Climate system complexity and vulnerability approach: A broader perspective on climate change

Roger A. Pielke Sr., Professor and State Climatologist
Colorado State University and the University of Colorado

Hydrology Days

Fort Collins, Colorado, March 22, 2006

Global warming: Is it too late to save our planet?

By IAN JOHNSTON

from http://news.scotsman.com/features.cfm?id=76062006

- GLOBAL warming is irreversible and billions of people will die over the next century, one of the world's leading climate change scientists claimed yesterday. Professor James Lovelock, the scientist who developed the Gaia principle (that Earth is a self-regulating, interconnected system), claimed that by the year 2100 the only place where humans will be able to survive will be the Arctic.
- In a forthcoming book, The Revenge of Gaia, Lovelock warns that attempts to reduce levels of greenhouse gases in the atmosphere may already be too late.

'This is meant as a wake-up call'

PROFESSOR JOHN SCHELLNHUBER
Director of the Potsdam Institute for Climate Change Research

I KNOW James Lovelock and respect him tremendously. He's been one of the most influential scientists on the environment for many years now.

Everything he's writing has to be taken very seriously. It's not just some 'Doomsday' prediction.

I think this is really meant as a wake-up call - among the many scenarios about the future of the planet. If we do not really fight global warming, then this is certainly in the upper range of catastrophe, the worst-case scenario.

The probability of the scenario is pretty low, but it cannot be completely ruled out.

Many human lives are at stake if we don't do anything about global warming.

If there was five or six degrees Celsius of warming over the century, that would be a different world.

It is a very extreme scenario he is using, but we are at least on the road towards disaster.

'It is bad news as it stands'

DR DAVID VINER

Senior research scientist, Climatic Research Unit, University of East Anglia

CLIMATE change poses a big threat. I think Professor Lovelock is over-cooking it slightly, but even if you look at the scientific consensus, the rate of warming is going to cause significant problems. It's bad news as it stands and it is going to cause major problems.

We may get a runaway greenhouse effect, but, at the moment, we just don't know. It would be unwise for governments to throw in the towel now.

We do need to make sure we reduce carbon dioxide emissions. We have a responsibility to stabilise greenhouse gases in the atmosphere and, in the very long term, reduce them.

The scientific community have been telling the government to wake up to this for a while.

We may instigate feedback responses [in the environment] that may enhance the warming, but I'm not a big advocate of the Gulf Stream switching off. That will take a lot more warming than is probably happening. That's way over the top.

Hans Blix MTV Interview

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.

http://www.mtv.com/bands/i/iraq/news_feature_031203/index5.jhtml

The Observer

<u>Now the Pentagon Tells Bush: Climate Change Will Destroy Us</u>

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….

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International

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
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The Observer

Online
For the latest internet news click here

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

A secret report, suppressed by US defence chiefs and obtained by The Observer, warns that major European cities will be sunk beneath rising seas as Britain is plunged into a 'Siberian' climate by 2020. Nuclear conflict, mega-droughts, famine and widespread rioting will erupt across the world.

The document predicts that abrupt climate change could bring the planet to the edge of anarchy as countries develop a nuclear threat to defend and secure dwindling food, water and energy supplies. The threat to global stability vastly eclipses that of terrorism, say the few experts privy to its contents.

'Disruption and conflict will be endemic features of life,' concludes the Pentagon analysis. 'Once again, warfare would define human life.'

The findings will prove humiliating to the Bush administration, which has repeatedly denied that climate change even exists. Experts said that they will also make unsettling reading for a President who has insisted national defence is a priority.

The report was commissioned by influential Pentagon defence adviser Andrew Marshall, who has held considerable sway on US military thinking over the past three decades. He was the man behind a sweeping recent review aimed at transforming the American military under Defence Secretary Donald Rumsfeld.

Climate change 'should be elevated beyond a scientific debate

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The Observer
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The Coming Meltdown
A Review by Bill McKibben

But the hurricanes also demonstrated another fact about global warming, this one having nothing to do with chemistry or physics but instead with politics, journalism, and the rituals of science. Climate change somehow seems unable to emerge on the world stage for what it really is: the single biggest challenge facing the planet, the equal in every way to the nuclear threat that transfixed us during the past half-century and a threat we haven't even begun to deal with. The coverage of Katrina's aftermath, for instance, was scathing in depicting the Bush administration's incompetence and cronyism; but the President -- and his predecessors -- were spared criticism for their far bigger sin of omission, the failure to do anything at all to stanch the flood of carbon that America, above all other nations, pours into the atmosphere and that is the prime cause of the great heating now underway. Though Bush has been egregious in his ignorance about climate change, the failure to do anything about it has been bipartisan; Bill Clinton and Al Gore were grandly rhetorical about the issue, but nonetheless presided over a 13 percent increase in America's carbon emissions.

From The New York Review of Books, January 12, 2006
http://www.nybooks.com/articles/18616

Views of Climate Change Science

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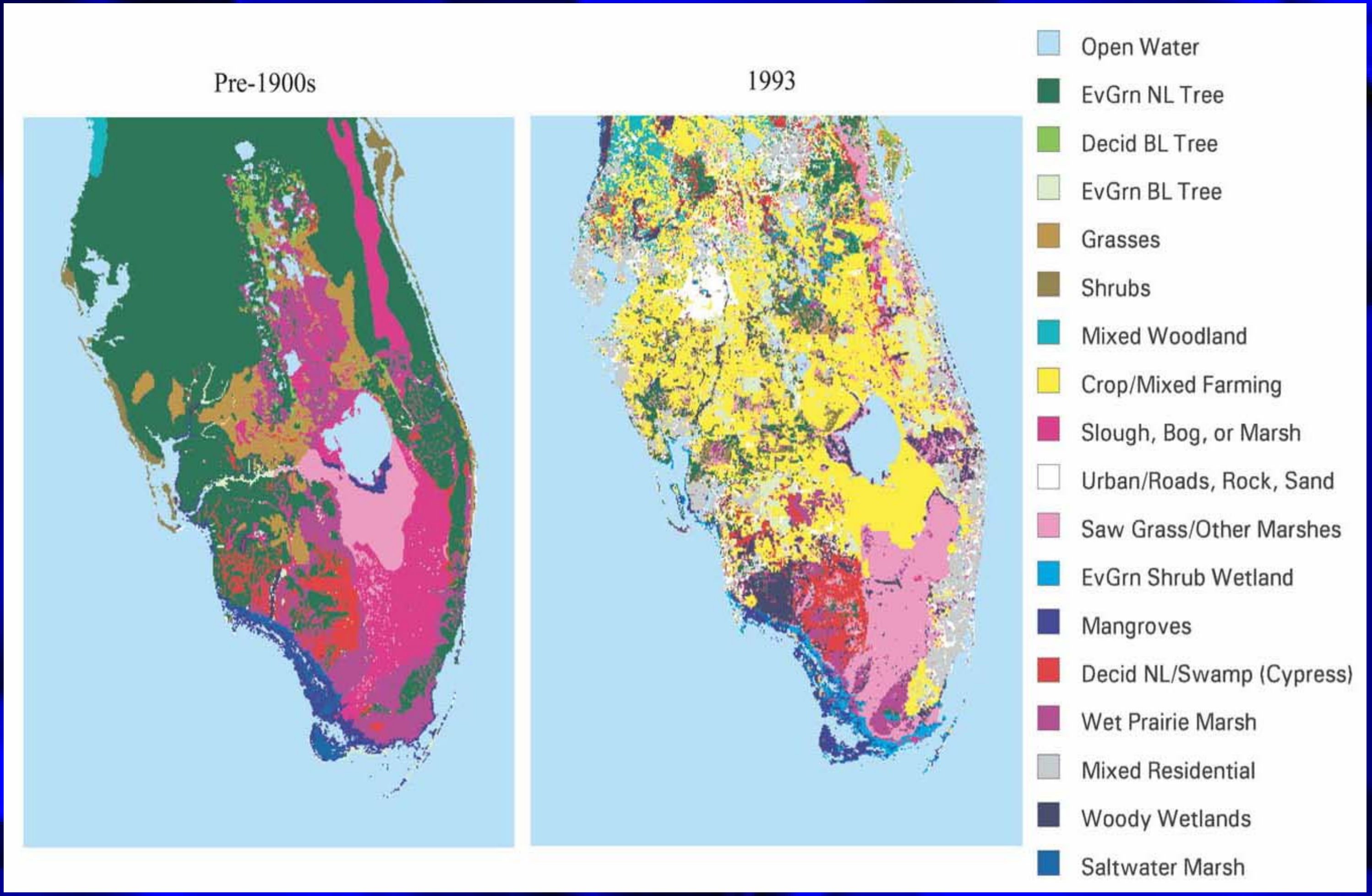
- Climate change including regional impacts can be skillfully predicted by knowledge of the concentration of well-mixed greenhouse gases.
- Surface temperatures are the most appropriate metric to assess “global warming.”
- The global average temperature provides a useful assessment of climate.
- The 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.**

Environmental Doomsday Clock (Perception of the Crisis Facing Human Survival)

In Developed Regions – Global Warming

In Developing Regions – Deforestation, desertification, loss of biodiversity.



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

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

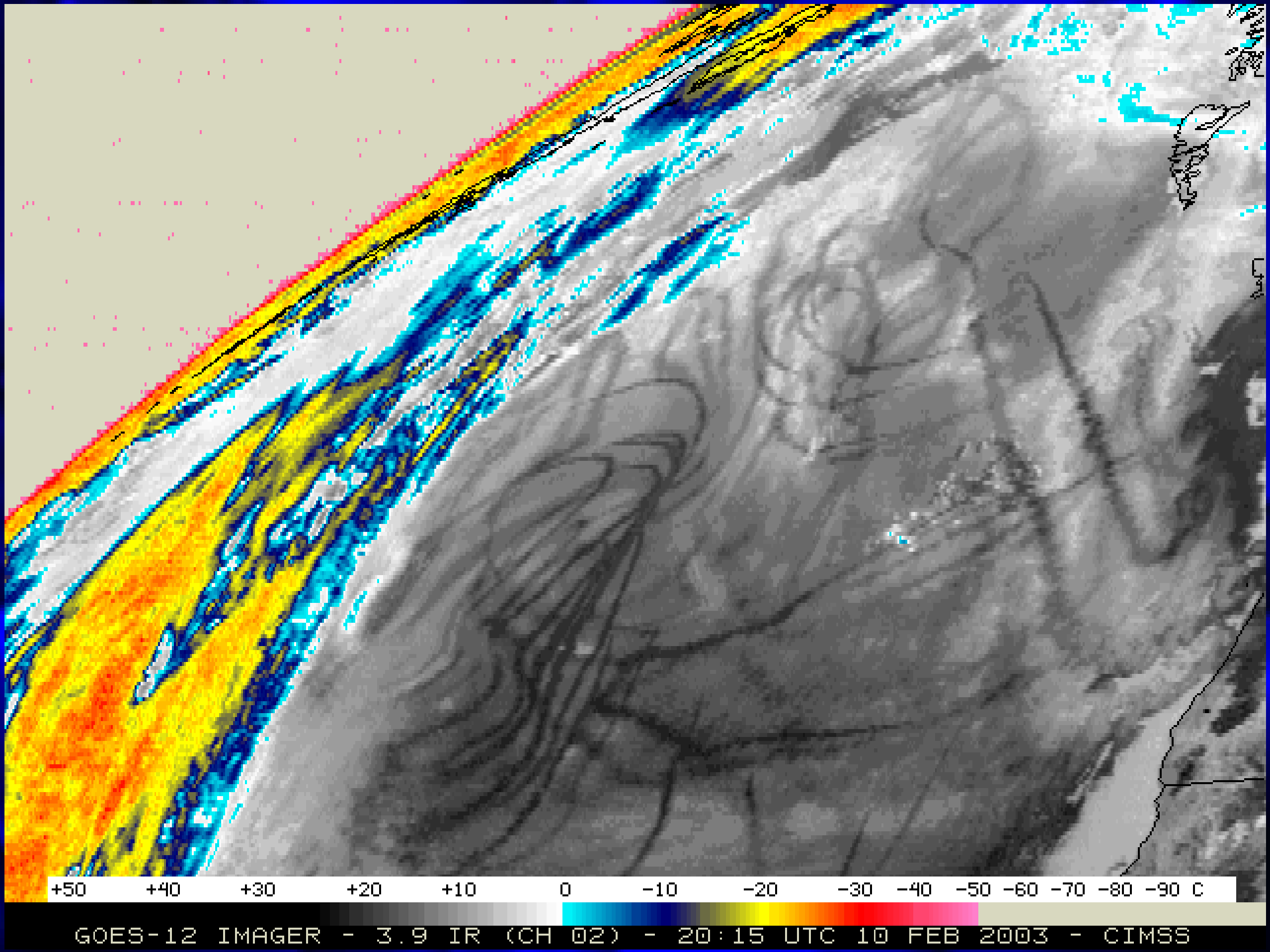
These effects alter not only the global radiative fluxes but the regional structure of spatial heating and cooling.

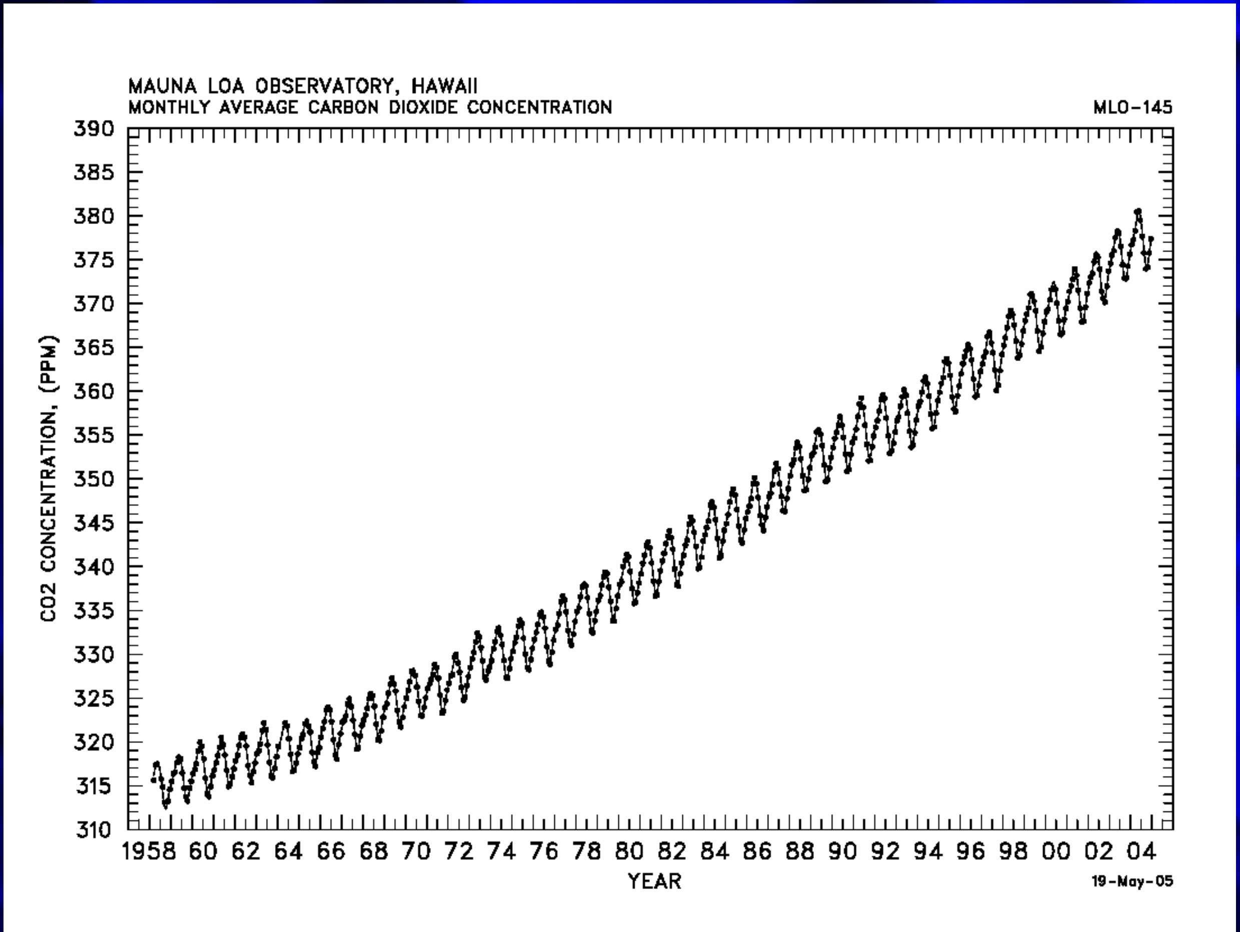
Example of a pyrocumulus cloud (copyright 2001, Axel Thielmann).

Example of industrial emissions from a smokestack

From http://earthobservatory.nasa.gov/Laboratory/Aerosol/Images/anthro_smokestack.jpg

GOES-12 imagery over the northern East Pacific Ocean on 10 February 2003. Particles in the exhaust plumes of ships tend to act as cloud condensation nuclei (CCN), creating streaks consisting of smaller cloud droplets within the pre-existing cloud deck. The resulting changes in the emissivity of the marine layer stratocumulus are easily detected using the 3.9 micrometer (shortwave)IR channel data. The ship tracks exhibit a colder 3.9 micrometer Infrared (IR) brightness temperature at night (above, darker blue enhancement), while during daylight hours these features exhibit a warmer brightness temperature (below, darker gray enhancement) due to this channel's sensitivity to the component of reflected sunlight (Image courtesy of the Cooperative Institute for Research in the Atmosphere website original imagery from the NOAA/NESDIS Forecast Products Development Team.)

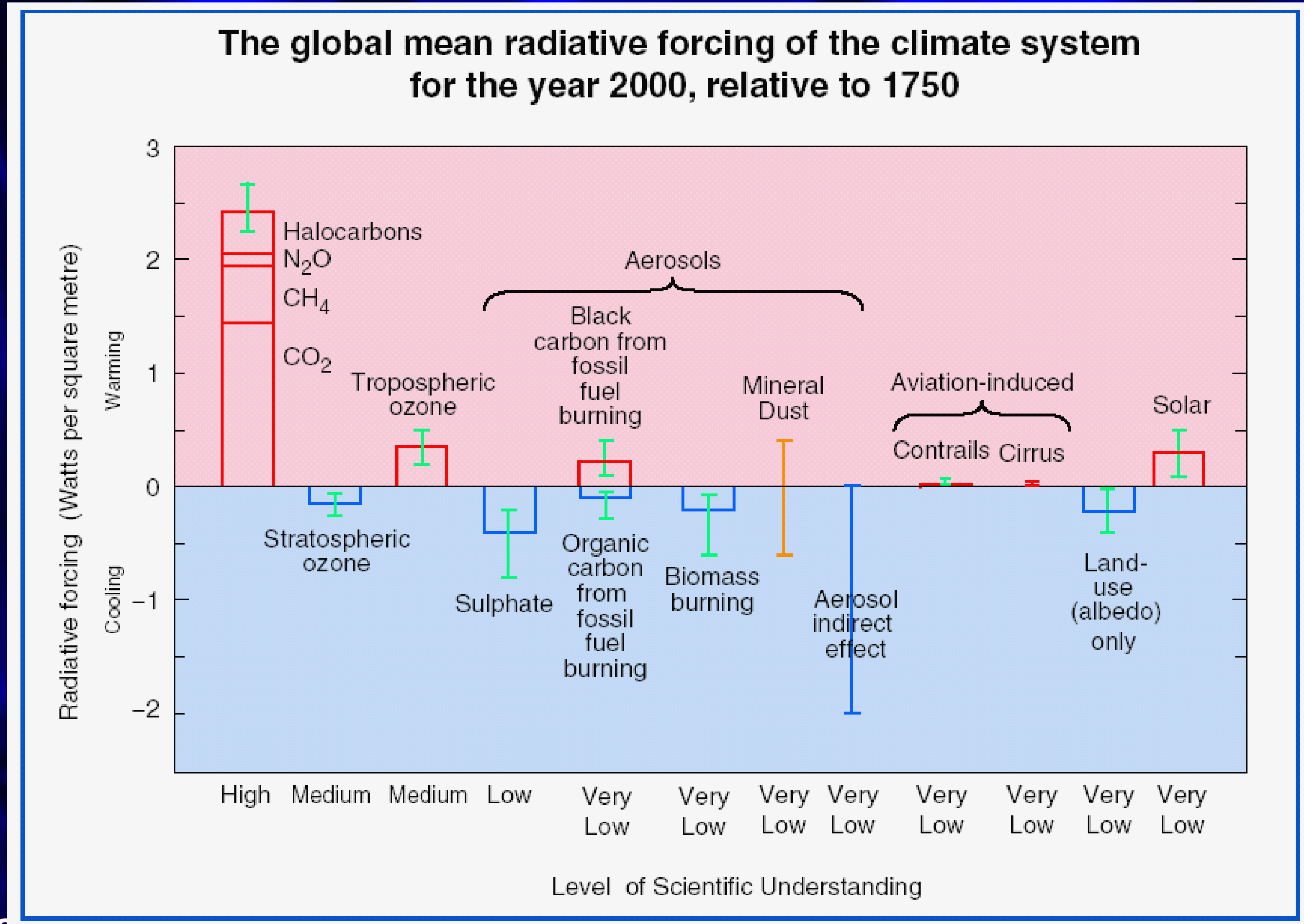




Atmospheric carbon dioxide record from Mauna Loa. C.D. Keeling and T.P. Whorf, Carbon Dioxide Research Group, Scripps Institution of Oceanography, University of California, La Jolla, California 92093-0444. Period of Record, 1958-2004

http://cdiac.esd.ornl.gov/trends/co2/graphics/mlo145e_thrudc04.pdf

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.

NRC 2005 Perspective

Breath of Fresh Air

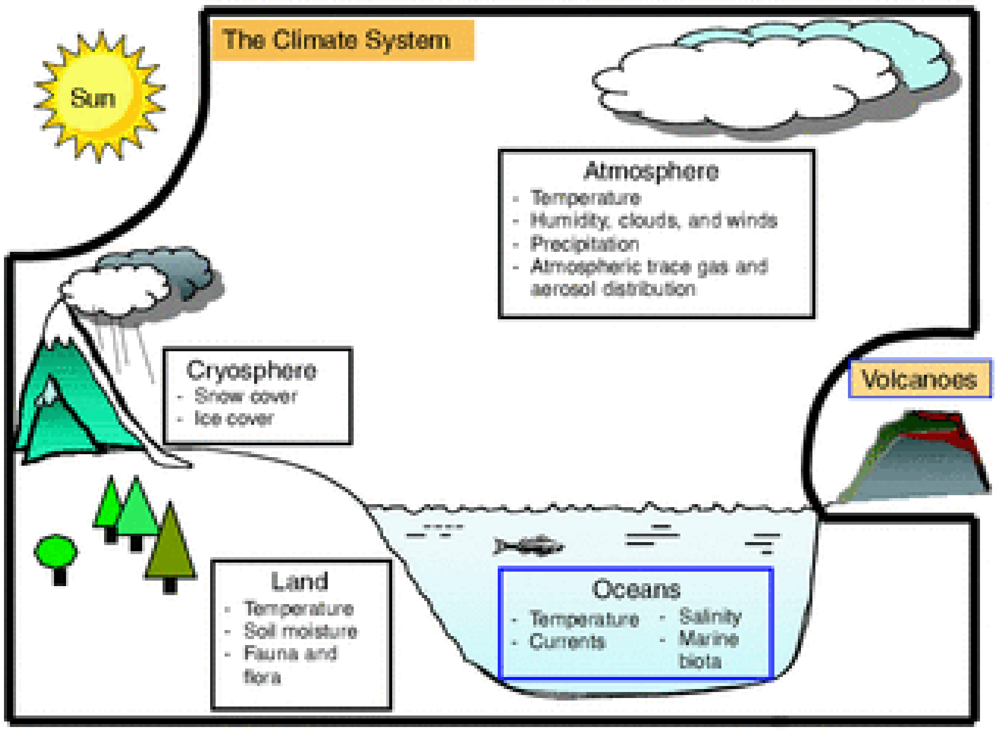


FIGURE 1-1 The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes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

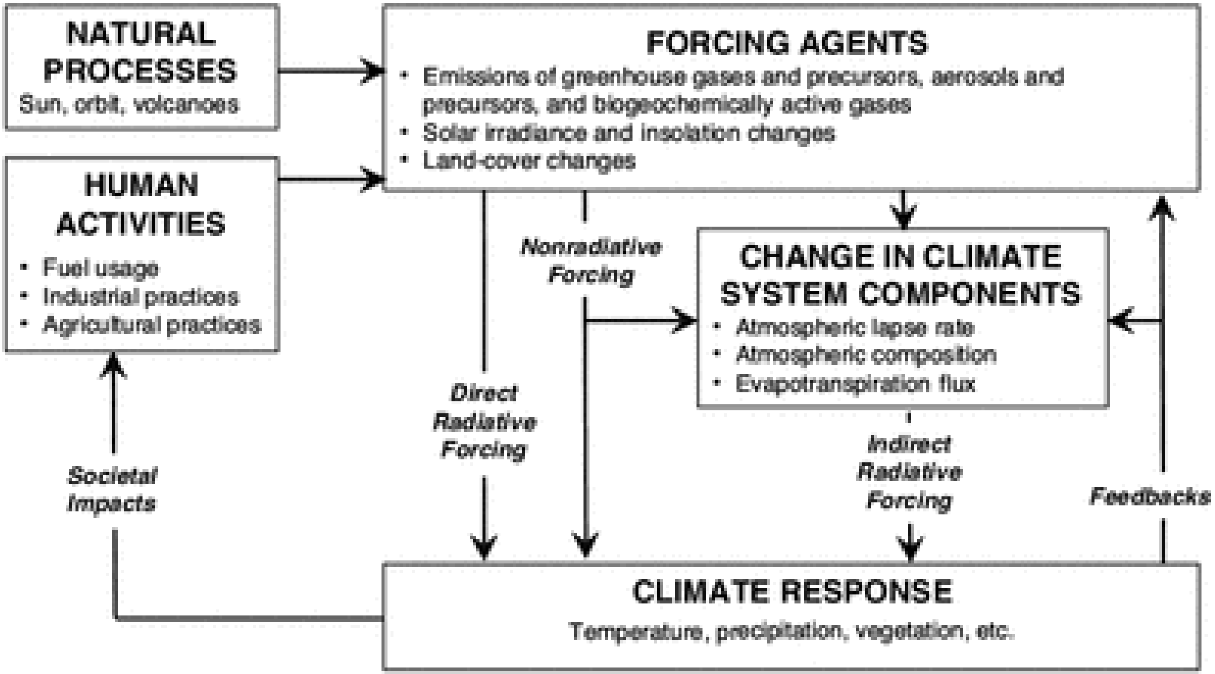


FIGURE 1-2 Conceptual framework of climate forcing, response, and feedbacks under present-day climate conditions. Examples of human activities, forcing agents, climate system components, and variables that can be involved in climate response are provided in the lists in each box.

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.
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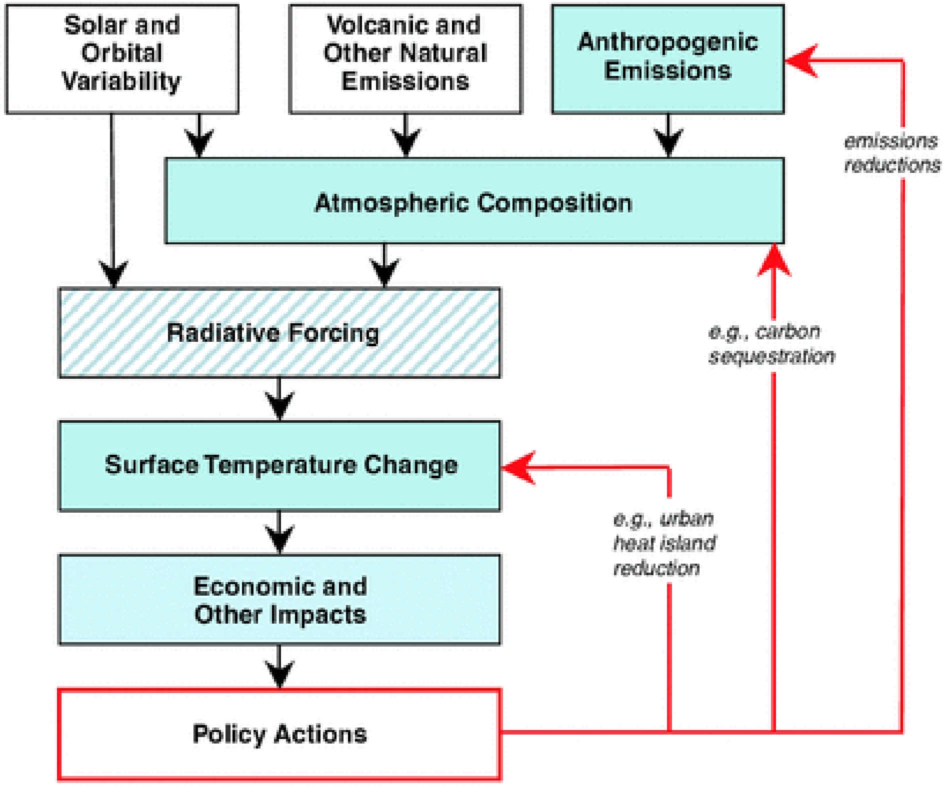


FIGURE 1-4 Conceptual framework for how radiative forcing fits into the climate policy framework. Blue-shaded boxes indicate quantities that have been considered as policy targets in international negotiations and other policy analyses. Radiative forcing (striped box) has not been treated as a policy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

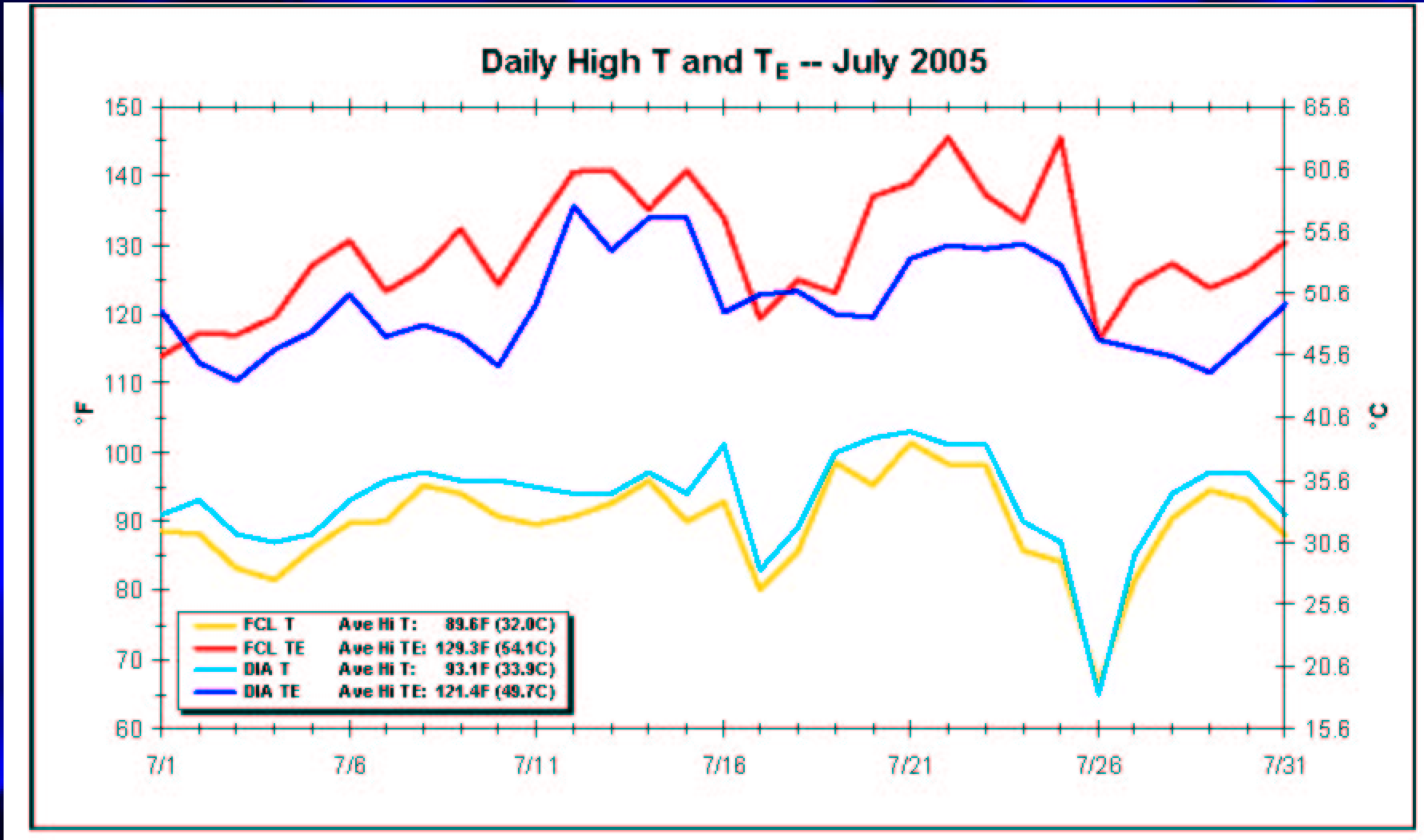
Missing Land - Atmosphere Surface Data Issues

- 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

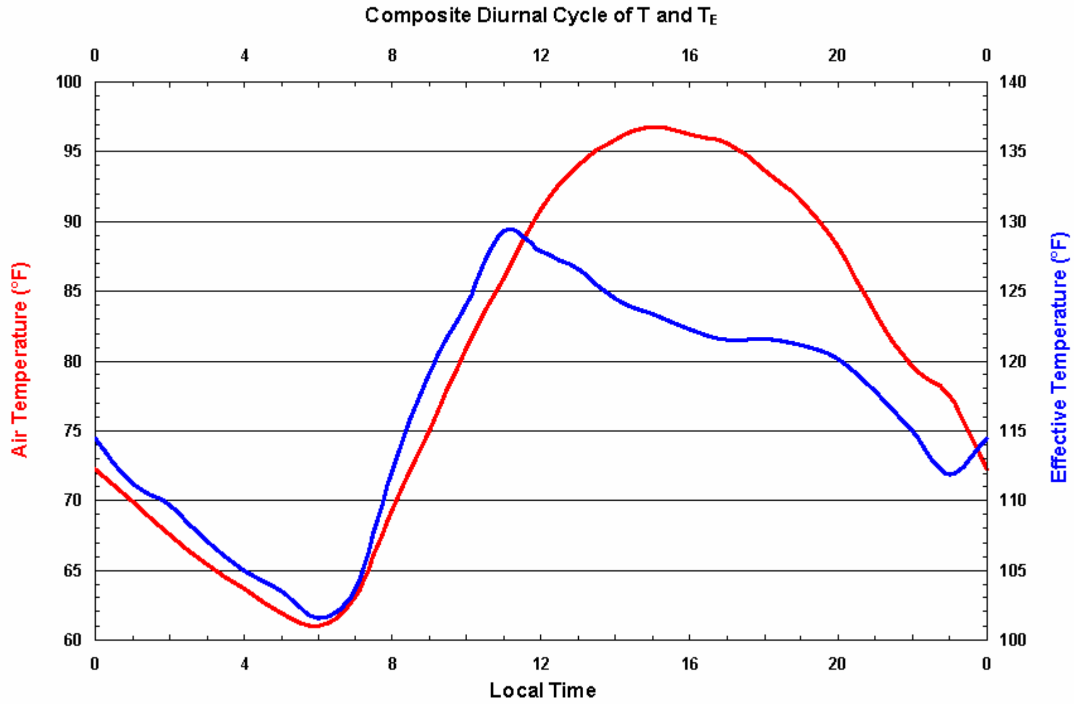
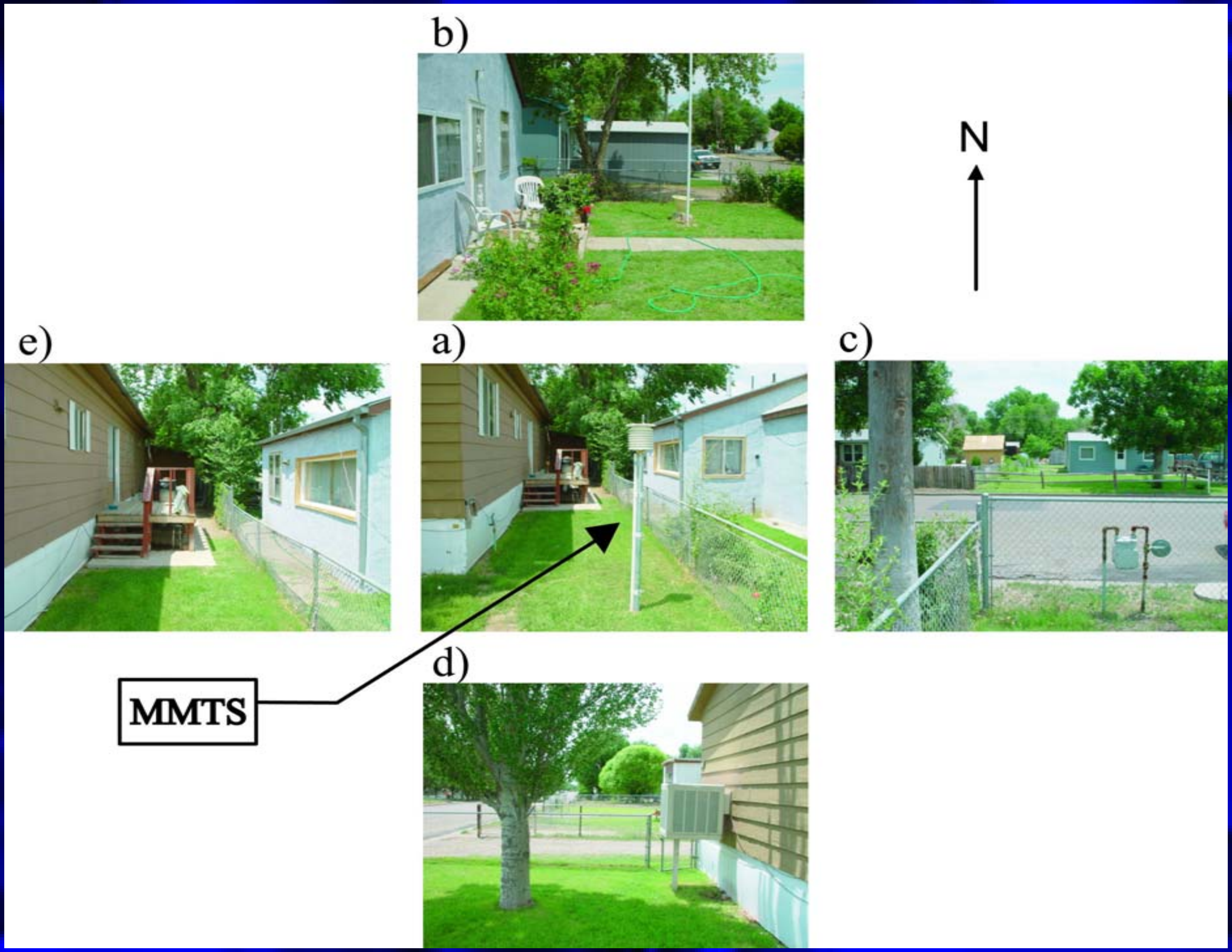


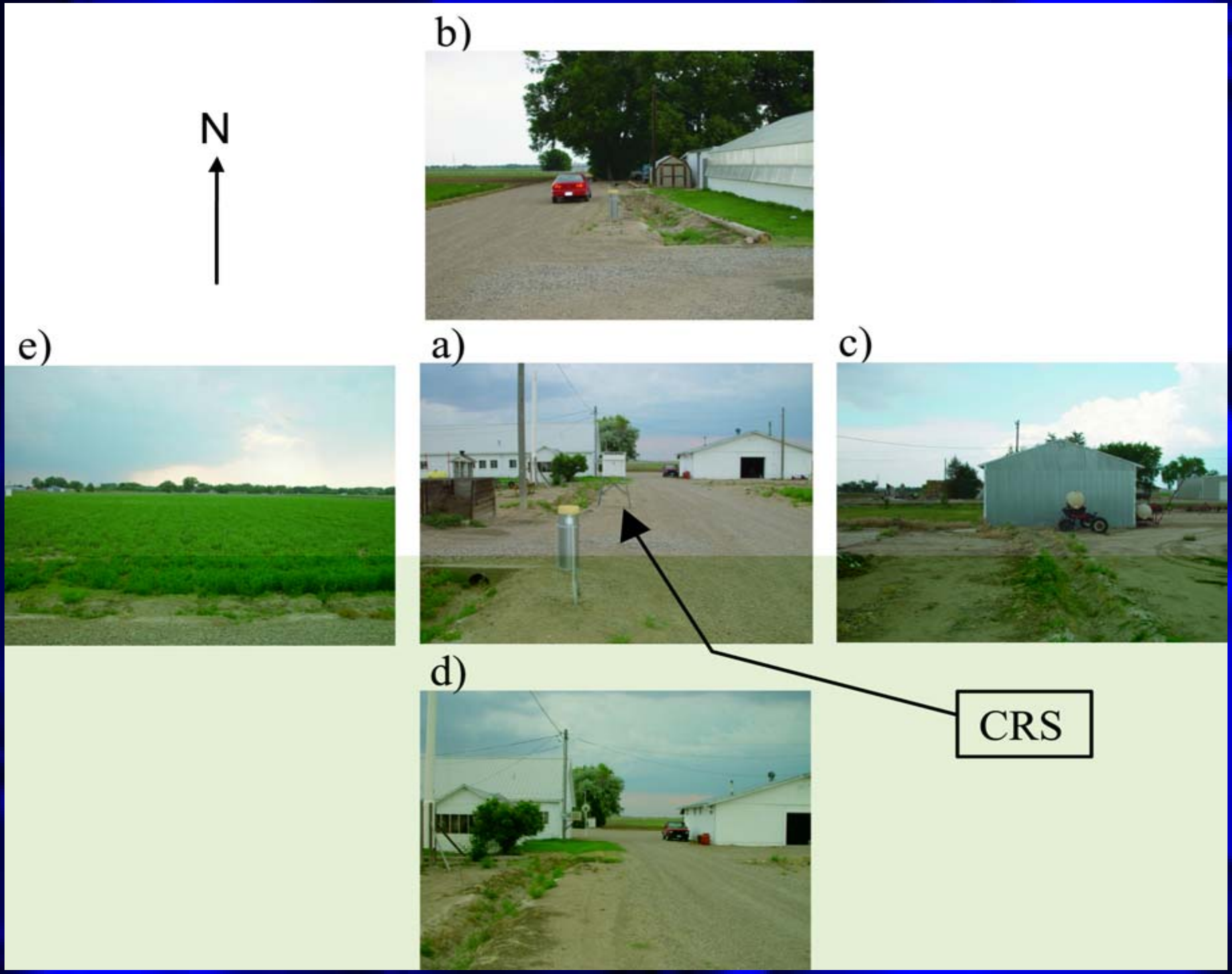
Figure 10. A daily composite of air temperature (red line) and effective temperature (blue line). The composite is created by averaging hourly data during the five days with highest air temperature in each of the three years considered in this section – fifteen days total. This shows the pattern of heating 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.

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

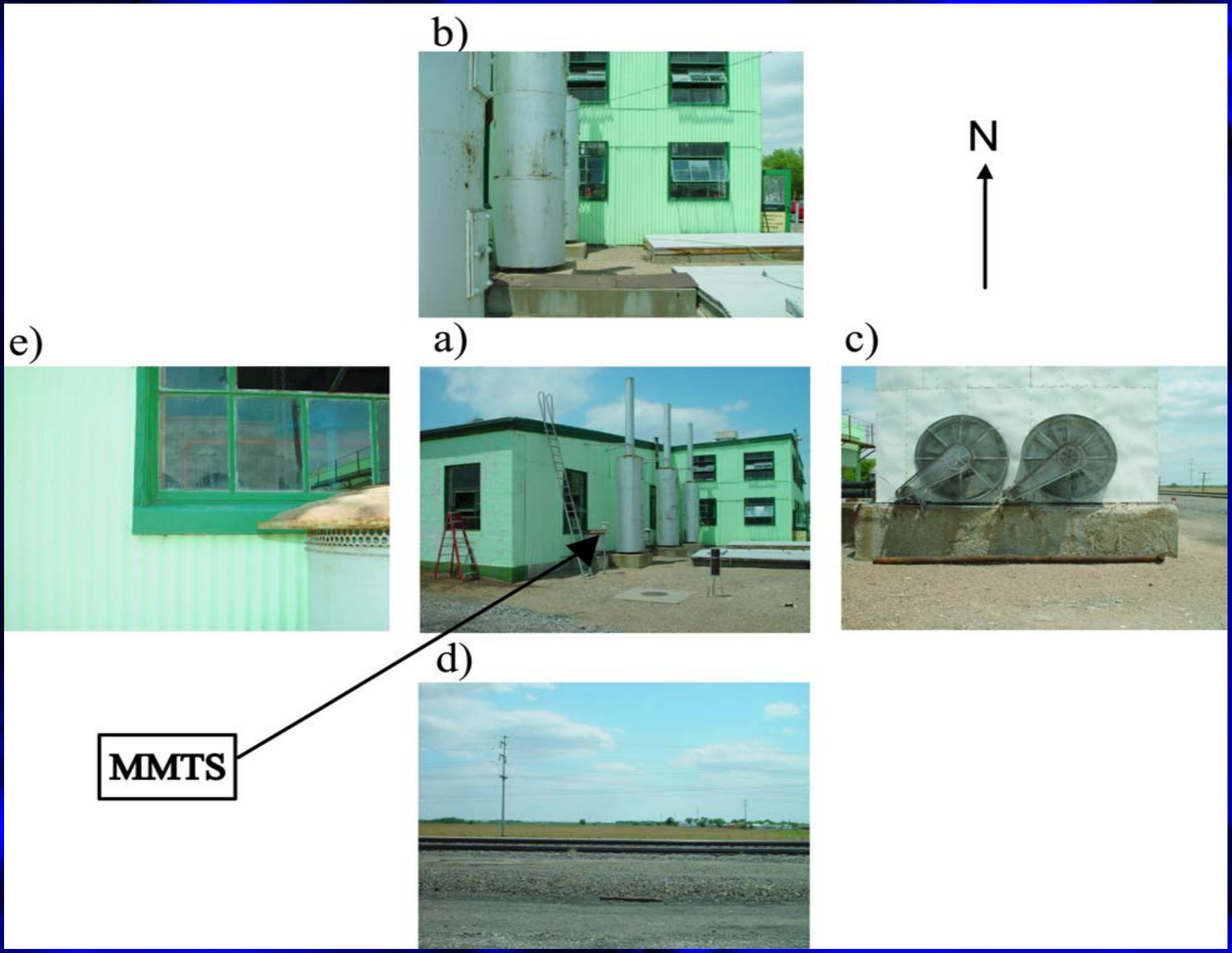
Microclimate Exposure



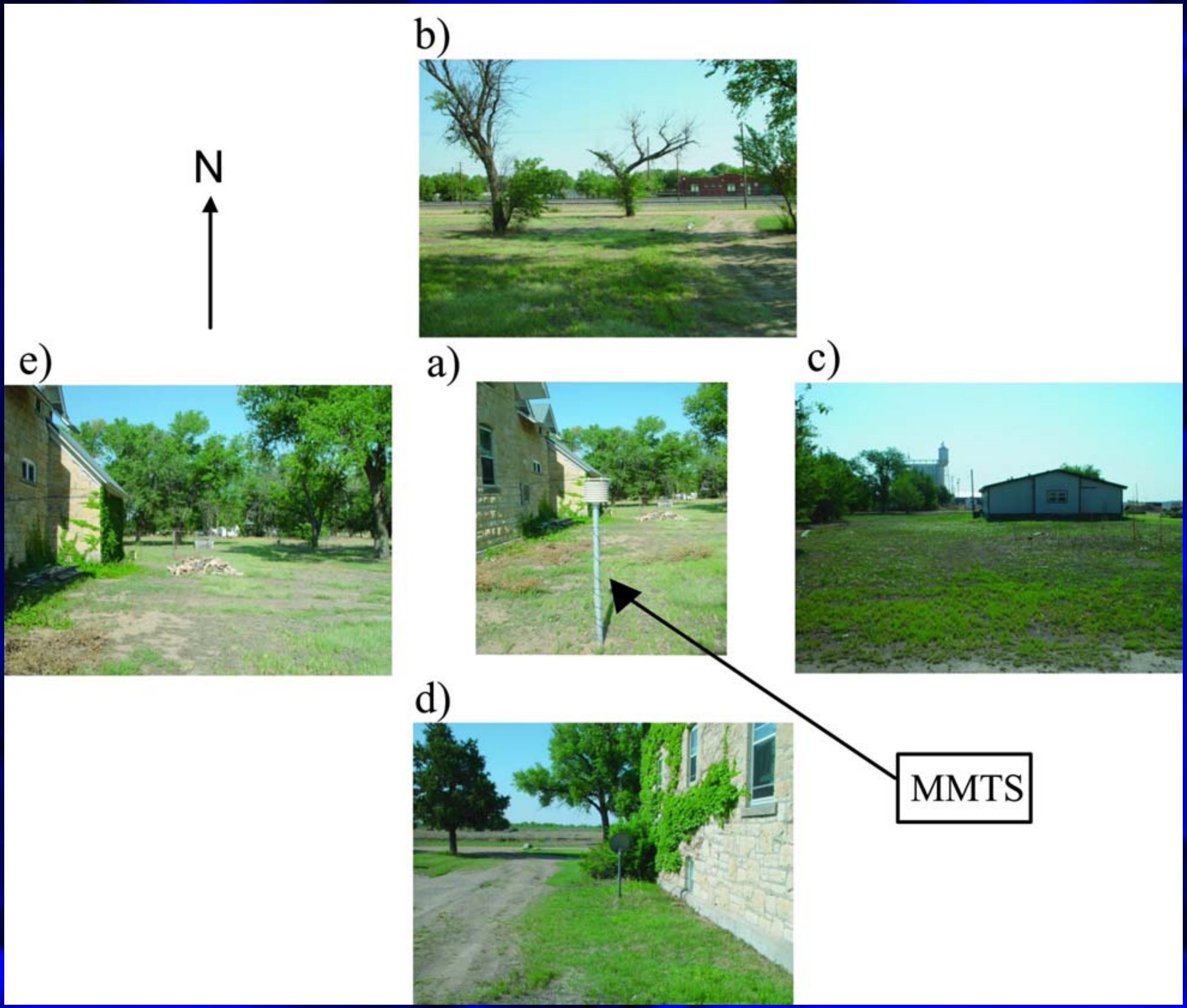
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Lamar, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively. From Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate 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



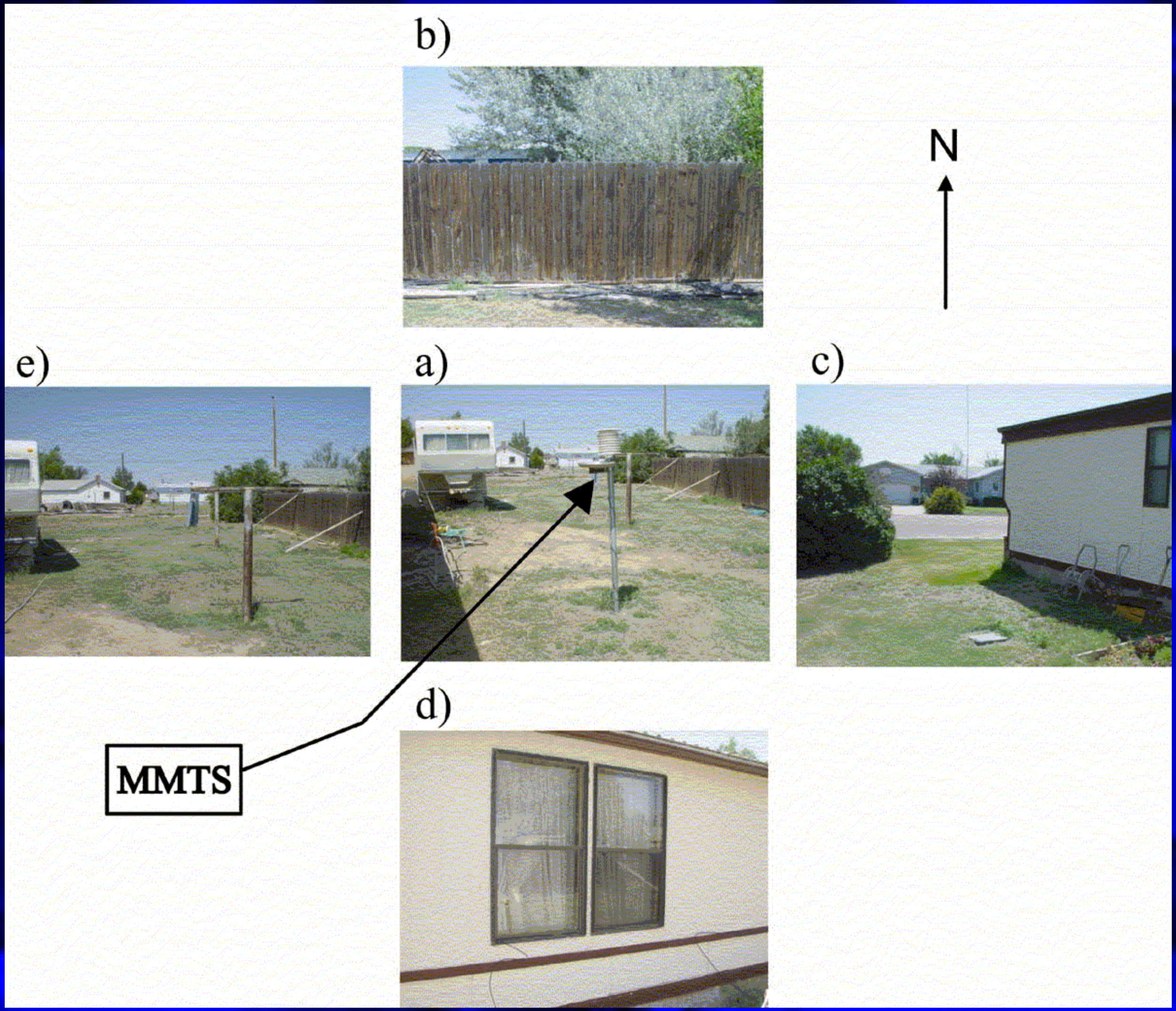
Photographs of the temperature sensor exposure characteristics for the NWS COOP station near Rocky Ford, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively. (CRS- Cotton Region Shelter). 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



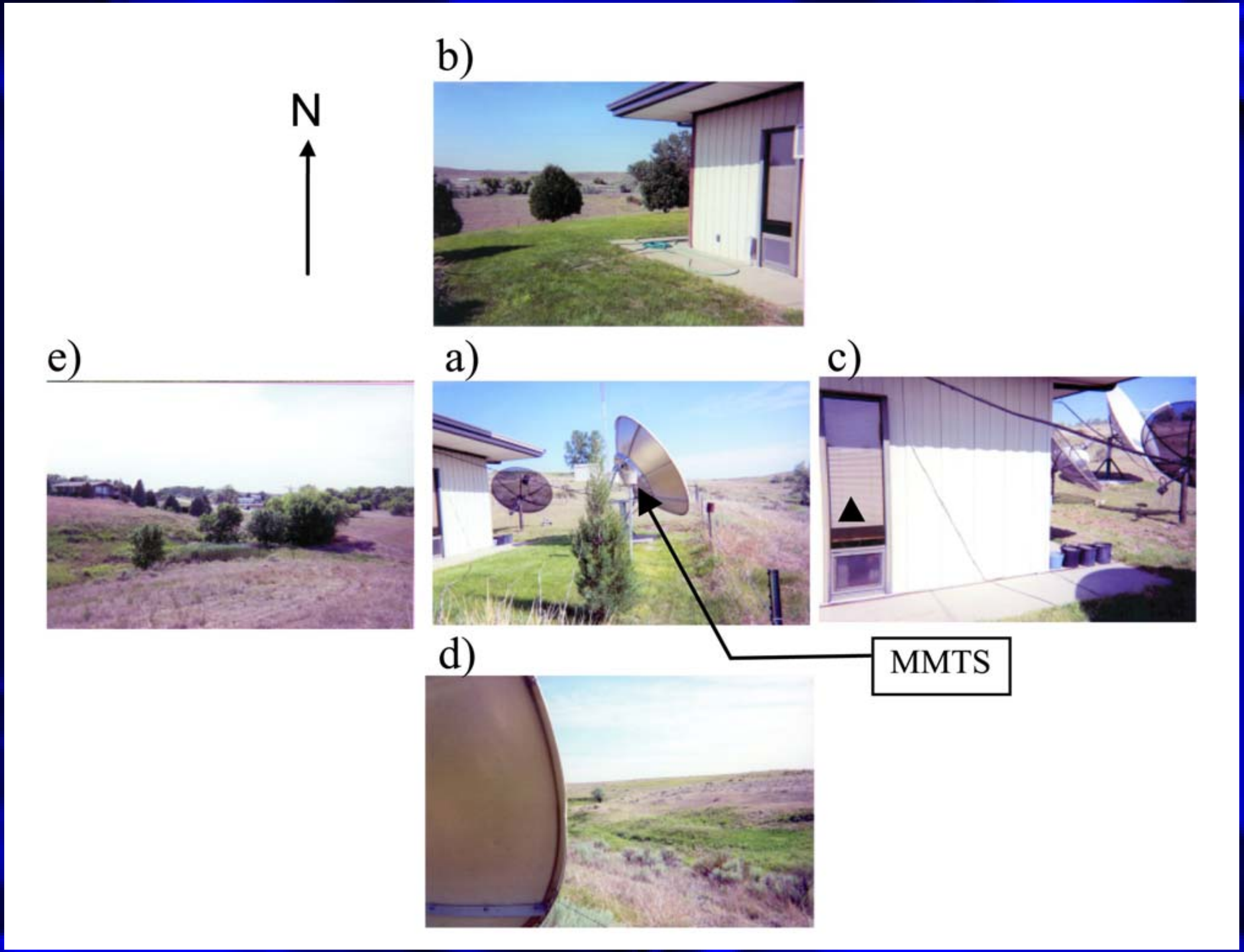
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Las Animas, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively. From Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate 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



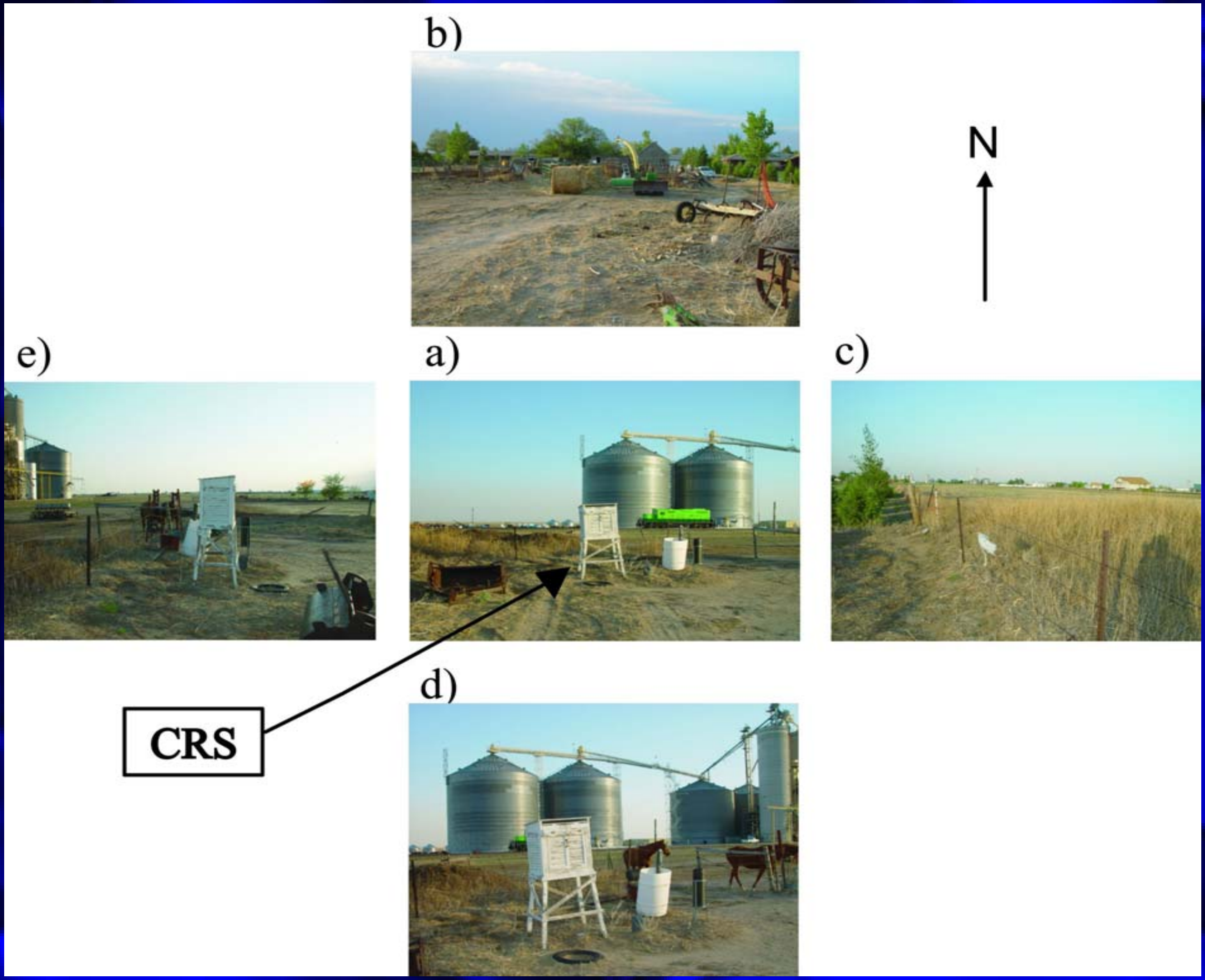
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Holly, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively. From Davey, C.A., and R.A. Pielke Sr., 2005: 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



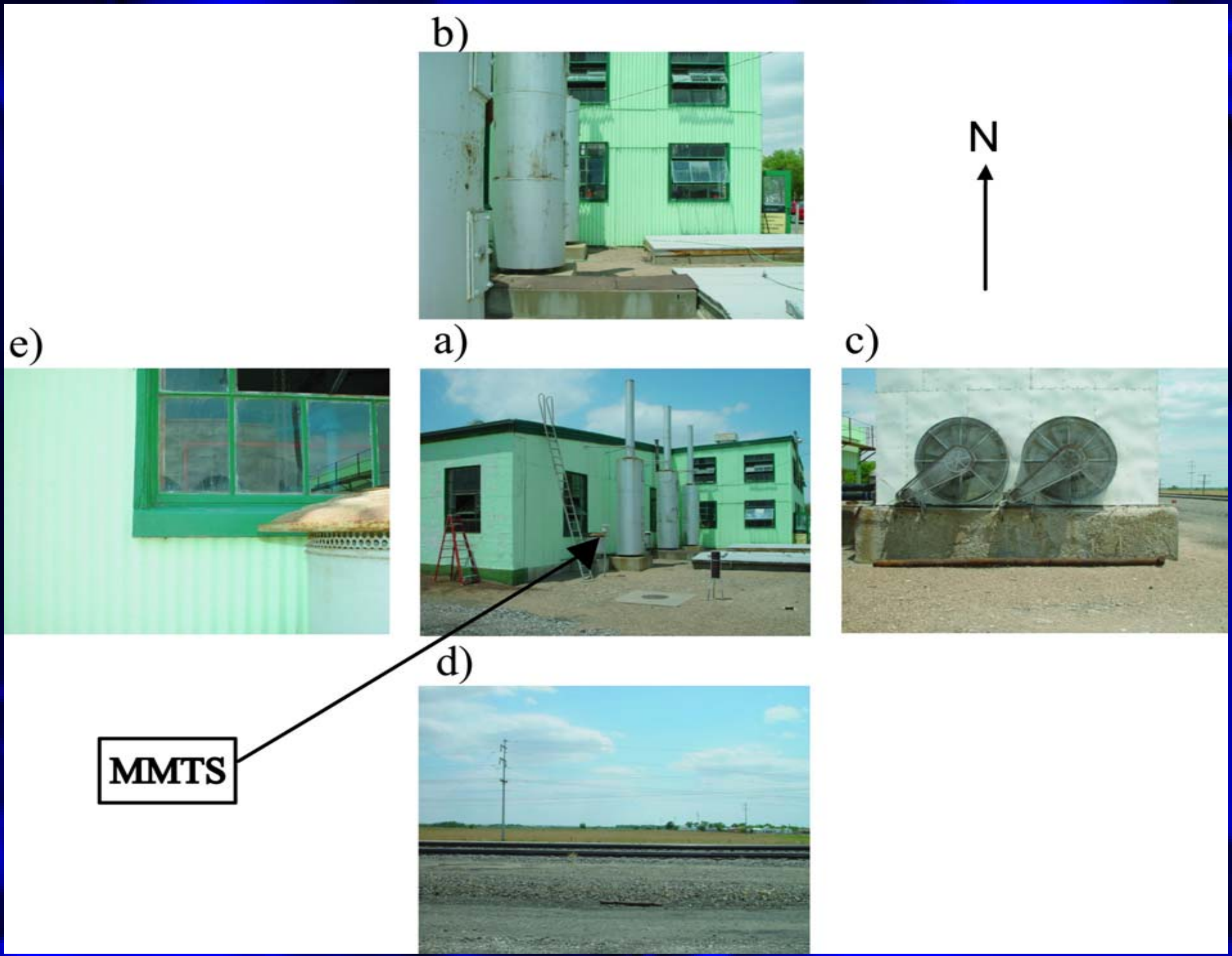
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Eads, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively. From Davey, C.A., and R.A. Pielke Sr., 2005: 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 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. 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 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. 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.

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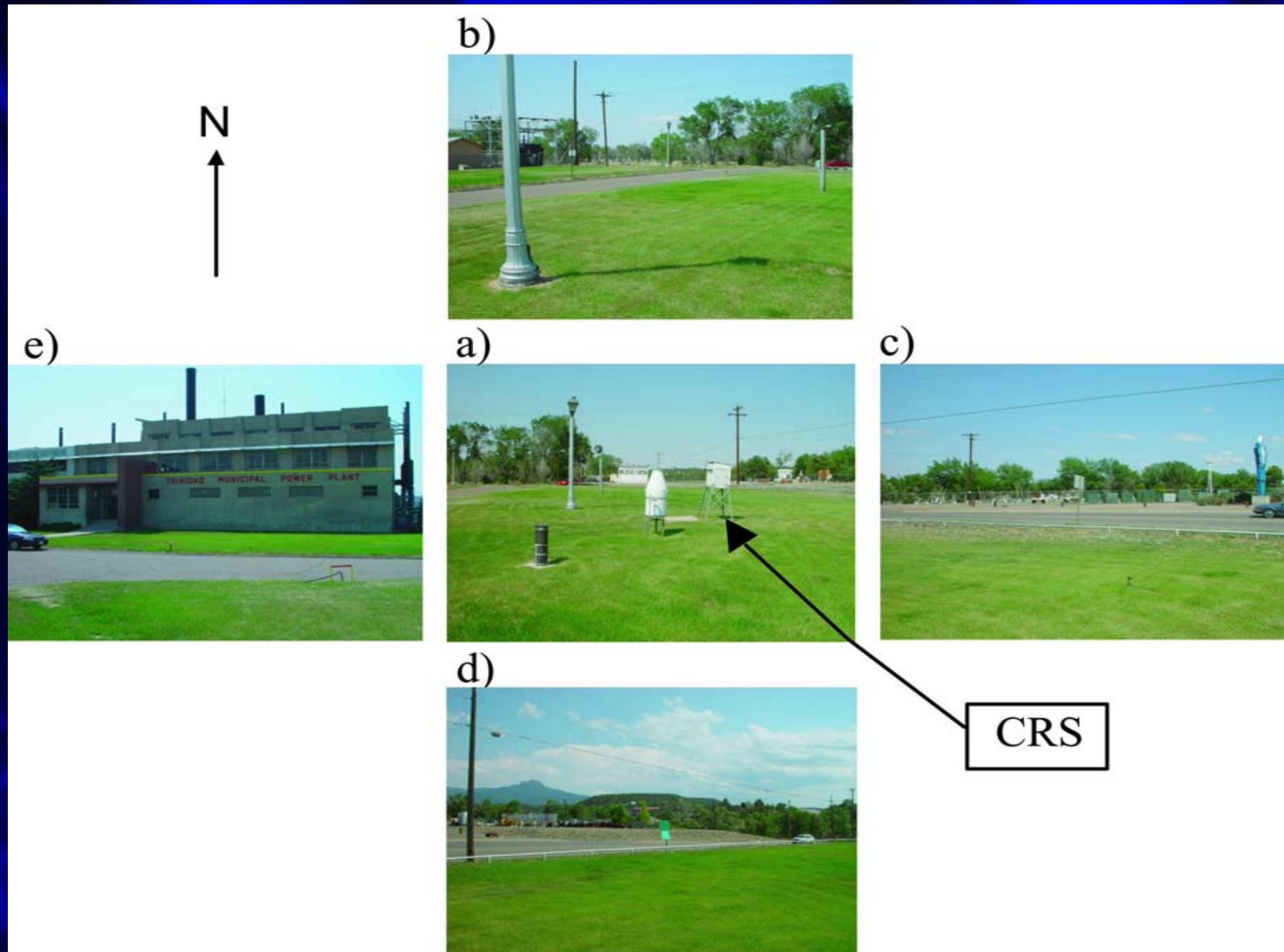
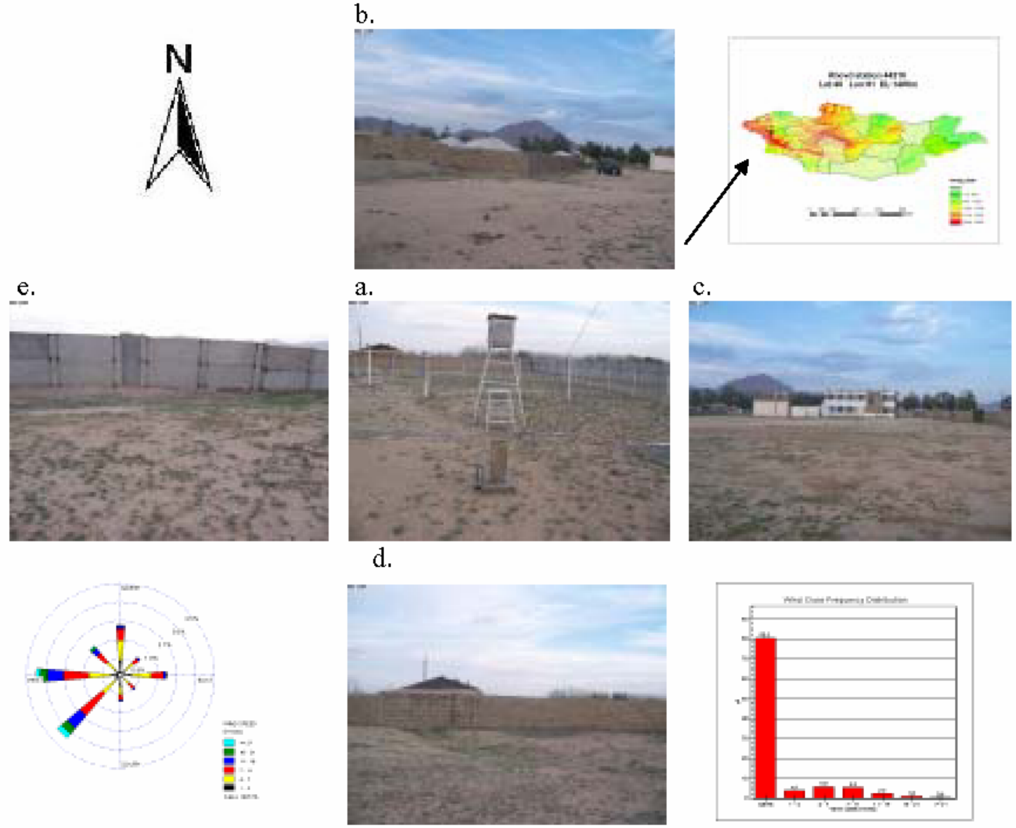


Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Trinidad, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively. From Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate 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

Fort Morgan site showing images of the cardinal directions from the sensor (from Hanamean et al. 2003)

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

GCON sites in residential area. 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.



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).

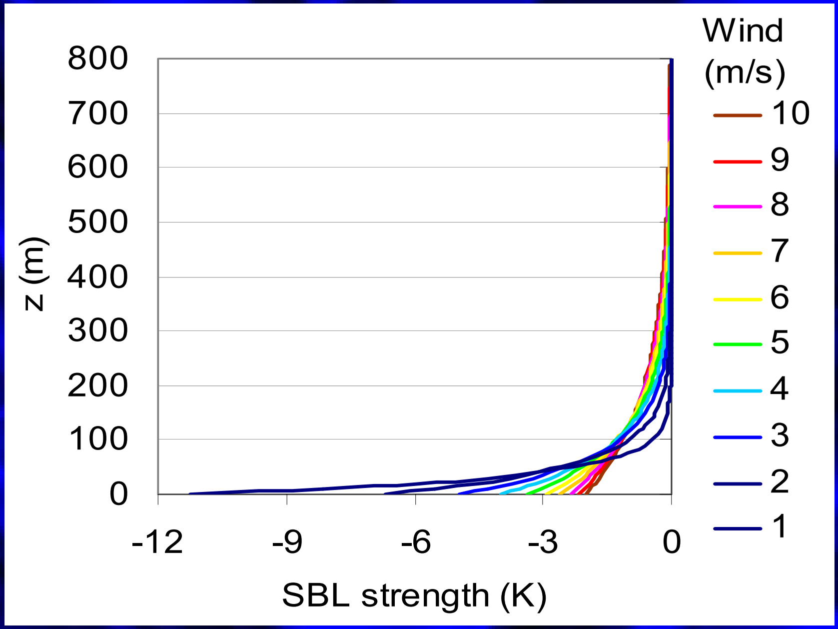


Figure 1. (SBL strength) profile in different wind conditions for cases of -10 W m-2 constant cooling rate over night.

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

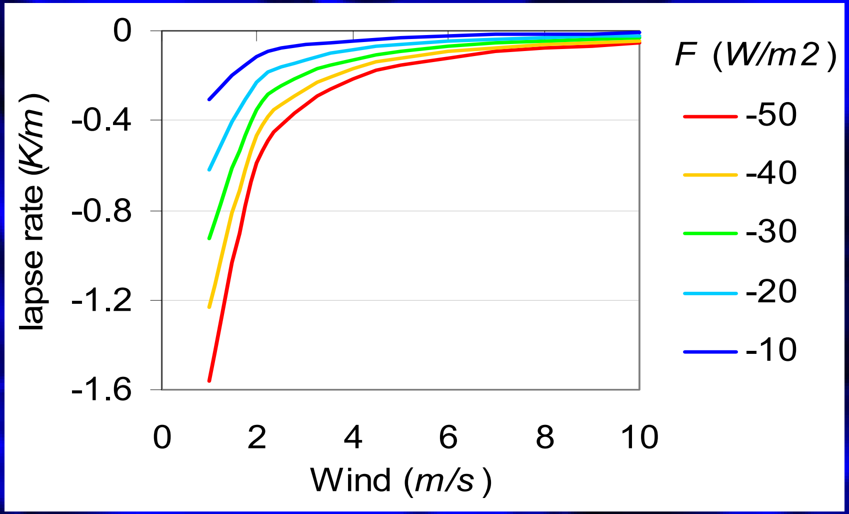


Figure 2: Lapse rate of potential temperature profile for the lowest 0~10 m for different wind conditions and five different values of the flux divergence.

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

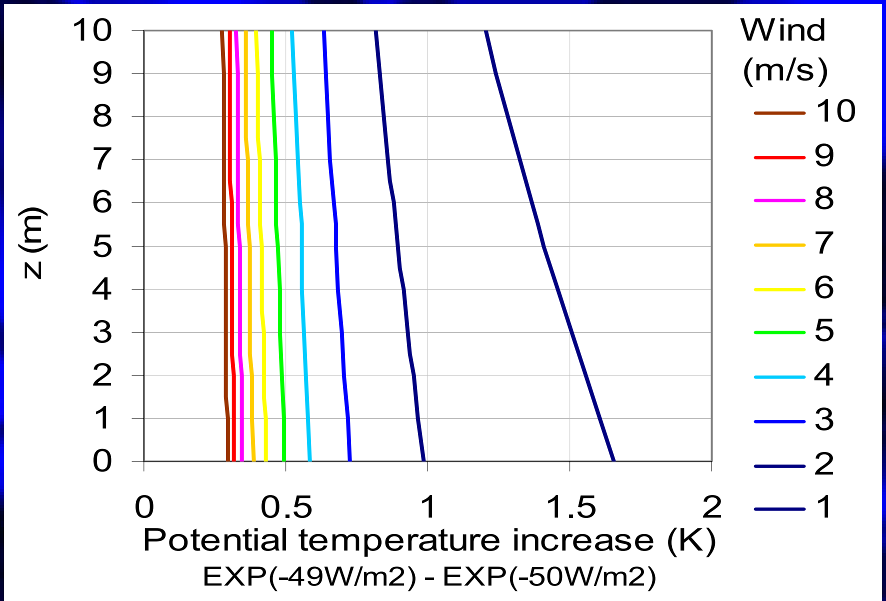


Figure 3: Potential temperature increase at different levels from the experiment with -49 W m-2 cooling to the experiment with -50 W m^{-2} cooling.

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

There is a Warm Bias in the Land-Surface Temperature Record

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"?

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

Question: What is the magnitude of the warm bias identified in Pielke and Matsui (2005) GRL in the analyses of the global surface 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?

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?

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

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 Land-Use Change Effects on Climate in the Winter

Marshall, C.H. Jr., R.A. Pielke Sr., and L.T. Steyaert, 2003: Crop freezes and land-use change. *Nature*, 426, 29-30.
http://blue.atmos.colostate.edu/publications/pdf/R-277.pdf

Marshall, C.H., R.A. Pielke Sr., and L.T. Steyaert, 2004: Has the conversion of natural wetlands to agricultural land increased the incidence and severity of damaging freezes in south Florida? Mon. Wea. Rev., submitted.
http://blue.atmos.colostate.edu/publications/pdf/R-281.pdf

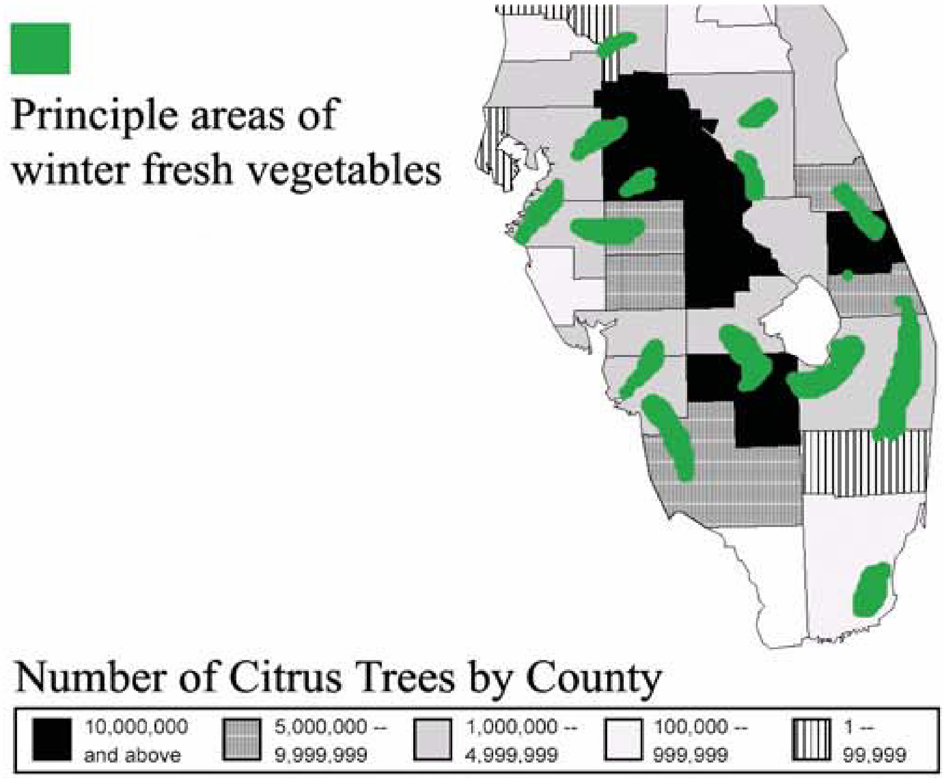


Fig. 1. Number of citrus trees per county and principle areas of winter fresh vegetable production. Figure adapted from Florida Agriculture Facts Directory 2002.

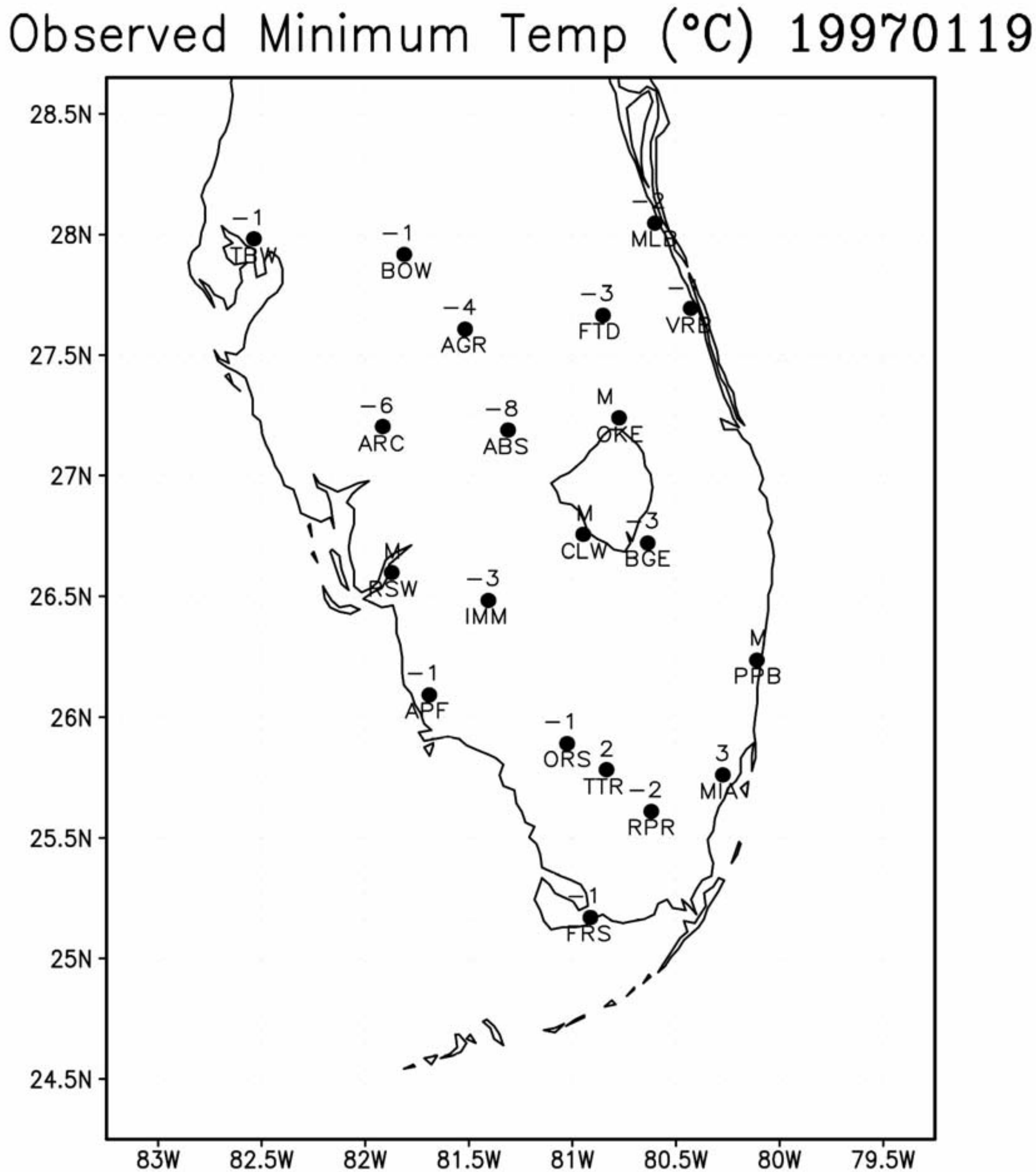


Fig. 2. Observations of minimum temperature from the National Weather Service Cooperative Observer Network on the morning of January 19, 1997.

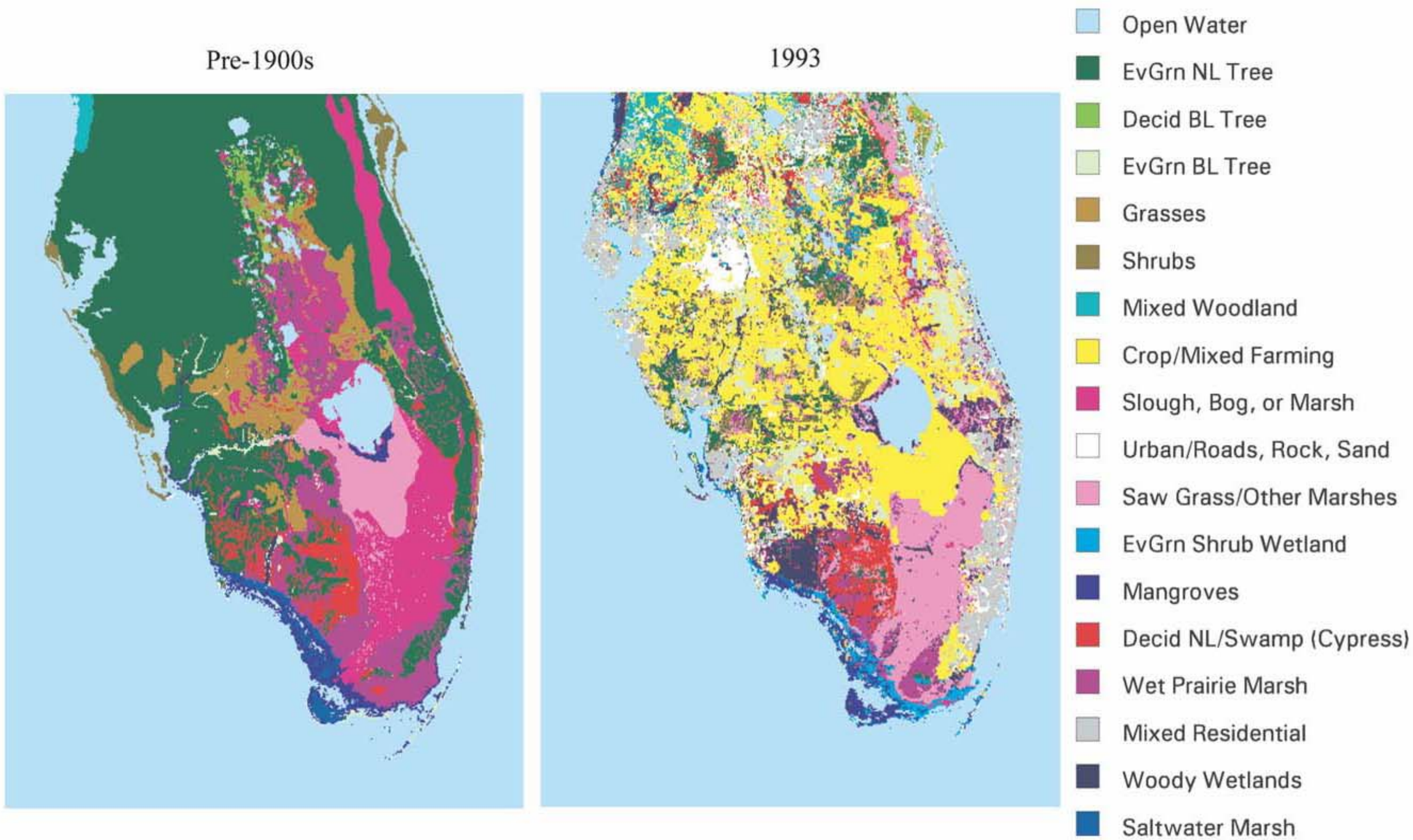


Fig. 3. U.S. Geological Survey land cover classes for pre-1900s natural conditions (left) and 1993 land use patterns.

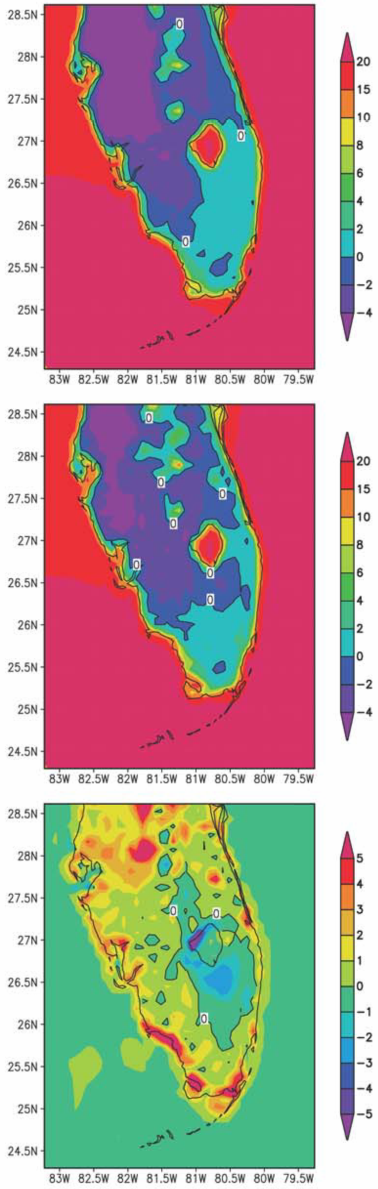


Fig. 4. Model simulated 2 meter minimum temperatures on the morning of January 19, 1997 for the pre-1900s scenario (top panel), the1993 sceanrio (middle panel), and the difference of the two (1993 minus pre-1900s scenario; bottom panel).

1997

Min T

1997

duration

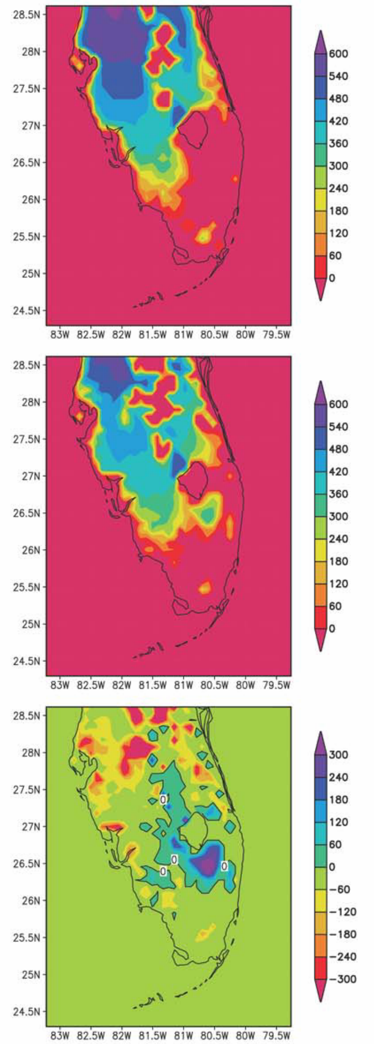


Fig. 5. Time spent below freezing (minutes) for the night prior to the morning of January 19. 1997, for the pre-1900s land cover scenario (top), the 1993 land cover scenario (middle) and the difference of the two (bottom).

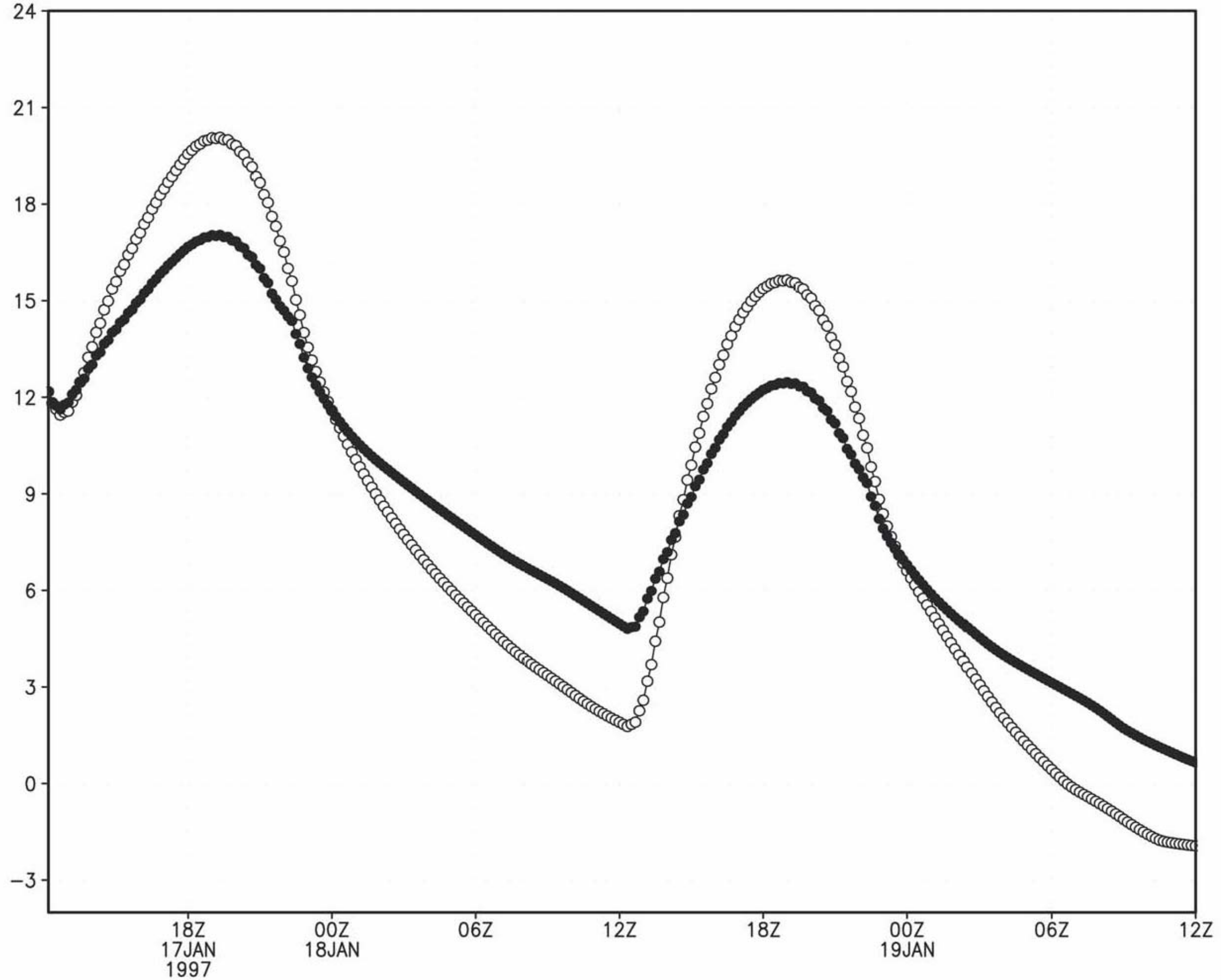


Fig. 7. Time series of 2 meter temperature for a model grid point located just south of Lake Okeechobee for the pre-1900s land cover scenario (filled circles) and the 1993 land cover scenario (open circles).

Regional Land-Use Change Effects on Climate in the Summer

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

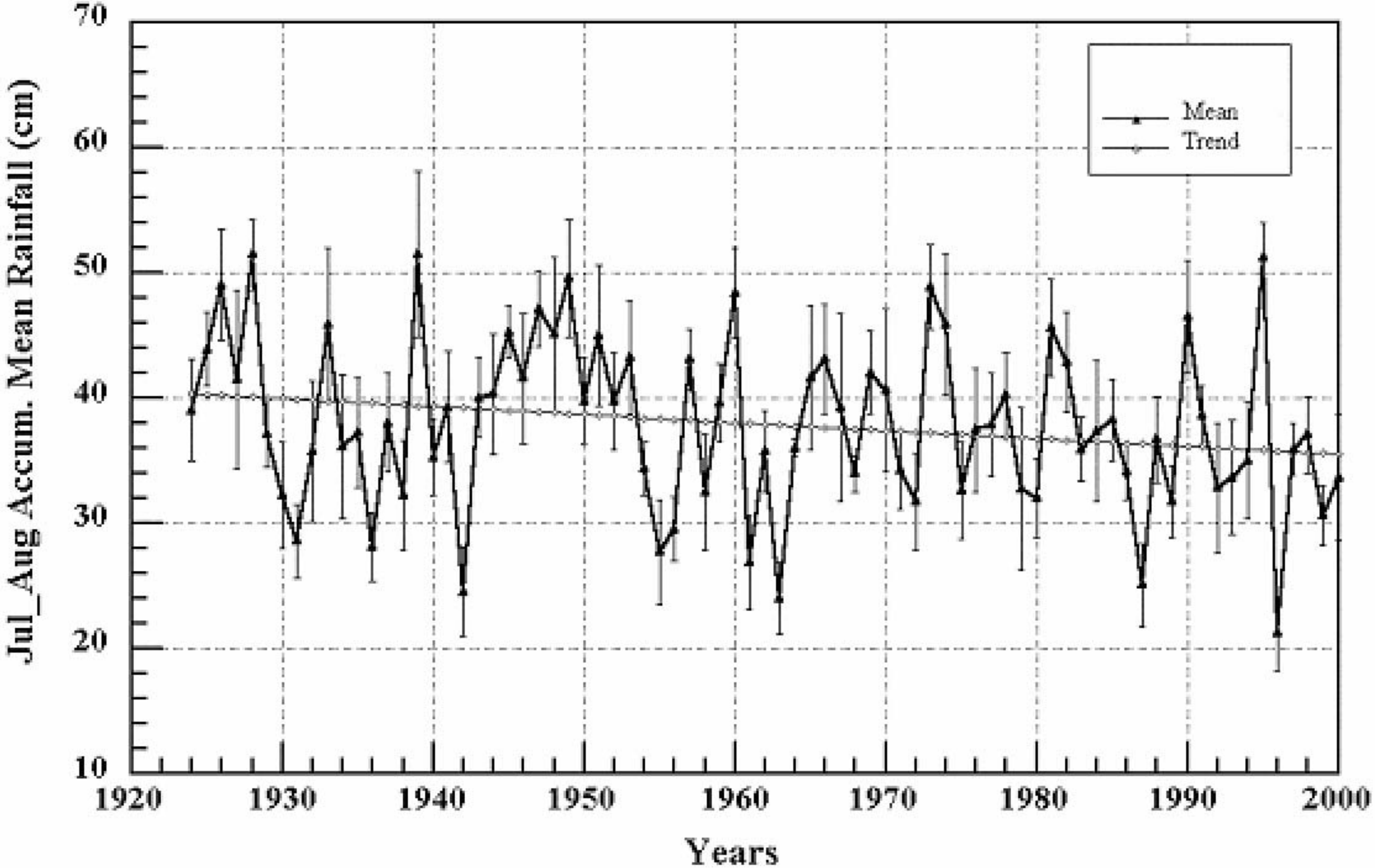


FIG. 25. Regional average time series of accumulated convective rainfall (cm) from 1924 to 2000, with corresponding trend based on linear regression of all July-August amounts. The vertical bars overlain on the raw time series indicate the value of the standard error of the July-August regional mean.

Max and Min Temp Trends

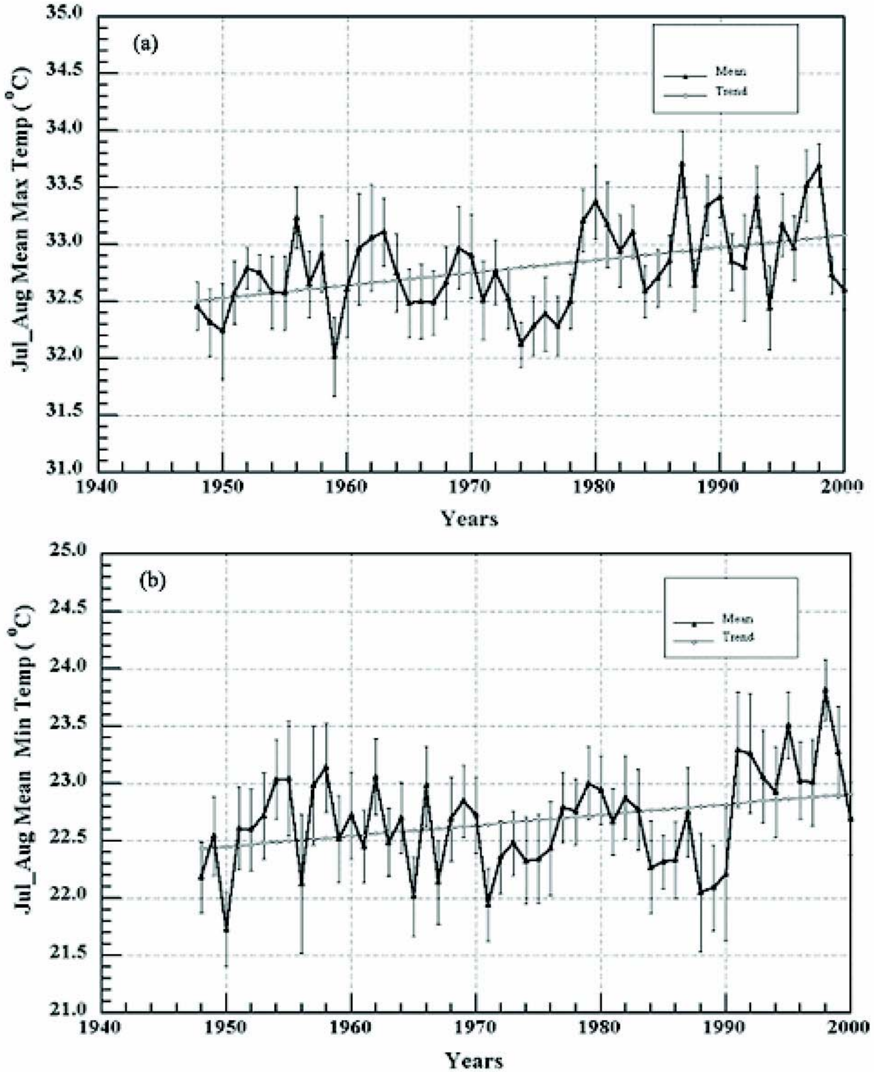


FIG. 26. Same as in Figure 25, except for daily (a) maximum and (b) minimum shelter-level temperature (°C)

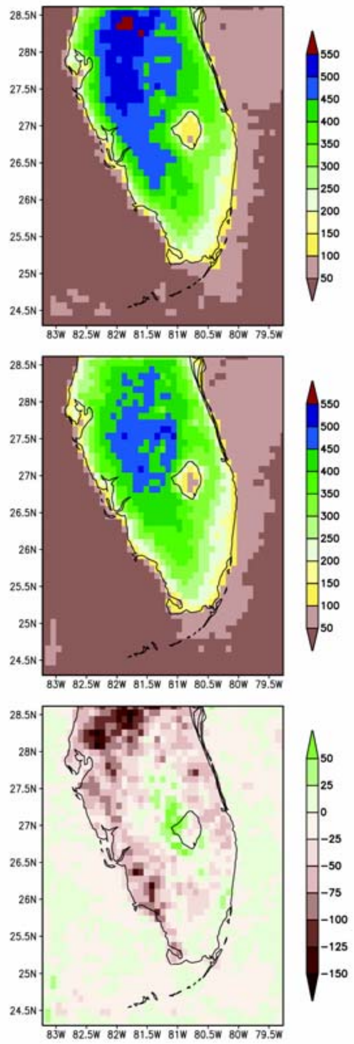


FIG. 4. Accumulated convective rainfall (mm) from the model simulations of July-August 1973 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).

1973

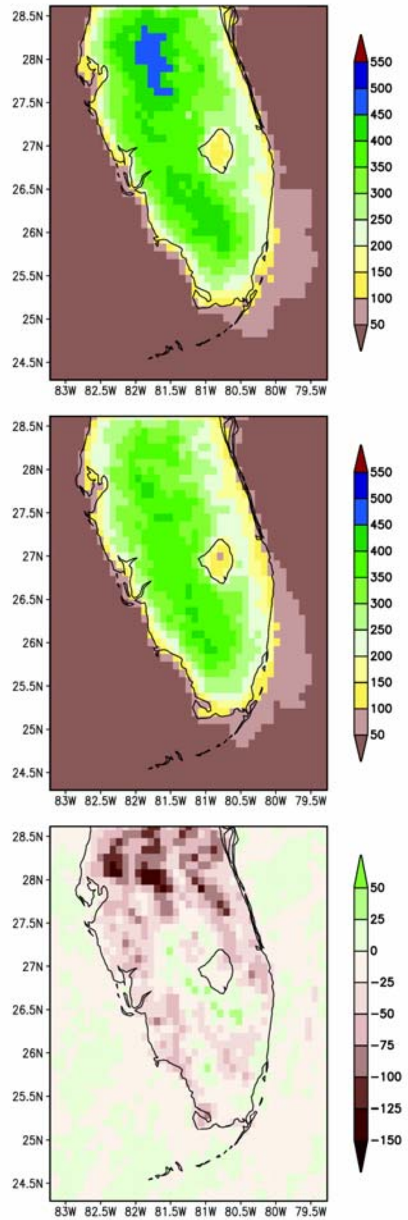


FIG. 5. Same as in Figure 4, except for July-August 1989.

1989

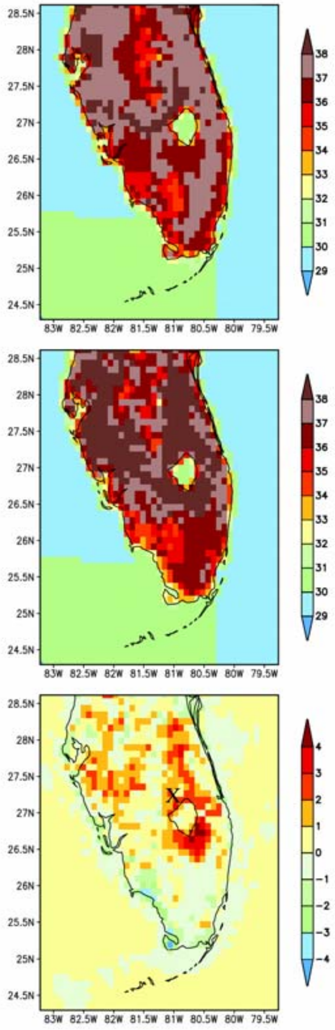
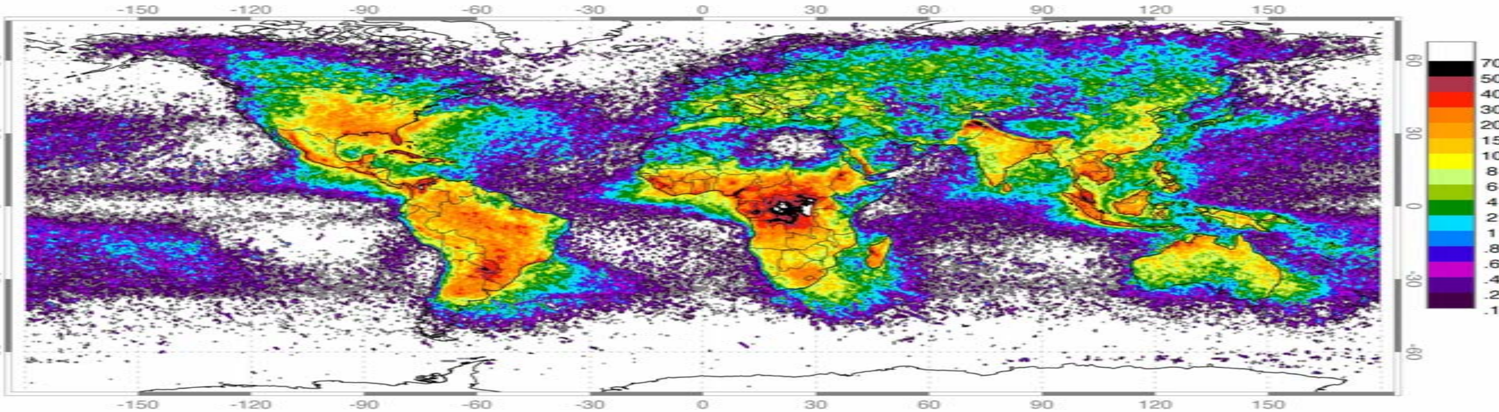


FIG. 13. Two-month average of the daily maximum shelter-level temperature from the model simulations of July-August 1989 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).

1989



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

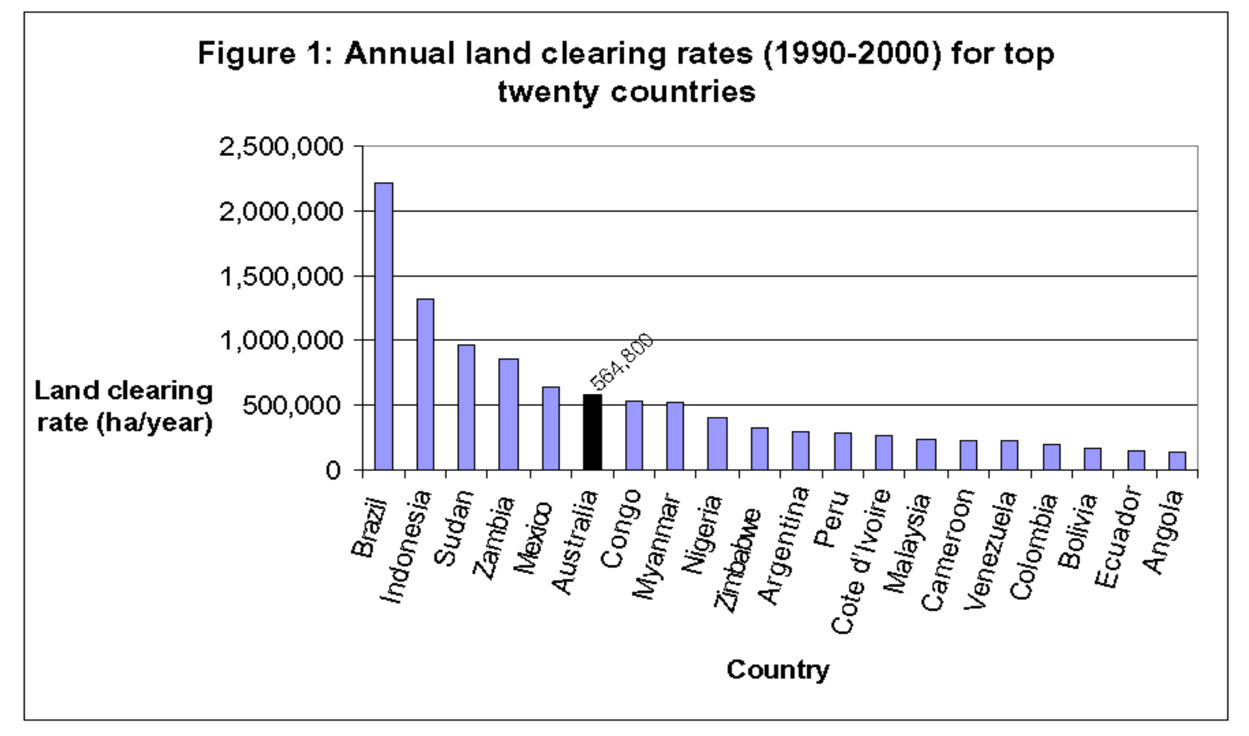
Global Climate Effects occur with ENSOs for the Following Reasons:

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 and Aerosol Effects!

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

Ocean Heat Content Change is a More Robust Metric of Climate System Heat Changes than a Global-Averaged Surface Temperature

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

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

NRC 2005 Executive Summary Headlines

EXPANDING THE RADIATIVE FORCING CONCEPT

Account for the Vertical Structure of Radiative Forcing

Determine the Importance of Regional Variation in Radiative Forcing

Determine the Importance of Nonradiative Forcings

Provide Improved Guidance to the Policy Community

ADDRESSING KEY UNCERTAINTIES

Conduct Accurate Long-Term Monitoring of Radiative Forcing Variables

Advance the Attribution of Decadal to Centennial Climate Change

Reduce Uncertainties Associated with Indirect Aerosol Radiative Forcing

Better Quantify the Direct Radiative Effects of Aerosols

Better Quantify Radiative Forcing by Ozone

Integrate Climate Forcing Criteria in Environmental Policy Analysis

from 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/

Skillful multidecadal climate forecasts have not been demonstrated

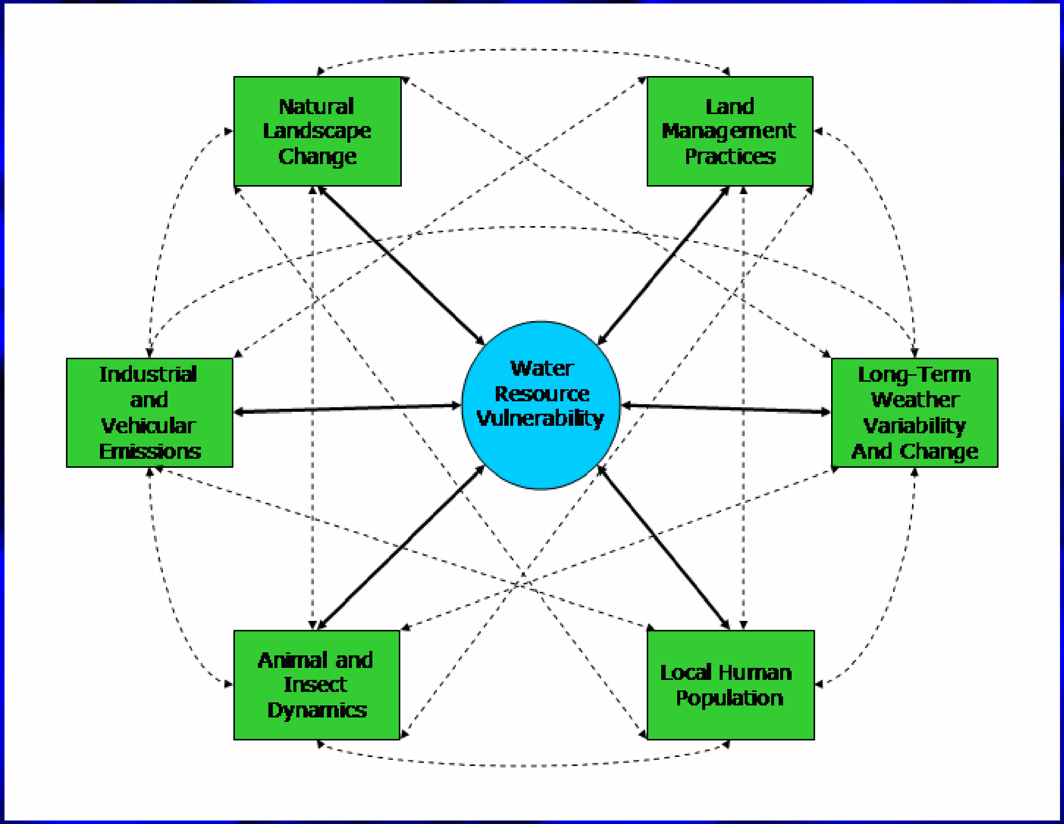
An inversion of the IPCC Assessment Procedure is needed

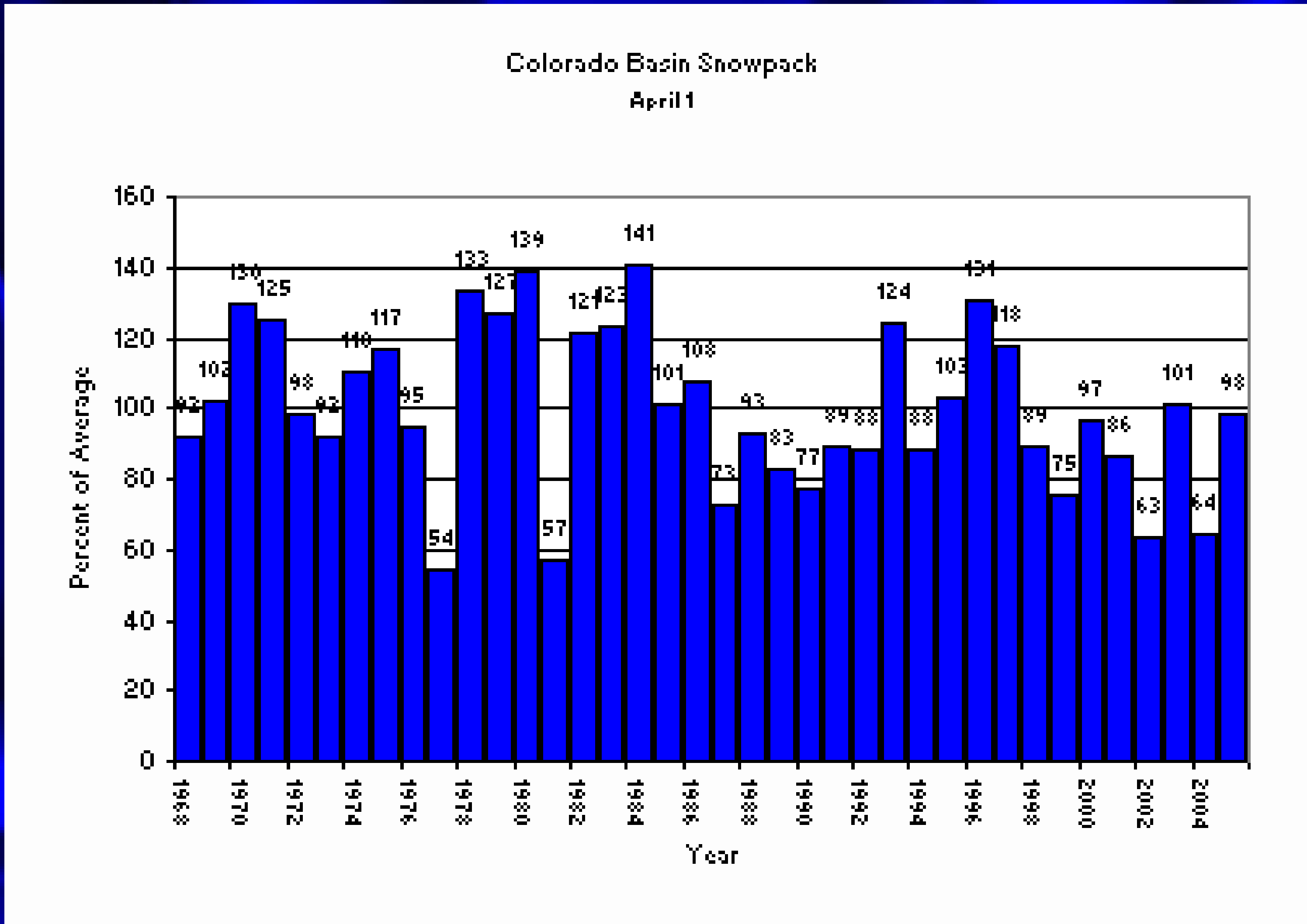
- We need an approach that is more inclusive and scientifically defensible

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

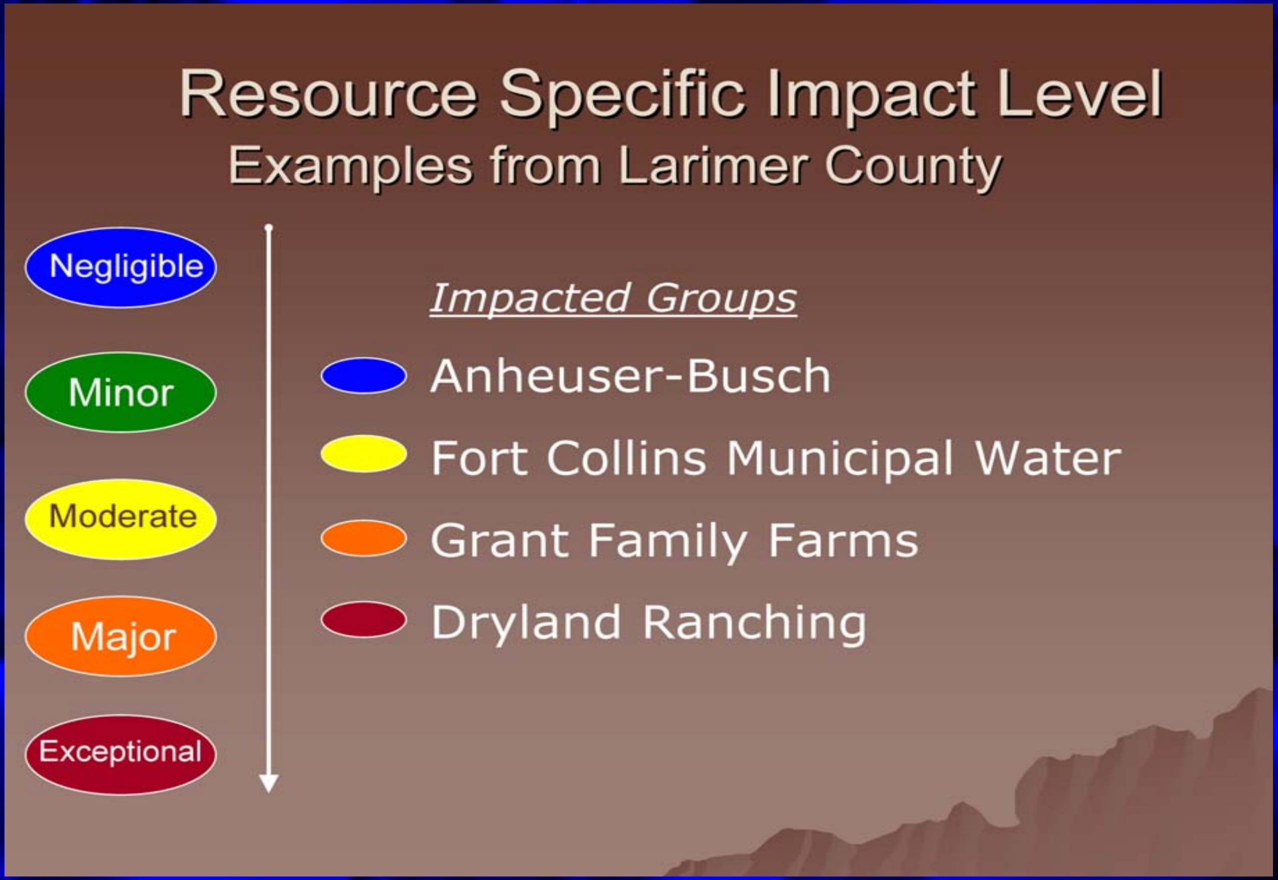




April 1 snowpack percent of average for the state of Colorado for years 1968 through 2005.

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."

QUESTION

If you were given 100 million dollars to spend on environmental benefits, where would you use that money?

1. **CO_2 reduction**
2. **Potable water**
3. **AIDS prevention**
4. **SO_2 reduction**

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/

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

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