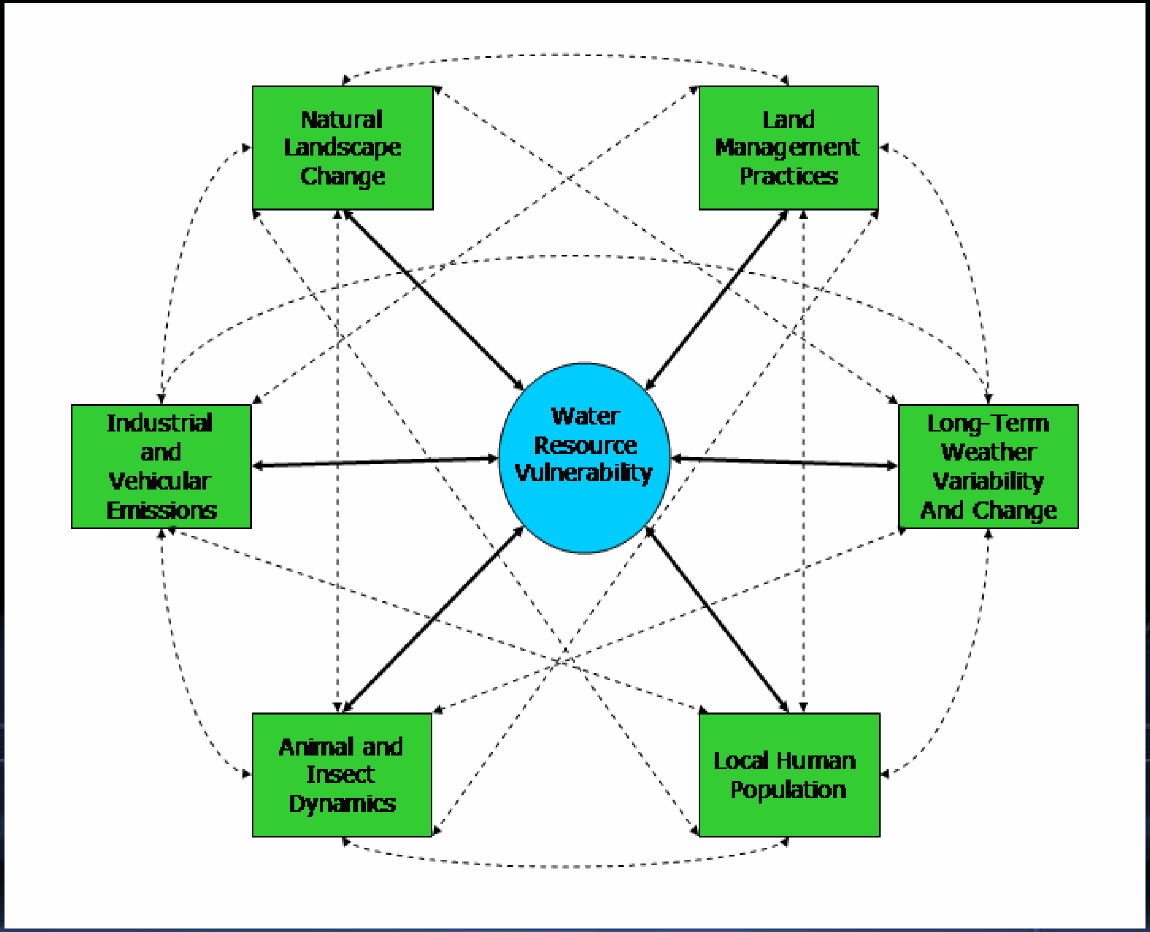
An inversion of the IPCC Assessment Procedure is needed

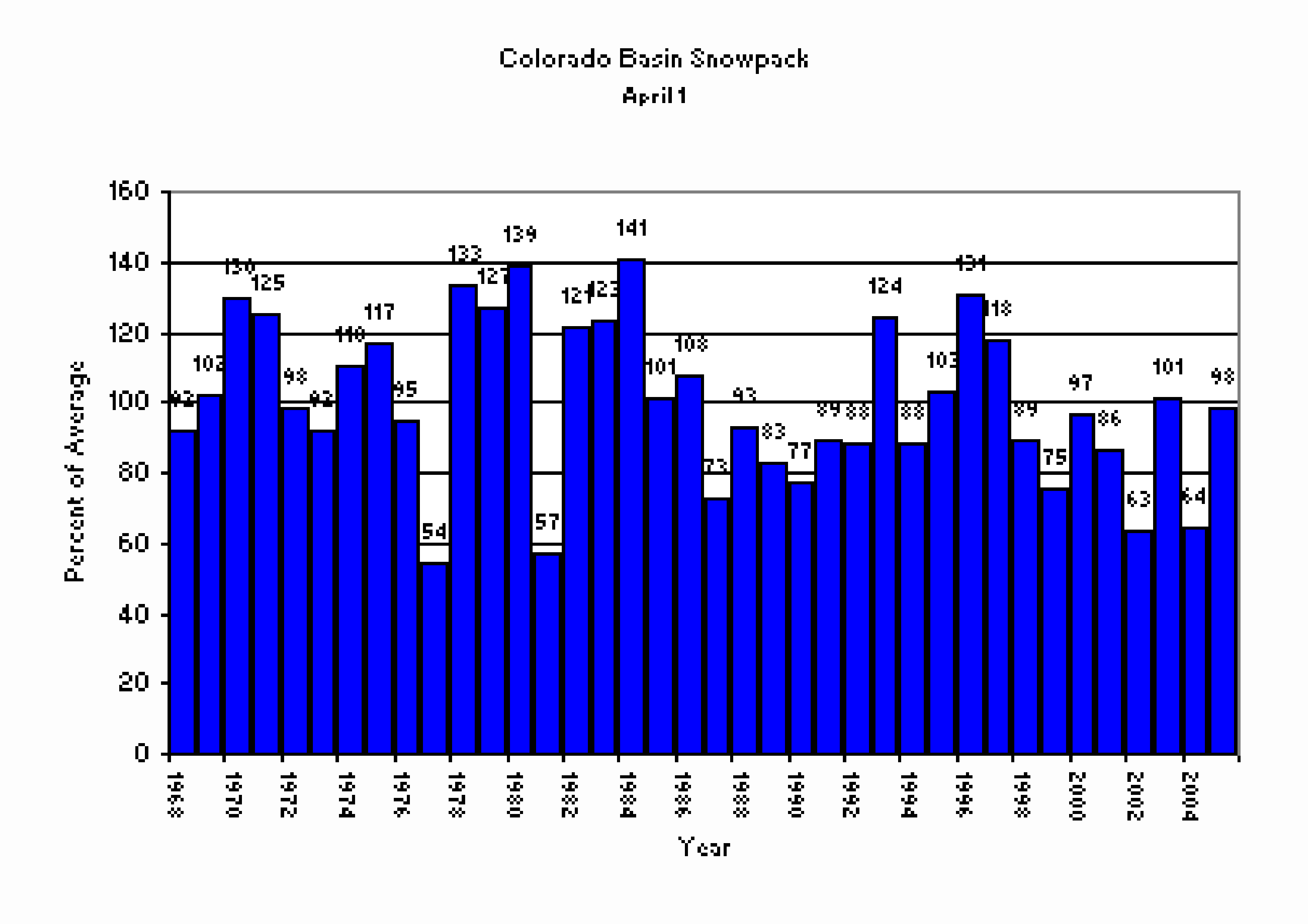
We need an approach that is more inclusive and scientifically defensible

An Alternate Paradigm is Needed

A Focus on Vulnerability

Schematic of the relation of water resource vulnerability to the spectrum of the environmental forcings and feedbacks (adapted from [3]). The arrows denote nonlinear interactions between and within natural and human forcings. From: Pielke, R.A. Sr., 2004: Discussion Forum: A broader perspective on climate change is needed. IGBP Newsletter, 59, 16-19.
http://blue.atmos.colostate.edu/publications/pdf/NR-139.pdf

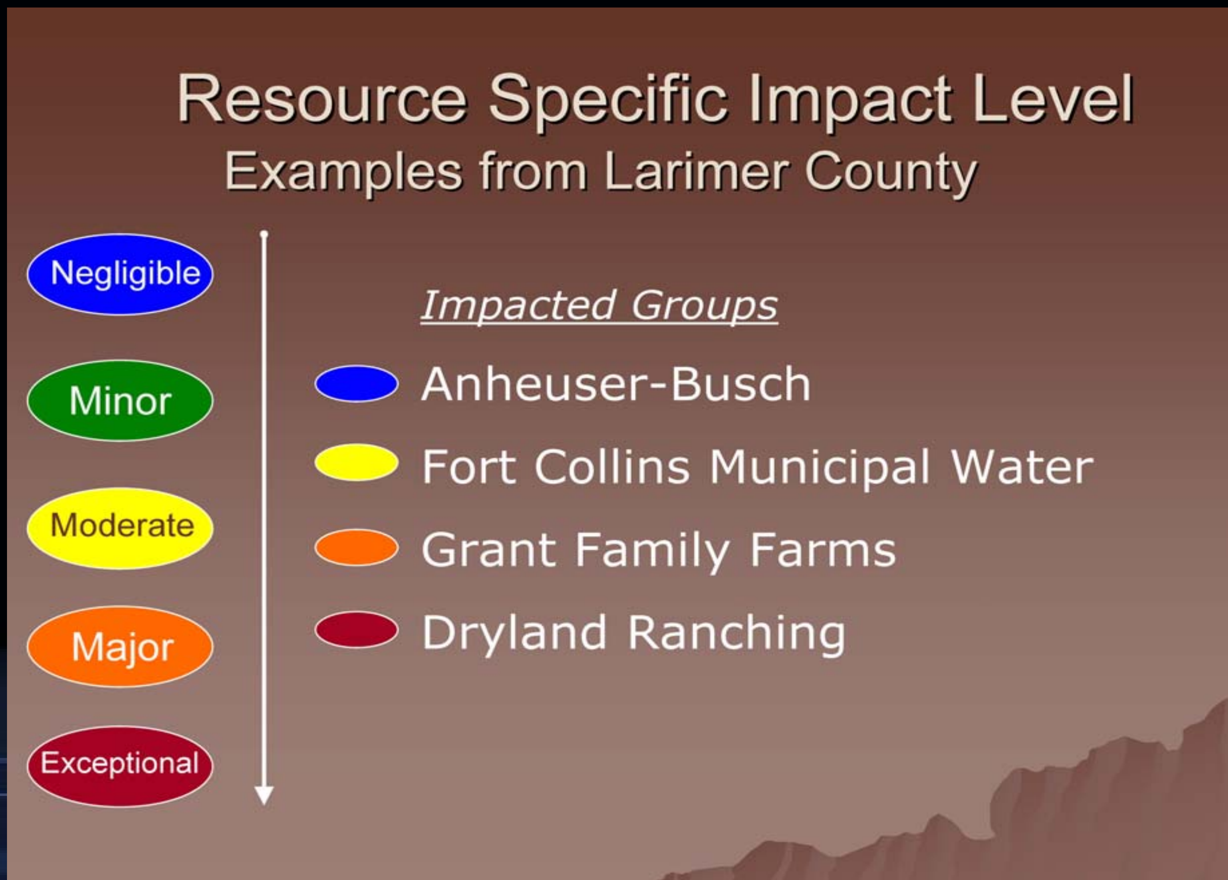




April 1 snowpack percent of average for the state of Colorado for years 1968 through 2005.

http://www.co.nrcs.usda.gov/snow/snow/watershed/current/monthly/maps_graphs/gettimeseries.html

Resource Specific Impact Level with Respect to Water Resources - June 2004



The Future of Climate Science

Climate is an integration of physical, chemical and biological processes

Climate involves the oceans, atmosphere, land surface, and continental ice

We need to move beyond the current narrow focus of climate change as equivalent to “global warming.”

Pielke Research Website: http://blue.atmos.colostate.edu/

Selected papers:

- Rial, J., R.A. Pielke Sr., M. Beniston, M. Claussen, J. Canadell, P. Cox, H. Held, N. de Noblet-Ducoudre, R. Prinn, J. Reynolds, and J.D. Salas, 2004: Nonlinearities, feedbacks and critical thresholds within the Earth's climate system. Climatic Change, 65, 11-38.

http://blue.atmos.colostate.edu/publications/pdf/R-260.pdf

- Pielke Sr., R.A., 2001: Influence of the spatial distribution of vegetation and soils on the prediction of cumulus convective rainfall. Rev. Geophys., 39, 151-177.

http://blue.atmos.colostate.edu/publications/pdf/R-231.pdf

- Pielke, R.A. Sr., J.O. Adegoke, T.N. Chase, C.H. Marshall, T. Matsui, and D. Niyogi, 2005: A new paradigm for assessing the role of agriculture in the climate system and in climate change. Agric. Forest Meteor., Special Issue, accepted.

http://blue.atmos.colostate.edu/publications/pdf/R-295.pdf

- Pielke, R.A. Sr., 2004: Discussion Forum: A broader perspective on climate change is needed. IGBP Newsletter, 59, 16-19.

http://blue.atmos.colostate.edu/publications/pdf/NR-139.pdf

- National Research Council, 2005: Radiative forcing of climate change: Expanding the concept and addressing uncertainties. Committee on Radiative Forcing Effects on Climate Change, Climate Research Committee, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C.,

http://www.nap.edu/openbook/0309095069/html/

- Kabat, P., Claussen, M., Dirmeyer, P.A., J.H.C. Gash, L. Bravo de Guenni, M. Meybeck, R.A. Pielke Sr., C.J. Vorosmarty, R.W.A. Hutjes, and S. Lutkemeier, Editors, 2004: Vegetation, water, humans and the climate: A new perspective on an interactive system. Springer, Berlin, Global Change - The IGBP Series, 566 pp.

Weblog of the Roger A. Pielke Sr. Research Group

http://climatesci.atmos.colostate.edu/

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