What is the Climate System and How are we Altering It?

Roger A. Pielke Sr.
University of Colorado at Boulder and Colorado State University, Fort Collins
pielke@atmos.colostate.edu

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Important Climate Science Issues Are Ignored or Poorly Discussed in International Assessments of Climate Change and Variability

- Is a global- or a zonally-averaged surface air temperature an effective metric of the Earth’s radiative imbalance?
- Is a global- or a zonally-averaged surface air temperature an effective metric of climate change?

- Does ocean heat content changes provide a more robust metric of the Earth's radiative imbalance?

  Pielke Sr., R.A., 2003: Heat storage within the Earth system. Bull. Amer. Meteor. Soc., 84, 331-335. http://blue.atmos.colostate.edu/publications/pdf/R-247.pdf

- Do spatial analyses of regional trends in tropospheric temperature, winds and humidity provide a more robust metric of the atmospheric component of climate change and variability?

  Chase, T.N., J.A. Knaff, R.A. Pielke Sr. and E. Kalnay, 2003: Changes in global monsoon circulations since 1950. Natural Hazards, 29, 229-254. http://blue.atmos.colostate.edu/publications/pdf/R-239.pdf

- Do Existing Climate Assessments Provide a Balanced View of the Diversity of Views on Climate?
  http://blue.atmos.colostate.edu/publications/pdf/SAP1.1Pielke.pdf

- Do the Media Present a Balanced View of Climate Science Research?
  http://climatesci.atmos.colostate.edu/

NCAR Press Release

Taken together, the impacts of greenhouse gases around the globe should far outweigh the regional effects of land-cover change, according to Feddema. However, the regions with extensive agriculture and deforestation also tend to be highly populated, so the effects of land-cover change are often focused where people live.

"Compared to global warming, land use is a relatively small influence. However, there are regions where it's really important," he says.

http://www.ucar.edu/news/releases

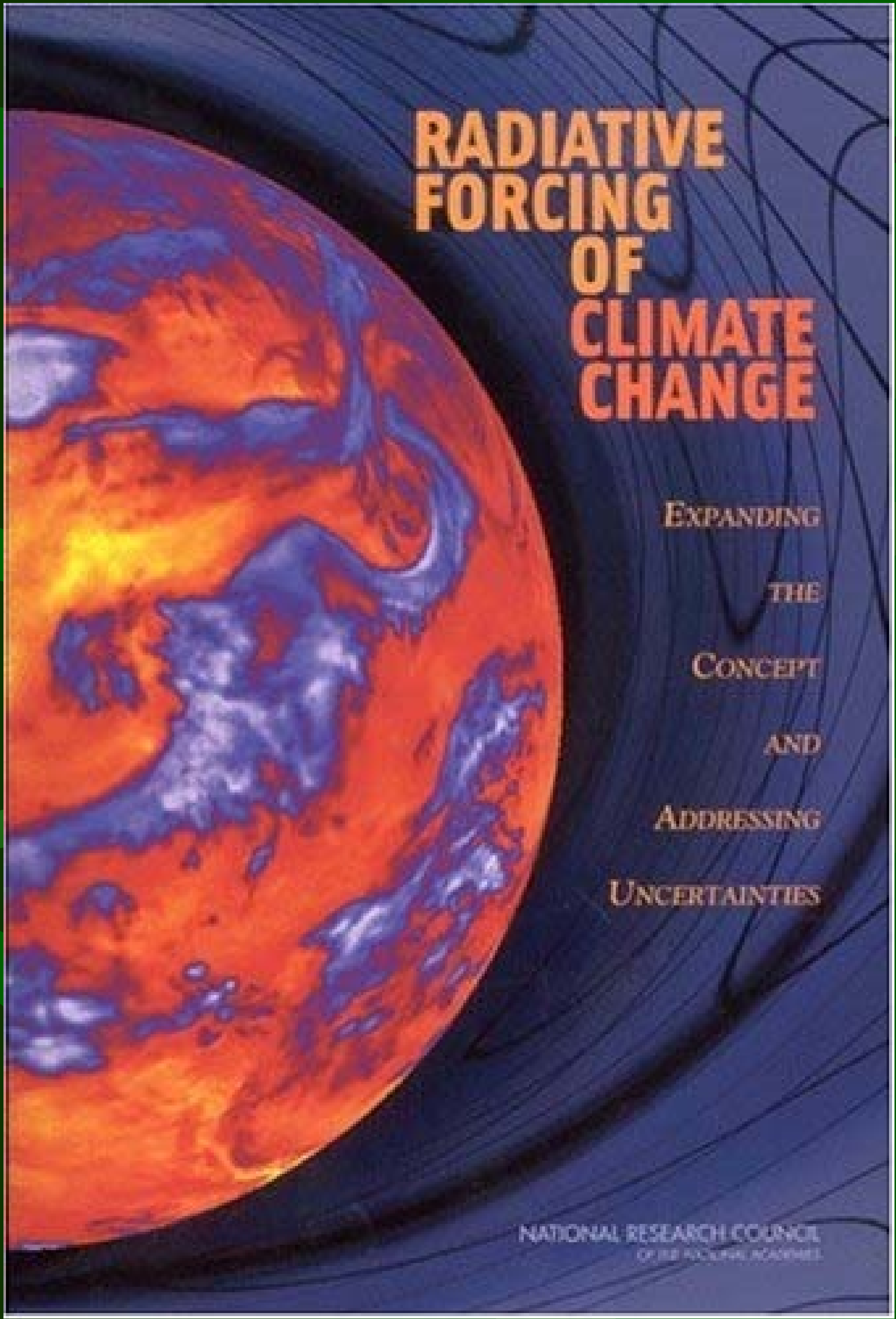
Conclusions from the Feddema et al. (2005) Science paper

The message from their paper, however, is that while a global average temperature effect is small, the effects that matter in terms of how people are affected are very significantly altered at the regional scale by land-cover change. They state this near the end of their paper

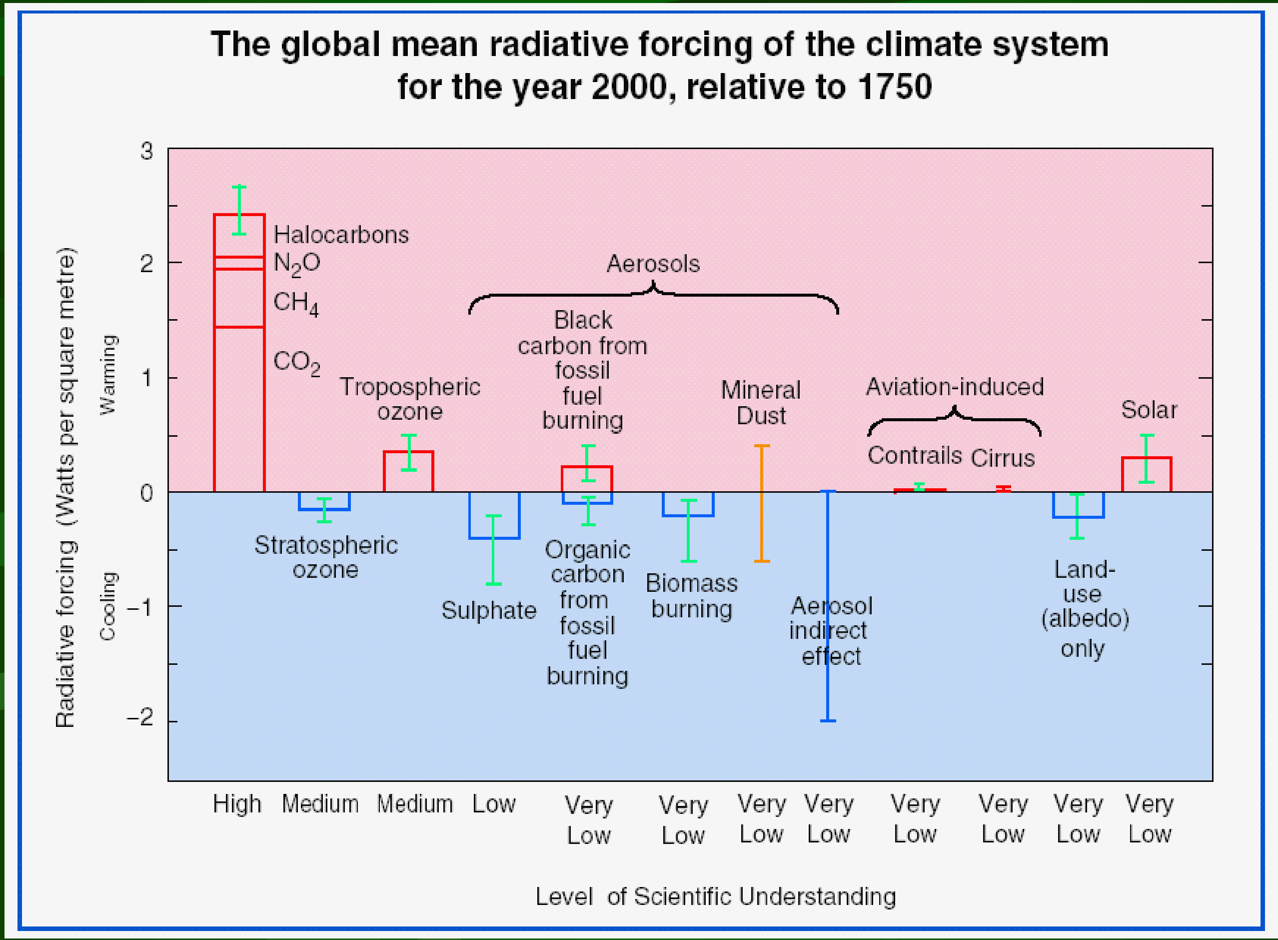
"*Results from this study suggest that the choices humans make about future land use could have a significant impact on regional and seasonal climates.*"

Further,

"Although land-cover effects are regional and tend to offset with respect to global average temperatures, they can significantly alter regional climate outcomes associated with global warming."



The following figures are 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



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: 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

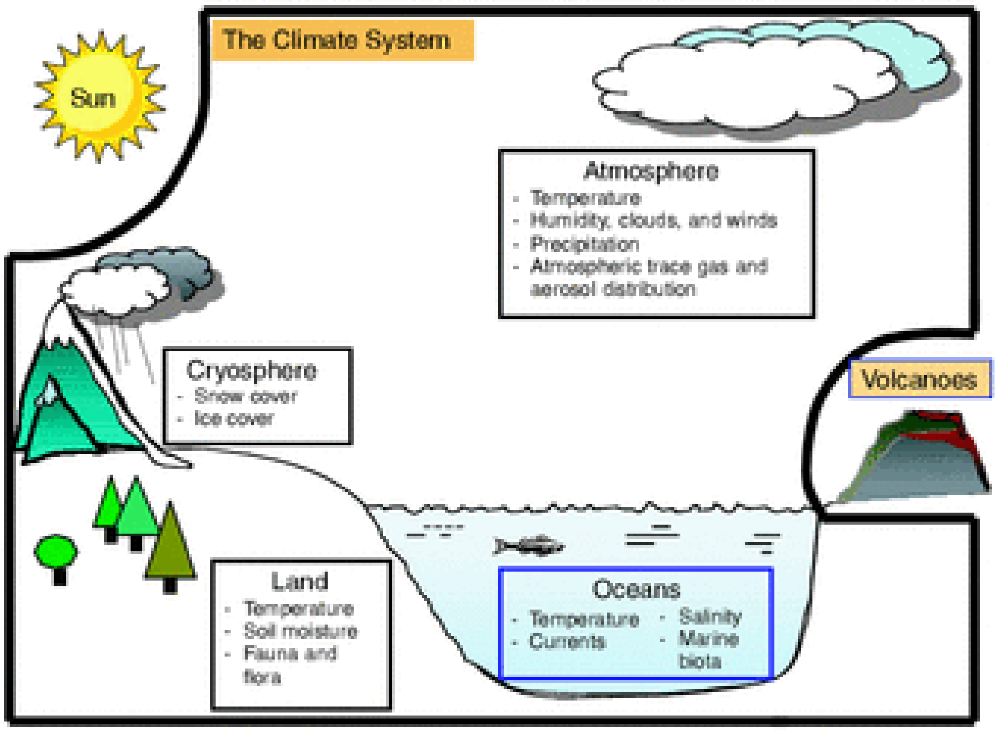


FIGURE 1-1 The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes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

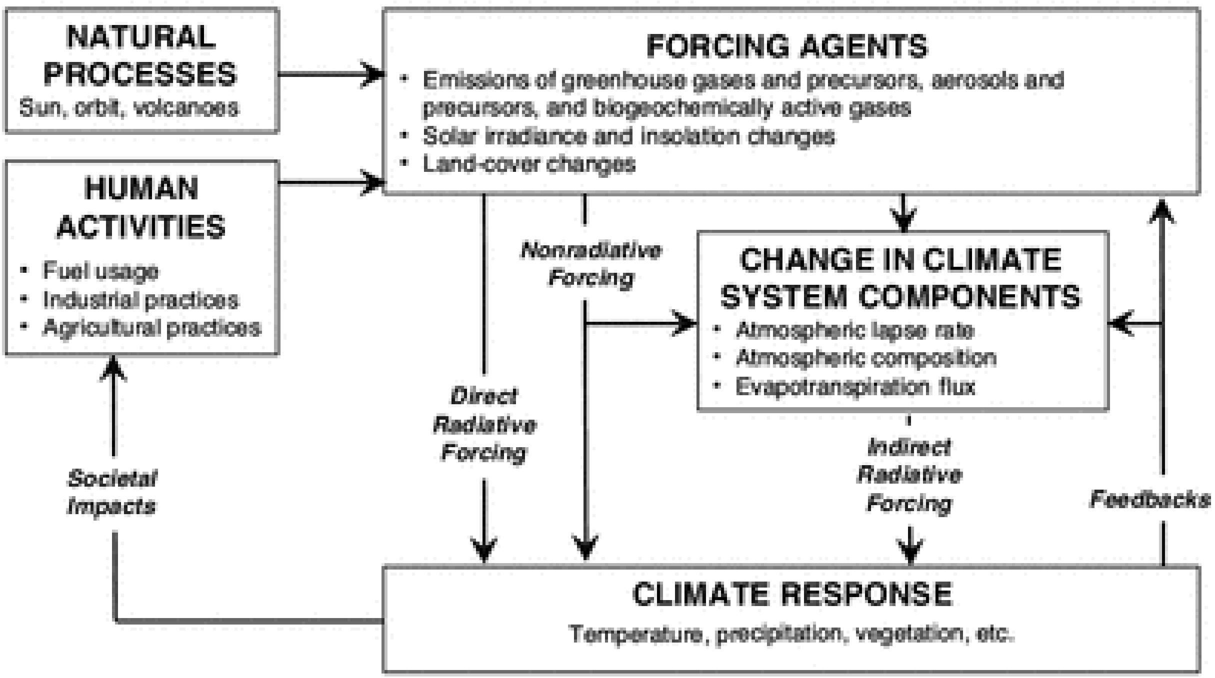


FIGURE 1-2 Conceptual framework of climate forcing, response, and feedbacks under present-day climate conditions. Examples of human activities, forcing agents, climate system components, and variables that can be involved in climate response are provided in the lists in each box.

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

BOX 1-1
Key Definitions

Climate system: The system consisting of the atmosphere, hydrosphere, lithosphere, and biosphere, determining the Earth's climate as the result of mutual interactions and responses to external influences (forcing). Physical, chemical, and biological processes are involved in the interactions among the components of the climate system.

Climate forcing: An energy imbalance imposed on the climate system either externally or by human activities.

- *Direct radiative forcing:* A climate forcing that directly affects the radiative budget of the Earth's climate system; for example, added carbon dioxide (CO_2) absorbs and emits infrared radiation. Direct radiative forcing may be due to a change in concentration of radiatively active gases, a change in solar radiation reaching the Earth, or changes in surface albedo. Radiative forcing is reported in the climate change scientific literature as a change in energy flux at the tropopause, calculated in units of watts per square meter ($W\ m^{-2}$); model calculations typically report values in which the stratosphere was allowed to adjust thermally to the forcing under an assumption of fixed stratospheric dynamics.
- *Indirect radiative forcing:* A climate forcing that creates a radiative imbalance by first altering climate system components (e.g., precipitation efficiency of clouds), which then almost immediately lead to changes in radiative fluxes. Examples include the effect of solar variability on stratospheric ozone and the modification of cloud properties by aerosols.
- *Nonradiative forcing:* A climate forcing that creates an energy imbalance that does not immediately involve radiation. An example is the increasing evapotranspiration flux resulting from agricultural irrigation.

Climate response: Change in the climate system resulting from a climate forcing.

Climate feedback: An amplification or dampening of the climate response to a specific forcing due to changes in the atmosphere, oceans, land, or continental glaciers.

NOTE: Additional definitions are provided in Appendix C.

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

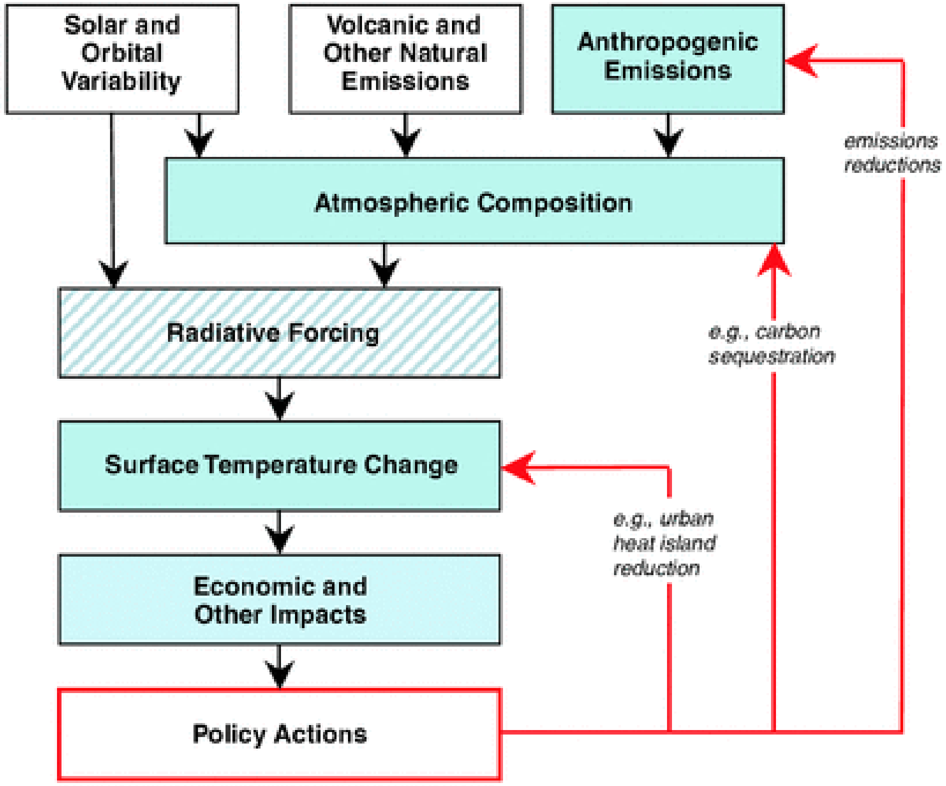


FIGURE 1-4 Conceptual framework for how radiative forcing fits into the climate policy framework. Blue-shaded boxes indicate quantities that have been considered as policy targets in international negotiations and other policy analyses. Radiative forcing (striped box) has not been treated as a policy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

TABLE 2-2 Overview of the Different Aerosol Indirect Effects Associated with Clouds

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

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

- Is There Non-Spatially Representative Surface Temperature Data?

- Can This Non-Spatially Representative Surface Temperature Data Be “Homogenized” For Grid Area Averages?

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

$$T_E = H/C_p$$

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

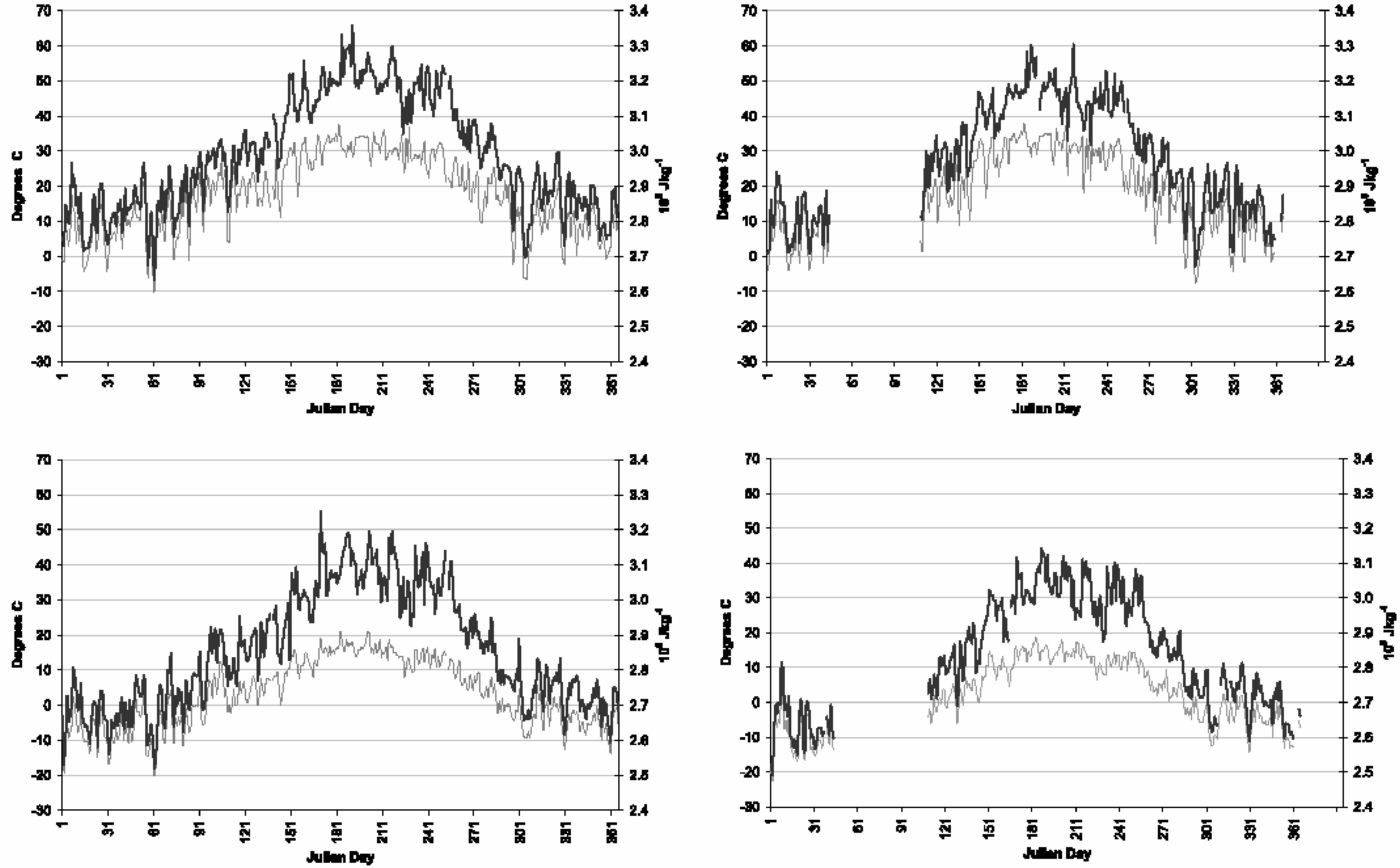


Fig. 1. T and T_E in °C (S and H, in 10^4 J kg^{-1}) for Fort Collins, Colorado, (left panels) and the CPER ungrazed site (right panels) are shown for 2002. The top two panels are for maximum daily temperature while the bottom two panels are for minimum daily temperature. The grey lines represent T (and S) while the black lines represent T_E (and H).

From: Pielke, R.A. Sr., C. Davey, and J. Morgan, 2004: Assessing "global warming" with surface heat content. Eos, 85, No. 21, 210-211.
http://blue.atmos.colostate.edu/publications/pdf/R-290.pdf

Temperature and equivalent temperature trend differences from 1982-1997 are examined for surface sites in the Eastern U.S. Overall trend differences at the surface indicate equivalent temperature trends are relatively warmer than temperature trends in the Eastern U.S. Seasonally, equivalent temperature trends are relatively warmer than temperature trends in winter and are relatively cooler in the fall. These patterns, however, vary widely from site to site.

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

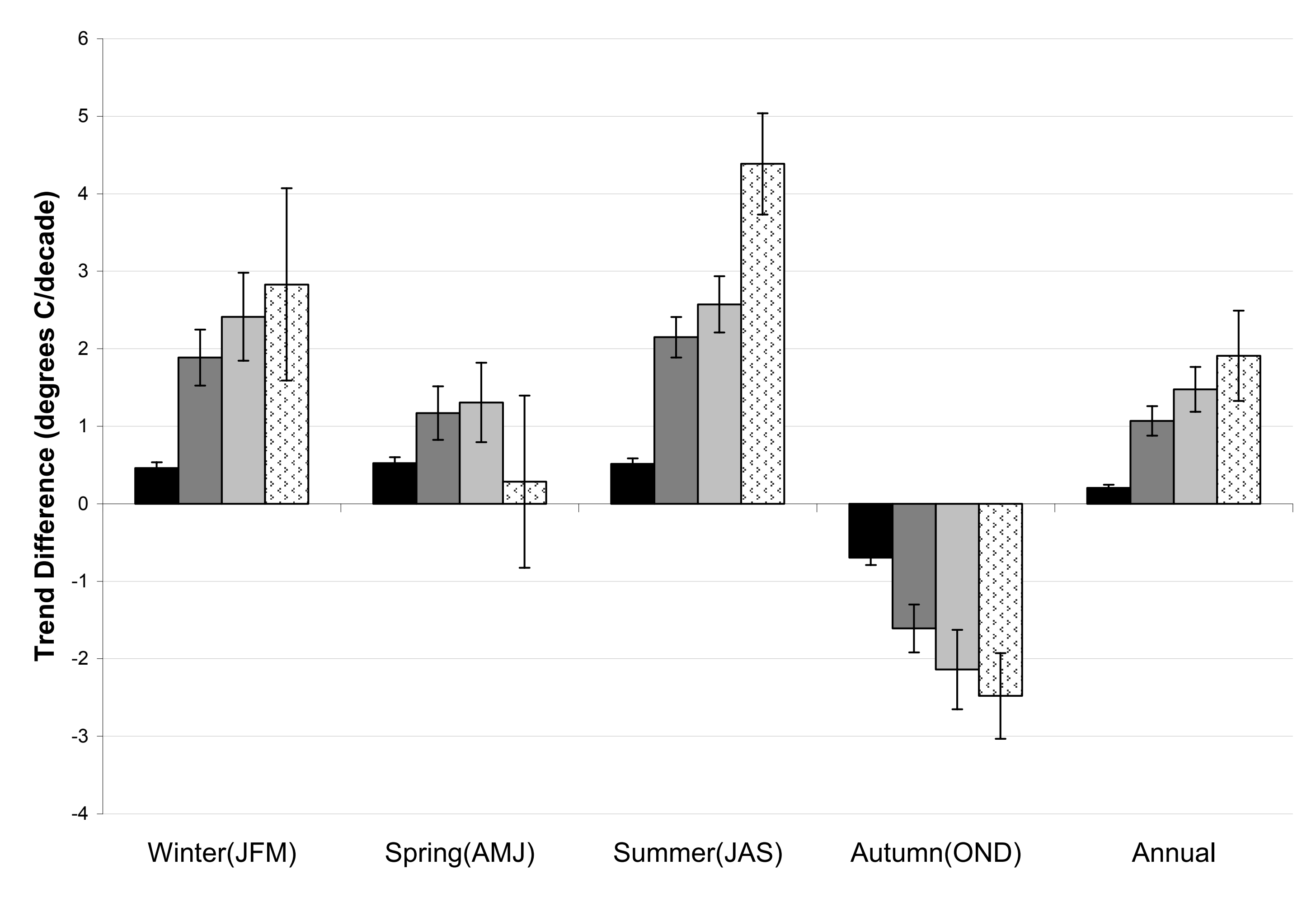


Figure 2. Seasonally-averaged 1982-1997 differences between *T*E trends and *T* trends for all individual trends (black bars), individual trends that are at least 90% significant (dark gray bars), individual trends that are at least 95% significant (light gray bars), and individual trends that are at least 99% significant (stippled bars). Error bars indicate standard errors. For each computation, each station is weighted equally.

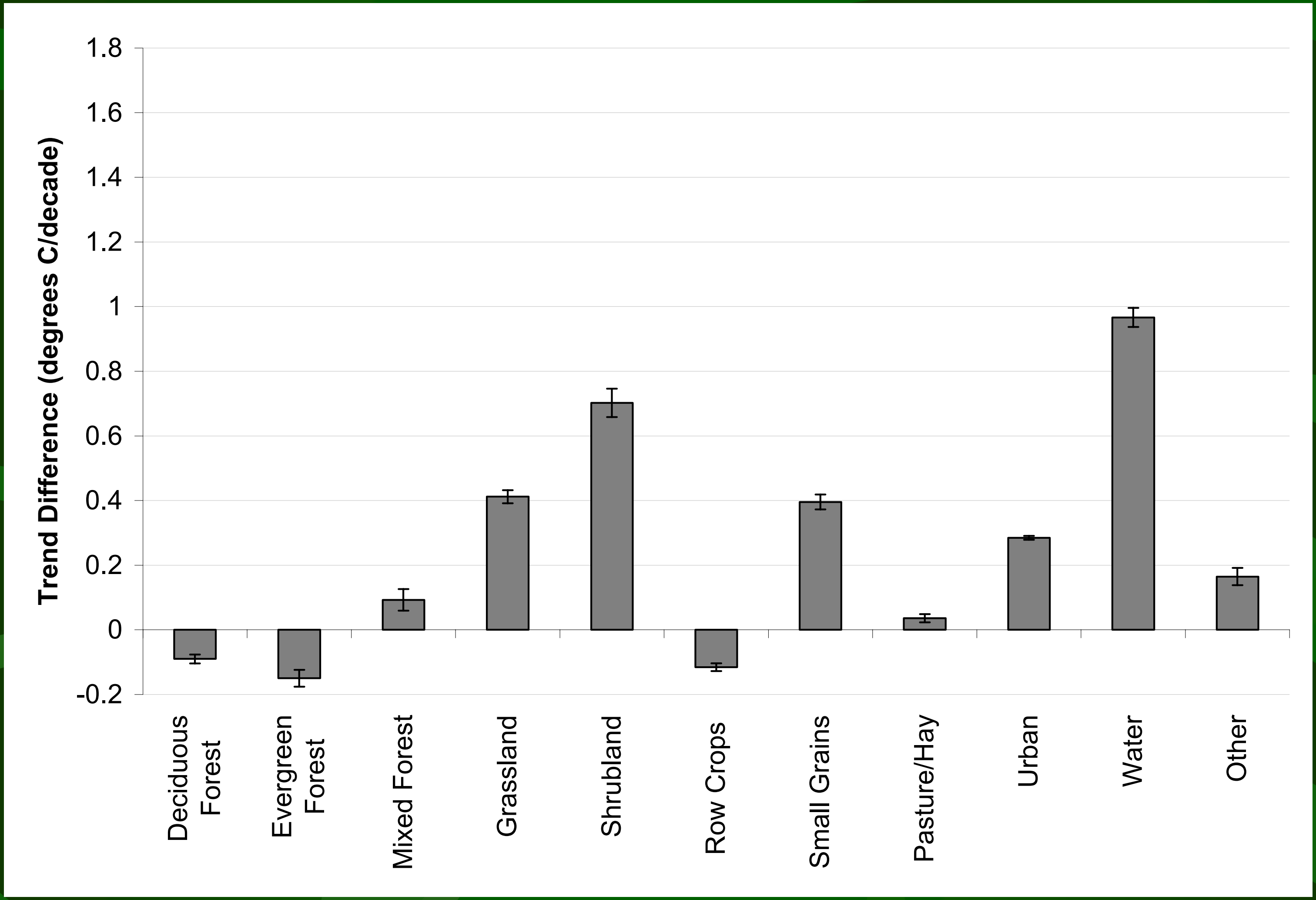


Figure 3. Annually-averaged differences between *T*E and *T* trends for 1982-1997, as a function of the land-cover classes listed in Table 2. Error bars indicate standard errors. All individual trends are considered.

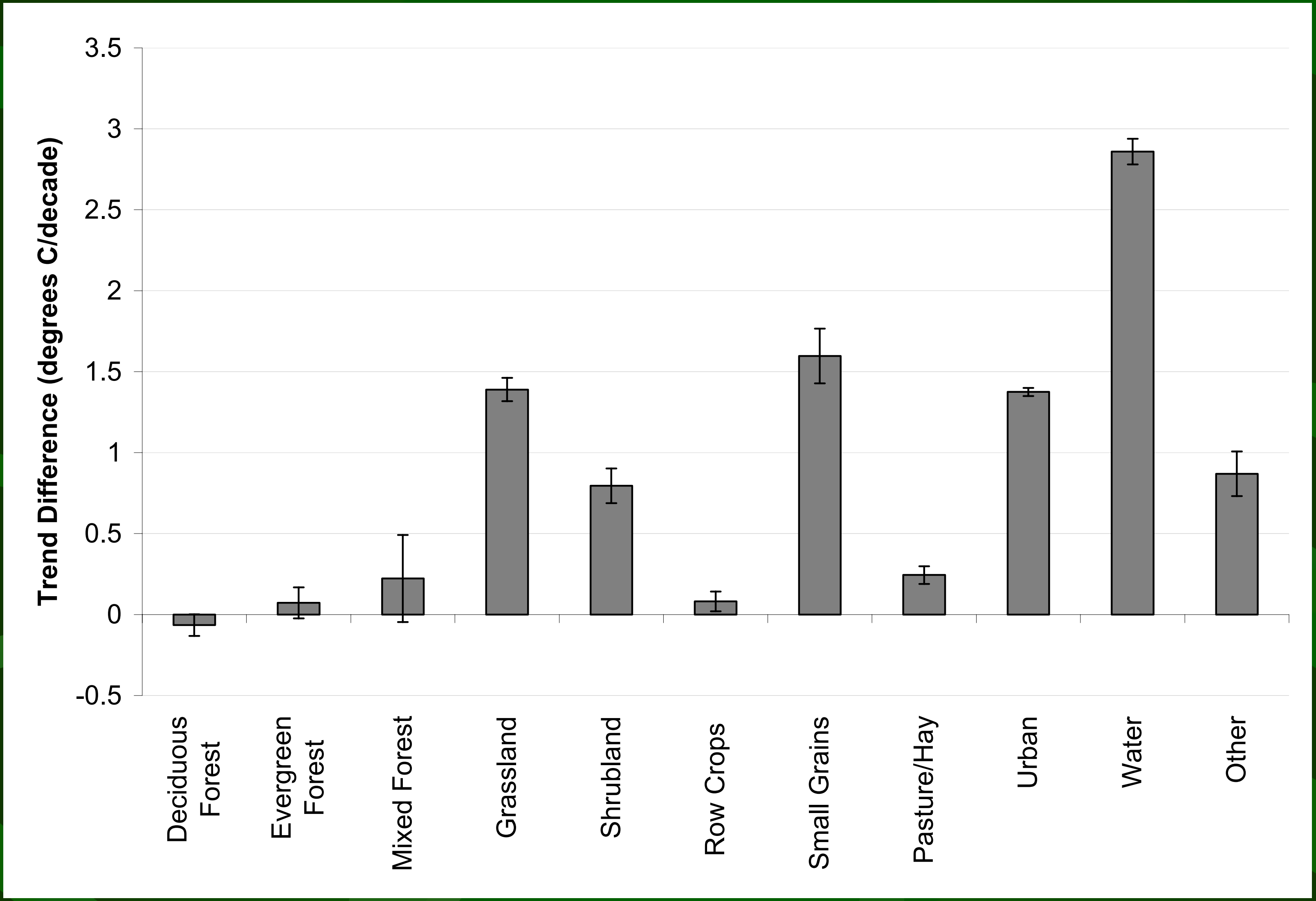


Figure 4a. Same as Figure 3, but for individual trends that are at least 90% significant and individual trends that are at least 95% significant.

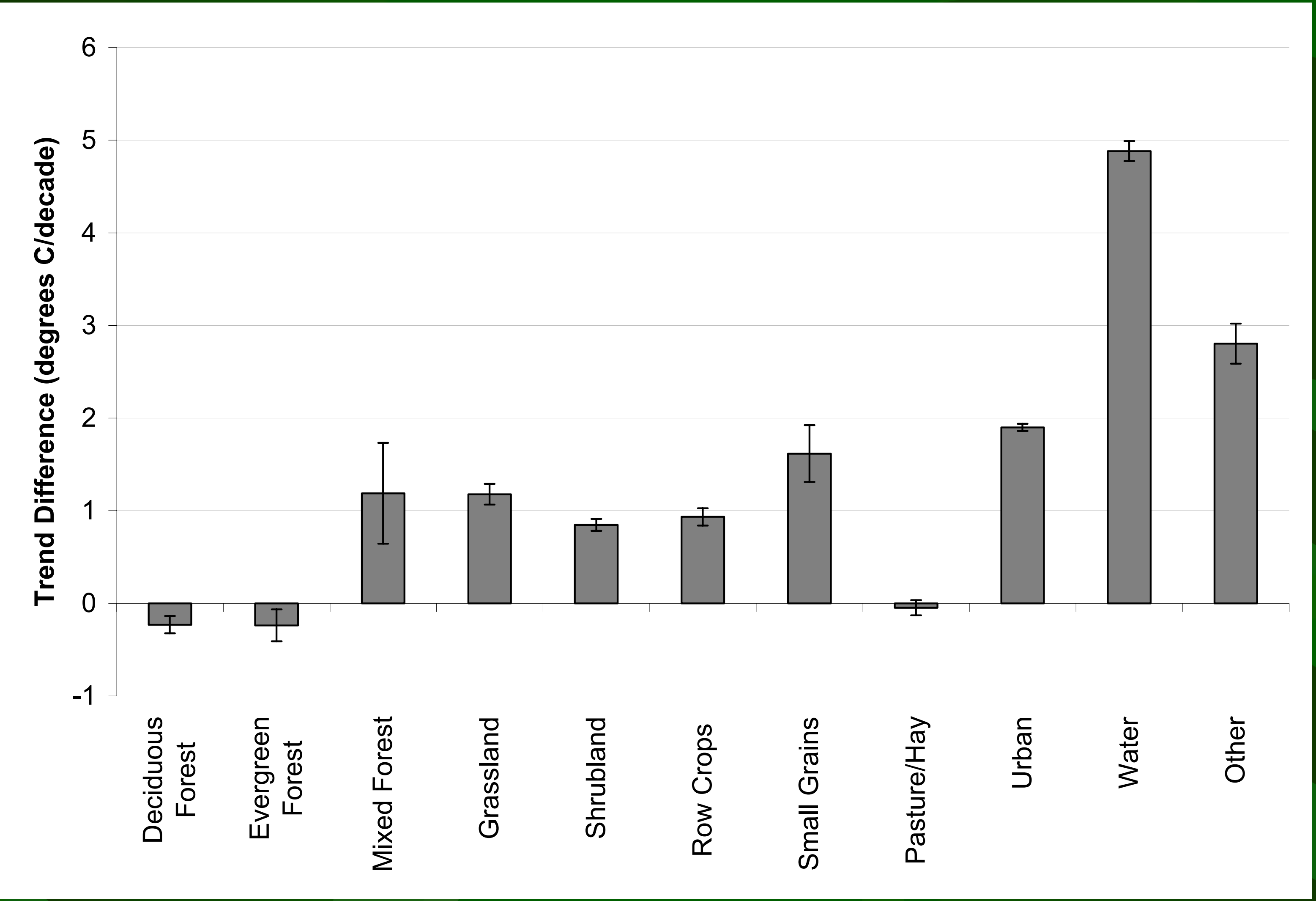


Figure 4b. Same as Figure 3, but for individual trends that are at least 90% significant and all stations in these computations are weighted equally.

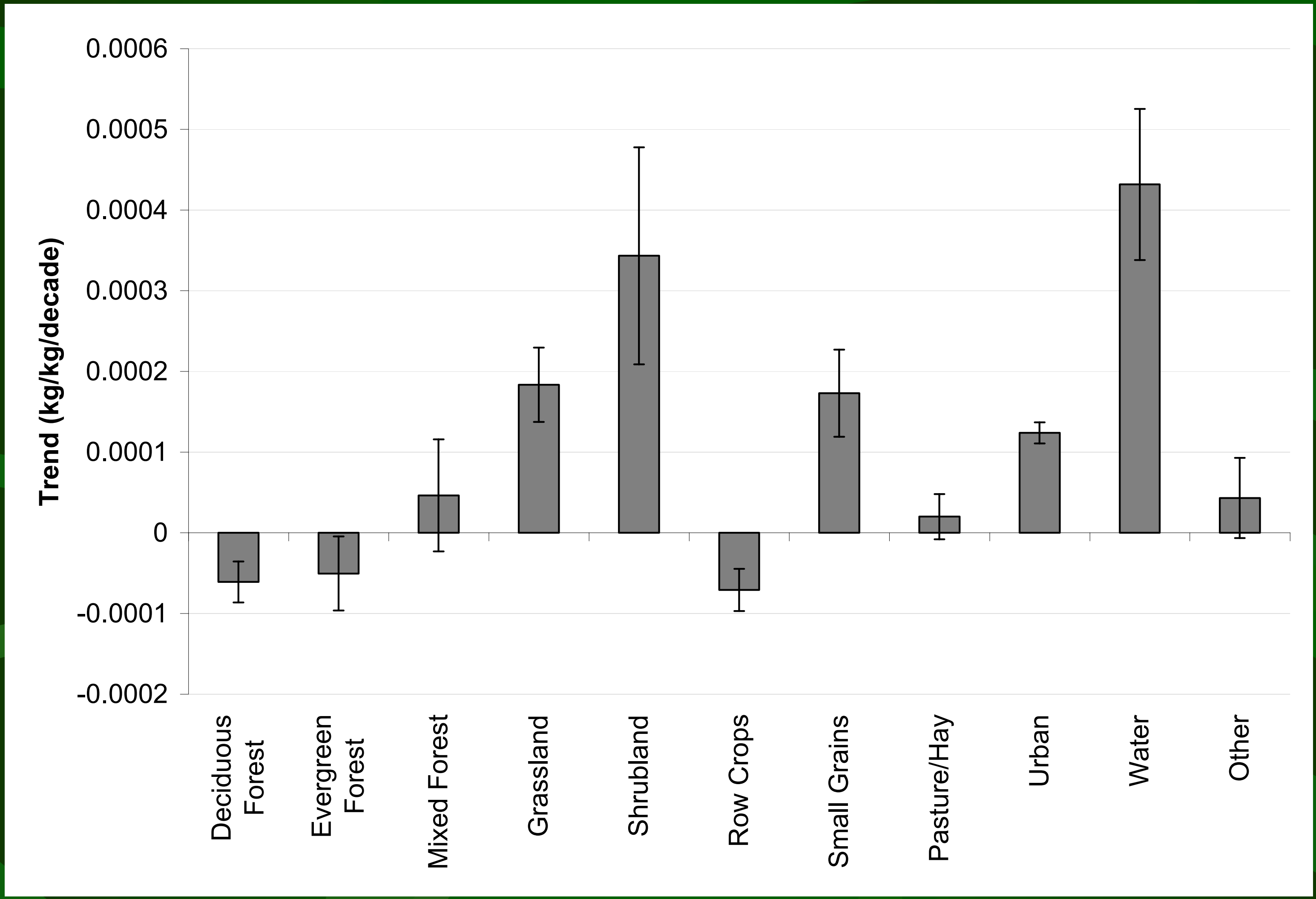
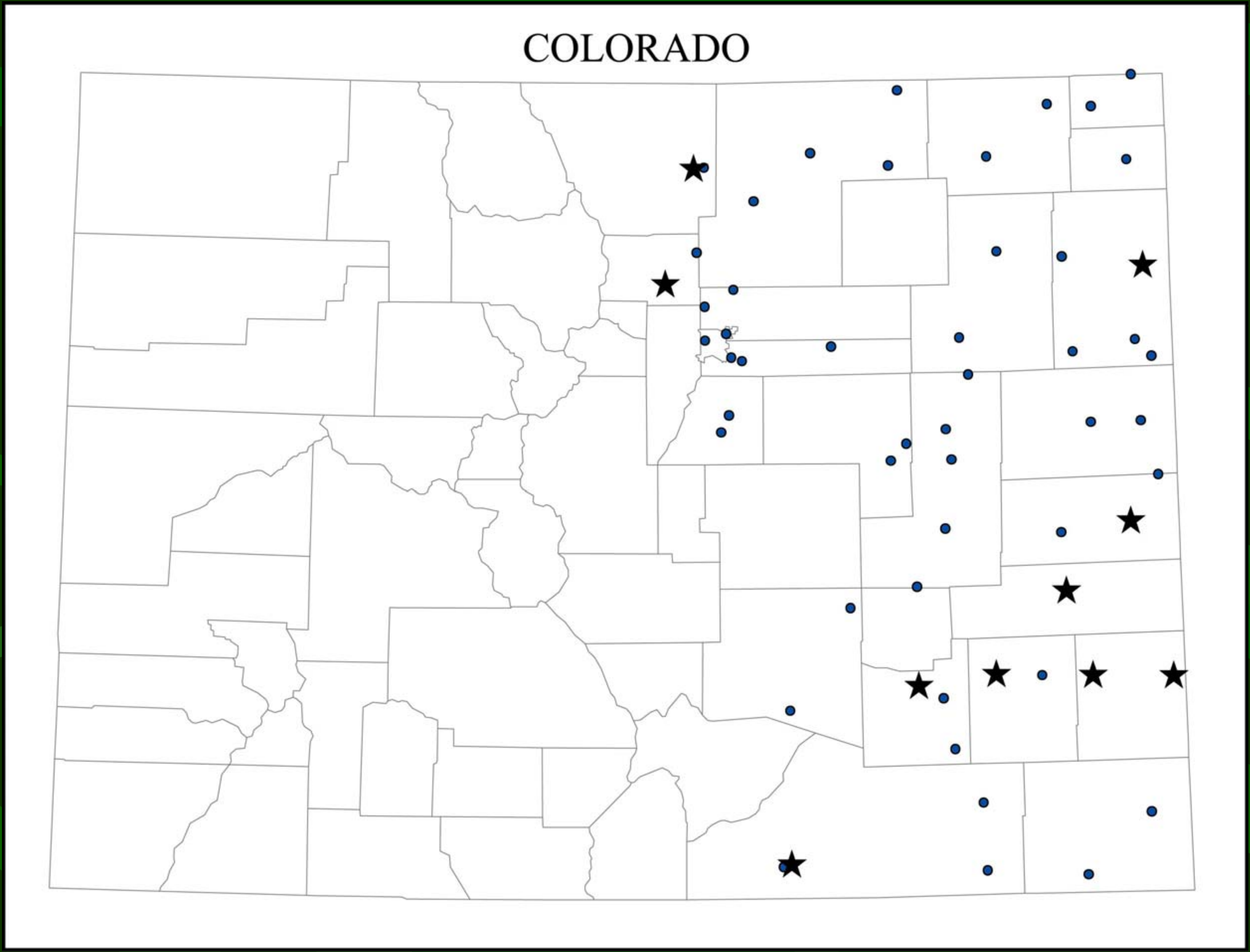


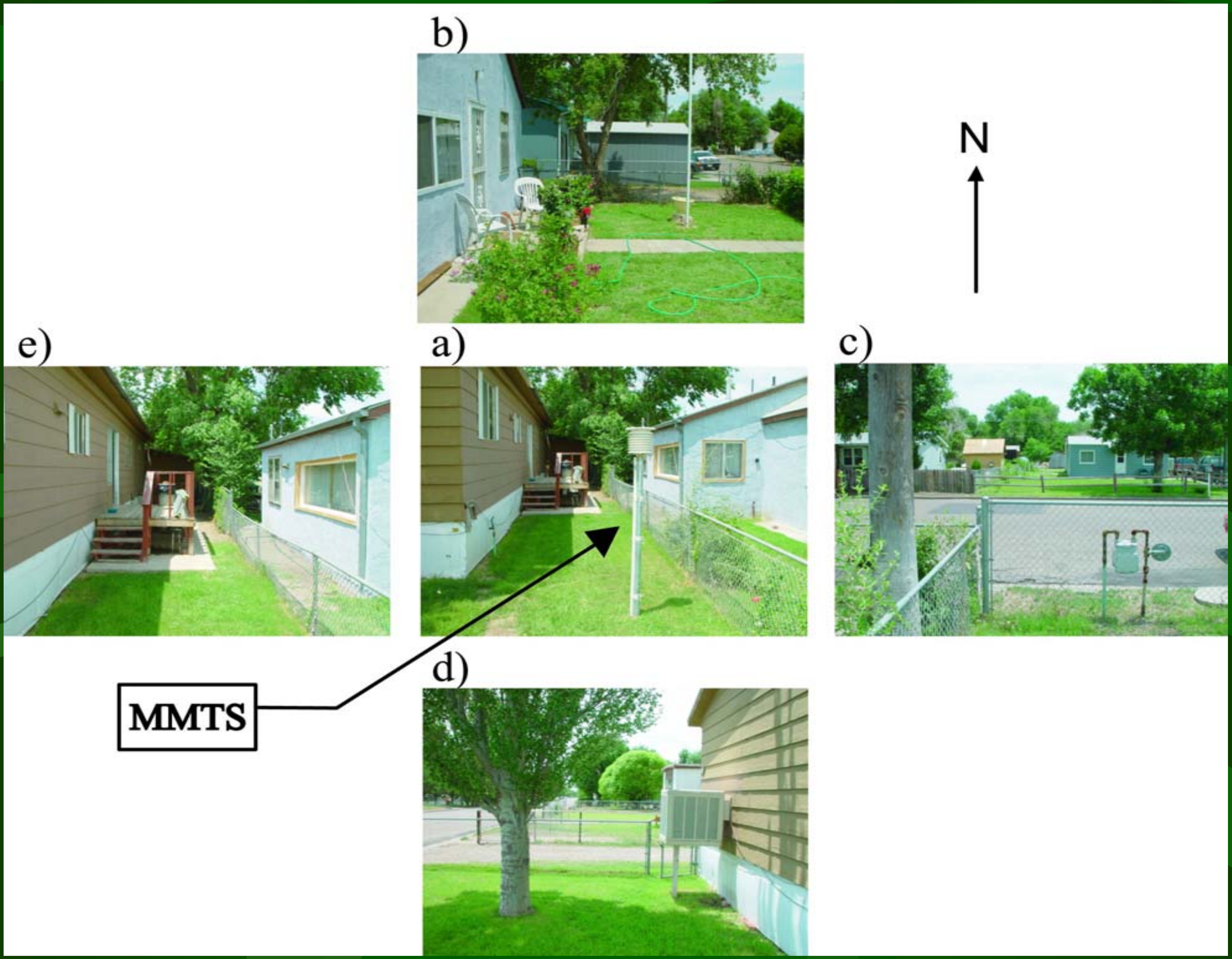
Figure 5. Annually-averaged *q* trends for 1982-1997, as a function of the land-cover classes listed in Table 2. Error bars indicate standard errors. All individual trends are considered and are weighted equally.

The following figures are 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., in press.

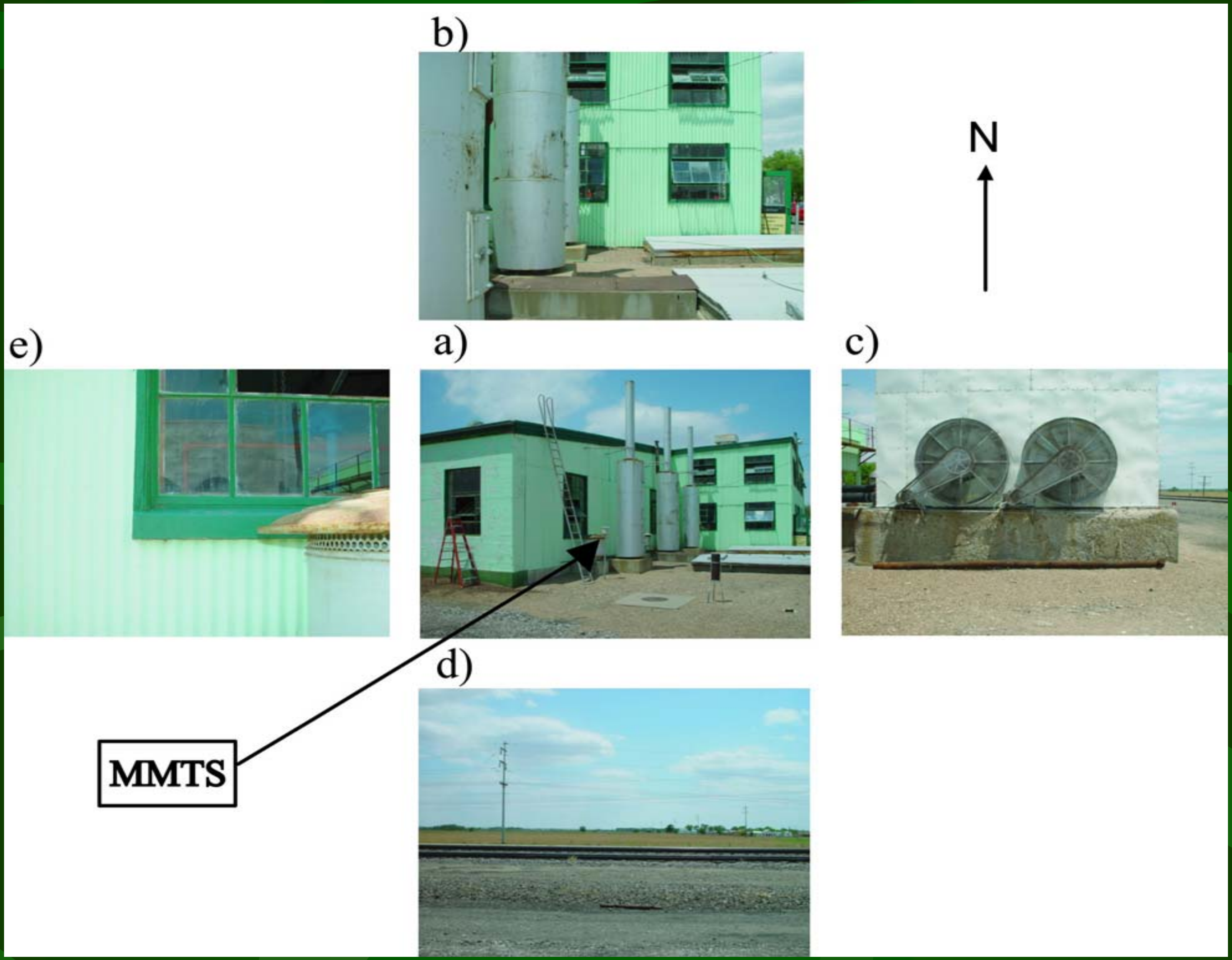
http://blue.atmos.colostate.edu/publications/pdf/R-274.pdf



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 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 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)

Courtesy of Karen O’Brien

The Globally-Averaged Surface Temperature Trend – Incompletely Assessed? Is It Even Relevant?

There are several issues with respect to the spatial representativeness of the trends that have been incompletely (or not at all) investigated. These are:

1. Poor microclimate exposure:

This is a land issue. The use of photographs to exclude questionable stations is obvious (and we are quite puzzled why anyone would not make this a high priority). The effect of poor exposure (which results in different site exposure depending on the wind direction) and changes in the site conditions over time have not been quantified. Our qualitative assessment based on the photographs that we have seen is that this it is likely to insert a warm bias for most sites.

2. Moist enthalpy:

This is both a land and an ocean issue. The use of the terms "warming" and "cooling" are being incompletely used when there is significant water vapor in the surface air (tropics and mid-latitude warm seasons, in particular). This will produce a warm bias when the air actually became drier over time, and a cool bias when the air becomes more humid over time. This effect has not been quantified with respect to how it influences regional and global surface temperature trends. It has been shown to be significant for individual sites.

3. Vertical lapse rate issues:

The influence of different lapse rates, heights of observations and surface roughness have not been quantified. For example, windy and light wind nights should not have the same trends at most levels in the surface layer, even if the surface-layer averaged temperature trend was the same.

4. Uncertainty in homogeneity adjustments:

Time of observation, instrument changes, and urban effects have been recognized as important adjustments (see R-234) that are required to revise temperature trend information in order to produce improved temporal and spatial homogeneity. However, these adjustments do not report in the final homogenized temperature anomalies, the statistical uncertainty that is associated with each step in the homogenization process.

Our recommendation, however, is to deemphasize the globally-averaged surface temperature as a climate change metric and assess instead circulation changes as defined by tropospheric temperature and water vapor (and for the ocean, temperature and salinity) variability and trends.

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).

The following figures and equations are from: 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? Geophys. Res. Letts., 32, No. 21, L21813, 10.1029/2005GL024407.

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

$$J_1 = C_p T_1 + L q_1$$

$$J_2 = C_p T_2 + L q_1$$

Eq. 1

$J_1 = C_p T_1 + Lq_1$

$J_2 = C_p T_2 + Lq_1$

Windy Nights

$$\boxed{\frac{\partial T_1}{\partial z} \approx 0 \ \ and \ \frac{\partial q_1}{\partial z} \approx 0 \, (and \ thus \ \frac{\partial J_1}{\partial z} \approx 0)}$$

Eq. 2

Light Wind Nights

$$\boxed{\frac{\partial q_2}{\partial z} = \frac{q^* \cdot (0.74 + 4.7 \cdot z / L)}{k \cdot z}}$$

$$\boxed{\frac{\partial T_2}{\partial z} = \frac{T^* \cdot (0.74 + 4.7 \cdot z / L)}{k \cdot z}}$$

Eq. 3

$$\boxed{\frac{\partial J_2}{\partial z} = \frac{(C_p T^* + L q^*) \cdot (0.74 + 4.7 \cdot z / L)}{k \cdot z}}$$

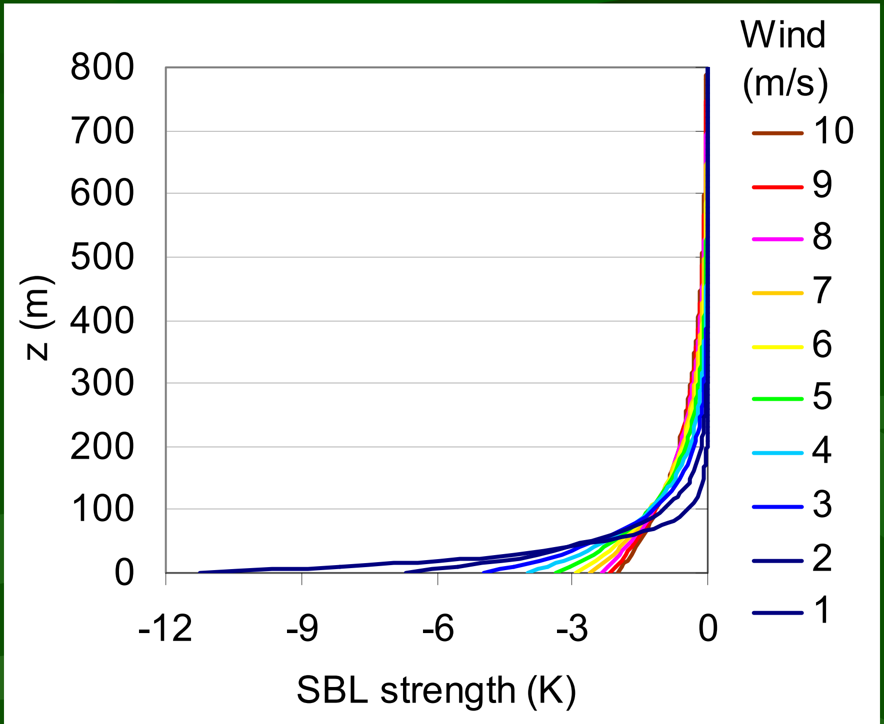


Figure 1. (SBL strength) profile in different wind conditions for cases of -10 W m-2 constant cooling rate over night.

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

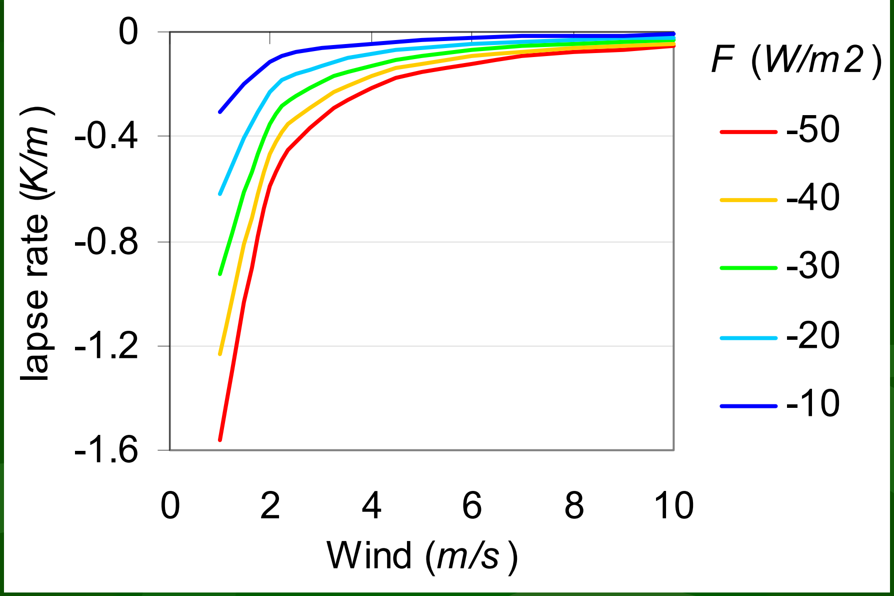


Figure 2: Lapse rate of potential temperature profile for the lowest 0~10 m for different wind conditions and five different values of the flux divergence.

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

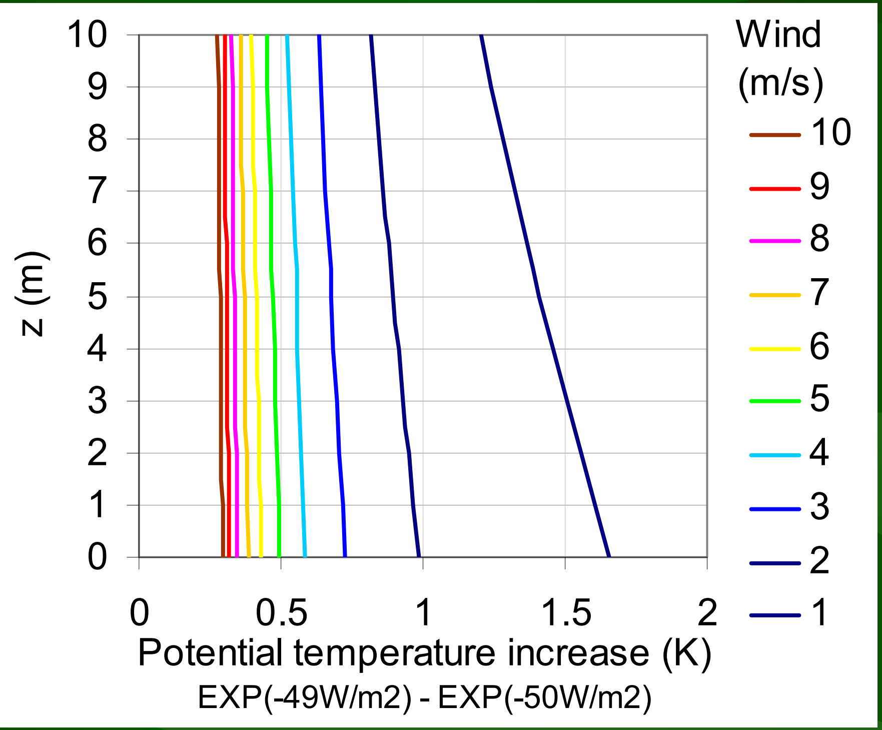


Figure 3: Potential temperature increase at different levels from the experiment with -49 W m-2 cooling to the experiment with -50 W m^{-2} cooling.

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

Table 1: Same as Figure 3, but in Table format. Potential temperature increase at different levels from the experiment with -49 W m^{-2} cooling to the experiment with -50 W m^{-2} cooling.

Table 1. Tabulated Version of Figure 3[a]

	Wind Speed, m s^{-1}									
Z, m	10	9	8	7	6	5	4	3	2	1
10	0.28	0.30	0.33	0.36	0.40	0.45	0.52	0.63	0.81	1.20
9	0.28	0.30	0.33	0.36	0.40	0.45	0.53	0.64	0.83	1.24
8	0.28	0.30	0.33	0.36	0.40	0.46	0.53	0.65	0.85	1.28
7	0.28	0.31	0.33	0.37	0.41	0.46	0.54	0.66	0.86	1.32
6	0.28	0.31	0.33	0.37	0.41	0.47	0.55	0.67	0.88	1.37
5	0.29	0.31	0.34	0.37	0.41	0.47	0.55	0.68	0.89	1.41
4	0.29	0.31	0.34	0.37	0.42	0.48	0.56	0.69	0.91	1.46
3	0.29	0.31	0.34	0.38	0.42	0.48	0.57	0.70	0.93	1.50
2	0.29	0.31	0.34	0.38	0.42	0.49	0.57	0.71	0.95	1.55
1	0.29	0.32	0.35	0.38	0.43	0.49	0.58	0.72	0.97	1.60
0	0.29	0.32	0.35	0.38	0.43	0.50	0.59	0.73	0.98	1.66

[a]Potential temperature increase at different levels from the experiment with -49 W m^{-2} cooling to the experiment with -50 W m^{-2} cooling.

Regional Effects of Landscape Change

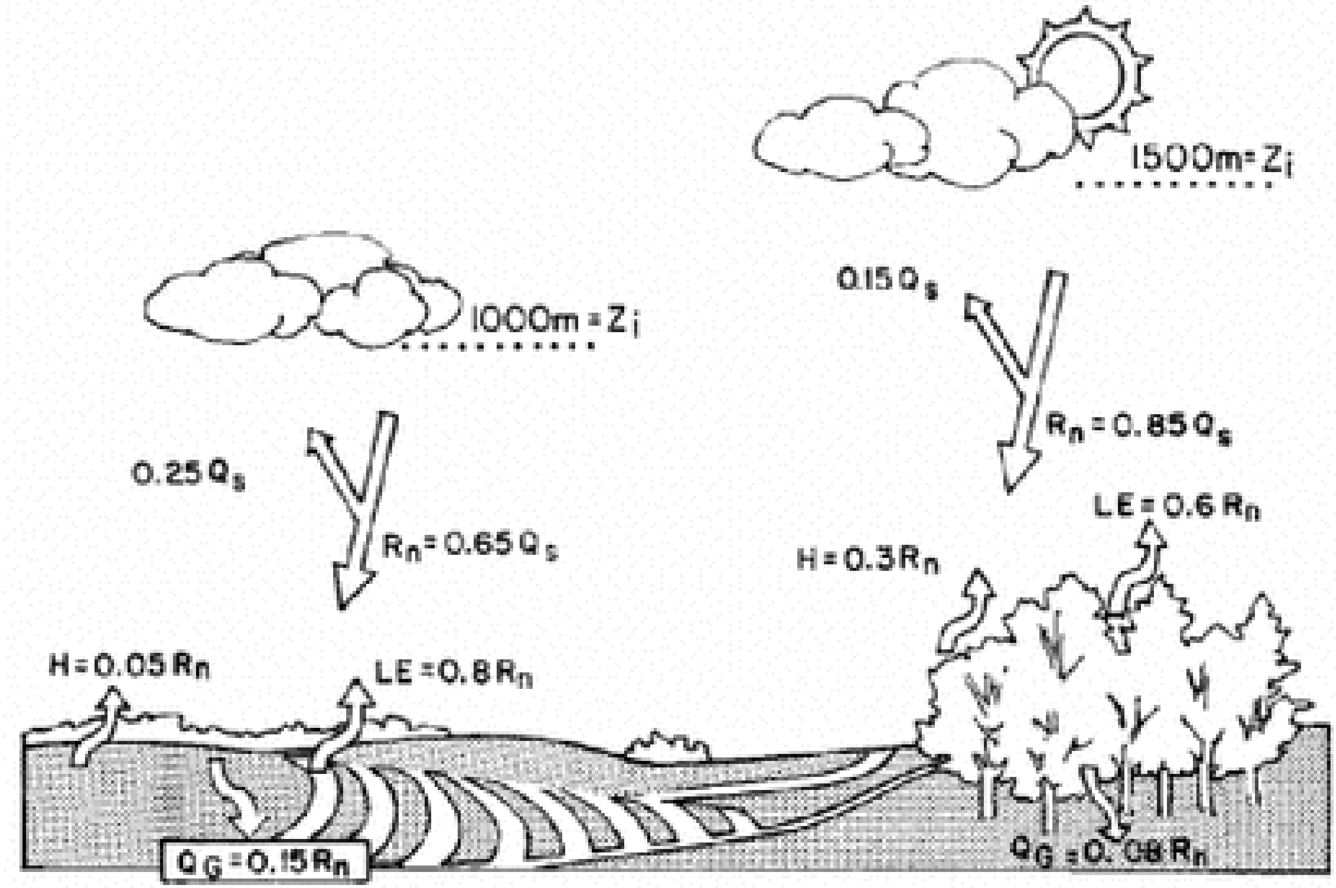


FIGURE 2-4 Schematic, based on observations in southwest France, of the influence on the surface energy budget of land-use change from forest to cropland. SOURCE: Kabat et al. (2004).

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

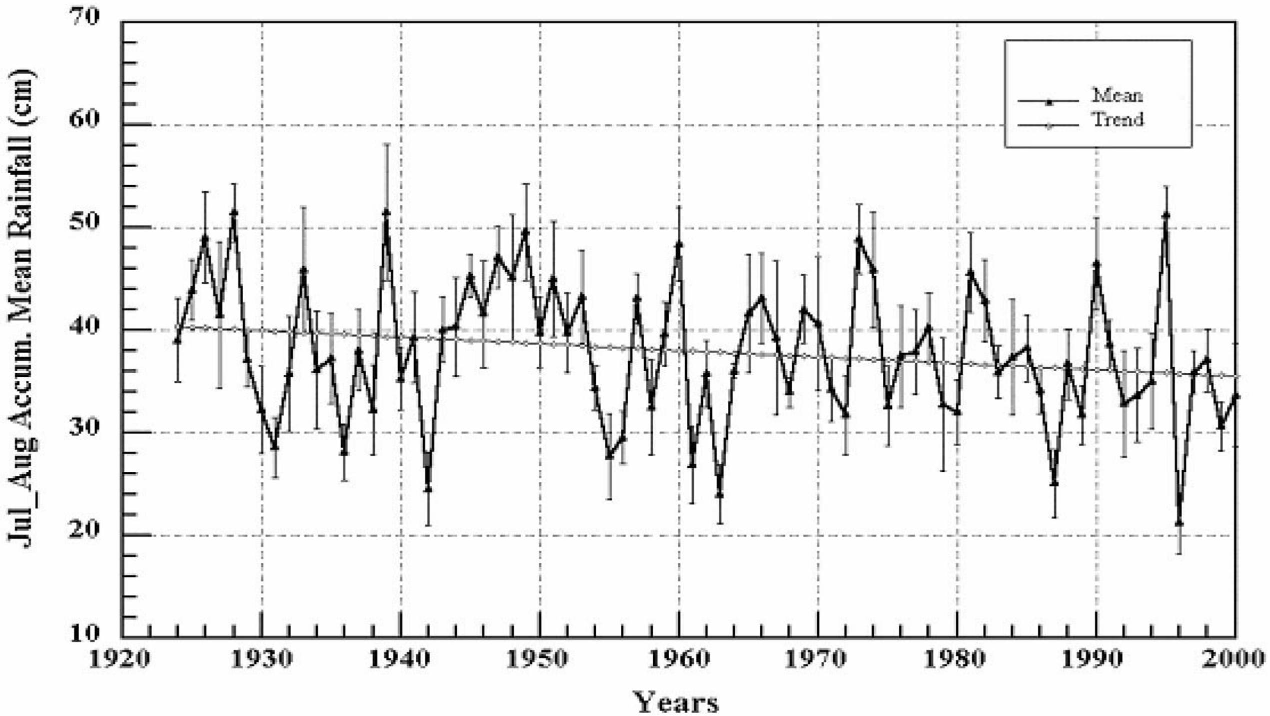


FIG. 25. Regional average time series of accumulated convective rainfall (cm) from 1924 to 2000, with corresponding trend based on linear regression of all July-August amounts. The vertical bars overlain on the raw time series indicate the value of the standard error of the July-August regional mean.

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

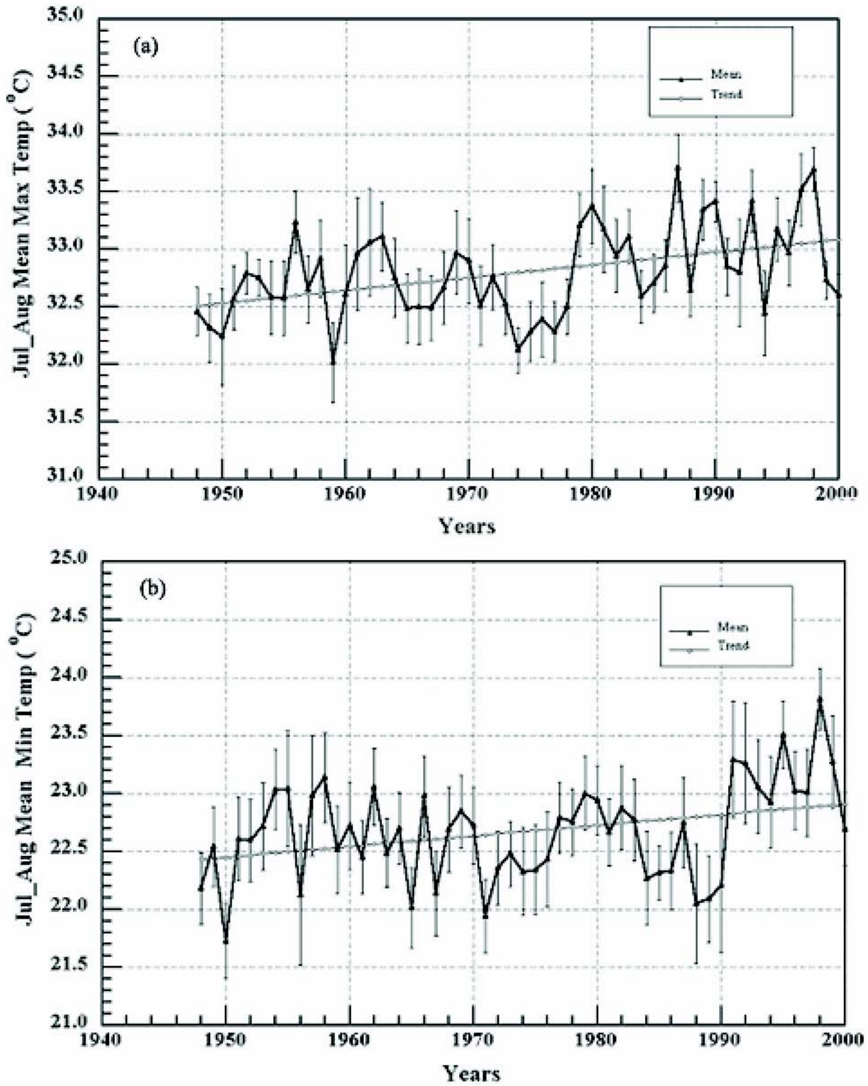
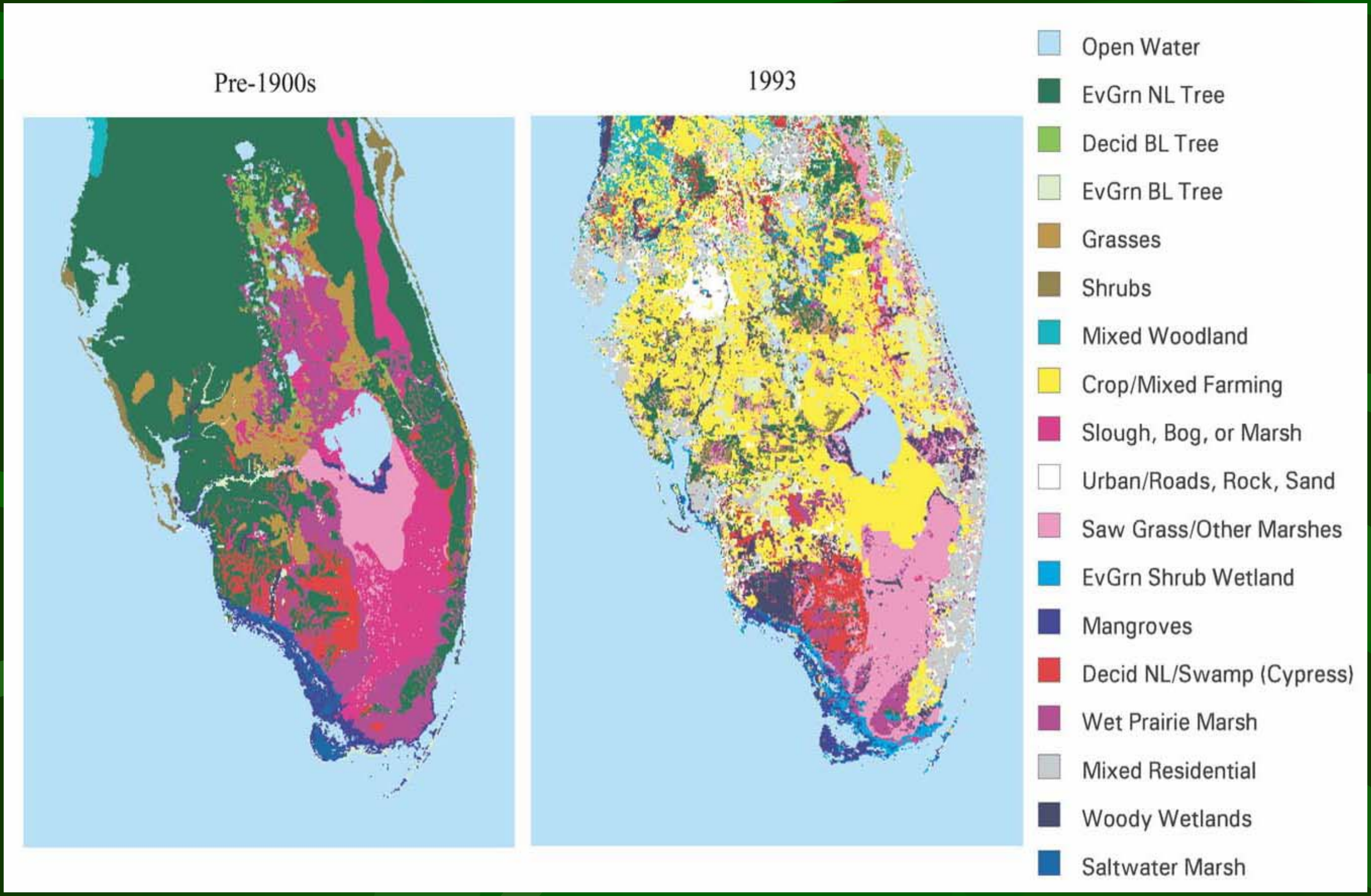


FIG. 26. Same as in Figure 25, except for daily (a) maximum and (b) minimum shelter-level temperature (°C)

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

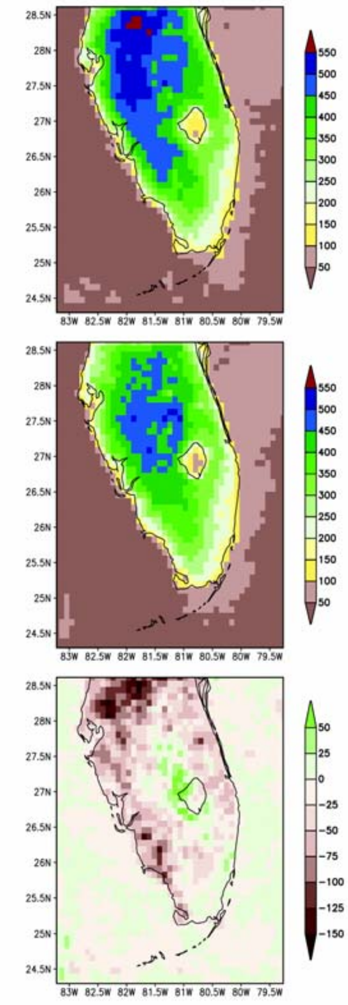


FIG. 4. Accumulated convective rainfall (mm) from the model simulations of July-August 1973 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).

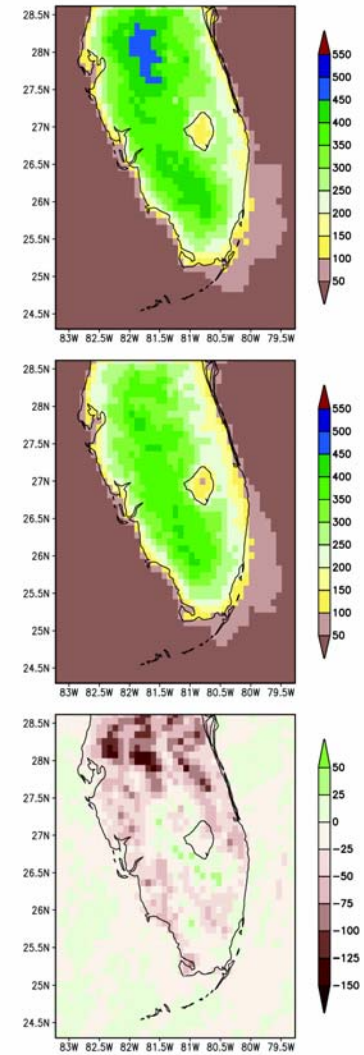


FIG. 5. Same as in Figure 4, except for July-August 1989.

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

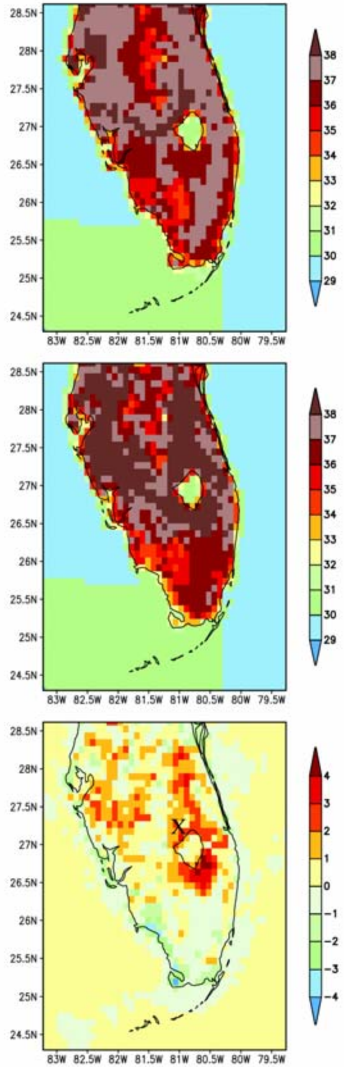


FIG. 13. Two-month average of the daily maximum shelter-level temperature from the model simulations of July-August 1989 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).

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

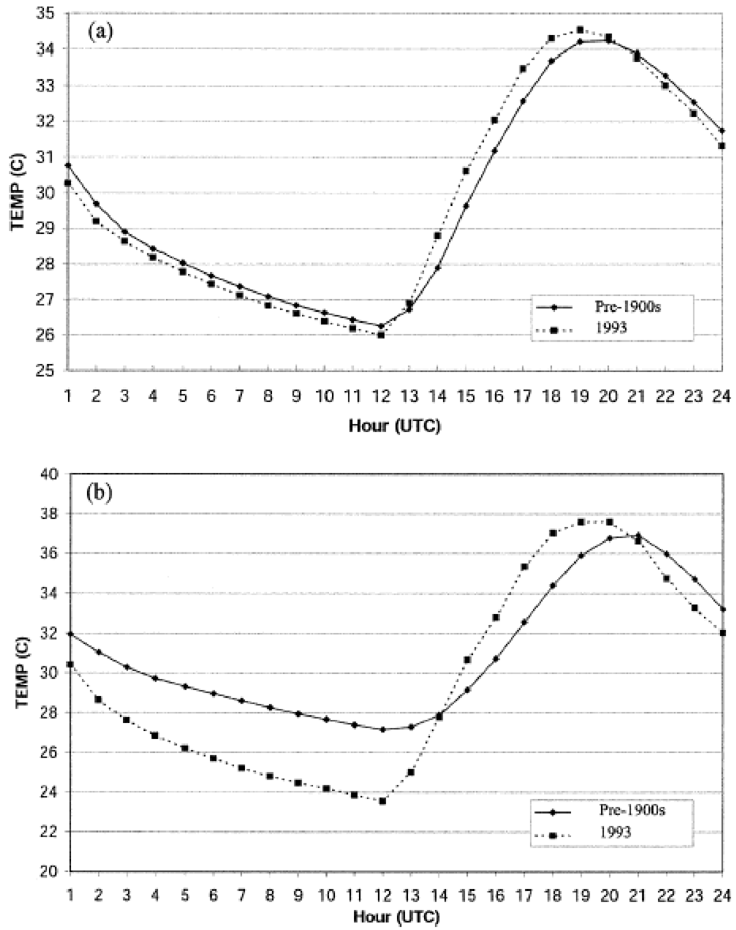
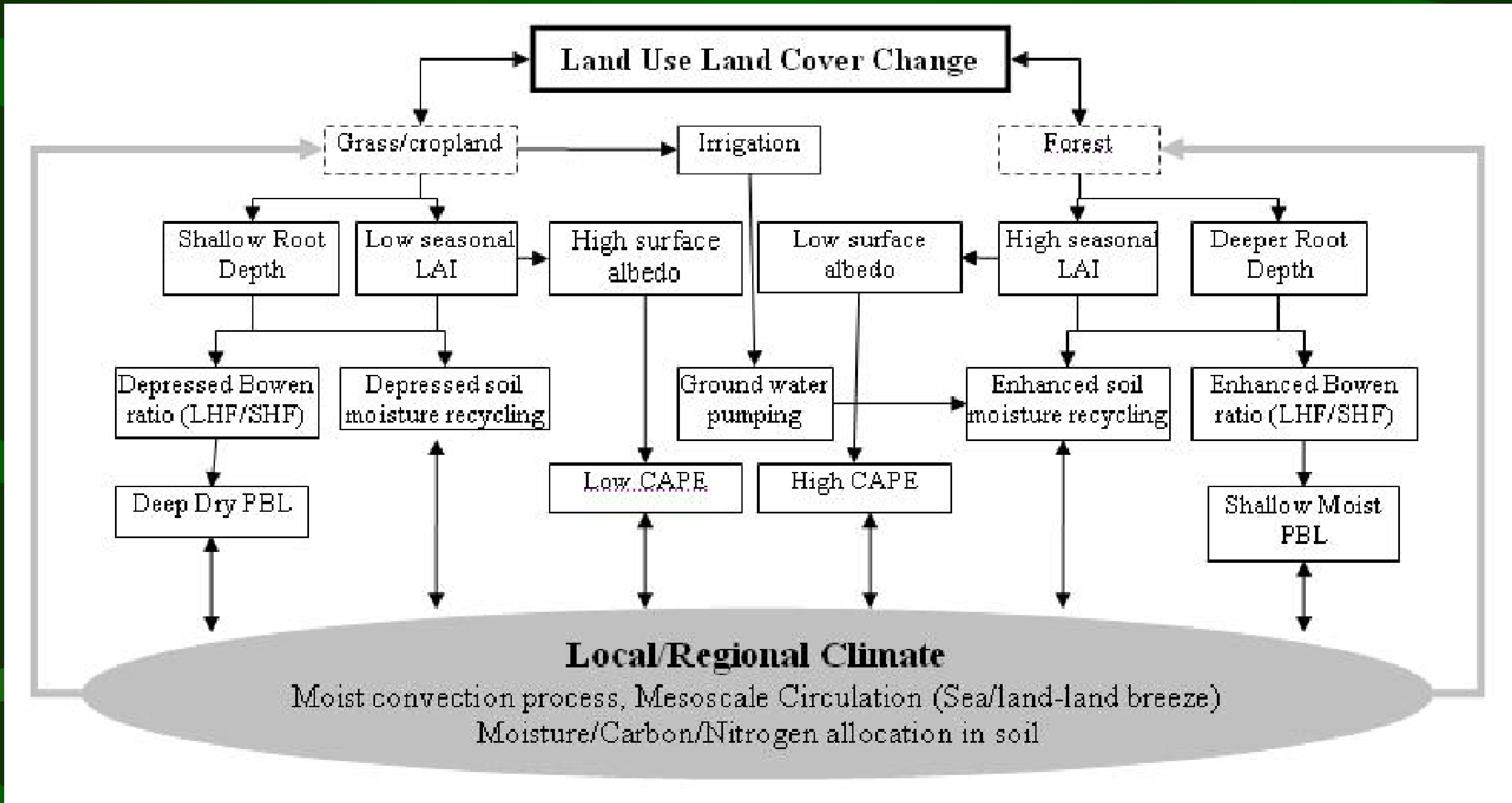


FIG. 15. Two-month average of the diurnal cycle of shelter-level temperature from the model simulations for Jul–Aug 1989 (a) averaged over all land grid points in the domain and (b) for a grid point in the Kissimmee River valley that is indicated by the "X" in Figs. 13 and 14.

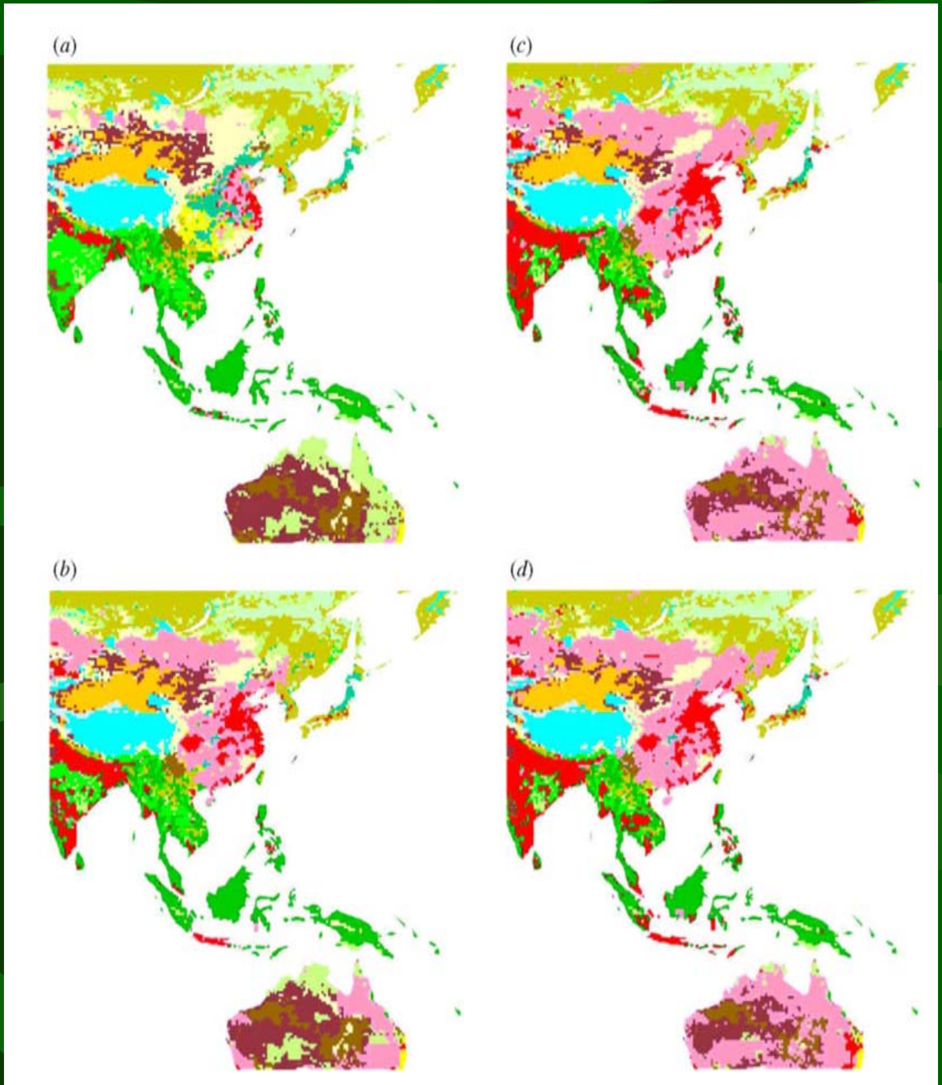
From: Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. *Mon. Wea Rev*., 132, 28-52.
http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf



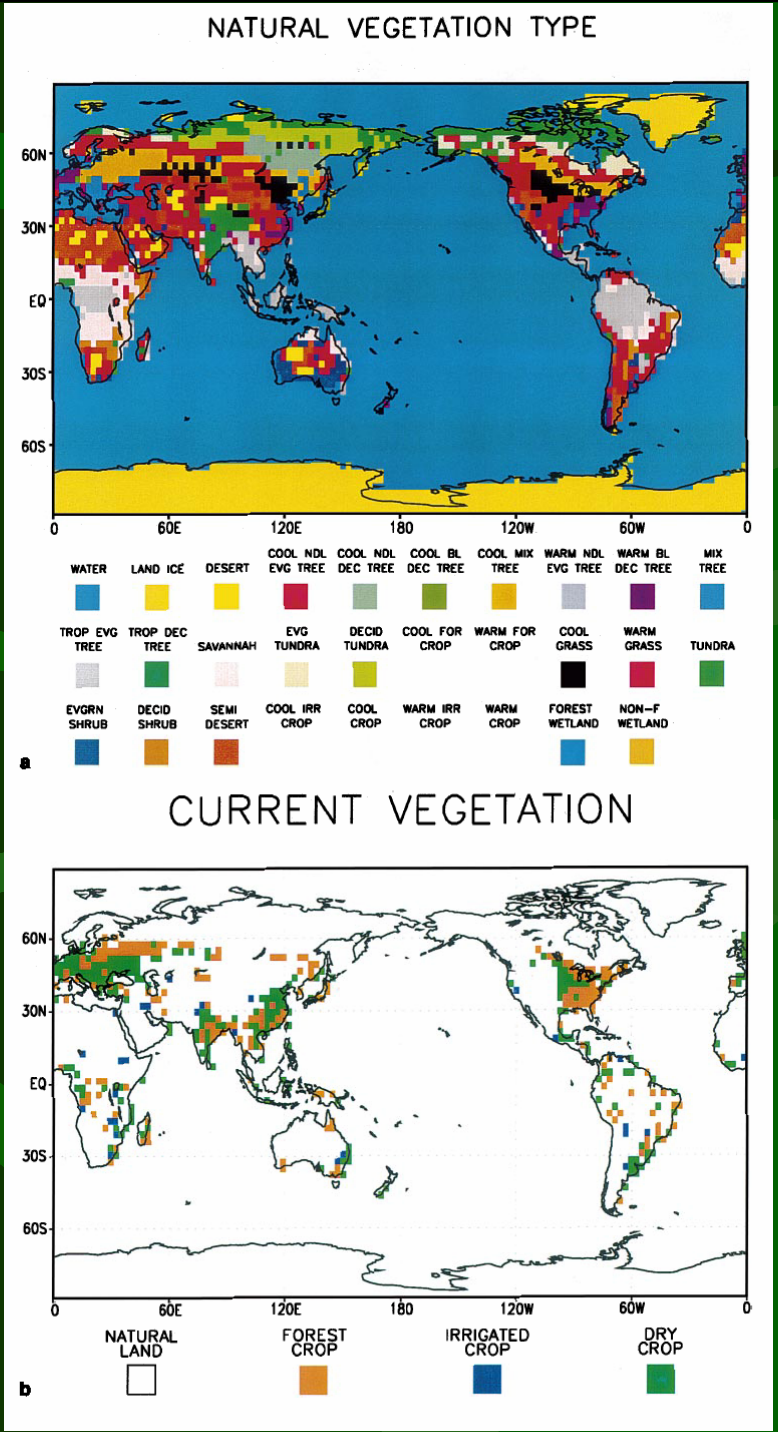
Hypotheses of the influence of LULCC on regional climate.

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

Global Effects of Landscape Change

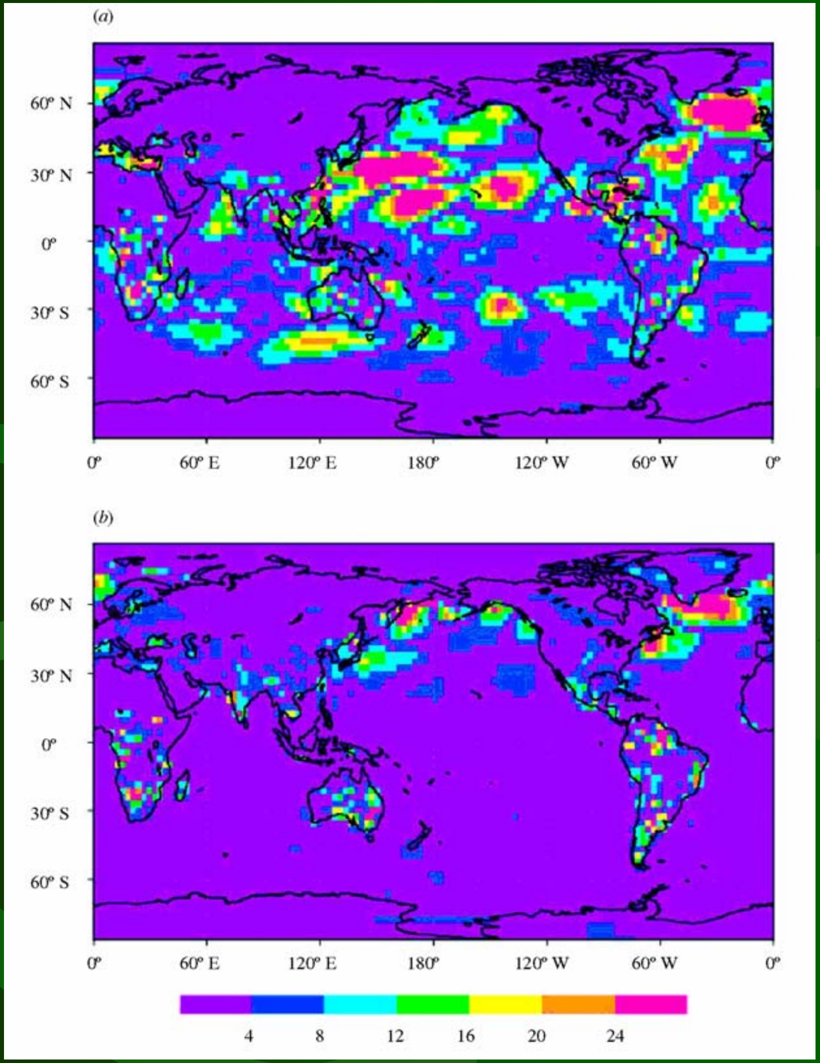


Examples of land-use change from (a) 1700, (b) 1900, (c) 1970, and (d) 1990. The human-disturbed landscape includes intensive cropland (red) and marginal cropland used for grazing (pink). Other landscape includes tropical evergreen forest and deciduous forest (dark green), savannah (light green), grassland 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.)



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). 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 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.)

Redistribution of Heat Due to the Human Disturbance of the Earth's Climate System

Globally-Average Absolute Value of Sensible Heat Plus Latent Heat		
Only Where Land Use Occurs	July January	1.9 Watts m^{-2} 0.7 Watts m^{-2}
Teleconnections Included	July January	8.9 Watts m^{-2} 9.5 Watts m^{-2}

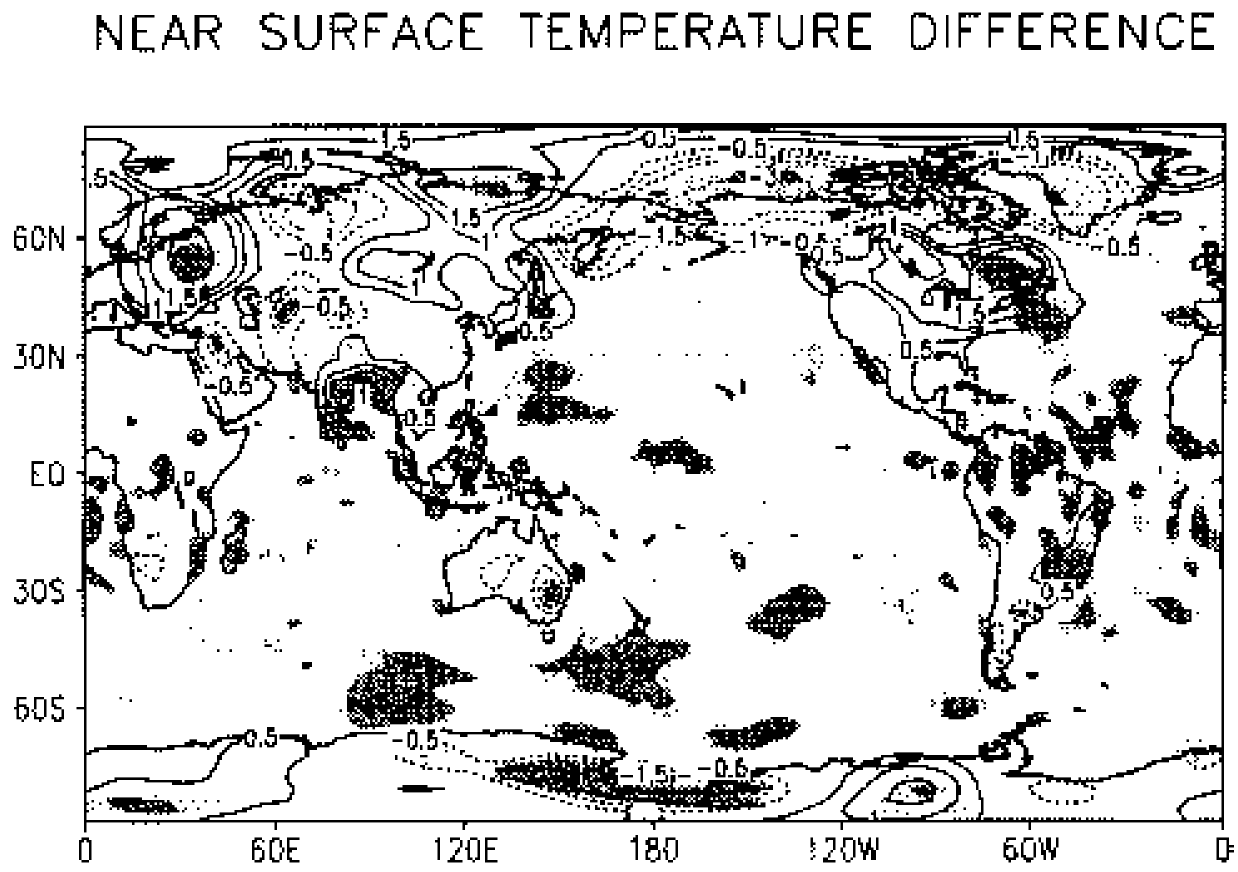
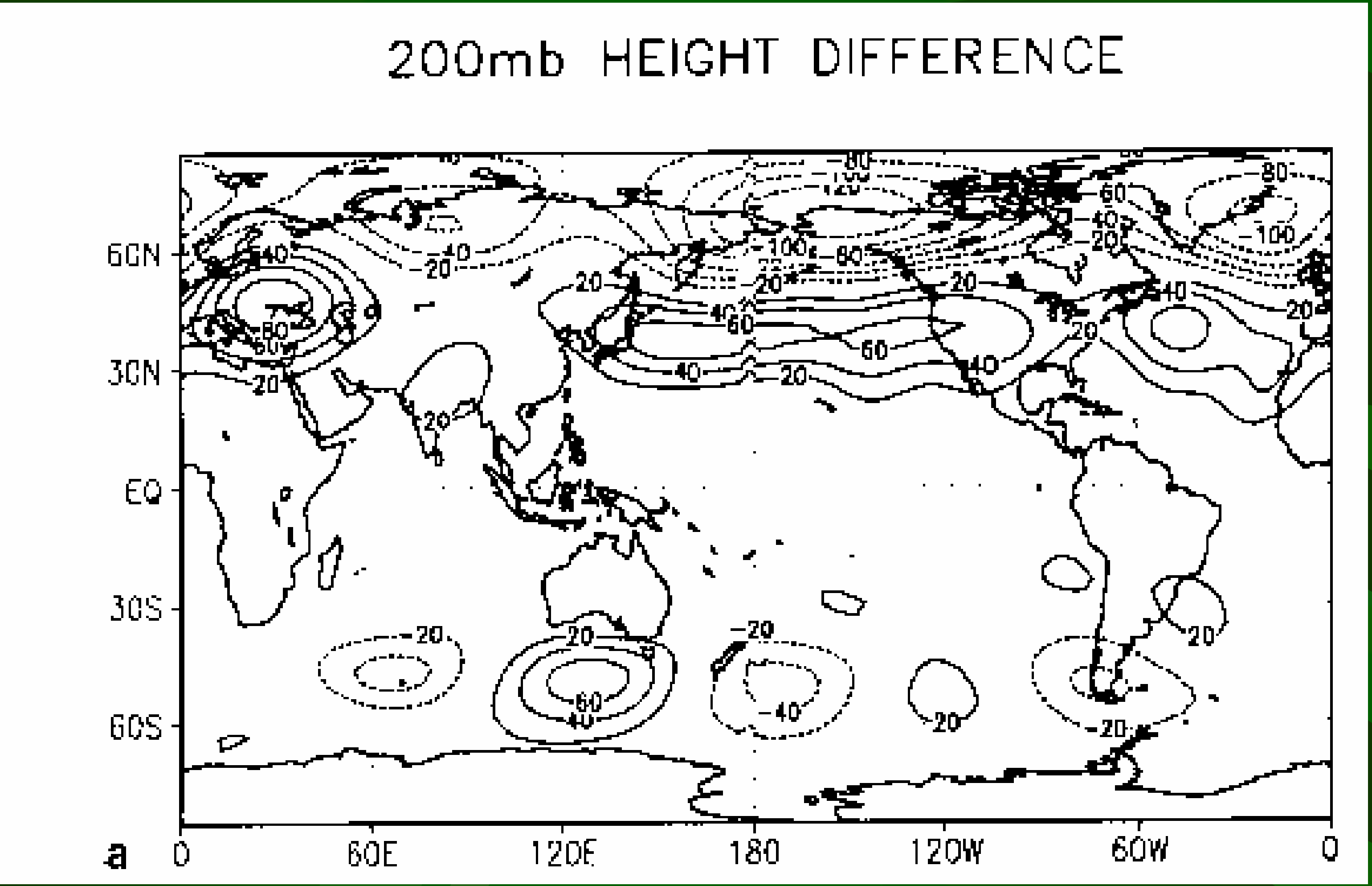


Fig. 11 Difference in near-surface air temperature (current-natural) using a 9-point spatial filter for easier visibility. Contours at 0.5, 1.0, 1.5, and 3.0 °C. *Shaded regions* as in Fig. 3

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

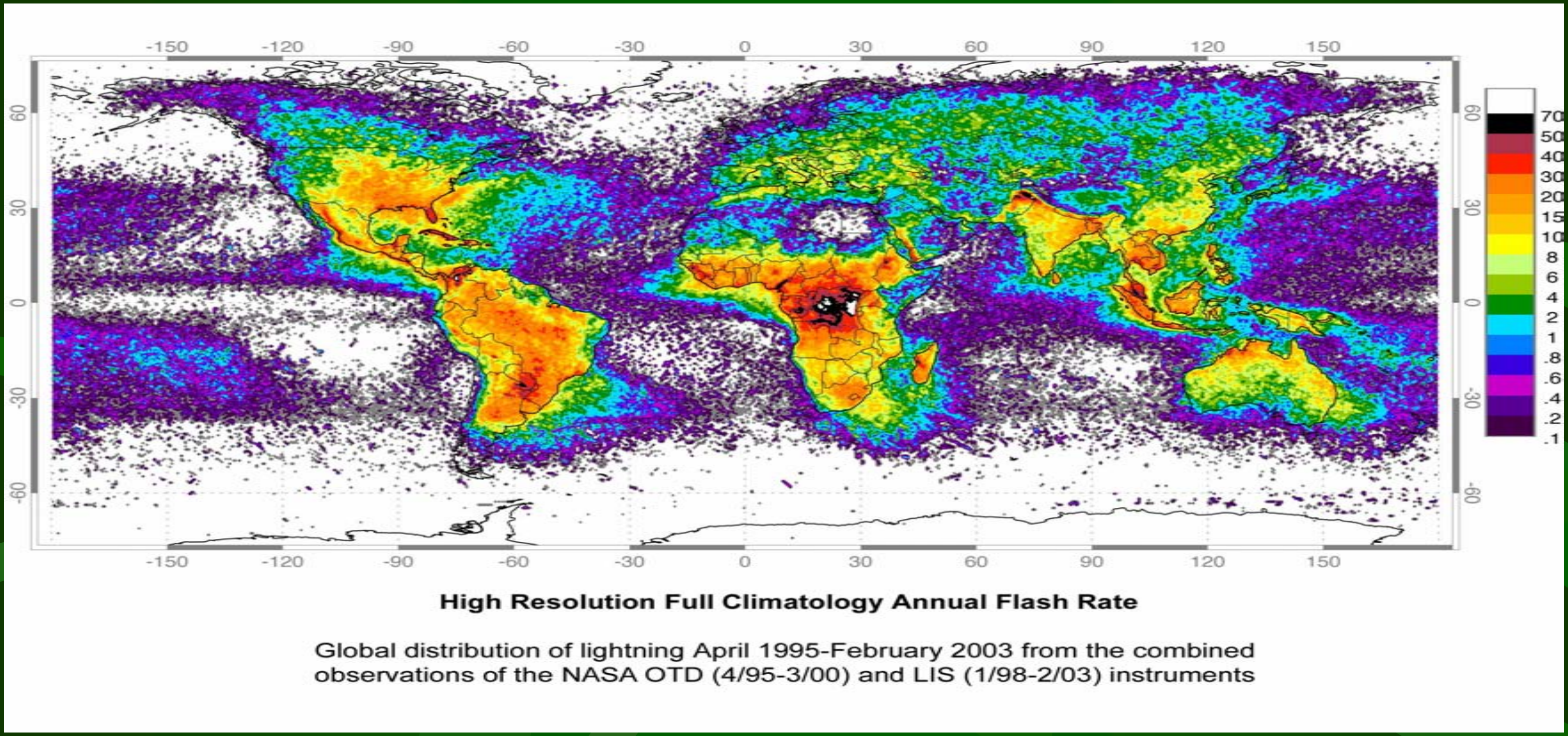
Why Should Landscape Effects, Which Cover Only a Fraction of the Earth’s Surface, Have Global Circulation Effects?

“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.

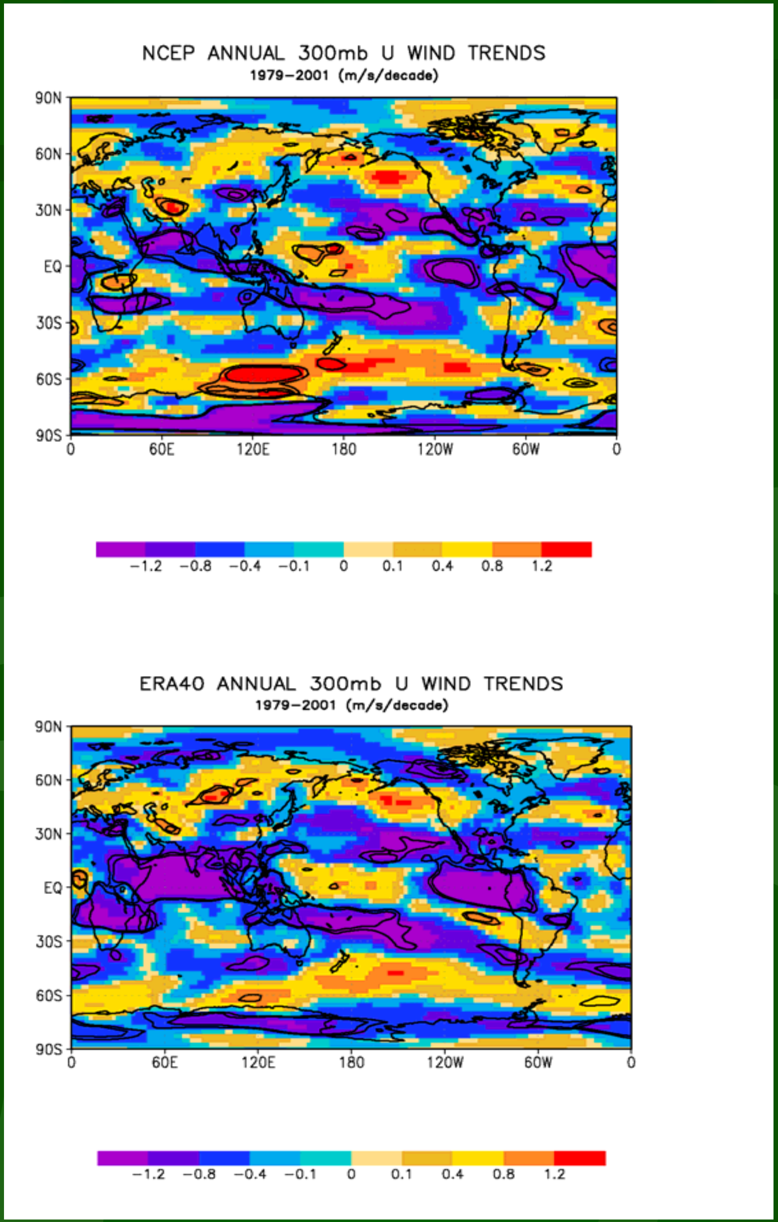
http://blue.atmos.colostate.edu/publications/pdf/R-231.pdf



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.

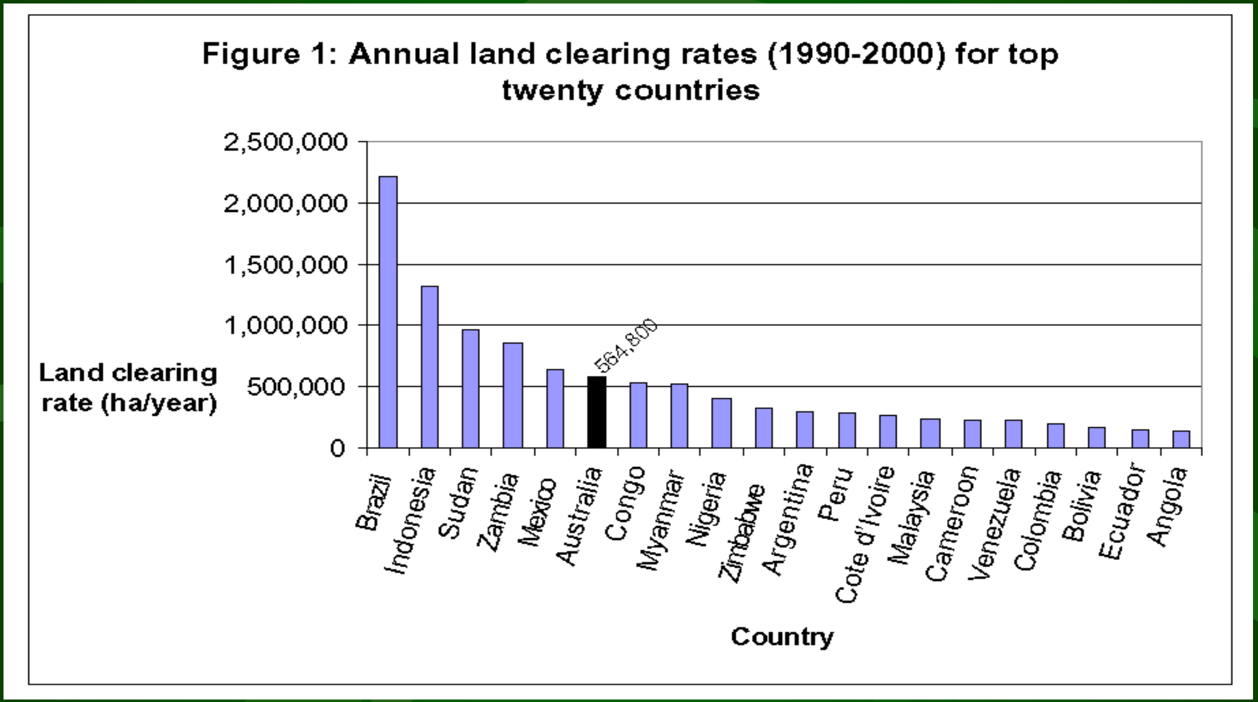
Global Climate Effects occur with ENSOs for the Following Reasons:

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.

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

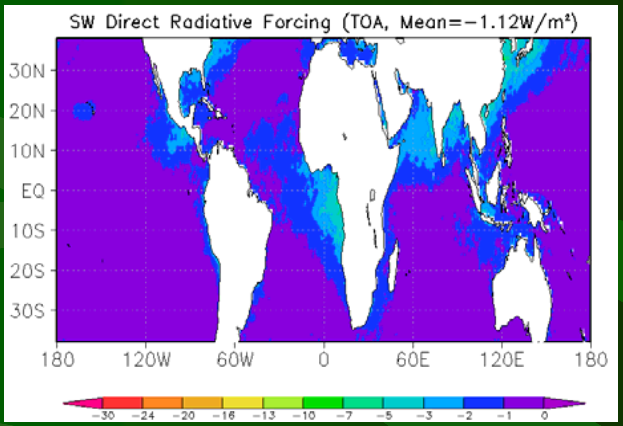
This Requires Spatial Analyses

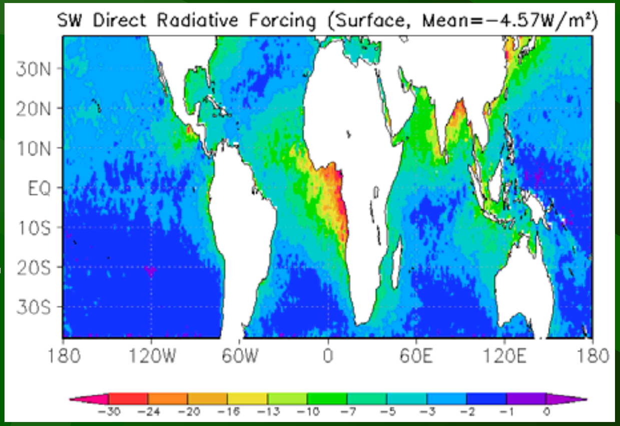
Example of Regional Forcings from Aerosol Climate Forcings

Aerosol Direct Solar Radiative Forcing

Experiment Setup

- Domain: Tropical ocean (lat = 37º S~ 37 º N)
- Period: 1st Mar 2000 ~ 28th Feb 2001
- Meteorology Forcing: Sounding [*McClatchey et al.* , 1972]
- Environment: clear sky conditions
- Radiative Transfer: Delta 4-stream CKD [*Fu and Liou* 1992]
- Ocean albedo: Spectral semi-empirical albedo [*Jin et al.* 2002]
- AOD: MODIS AOD at 0.55 and 0.875um
- Aerosol species and vertical profile: GOCART model
- Aerosol Direct Forcing: Current AOD (Sulfate, Organic Carbon, black carbon, *Sea Salt, Dust*) – Potential AOD (30% of Sulfate, 10% of Organic Carbon, *Sea Salt, Dust*)





Result

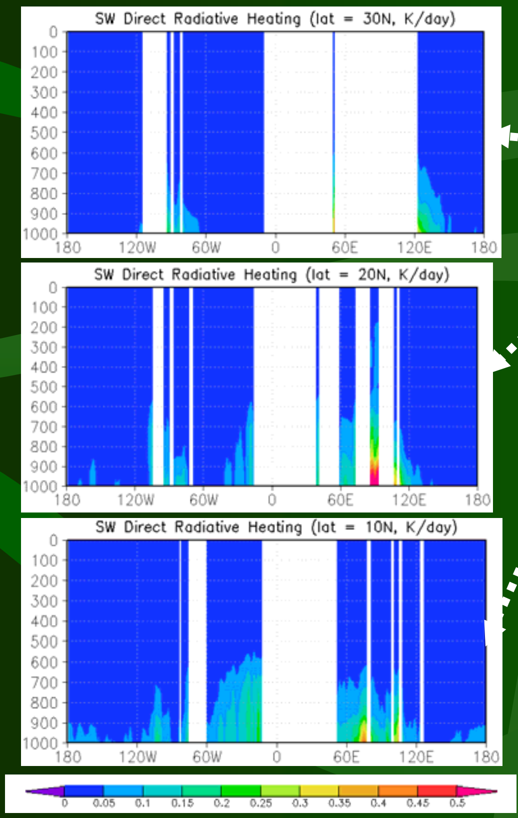
- Solar Radiative forcing is heterogeneous in space, ranging from 0 ~ -30 W/m^2 at surface level.
- Mean aerosol direct solar radiative forcing over tropical ocean is -1.12 and -4.57 W/m^2 at TOA and surface level, which are slightly different from those of Yu et al. [2004] (-1.3 and -3.6 W/m^2 at TOA, surface level), because our estimation focus on tropical ocean only.
- IPCC [2001] report the global mean aerosol direct forcing is in the range from -0.2 to -2.0 W/m^2 at TOA level.

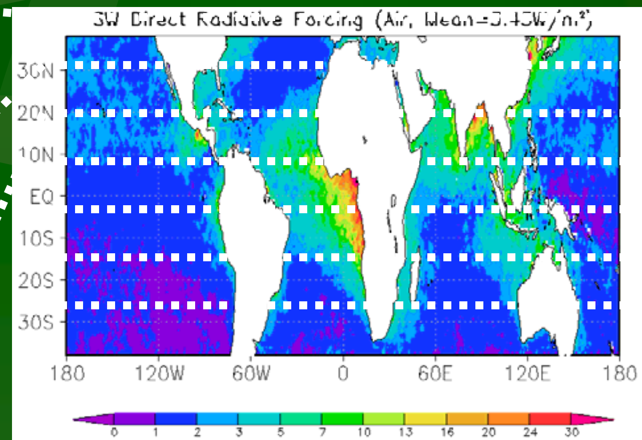
By Toshihisa Matsui @ CSU

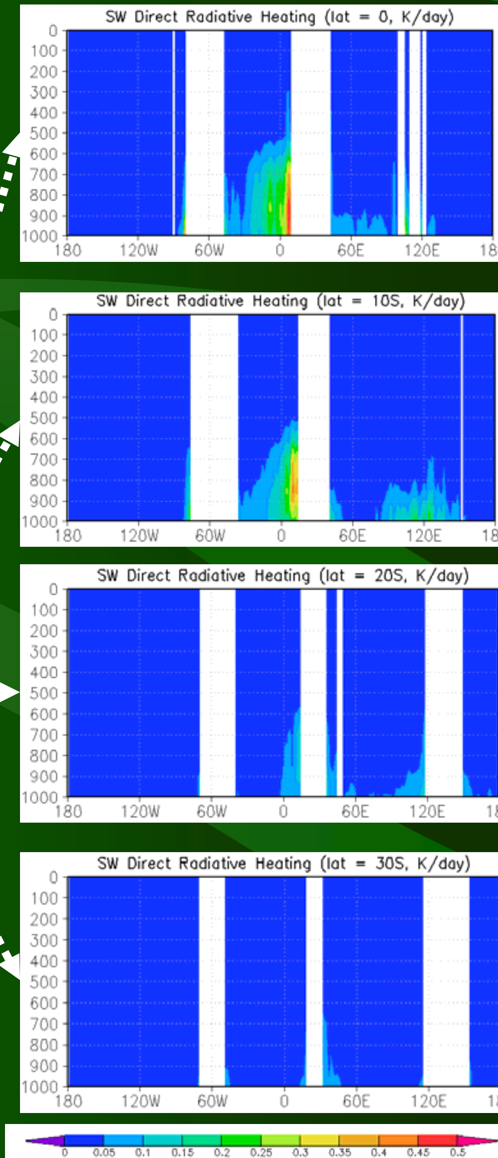
Aerosol Direct Solar Radiative Forcing

Vertical Profile of Aerosol Direct Atmospheric Heating

- Mean aerosol direct atmospheric heating in tropical ocean is 3.43 W/m^2, which is slightly higher than those of Yu et al. [2004] ($2.4 W/m^2$), because our estimation focus on tropical ocean only (more absorbing aerosol + smaller solar zenith angle).
- This diabatic heating can induce mesoscale-to-large scale circulations.
- South Asian brown haze induce atmospheric heating more than 20 W/m2, which is consistent to the INDOEX measurement.







- This diabatic heating can induce mesoscale-to-large scale circulations.
- Large heating extends up to 600mb near the equator.
- Heating up to 0.5 K/day in the boundary layer over the area of South Asian brown haze.

By Toshihisa Matsui @ CSU

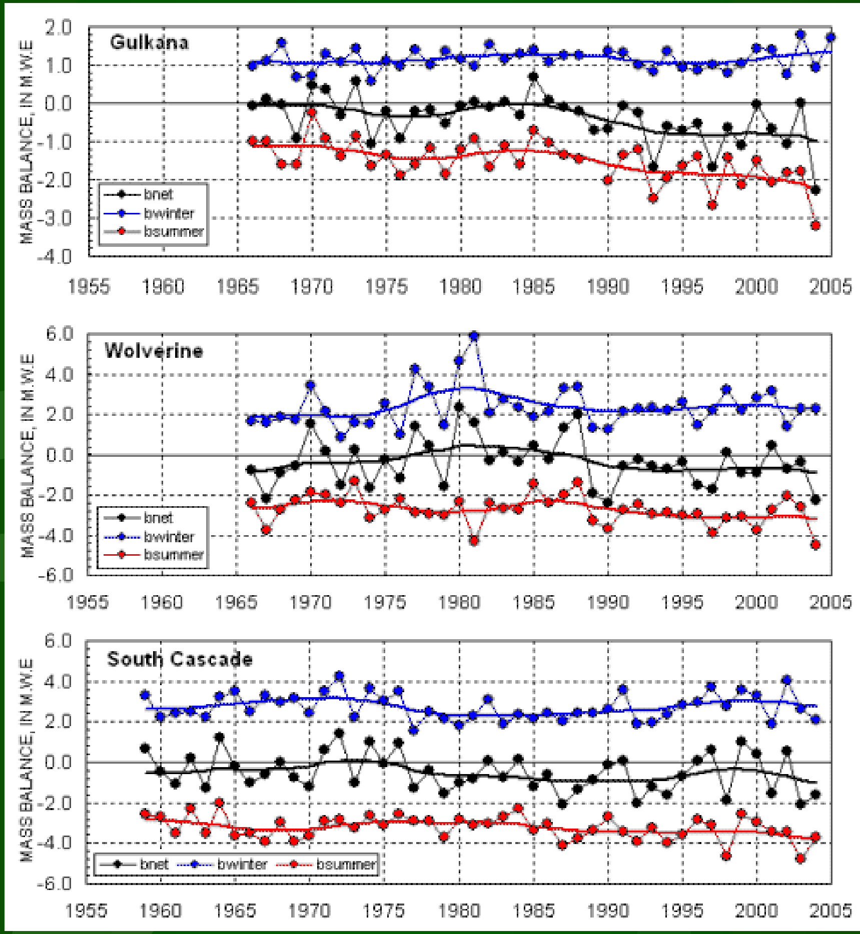
Reality Check With Climate Data

Three Examples Presented

- **Arctic Sea Ice**
- **Ocean Heat Content**
- **Glaciers**

http://blue.atmos.colostate.edu/courses/at786.shtml

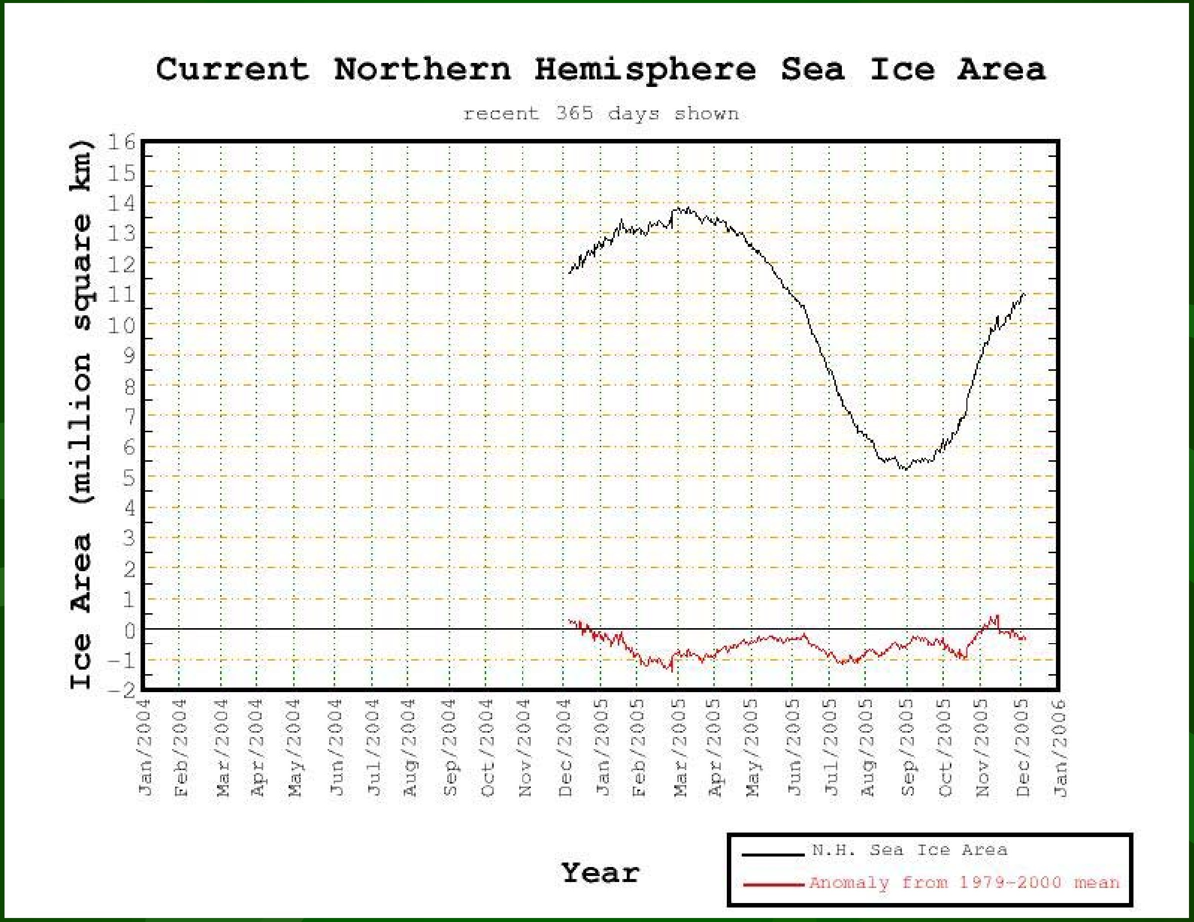
Glacier Mass Balance



Annual, net, and seasonal mass balance for three USGS benchmark glaciers.

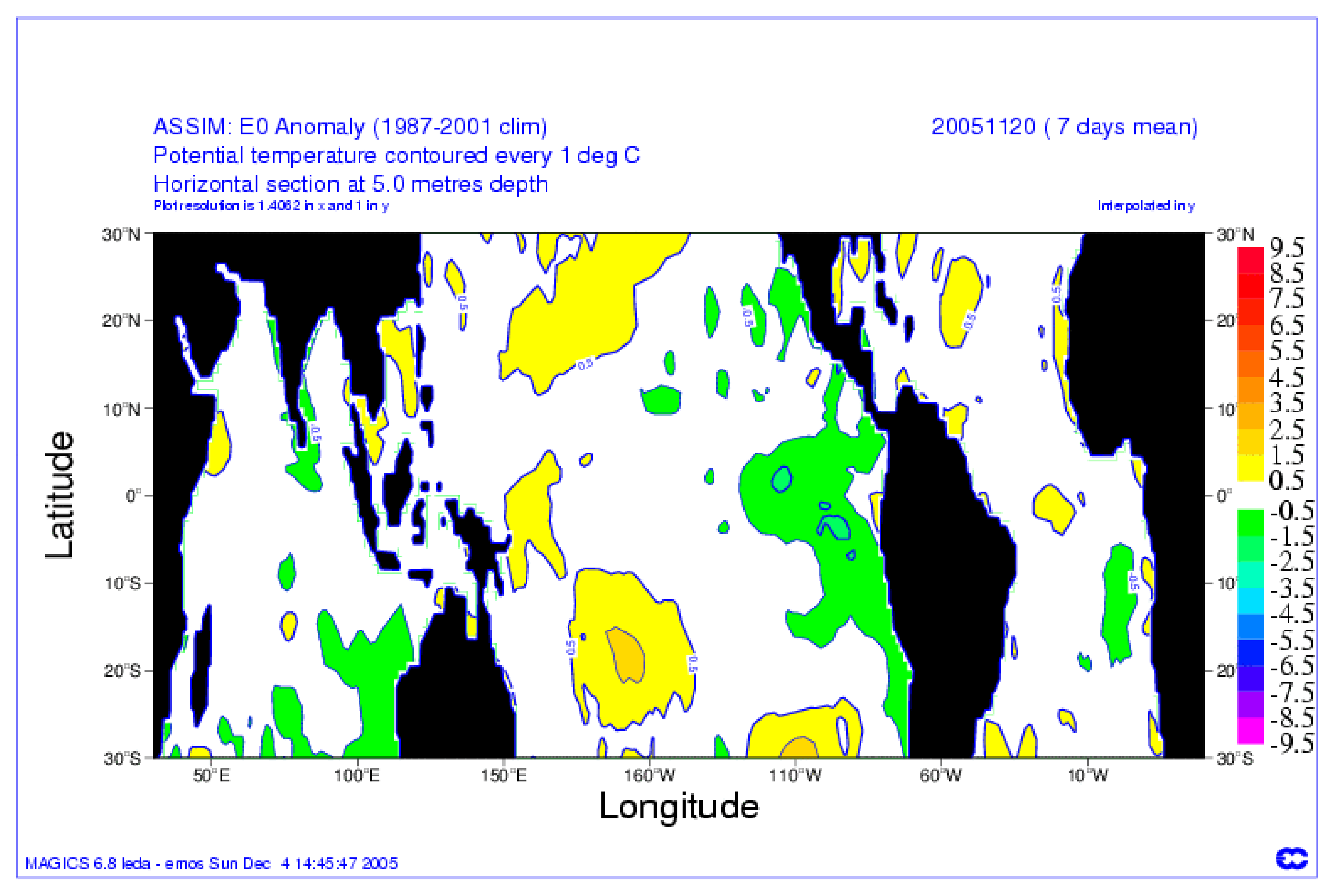
http://ak.water.usgs.gov/glaciology/all_bmg/3glacier_balance.htm

Arctic Sea Ice Area Anomaly



http://arctic.atmos.uiuc.edu/cryosphere/IMAGES/current.365.jpg

Ocean Heat Content Anomalies



http://www.ecmwf.int/products/forecasts/d/charts/seasonal/ocean/weekly_public/

Skillful multidecadal climate forecasts have not been demonstrated

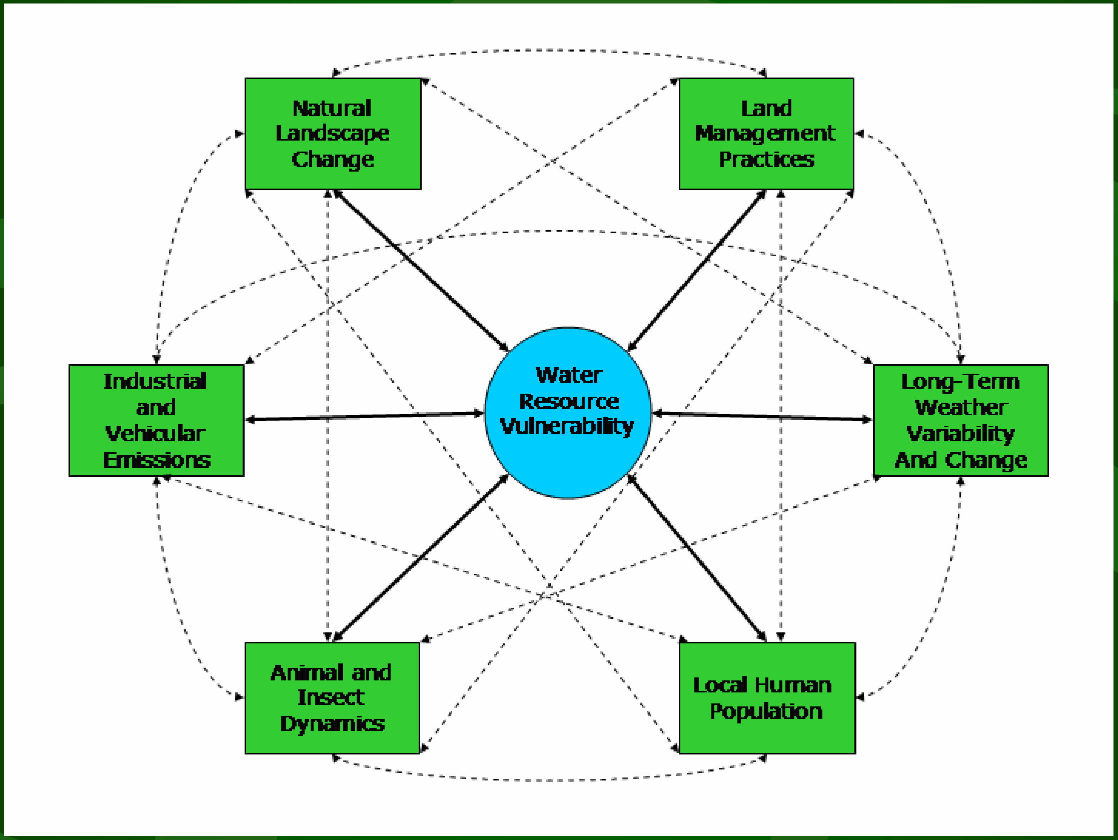
An inversion of the IPCC Assessment Procedure is needed

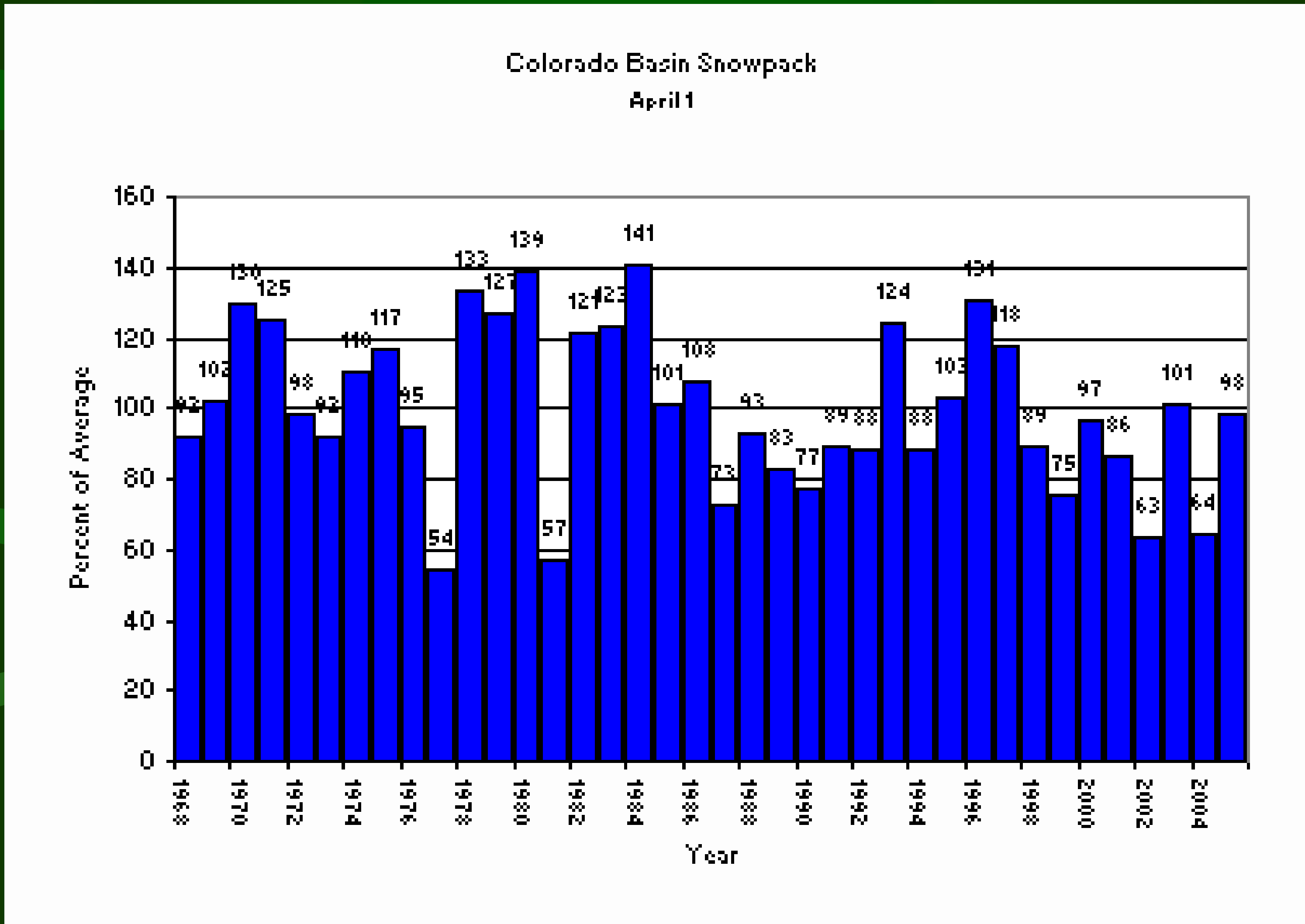
We need an approach that is more inclusive and scientifically defensible

An Alternate Paradigm is Needed

A Focus on Vulnerability

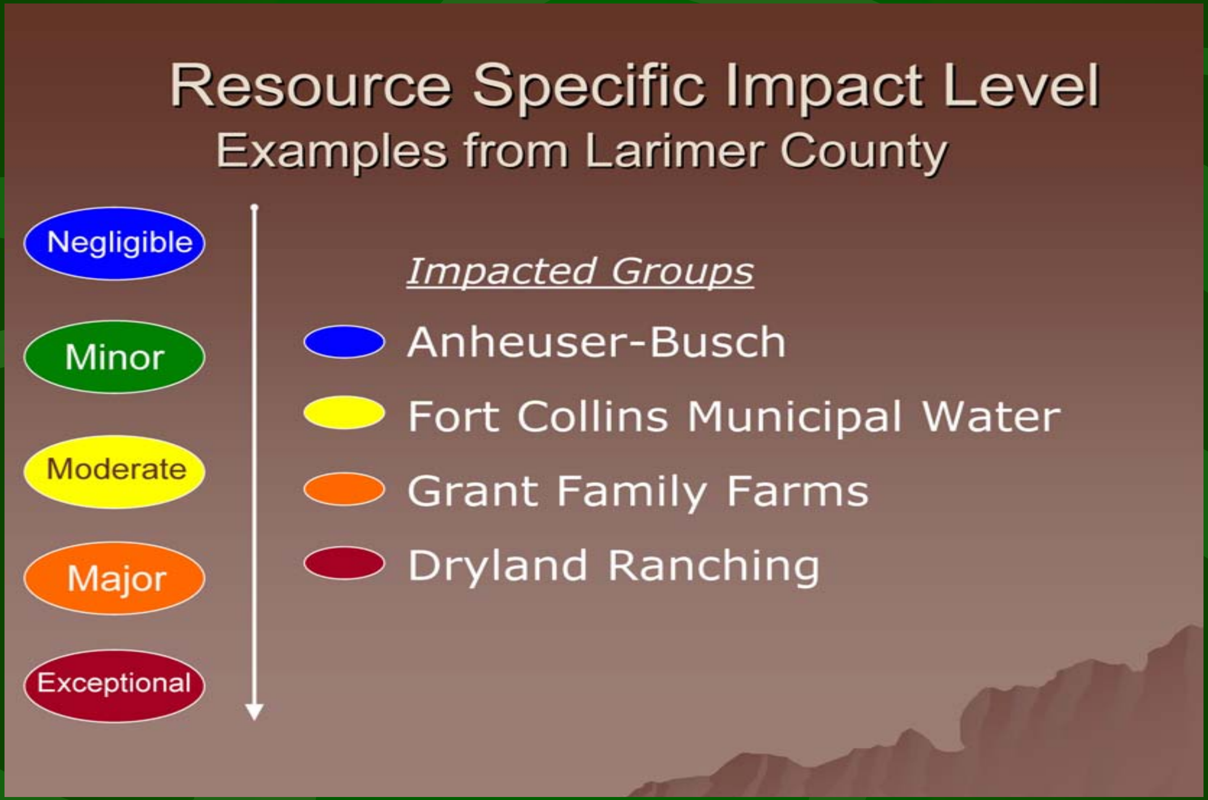
Schematic of the relation of water resource vulnerability to the spectrum of the environmental forcings and feedbacks (adapted from [3]). The arrows denote nonlinear interactions between and within natural and human forcings. From: Pielke, R.A. Sr., 2004: Discussion Forum: A broader perspective on climate 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.

PowerPoint Presentation Prepared by
Dallas Jean Staley
Research Coordinator
Colorado State University
Department of Atmospheric Science
Fort Collins, CO 80526