Overlooked Science Issues in Climate Change

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Politicalization of Climate Science

- The current focus is on carbon dioxide emissions from fossil fuel combustion (the IPCC view)

- Since the climate forcing of CO2 is only one of a diverse set of first order human climate forcings, and global warming is only a subset of climate change (NRC,2005; IGBP-BAHC, 2004), the current IPCC focus is an ineffective climate policy

- The current IPCC focus is to use the focus on CO2 to promote changes in energy policy.

- The use of carbon dioxide as the instrument to promote energy policy changes, however, is an inappropriately blunt instrument for this purpose, and can lead to poor energy policy decisions,

State Climate Offices

- Both Oregon and Delaware are AASC recognized state climate offices within the national climate services partnership. These State Climate Offices are called ARSCOs.
- The National Climatic Data Center, the Regional Climate Centers, and the American Association of State Climatologists are fully committed to supporting the development of the ARSCO program.
- The individual holding the directorship of the ARSCO, usually the State Climatologist, must also be qualified in terms of education and experience. The individual should also have the desire and the “heart” to serve his/her state’s need for climatological data and information. The individual should be a willing advocate on behalf of the ARSCO and the other partners. The individual must be able to devote an appropriate amount of time to make the ARSCO successful.”

- The Climate System is much more than long- term weather statistics.
- Climate is not a boundary value problem but an initial value problem.
- Skillful multi-decadal climate predictions on the global, zonally-averaged and regional scales have not been achieved.
- The global-averaged surface temperature trends assessment is an inadequate climate change metric.

The Climate

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.**

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

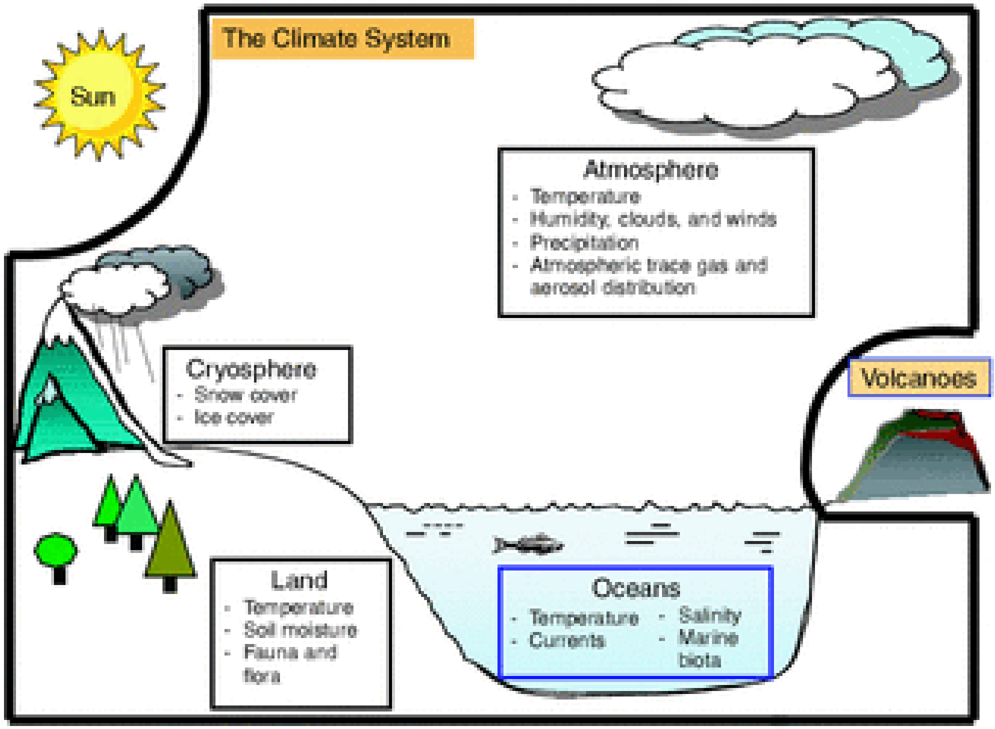


FIGURE 1-1 The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes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

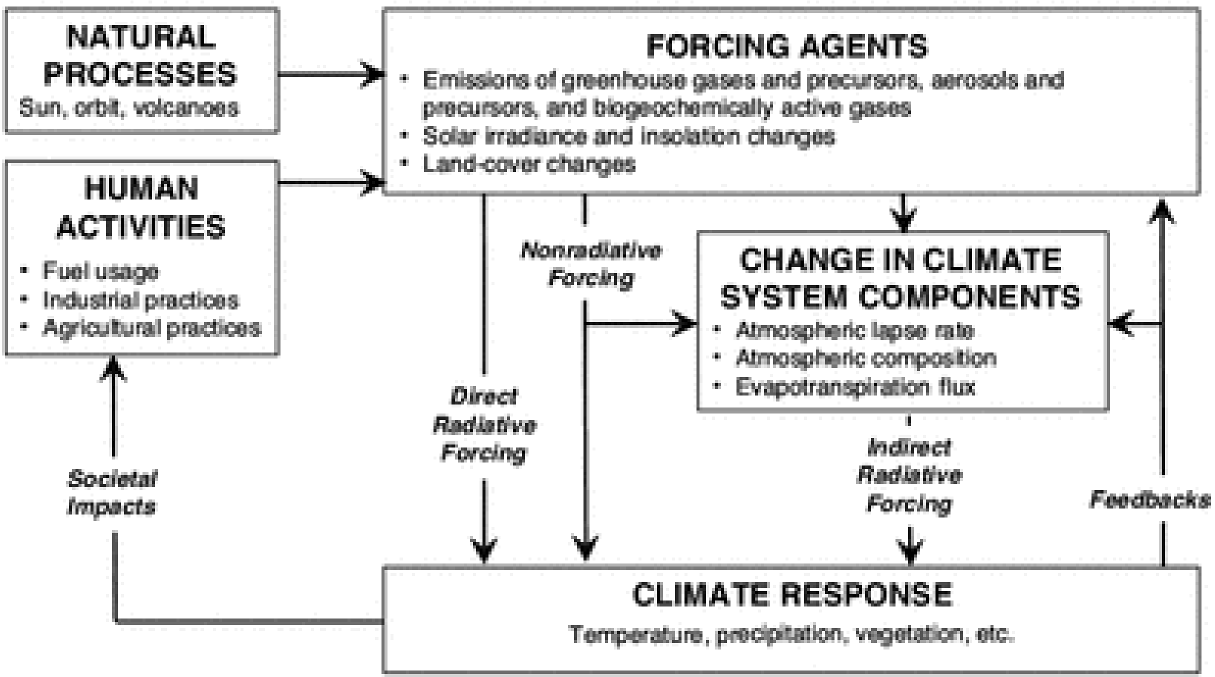


FIGURE 1-2 Conceptual framework of climate forcing, response, and feedbacks under present-day climate conditions. Examples of human activities, forcing agents, climate system components, and variables that can be involved in climate response are provided in the lists in each box.

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

EXPANDING THE RADIATIVE FORCING CONCEPT (NRC 2005 Recommendations)

- 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

Account for the Vertical Structure of Radiative Forcing

National Research Council Report PRIORITY RECOMMENDATIONS

- Test and improve the ability of climate models to reproduce the observed vertical structure of forcing for a variety of locations and forcing conditions.
- Undertake research to characterize the dependence of climate response on the vertical structure of radiative forcing.
- Report global mean radiative forcing at both the surface and the top of the atmosphere in climate change assessments.

Determine the Importance of Regional Variation in Radiative Forcing

National Research Council Report PRIORITY RECOMMENDATIONS:

- ➔ Use climate records to investigate relationships between regional radiative forcing (e.g., land use or aerosol changes) and climate response in the same region, other regions, and globally.

- ➔ Quantify and compare climate responses from regional radiative forcings in different climate models and on different timescales (e.g., seasonal, interannual), and report results in climate change assessments.

Determine the Importance of Nonradiative Forcings

National Research Council Report PRIORITY RECOMMENDATIONS

- Improve understanding and parameterizations of aerosol-cloud thermodynamic interactions and land-atmosphere interactions in climate models in order to quantify the impacts of these nonradiative forcings on both regional and global scales.

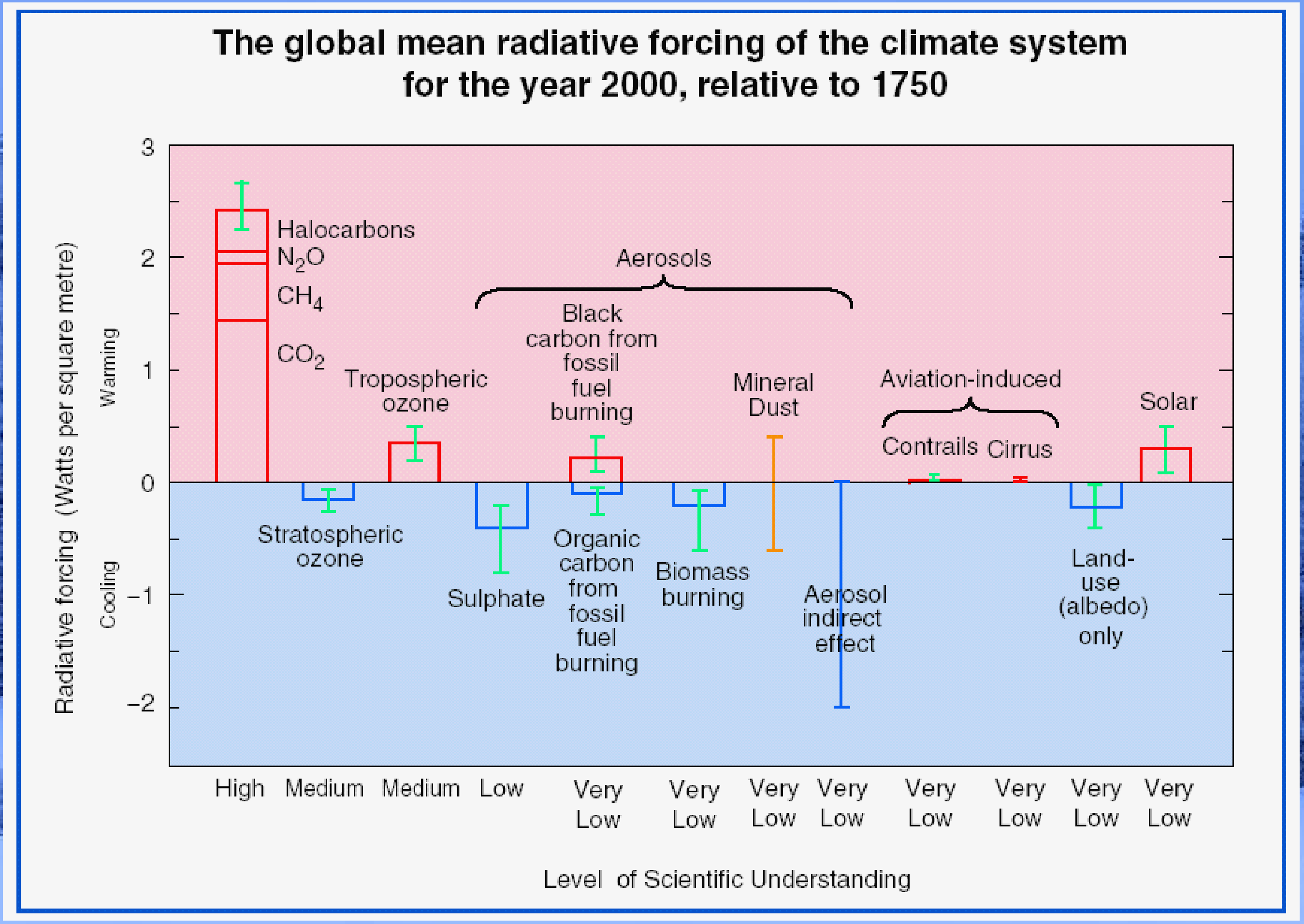
- Develop improved land-use and land-cover classifications at high resolution for the past and present, as well as scenarios for the future.

Provide Improved Guidance to the Policy Community

National Research Council Report PRIORITY RECOMMENDATIONS

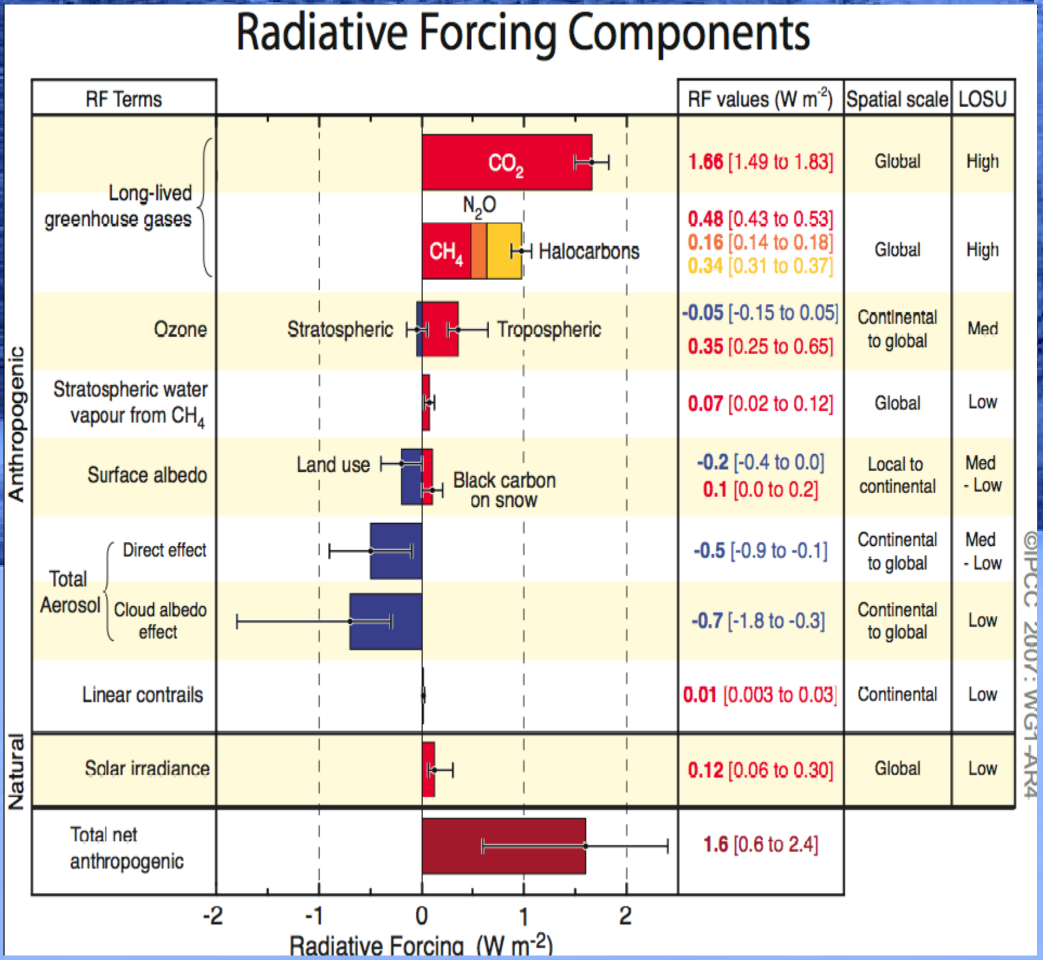
- Encourage policy analysts and integrated assessment modelers to move beyond simple climate models based entirely on global mean TOA radiative forcing and incorporate new global and regional radiative and nonradiative forcing metrics as they become available.

The Narrow Focus of the IPCC Assessment



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

2007 IPCC SPM View



2007 IPCC SPM Figure Caption

FIGURE SPM-2. Global-average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. Range for linear contrails does not include other possible effects of aviation on cloudiness.

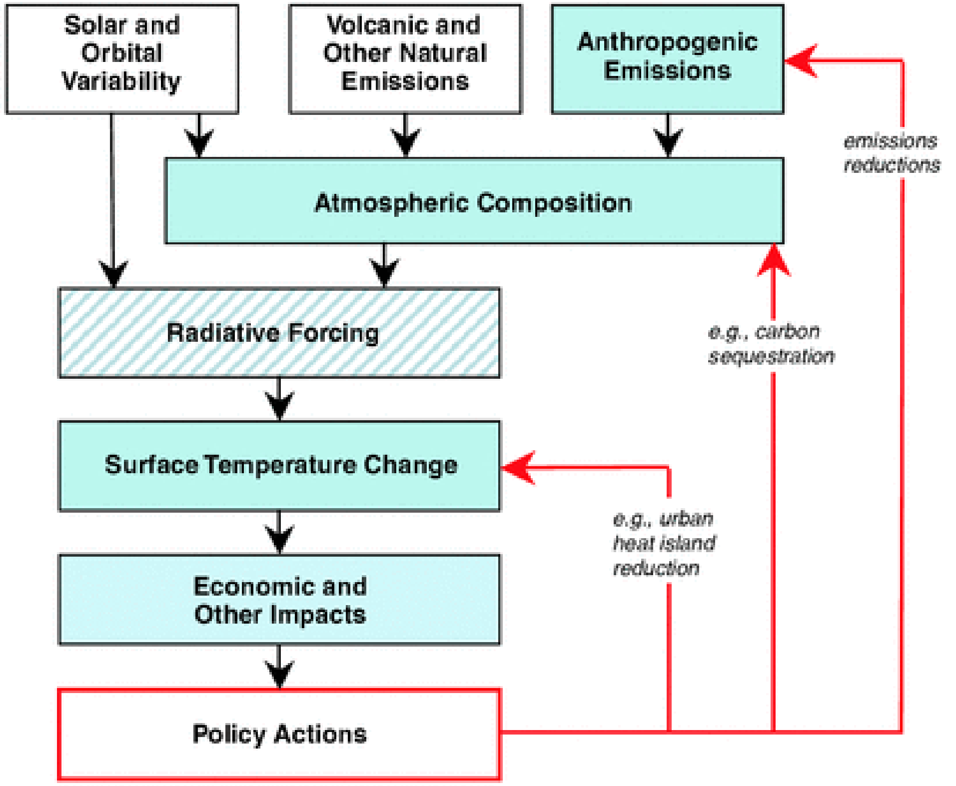


FIGURE 1-4 Conceptual framework for how radiative forcing fits into the climate policy framework. Blue-shaded boxes indicate quantities that have been considered as policy targets in international negotiations and other policy analyses. Radiative forcing (striped box) has not been treated as a policy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

What Fraction of Global Warming is Due to the Radiative Forcing of Increased Atmospheric Concentrations of CO_2?

2001 IPCC View:

- 58% of the radiative forcing of well-mixed greenhouse gases result from CO_2.
- 48% of the human-caused warming climate forcing result from the radiative effect of CO_2.

New Findings

- i) Ozone was responsible for one-third to one-half of the observed warming trend in the Arctic during winter and spring [Drew Shindell].
- ii) The new interpretations reveal methane emissions may account for a third of the climate warming from well-mixed greenhouse gases between the 1750s and today. [Drew Shindell and colleagues; Keppler et al.]
- iii) For the period 2000-2004, a CERES Science Team assessment of the shortwave albedo found a decrease by 0.0015 which corresponds to an extra 0.5 W m^{-2} of radiative imbalance according to their assessment. [CIRES Science Team]

New Findings

- iv) Model results indicate radiative forcings of +0.3 W m^{-2} in the Northern Hemisphere associated with albedo effects of soot on snow and ice [Hansen and Nazarenko 2004]
- v) There are a variety of direct and indirect aerosol effects that cause global warming including the black carbon direct effect, the semidirect effect, and the glaciation indirect effect, with the thermodynamic effect having an unknown influence (NRC 2005).
- (these findings are summarized at http://climatesci.atmos.colostate.edu/2006/04/27/what-fraction-of-global-warming-is-due-to-the-radiative-forcing-of-increased-atmospheric-concentrations-of-co2/)

New Relative Contribution Percent of the Radiative Effect of CO_2

In Watts per meter squared

- **Methane +0.8**
- **Short-wave albedo change +0.5**
- **Tropospheric ozone +0.3**
- **Aerosol black carbon +0.2**
- **Black carbon on snow and ice +0.3**
- **Semi-direct aerosol effect +0.1**
- **Glaciation effect +0.1**
- **Solar influences +0.25**

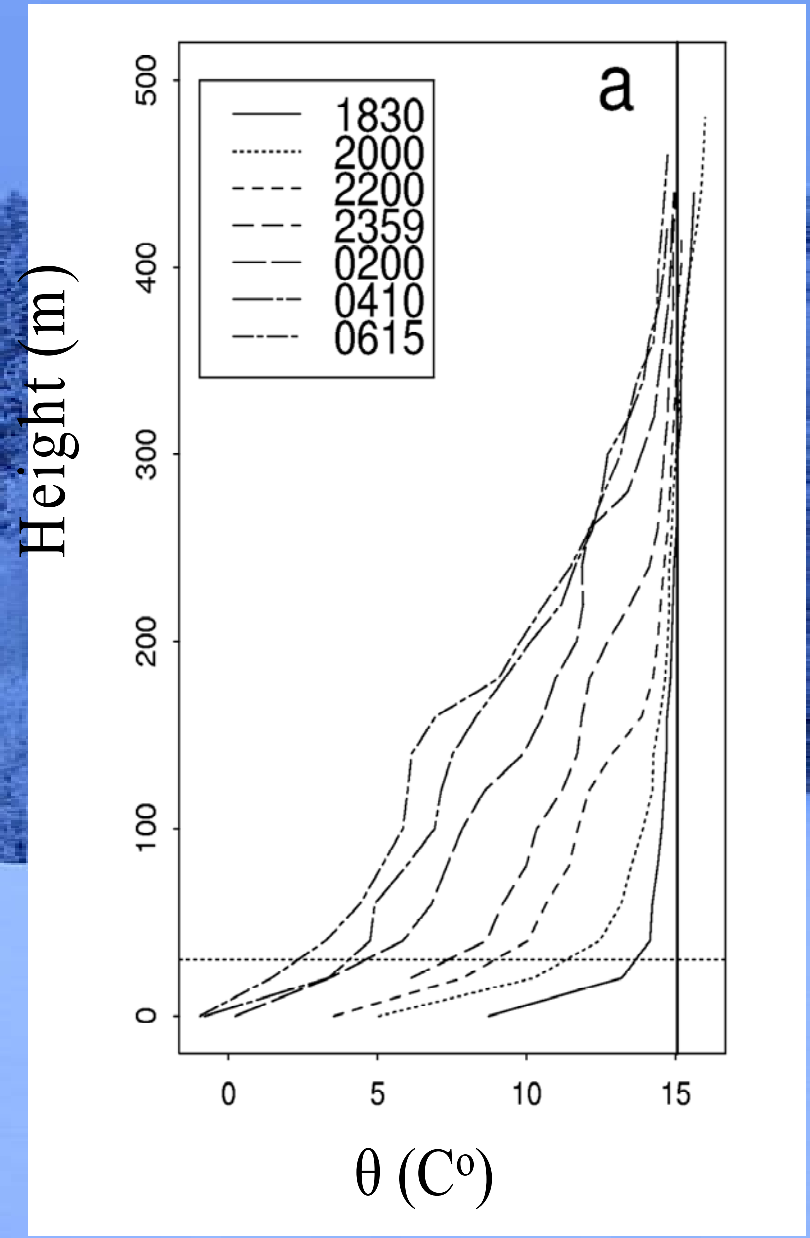
The CO_2 contribution to the radiative warming decreases to 26.5% using the IPCC framework.

Multi-Decadal Land Surface Air Temperature Trends are Not A Robust Measure Of Global Warming and Cooling

Where Surface Air Temperature is Measured Matters!

- If the goal is to assess a global average temperature trend in order to diagnose the radiative imbalance of the climate system (e.g. global warming), than sampling over land at night at any single layer near the surface introduces a warm bias whenever there is any reduction in long wave cooling at night

Observed time evolution of vertical potential temperature. Note large vertical gradients near the surface [after Acevedo and Fitzjarrald, 2004].

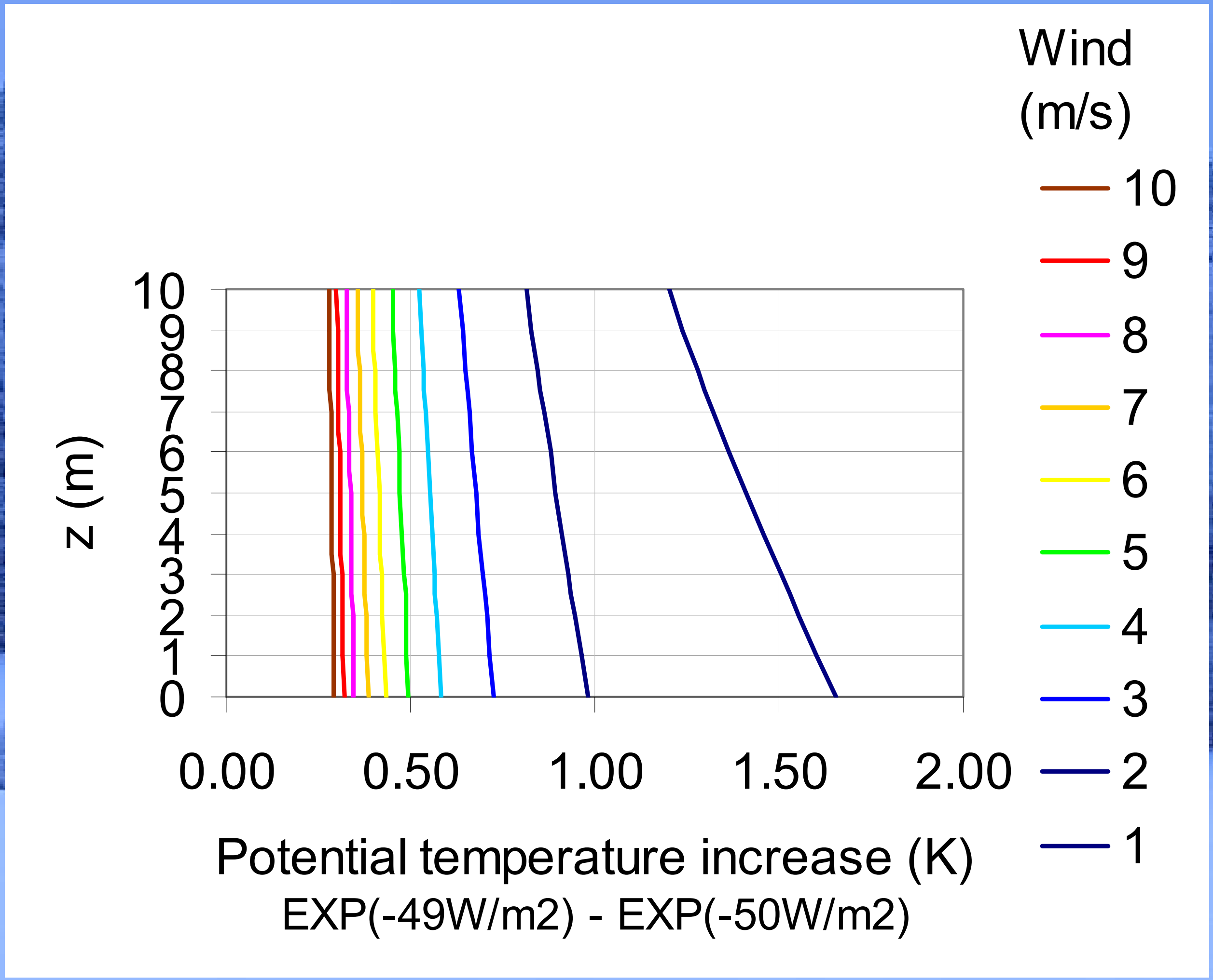


From: Pielke Sr. et al., 2006: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Research, accepted. http://blue.atmos.colostate.edu/publications/pdf/R-321.pdf

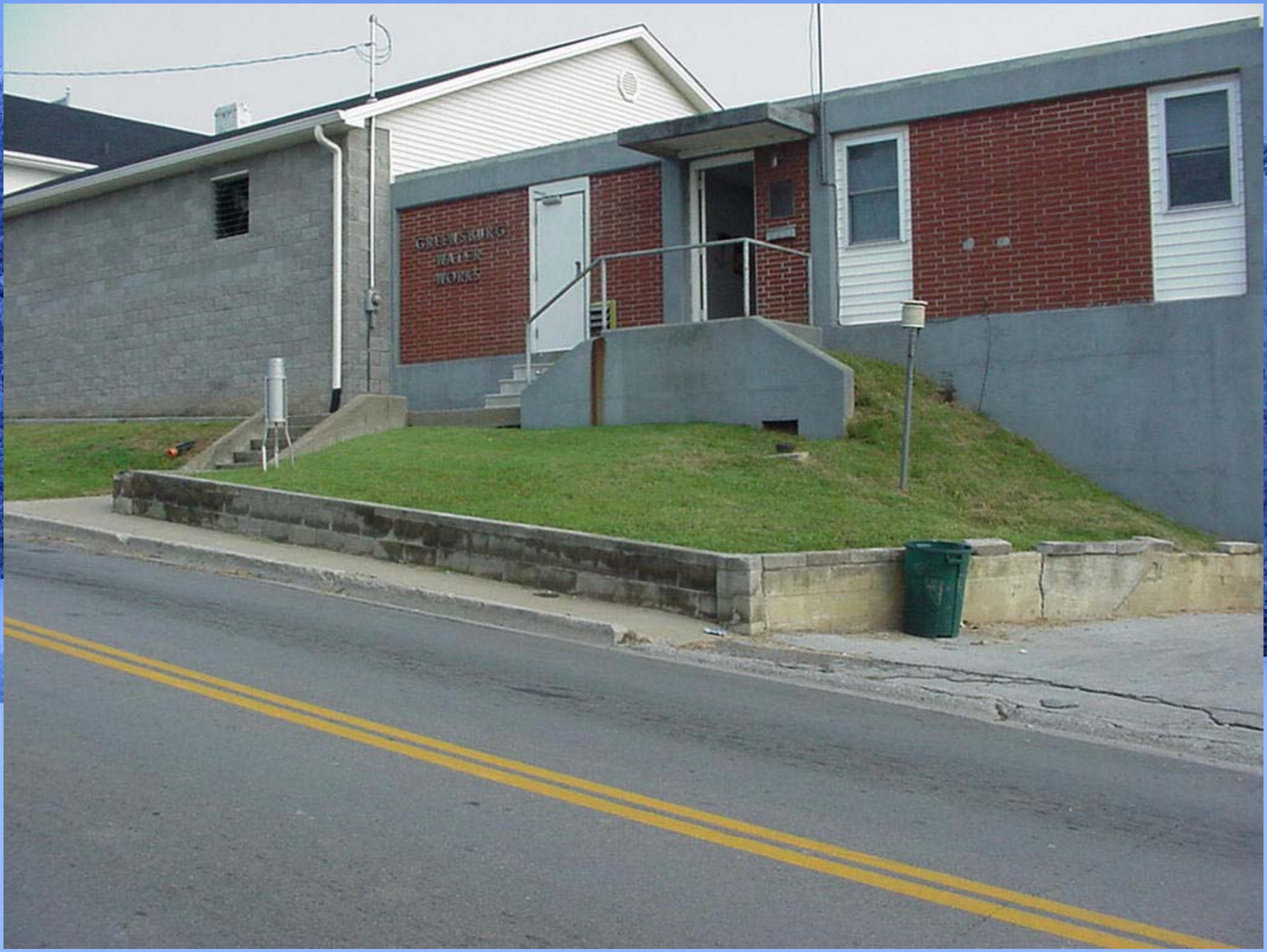
Z(m)	Wind Speed (m/s)									
	10	9	8	7	6	5	4	3	2	1
10	0.28	0.30	0.33	0.36	0.40	0.45	0.52	0.63	0.81	1.20
9	0.28	0.30	0.33	0.36	0.40	0.45	0.53	0.64	0.83	1.24
8	0.28	0.30	0.33	0.36	0.40	0.46	0.53	0.65	0.85	1.28
7	0.28	0.31	0.33	0.37	0.41	0.46	0.54	0.66	0.86	1.32
6	0.28	0.31	0.33	0.37	0.41	0.47	0.55	0.67	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

Potential temperature increase at different levels from the experiment with -49 W m-2 cooling to the experiment with -50 W m-2 cooling. From: Pielke Sr. et al., 2006: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Research, accepted.

http://blue.atmos.colostate.edu/publications/pdf/R-321.pdf



Potential temperature increase at different levels from the experiment at -49 W m^{-2} to the experiment with -50 W m^{-2} cooling. From: Pielke Sr. et al., 2006: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Research, accepted. http://blue.atmos.colostate.edu/publications/pdf/R-321.pdf



USHCN station exposure at Greensburg, Kentucky. From: Pielke Sr. et al., 2006: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Research, accepted.

http://blue.atmos.colostate.edu/publications/pdf/R-321.pdf

USHCN station exposure at Leitchfield_2_N, Kentucky. From: Pielke Sr. et al., 2006: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Research, accepted.
http://blue.atmos.colostate.edu/publications/pdf/R-321.pdf

USHCN station exposure at Leitchfield_2_N, Kentucky. From: Pielke Sr. et al., 2006: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Research, accepted.
http://blue.atmos.colostate.edu/publications/pdf/R-321.pdf

USHCN station exposure at Hopkinsville, Kentucky. From: Pielke Sr. et al., 2006: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Research, accepted.
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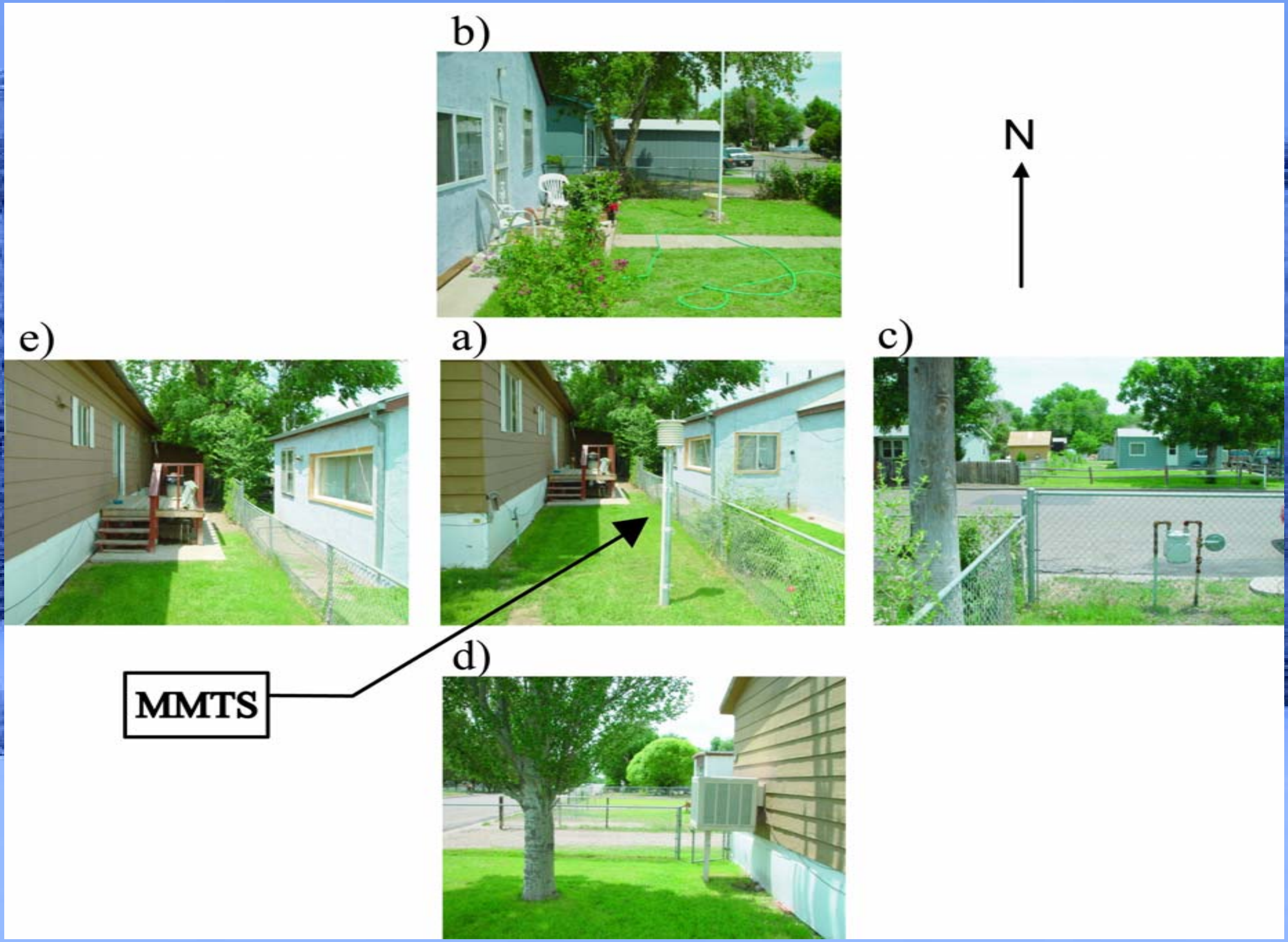
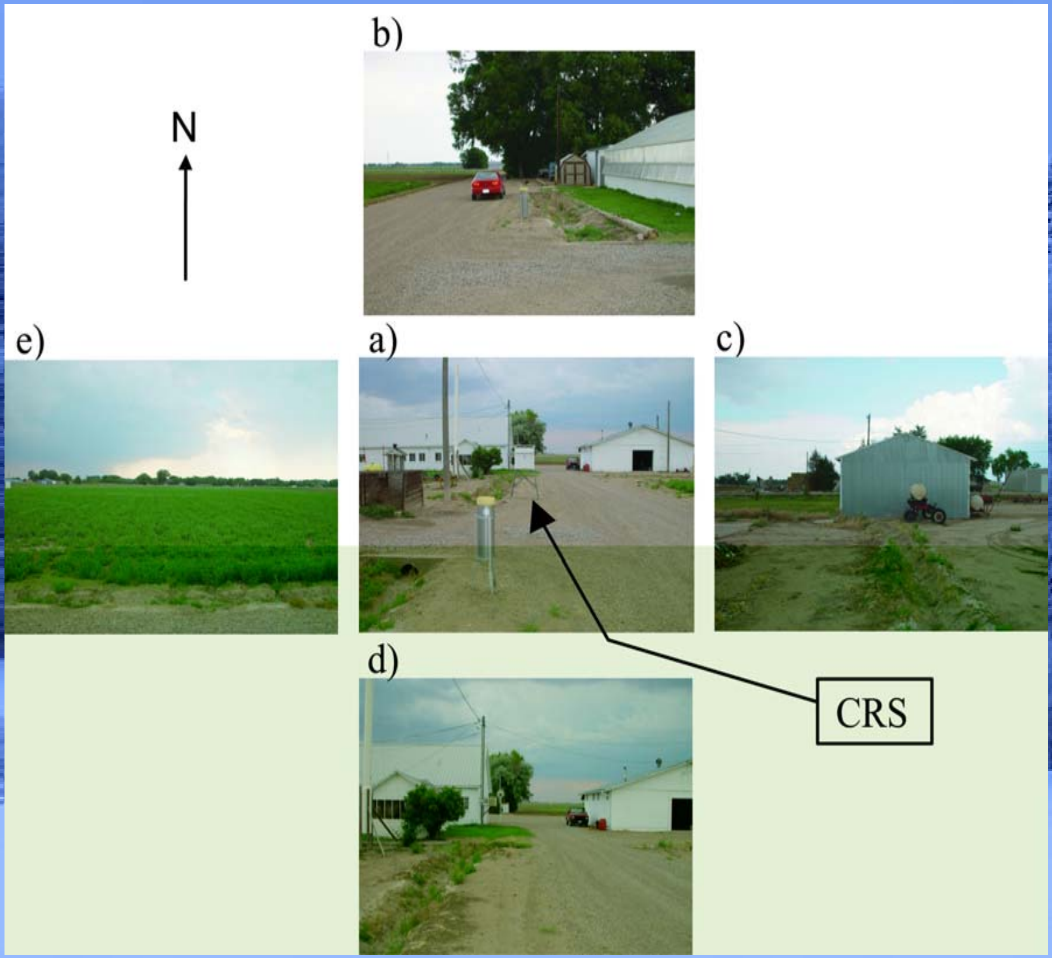
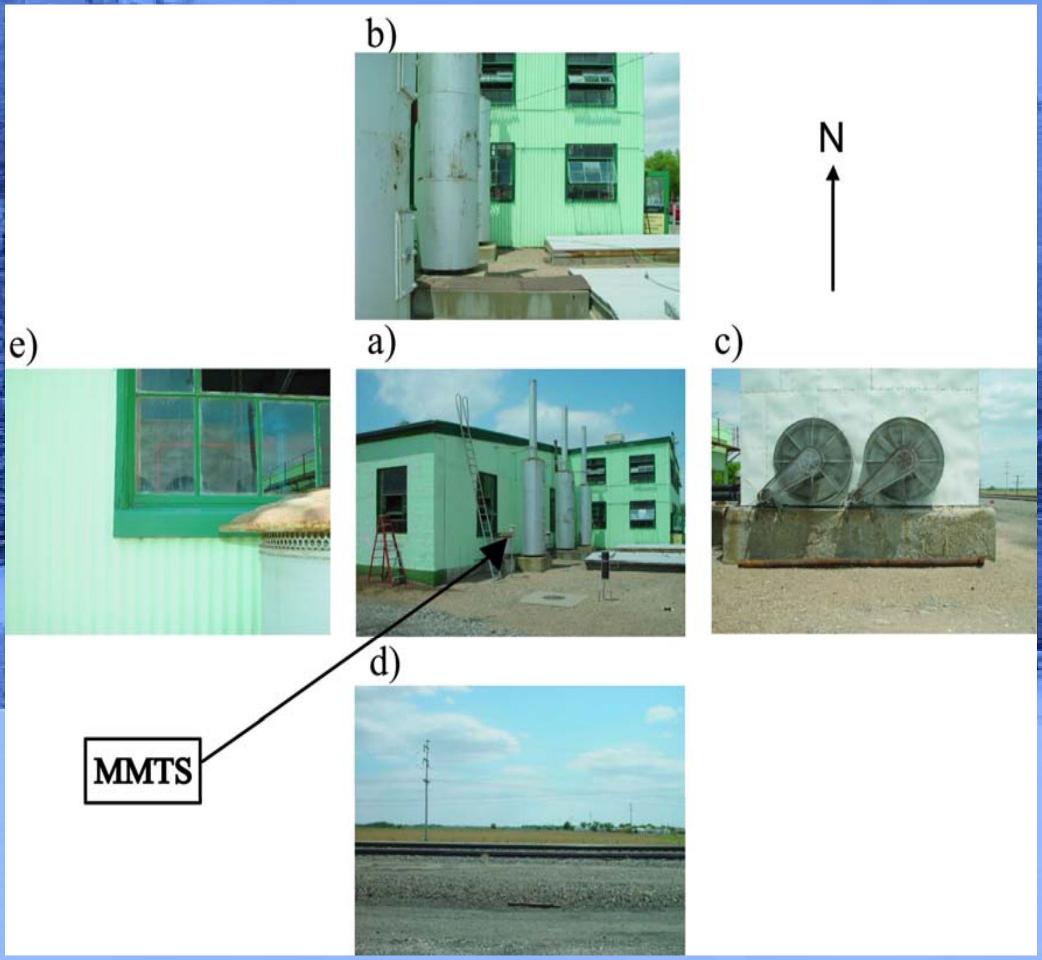


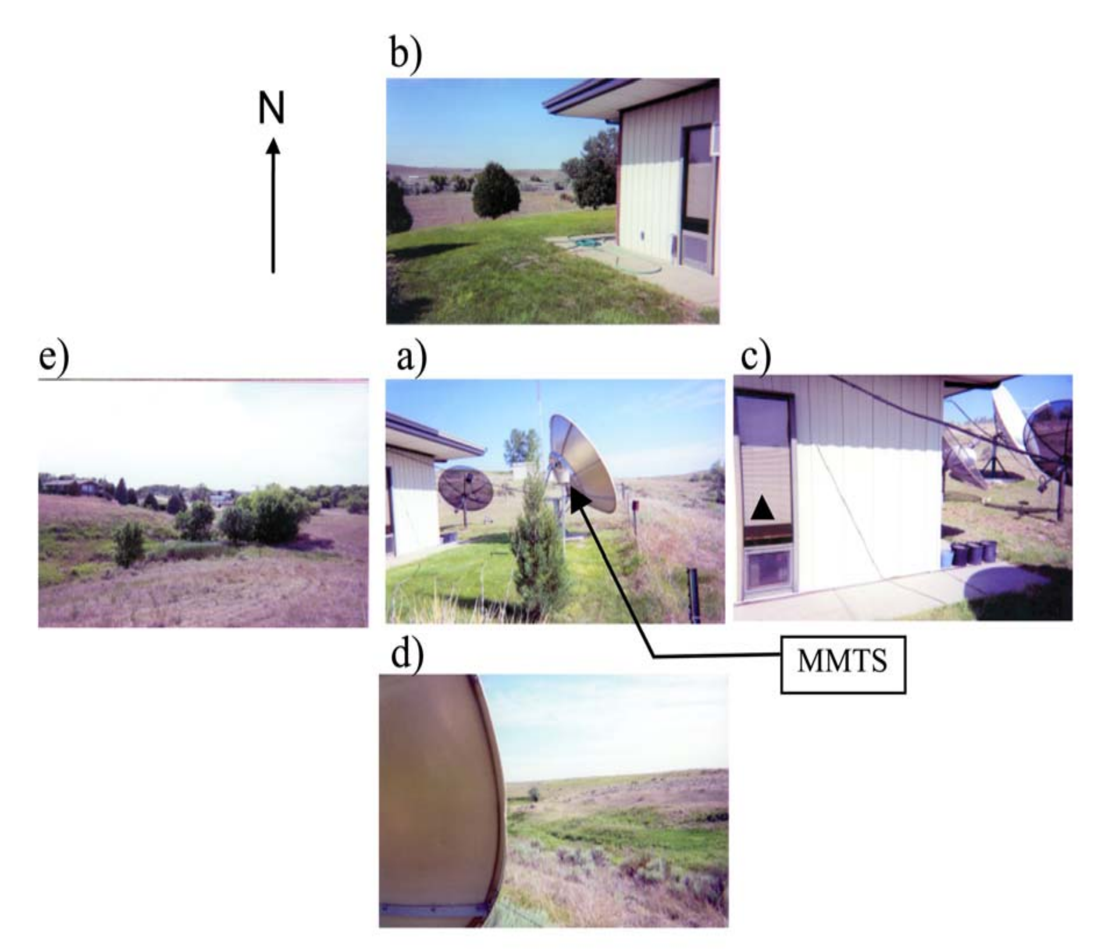
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Lamar, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively. From Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate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



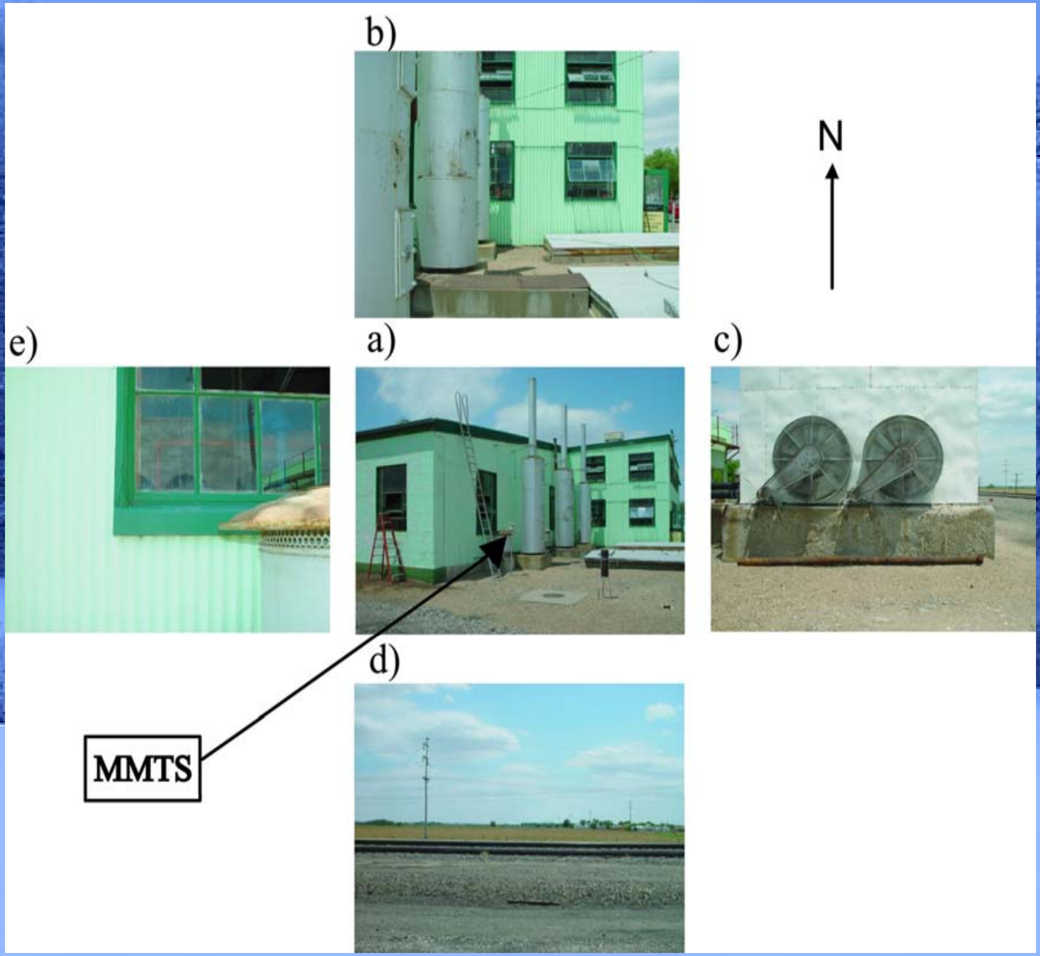
Photographs of the temperature sensor exposure characteristics for the NWS COOP station near Rocky Ford, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively. (CRS-Cotton Region Shelter). From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

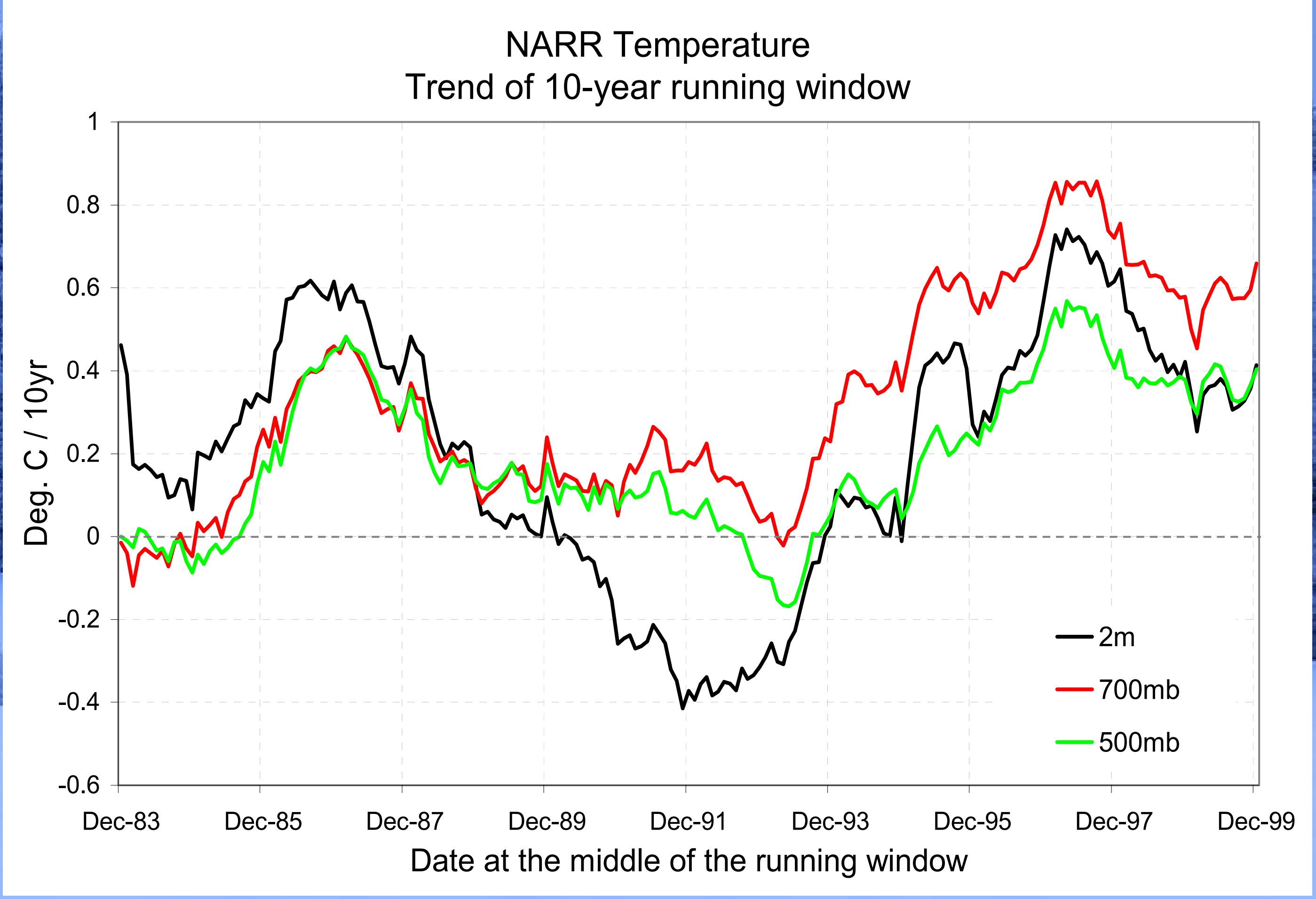


Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Wray, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the sensor looking N, E, S, and W, respectively. From Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate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

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



Trends of 10-year running windows for the NARR temperature anomalies. From: Pielke Sr. et al., 2006: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Research, accepted.

http://blue.atmos.colostate.edu/publications/pdf/R-321.pdf

Table 5. Comparison of temperature trend results for those stations included in *Hale et al.* [2006] with an additional eight ecoregions and 76 additional Normals stations included in the analysis. The number of stations with significant trends (positive or negative), prior to or after LULC changes, are indicated.

	trend prior to LULC change		trend after LULC change	
	neg	pos	neg	pos
	(number of stations with significant trends)			
min	32	33	2	110
max	9	12	8	98
mean	11	20	3	110

From: Pielke Sr., R.A, C. Davey, J. Angel, O. Bliss, M. Cai, N. Doesken, S. Fall, K. Gallo, R. Hale, K.G. Hubbard, H. Li, X. Lin, J. Nielsen-Gammon, D. Niyogi, and S. Raman, 2006: Documentation of bias associated with surface temperature measurement sites. Bull. Amer. Meteor. Soc., accepted. http://blue.atmos.colostate.edu/publications/pdf/R-318.pdf

Ocean Heat Content Changes Over Time Provides An Effective Metric To Diagnose The Radiative Imbalance of the Climate System

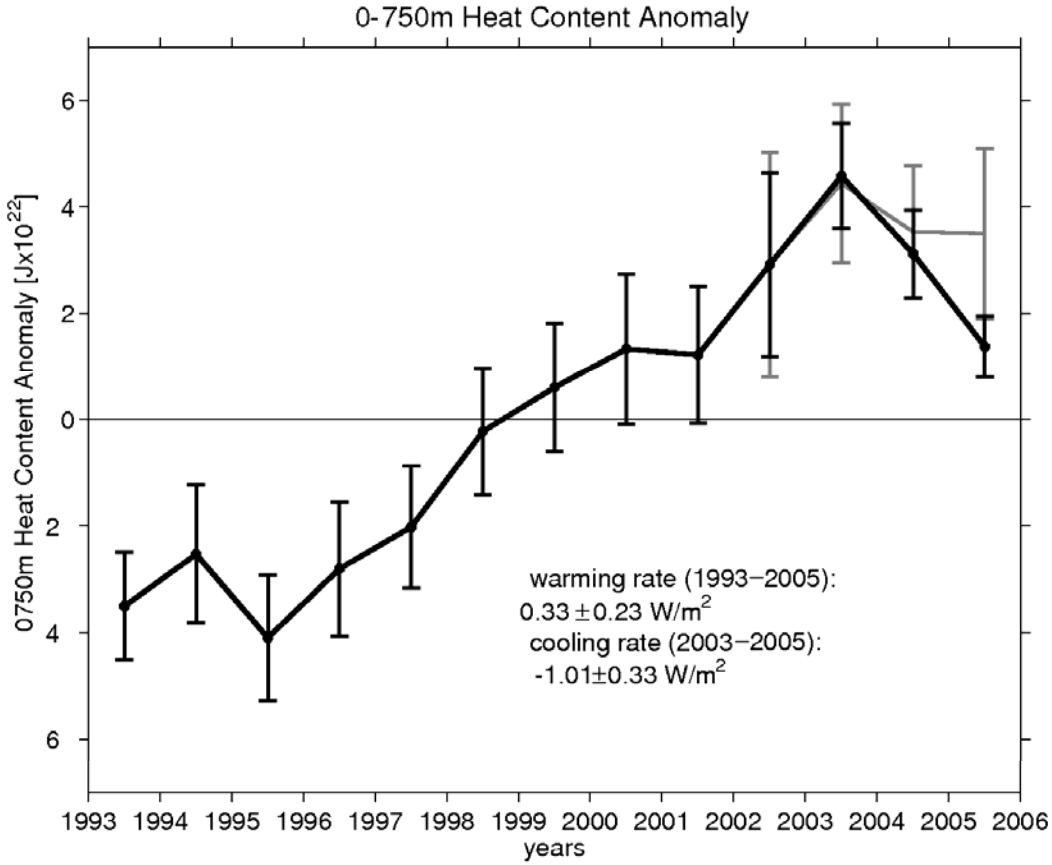
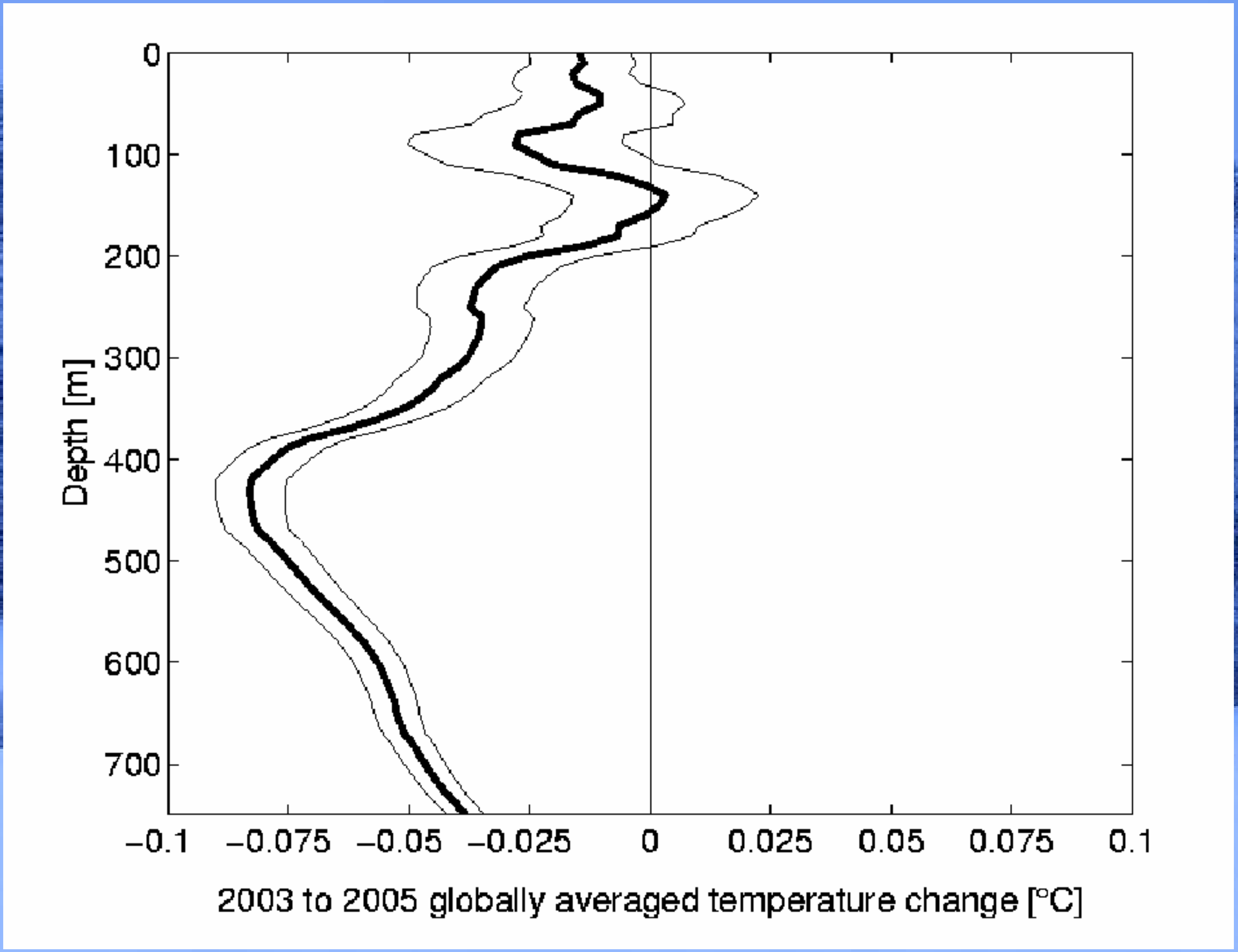


Figure 1. Globally averaged annual OHCA [10^{22} J] in the upper 750 m estimated using in situ data alone from 1993 through 2005 (black line) and using in situ data excluding profiling floats (gray line). Error bars (from Figure 3) reflect the standard error estimates discussed in Section 3. Linear trends are computed from a weighted least square fit [*Wunsch,* 1996] and reflect the OHCA estimate made using all available profile data. Errors for inset linear trend estimates are quoted at the 95% confidence interval.

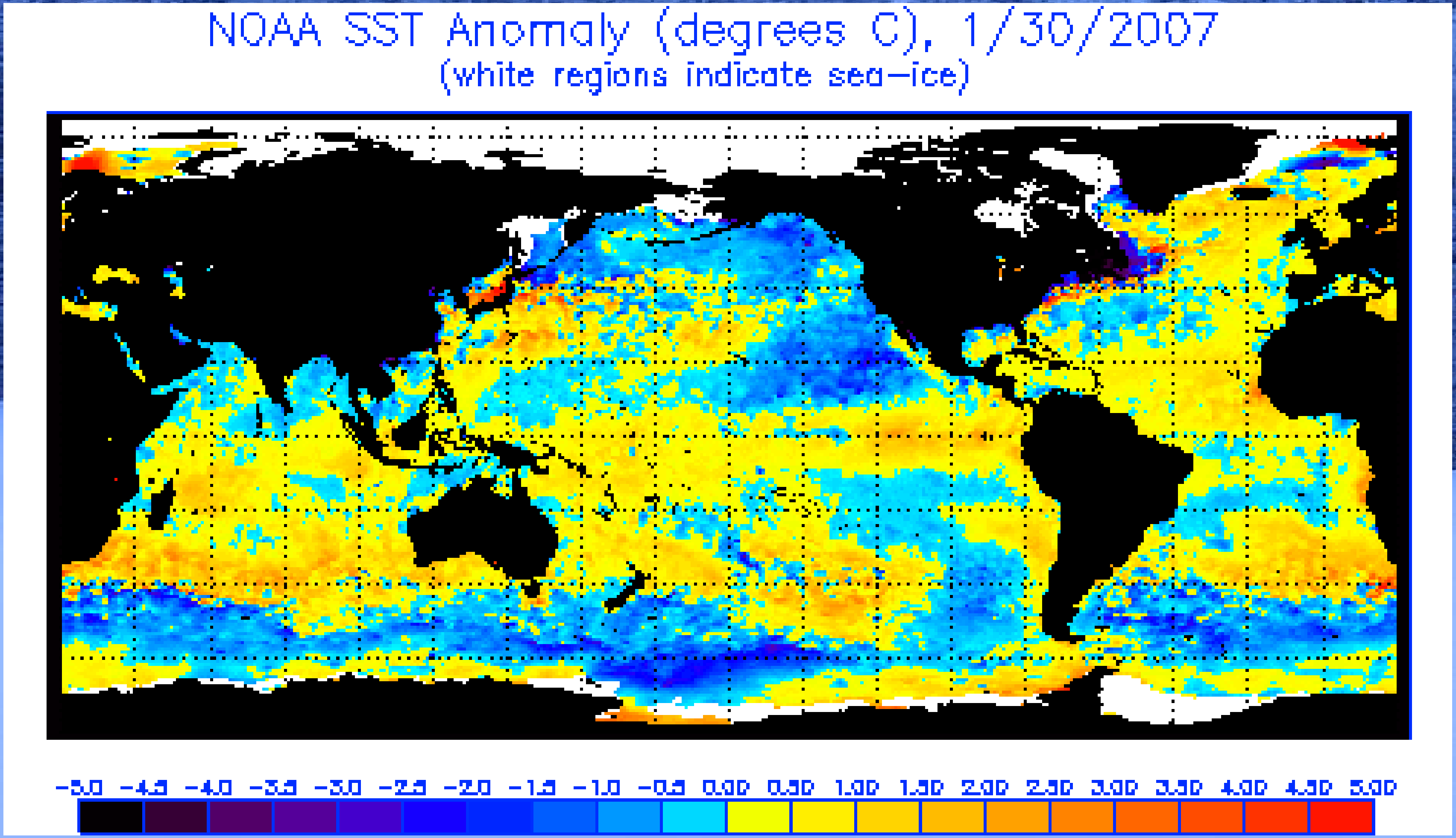
From Lyman, J.M., J. Willis, and G. Johnson, 2006: Recent cooling of the upper ocean. Geophys Res. Lett., 33, L18604, doi:10.1029/2006GL027033.



Globally averaged ocean temperature change in °C from 2003 to 2006 versus depth (m). Think black lines represent error bounds determined by scaling the uncertainty in heat content using regression coefficients.

From Lyman, J.M., J. Willis, and G. Johnson, 2006: Recent cooling of the upper ocean. Geophys. Res. Lett., 33, L18604, doi:10.1029/2006GL027033.

Current SST Anomalies



http://www.osdpd.noaa.gov/PSB/EPS/SST/climo.html

New or Under-Recognized Human Climate Forcings

- Biogeochemical Effect of CO_2
- Nitrogen Deposition
- Land-Use/Land-Cover Change
- Glaciation Effect of Aerosols
- Thermodynamic Effect of Aerosols
- Surface Energy Budget Effect

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

New Climate Change Metrics Are Needed

- Gradient of Radiative Forcing

  Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974.

  http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

- Change in Portioning Between Latent and Sensible Surface Heat Fluxes

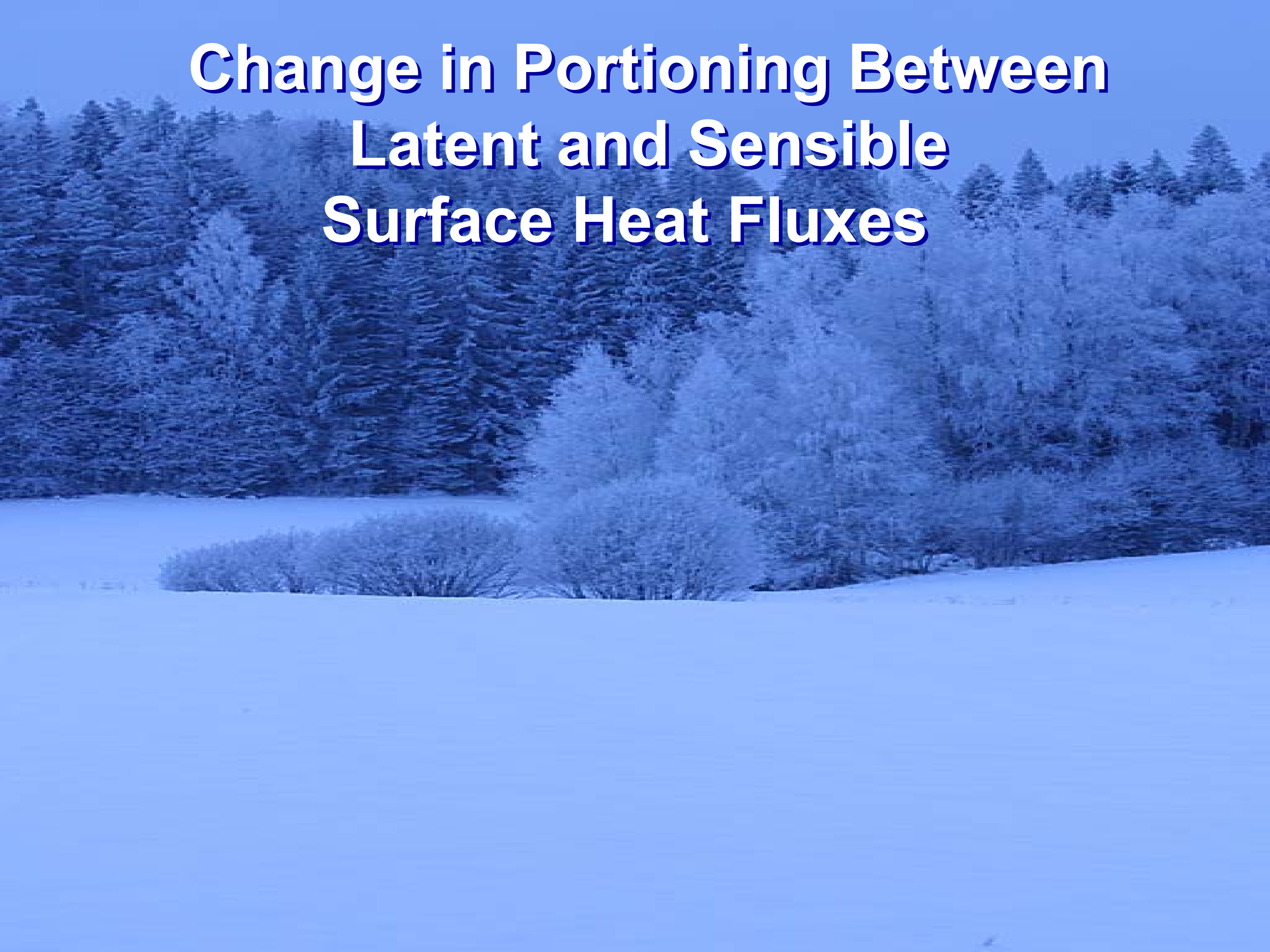
  Chase, T.N., R.A. Pielke, T.G.F. Kittel, R.R. Nemani, and S.W. Running, 2000: Simulated impacts of historical land cover changes on global climate in northern winter. Climate Dynamics, 16, 93-105. http://blue.atmos.colostate.edu/publications/pdf/R-214.pdf

- Change in Global and Regional Water Cycle

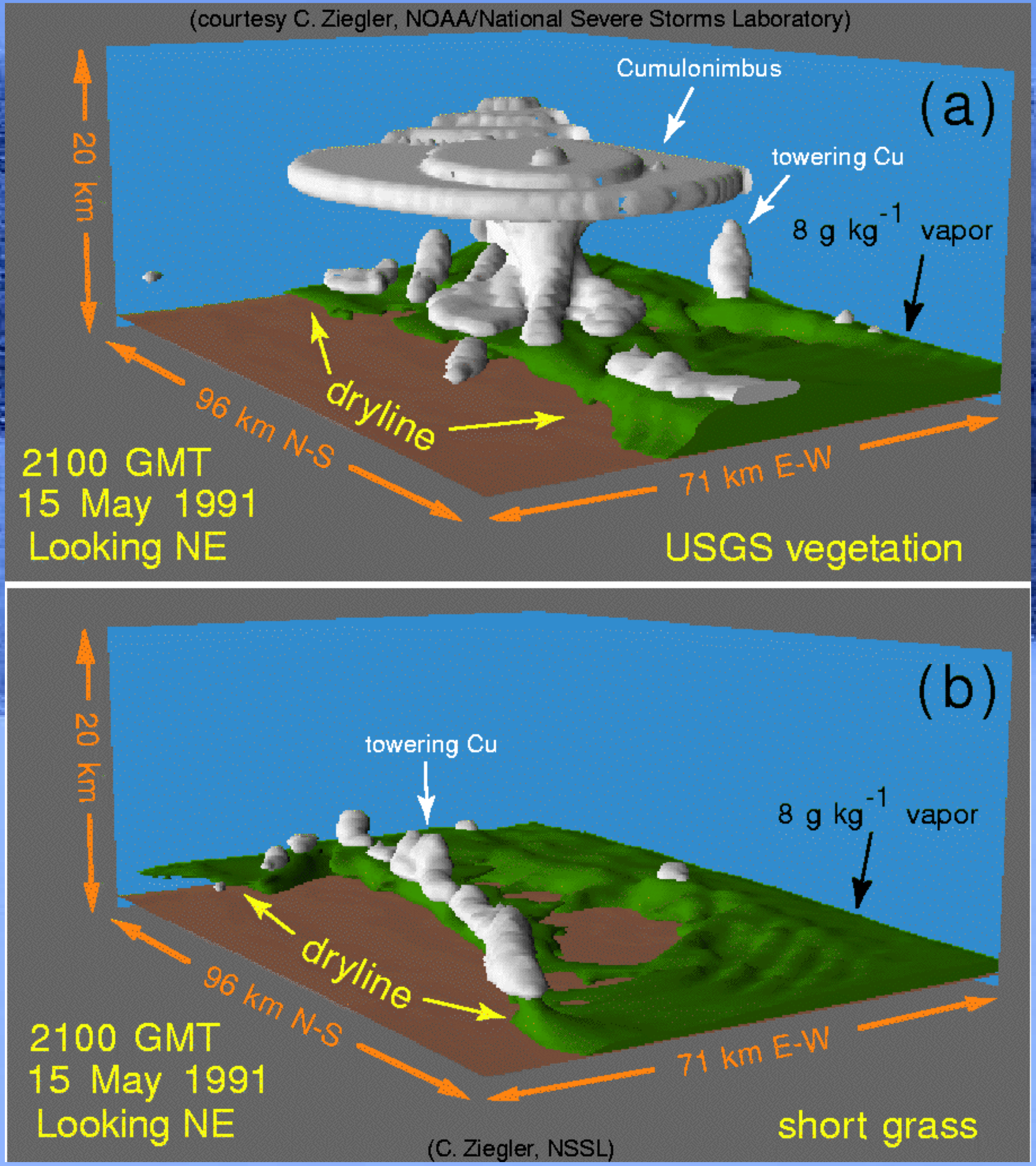
  Marshall, C.H., R.A. Pielke Sr., and L.T. Steyaert, 2004: Has the conversion of natural wetlands to agricultural land increased the incidence and severity of damaging freezes in south Florida? Mon. Wea. Rev., 132, 2243-2258. http://blue.atmos.colostate.edu/publications/pdf/R-281.pdf

  Pielke, R.A. Sr., and T.N. Chase, 2003: A proposed new metric for quantifying the climatic effects of human-caused alterations to the global water cycle. Preprints, Symposium on Observing and Understanding the Variability of Water in Weather and Climate, 83rd AMS Annual Meeting, February 9-13, Long Beach, CA. http://blue.atmos.colostate.edu/publications/pdf/PPR-249.pdf

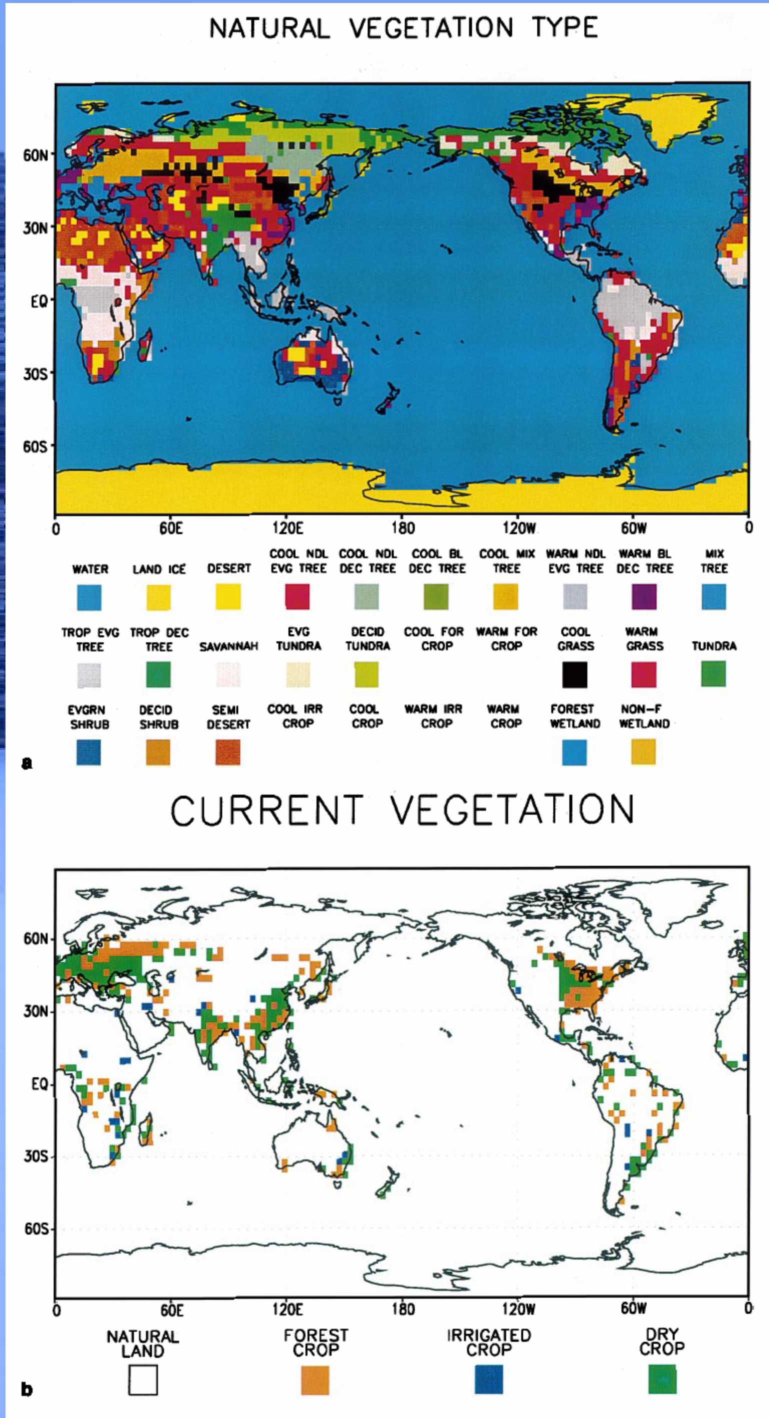
Change in Portioning Between Latent and Sensible Surface Heat Fluxes



Effect of Land-Use Change on Deep Cumulonimbus Convection



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



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

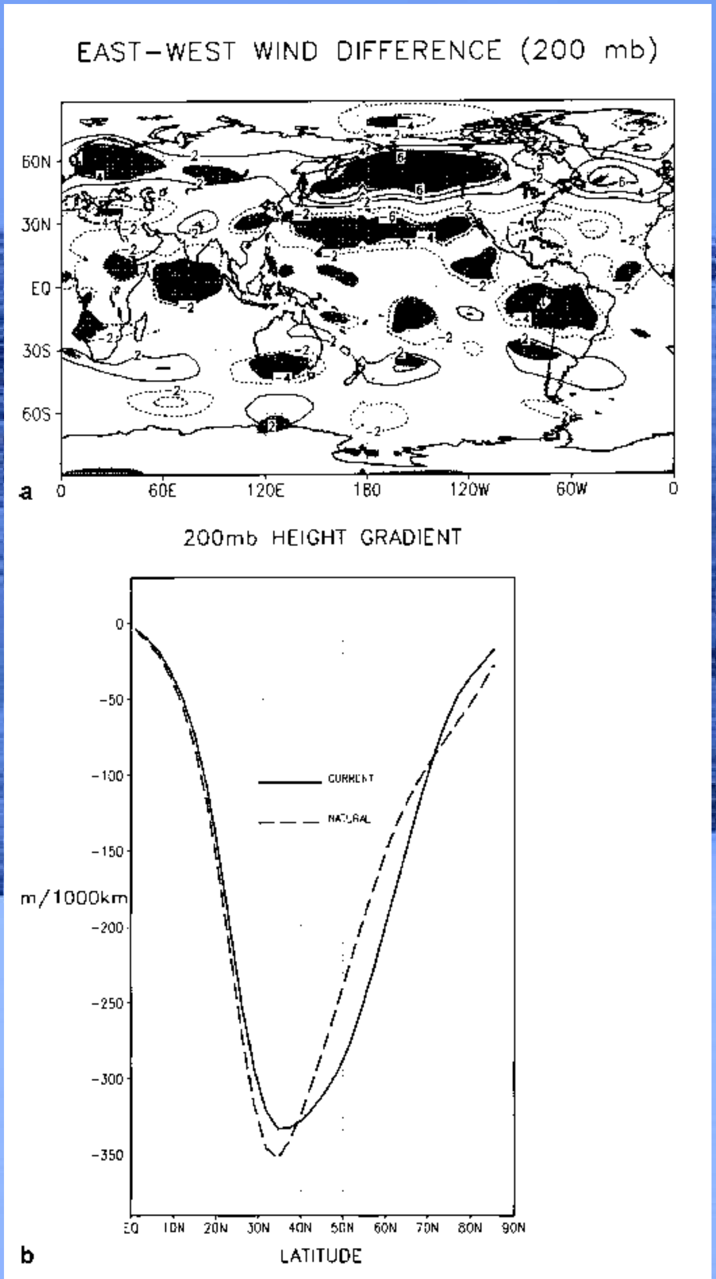
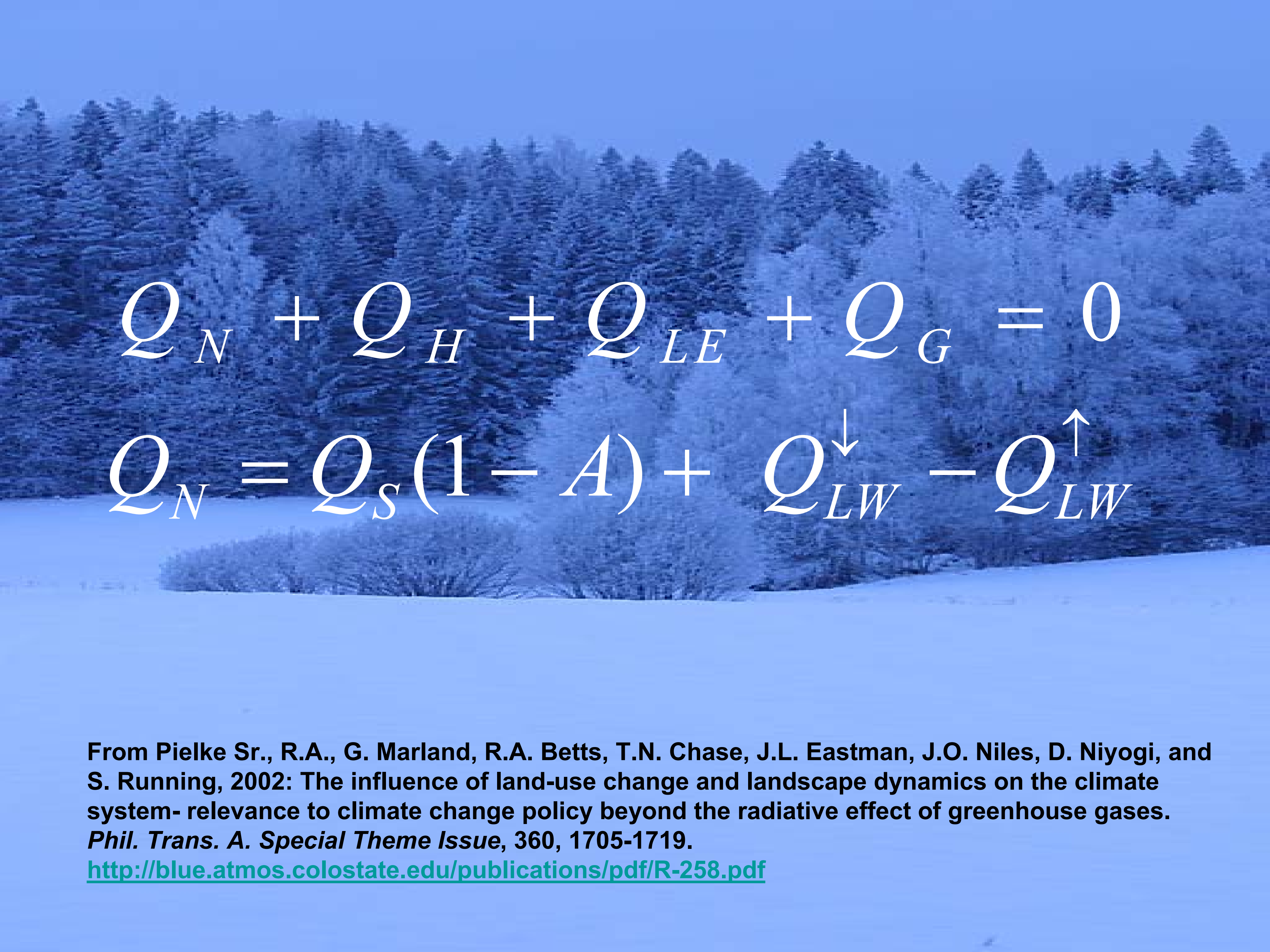


Fig. 9 **a** Difference in 200 hPa east-west wind (current-natural), contours are 2 m s^{-1}. *Shaded regions* as in Fig. 3. **b** Comparison of north-south derivative of zonally averaged 200 hPa heights (d(Z200)/dy) in Northern Hemisphere

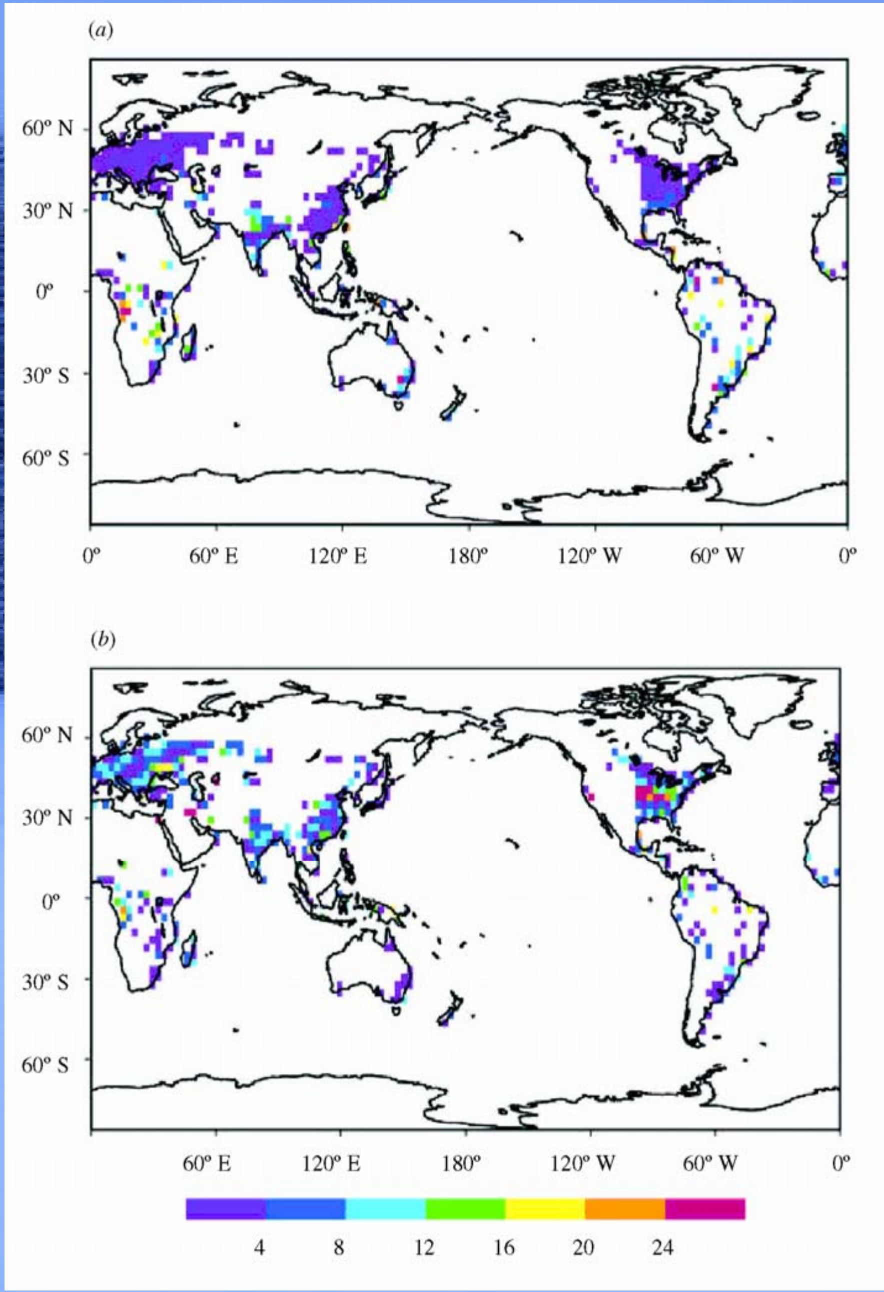
From: Chase, T.N., R.A. Pielke, T.G.F. Kittel, R.R. Nemani, and S.W. Running, 2000: Simulated impacts of historical land cover changes on global climate in northern winter. Climate Dynamics, 16, 93-105. http://blue.atmos.colostate.edu/publications/pdf/R-214.pdf



$$Q_N + Q_H + Q_{LE} + Q_G = 0$$

$$Q_N = Q_S(1 - A) + Q_{LW}^{\downarrow} - Q_{LW}^{\uparrow}$$

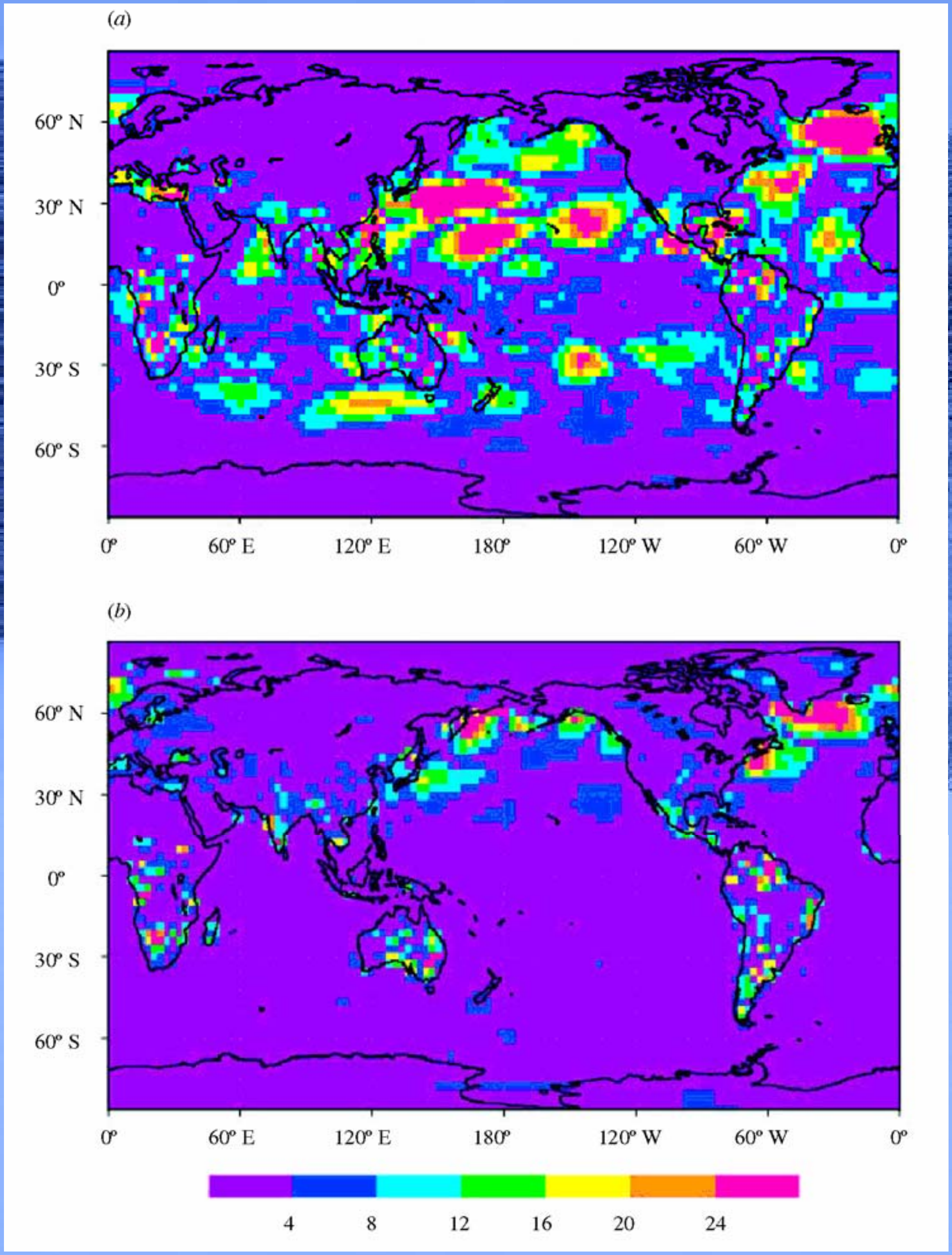
From Pielke Sr., R.A., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D. Niyogi, and S. Running, 2002: The influence of land-use change and landscape dynamics on the climate system- relevance to climate change policy beyond the radiative effect of greenhouse gases. *Phil. Trans. A. Special Theme Issue*, 360, 1705-1719.
http://blue.atmos.colostate.edu/publications/pdf/R-258.pdf



The ten-year average absolute-value change in surface latent turbulent heat flux in W m^{-2} at the locations where land-use change occurred for (a) January, and (b) July.

From Pielke Sr., R.A., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D. Niyogi, and S. Running, 2002: The influence of land-use change and landscape dynamics on the climate system- relevance to climate change policy beyond the radiative effect of greenhouse gases. *Phil. Trans. A. Special Theme Issue*, 360, 1705-1719.

http://blue.atmos.colostate.edu/publications/pdf/R-258.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.)

From Pielke Sr., R.A., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D. Niyogi, and S. Running, 2002: The influence of land-use change and landscape dynamics on the climate system- relevance to climate change policy beyond the radiative effect of greenhouse gases. *Phil. Trans. A. Special Theme Issue*, 360, 1705-1719.

http://blue.atmos.colostate.edu/publications/pdf/R-258.pdf

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 Occurred	July January	1.08 Watts m^{-2} 0.7 Watts m^{-2}
Teleconnections Included	July January	8.90 Watts m^{-2} 9.47 Watts m^{-2}

Global redistribution of heat is on the same order as an El Niño.

Change in the Global Water Cycle

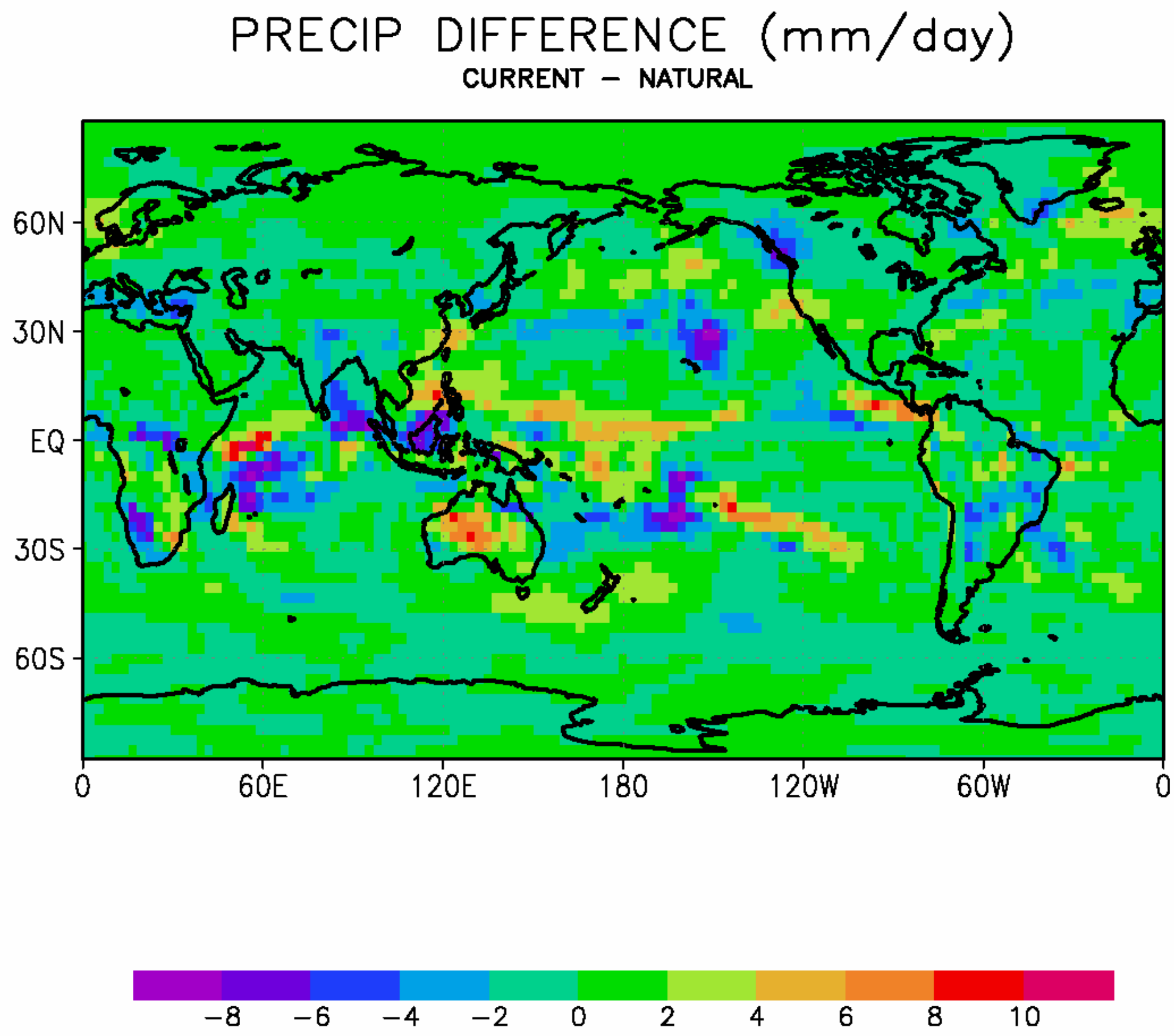
Spatial Redistribution of Heat is also Associated with a Spatial Redistribution of Water

$$R_N = Q_G + H + L(E+T)$$

$$P = E + T + RO + I$$

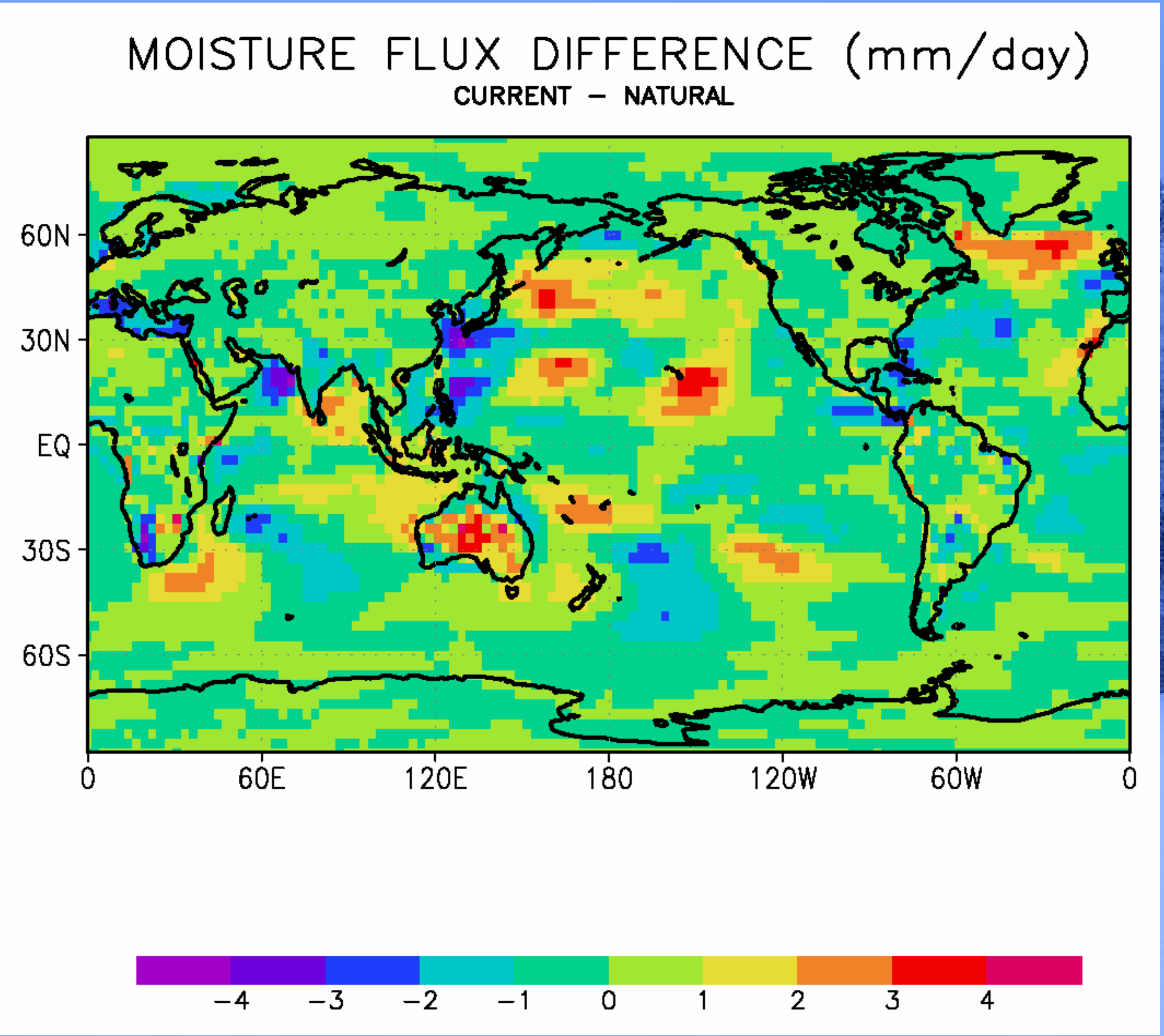
New Metric: Changes in δP; δT; δRO; δI

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



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

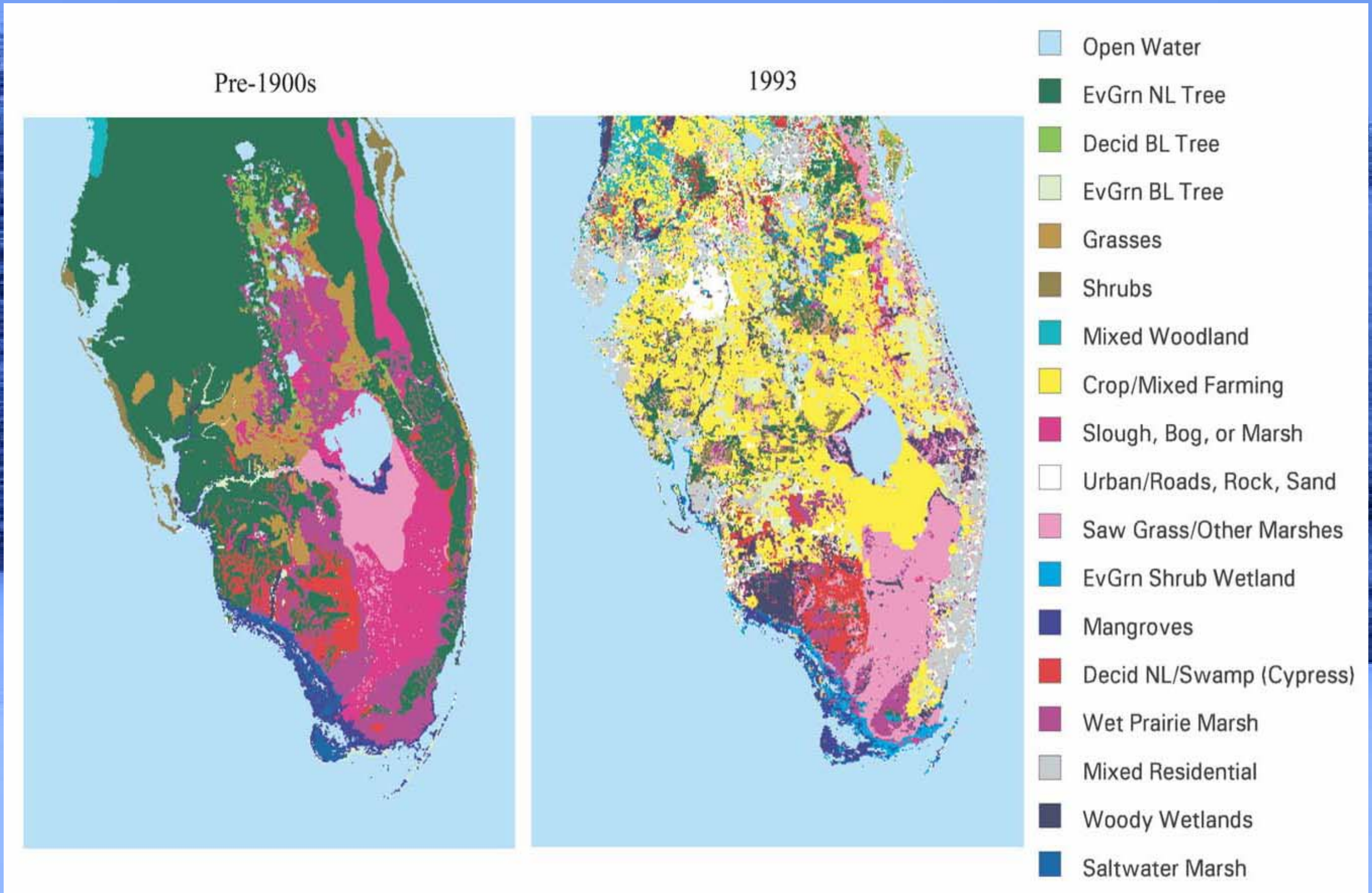
Prepared by T.N. Chase, CU, Boulder, CO.



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

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

Change In Regional Water Cycle



U.S. Geological Survey land-cover classes for pre-1900's natural conditions (left) and 1993 land-use patterns (right). 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 the Florida peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev., 132, 28-52. http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf

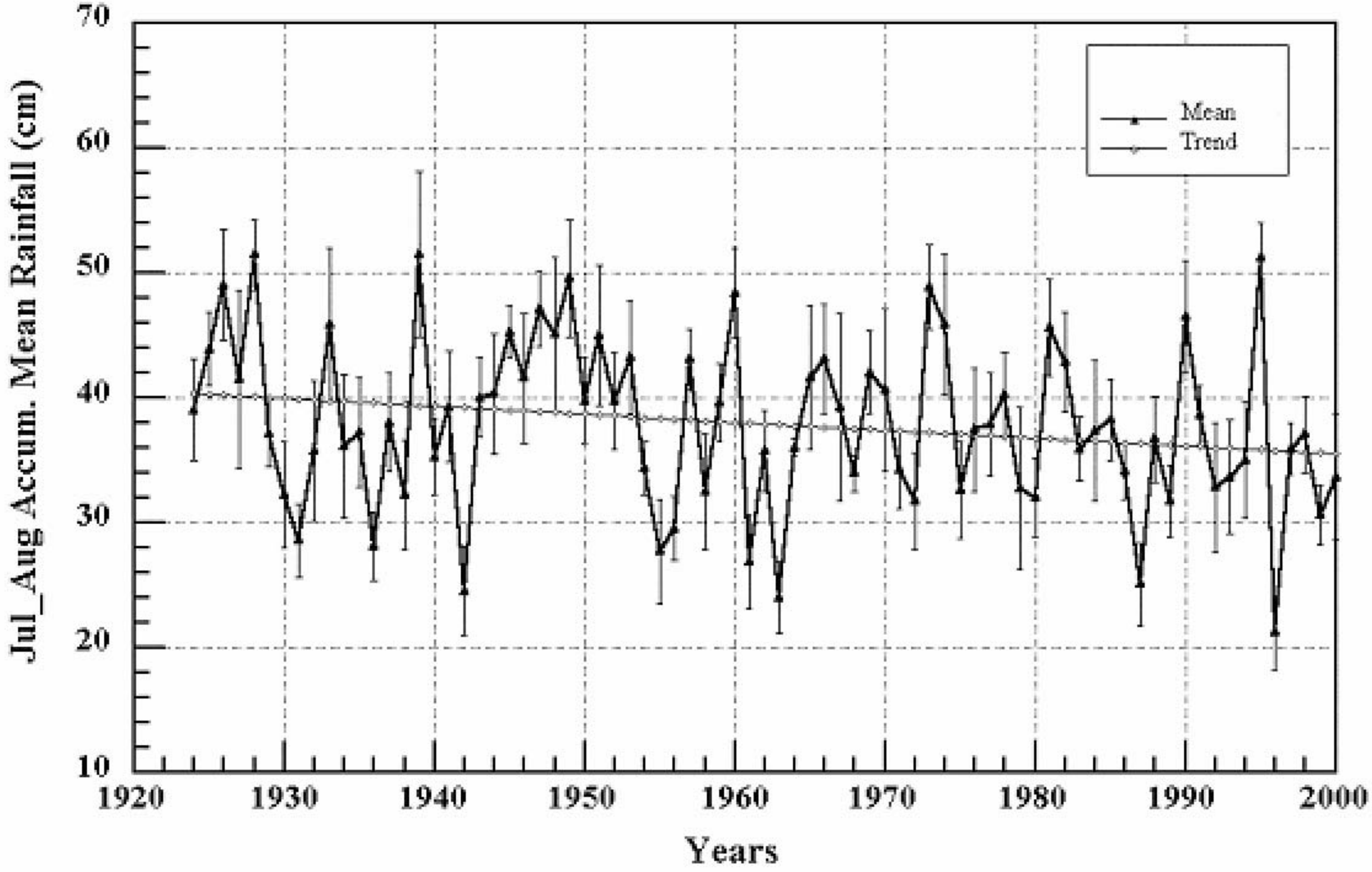


FIG. 25. Regional average time series of accumulated convective rainfall (cm) from 1924 to 2000, with corresponding trend based on linear regression of all July-August amounts. The vertical bars overlain on the raw time series indicate the value of the standard error of the July-August regional mean.

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 the Florida peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev., 132, 28 52. http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf

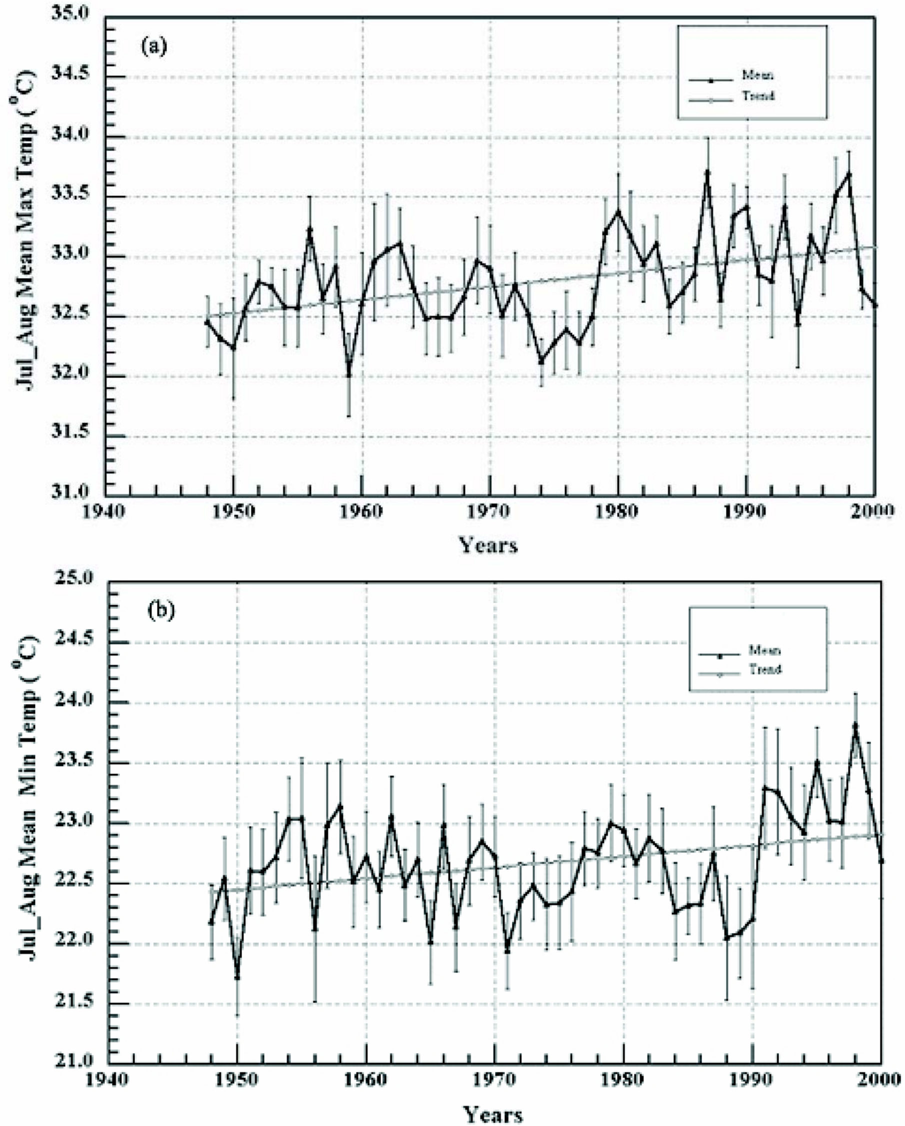
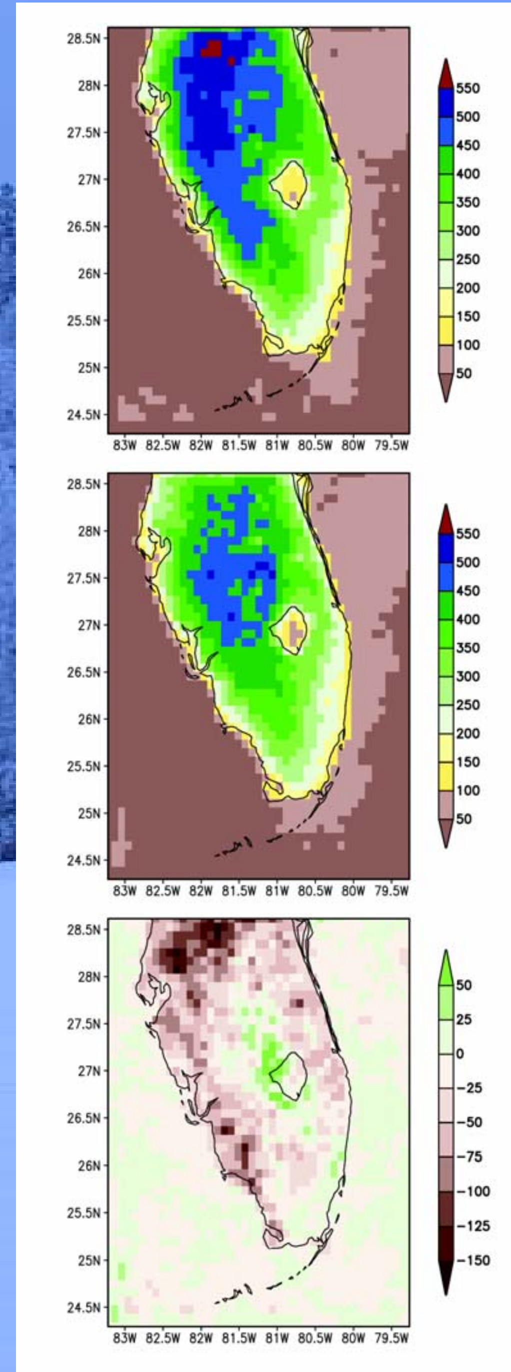


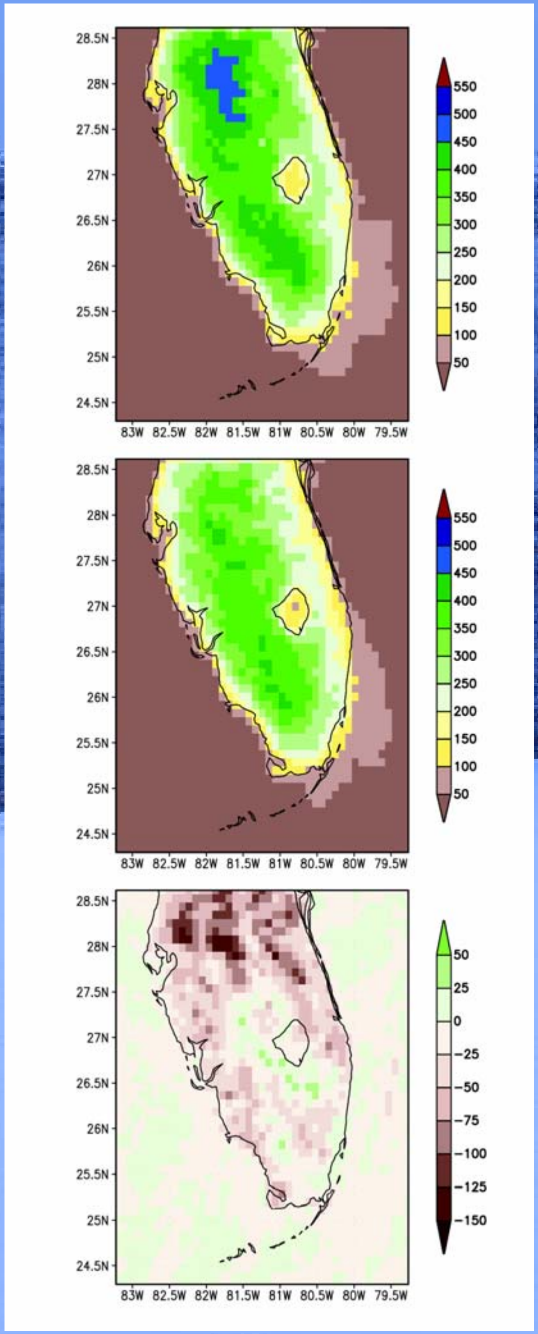
FIG. 26. Same as in Figure 25, except for daily (a) maximum and (b) minimum shelter-level temperature (°C)

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 the Florida peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev., 132, 28-52. http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf

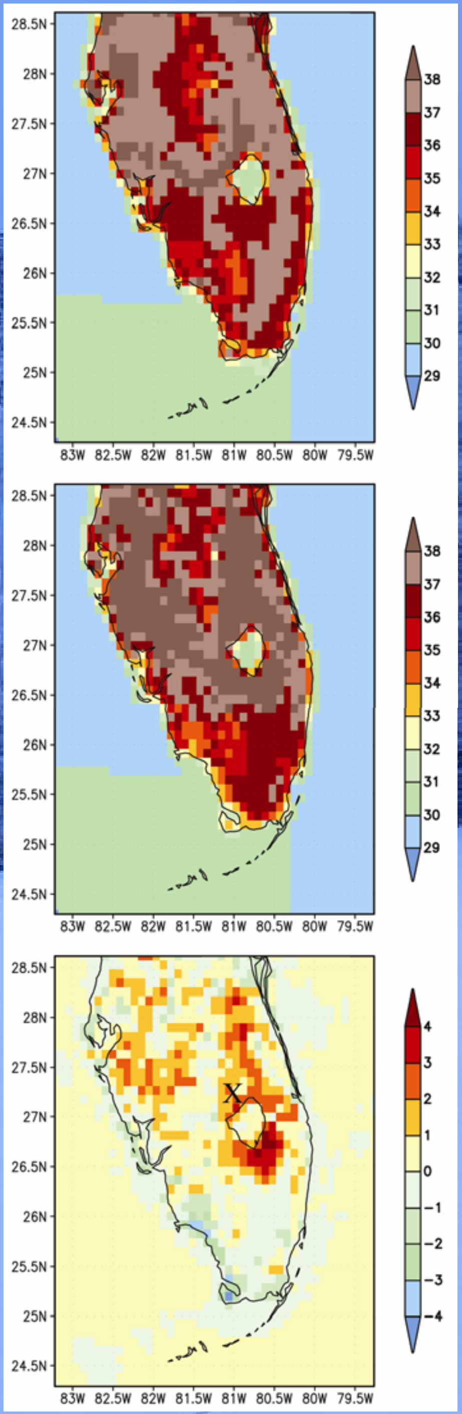


Associated convective rainfall (mm) from the model simulations of July-August 1973 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom; 1993 minus pre-1900s case). From Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land-cover change on the Florida peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev., 132, 28-52.

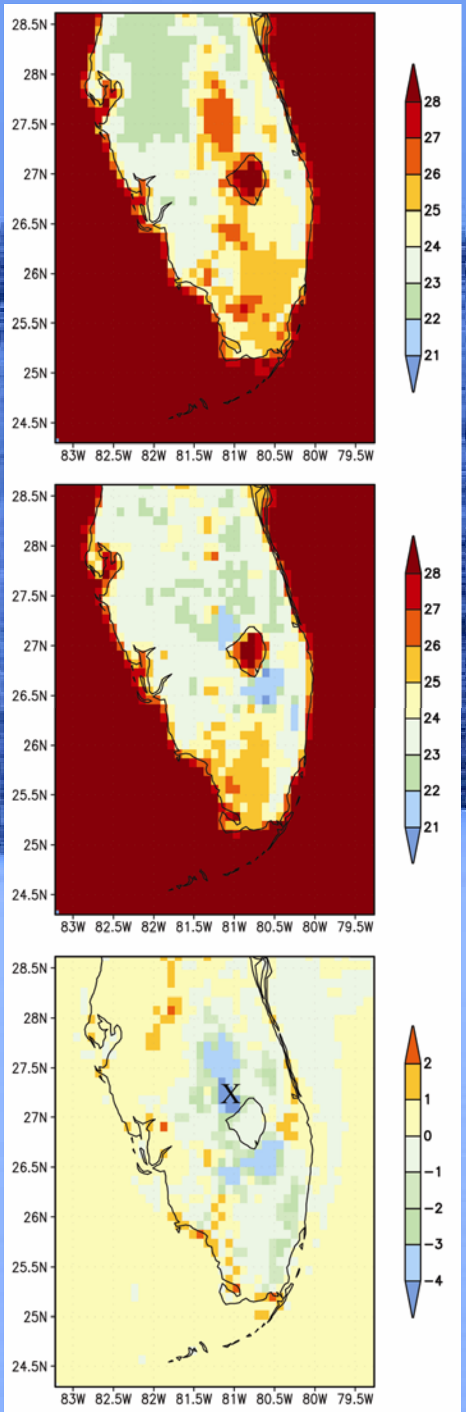
http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf



Same as previous figure except for July and 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 the Florida peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev., 132, 28-52. http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf



Two-month average of the daily maximum shelter-level temperature (°C) from the model simulations of Jul-Aug 1989 with (top) natural land cover, (middle) current land cover. 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 the Florida peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev., 132, 28-52.
http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf



Same as previous figure except for daily minimum temperature. 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 the Florida peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev., 132, 28-52.
http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf

Gradient of Radiative Forcing

The Normalized Gradient of Radiative Forcing (NGoRF) is the fraction of the present Earth’s heterogeneous insolation attributed to human activity on different horizontal scales

$$NGoRF = \frac{GoRF_{anthro}}{GoRF_{total}}$$

$$GoRF_{total} = \overline{\frac{\partial R_{total}}{\partial \lambda}}$$

$$GoRF_{anthro} = \overline{\frac{\partial R_{anthro}}{\partial \lambda}}$$

From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974. http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

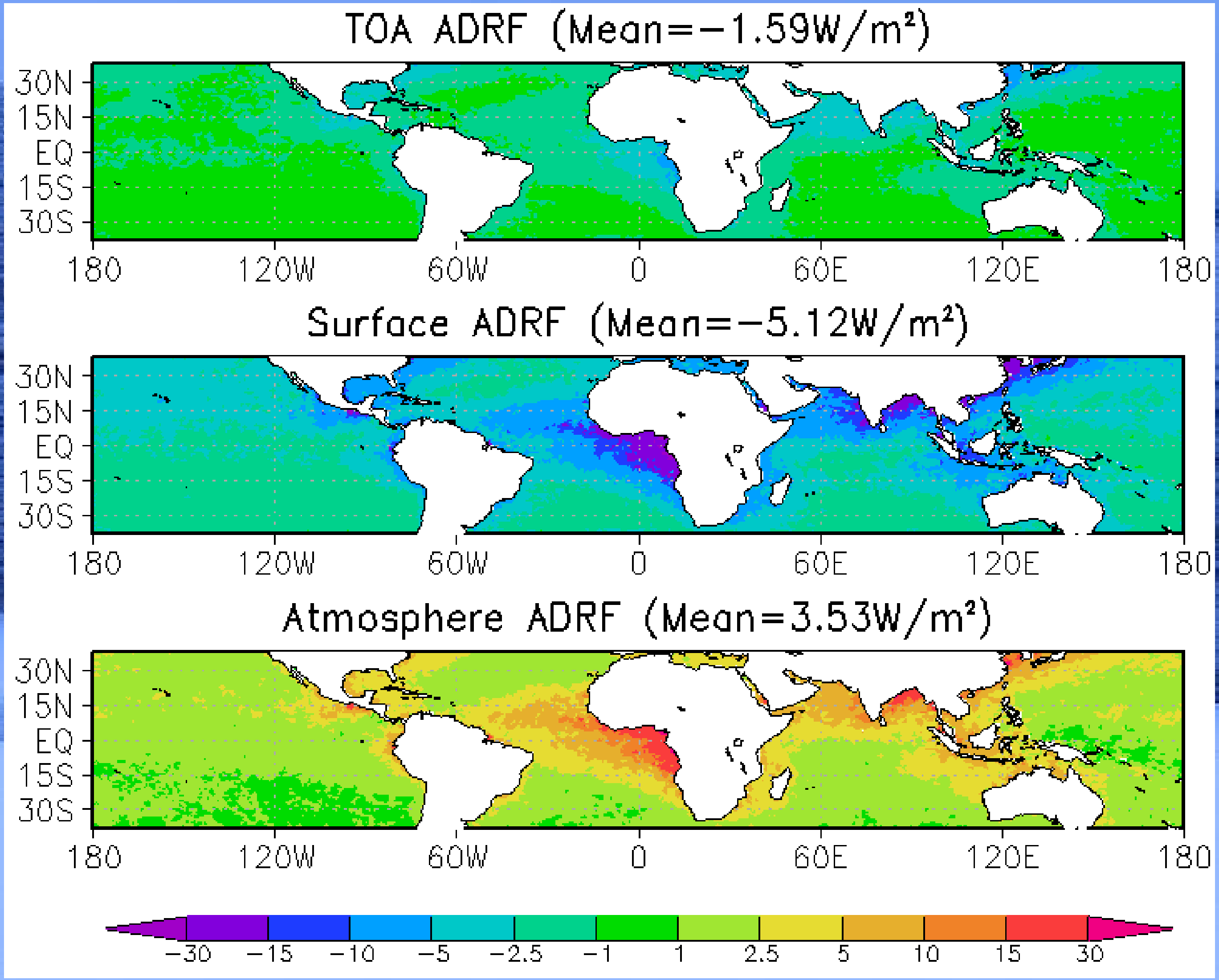


Figure 1. Shortwave aerosol direct radiative forcing (ADRF) for top-of atmosphere (TOA), surface, and atmosphere. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974. http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

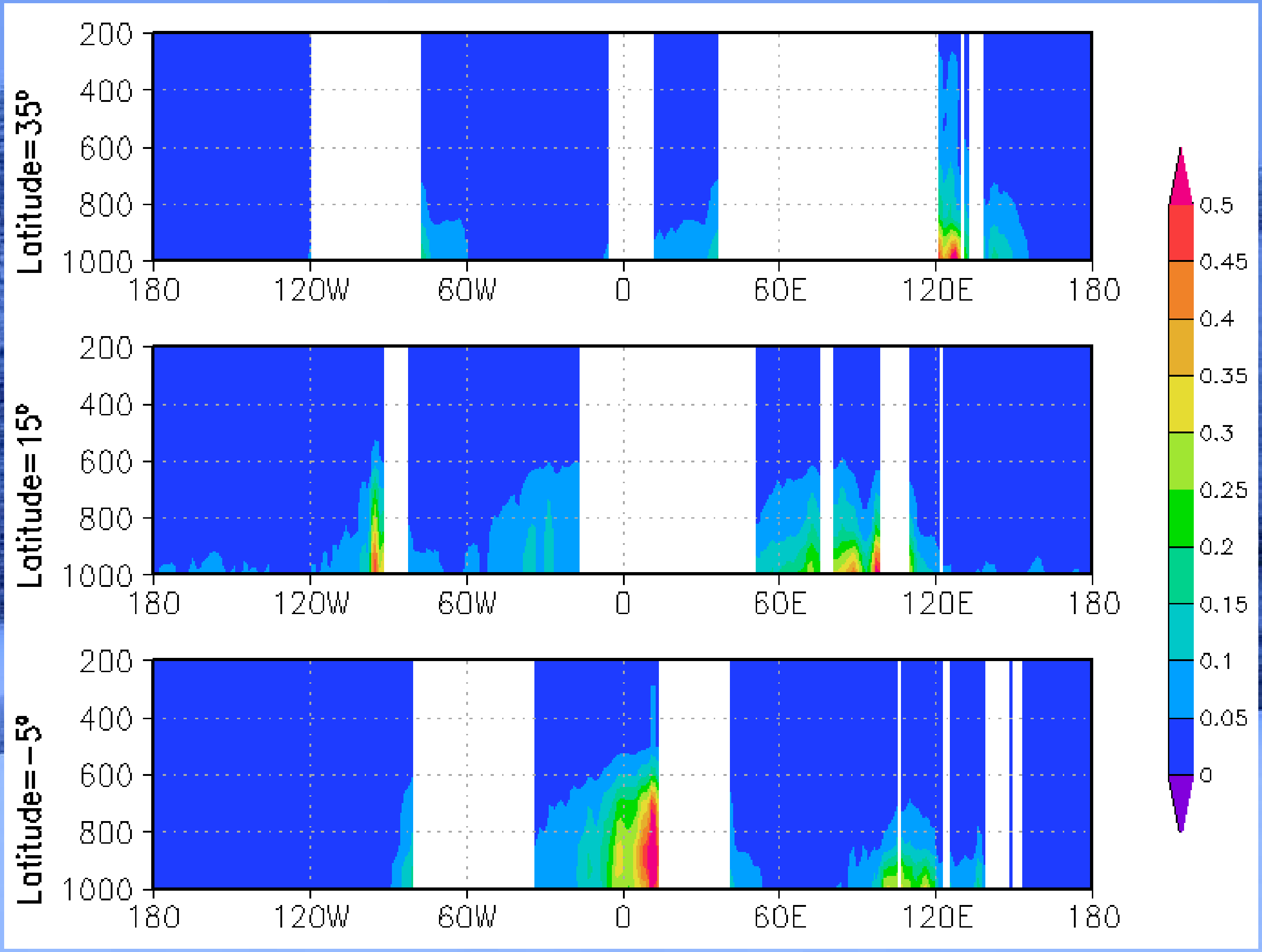


Figure 2. Vertical profile of atmospheric heating rate (K day^{-1}) due to shortwave ADRF. Vertical coordinate is pressure level (mb). From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974. http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

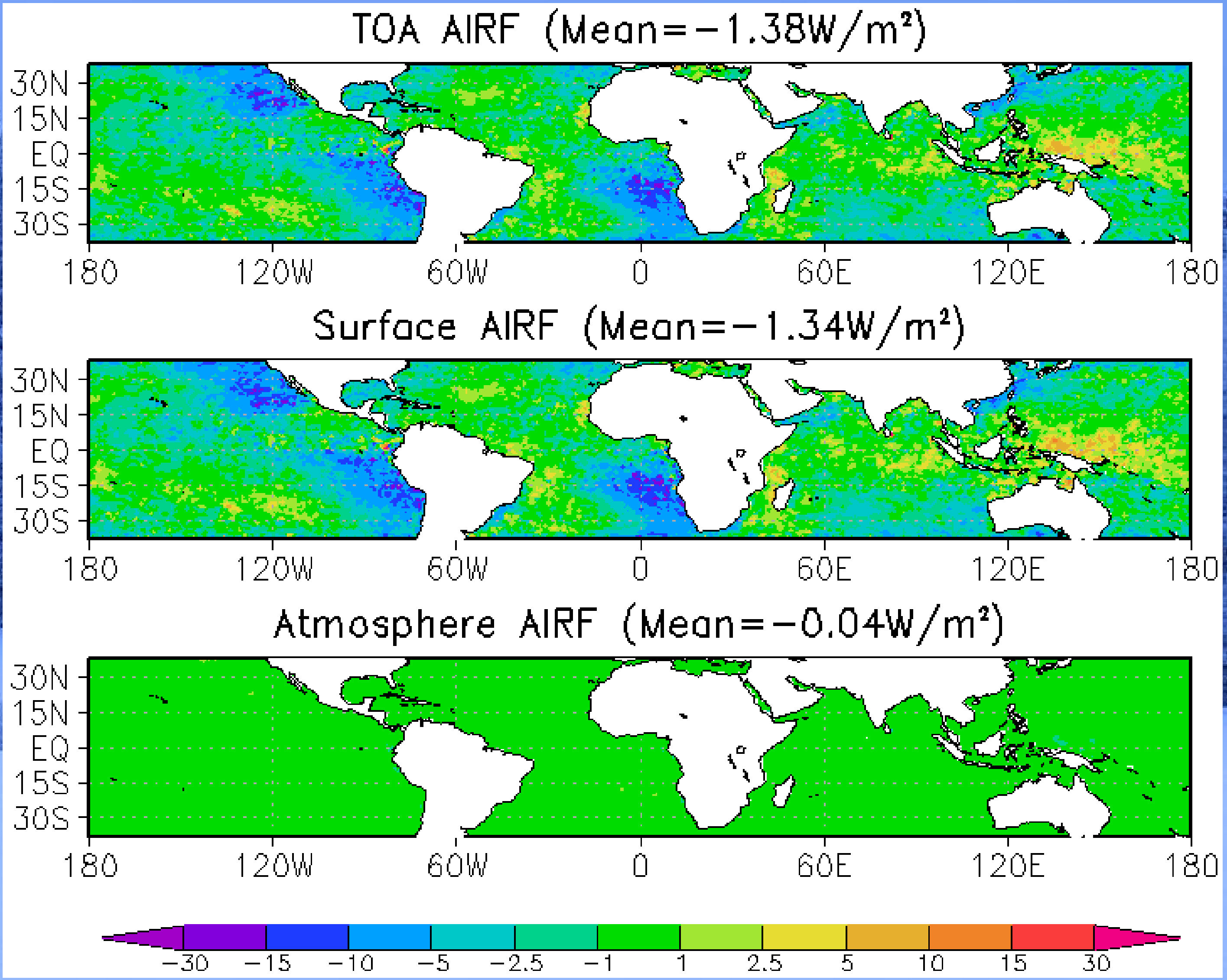


Figure 3. Shortwave aerosol indirect radiative forcing (AIRF) for top-of atmosphere (TOA), surface, and atmosphere. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974. http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

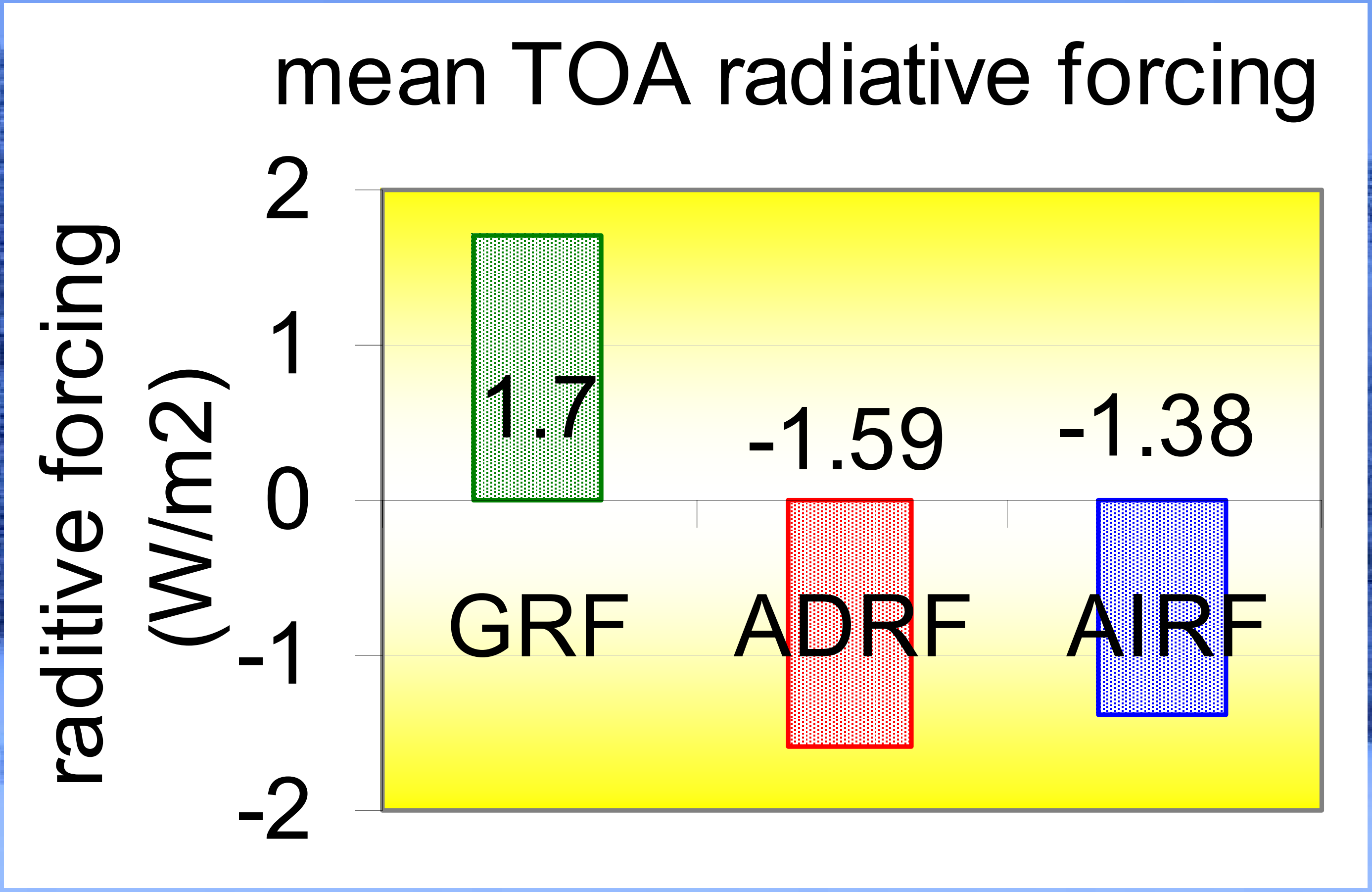


Figure 4. Comparison of Mean TOA radiative forcing between infrared GRF, shortwave ADRF, and shortwave AIRF. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974. http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

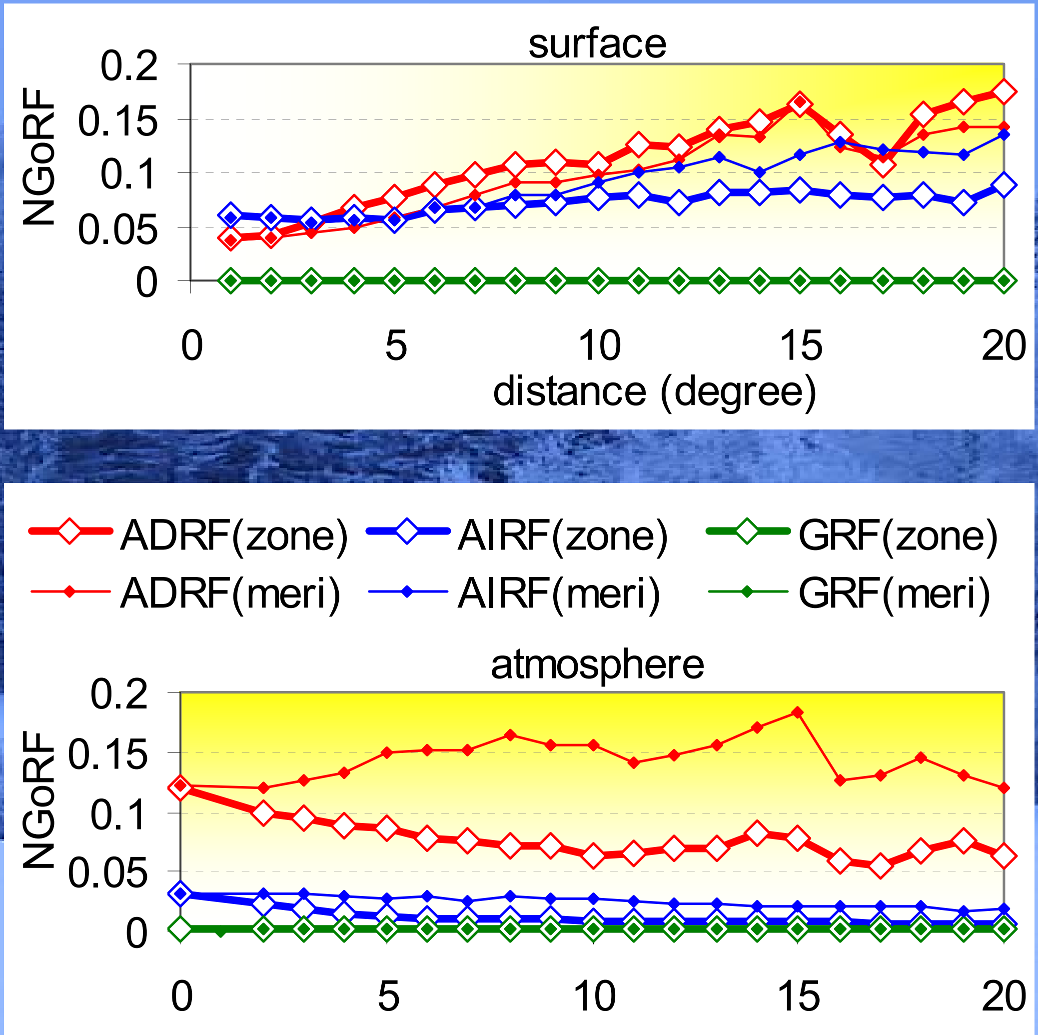
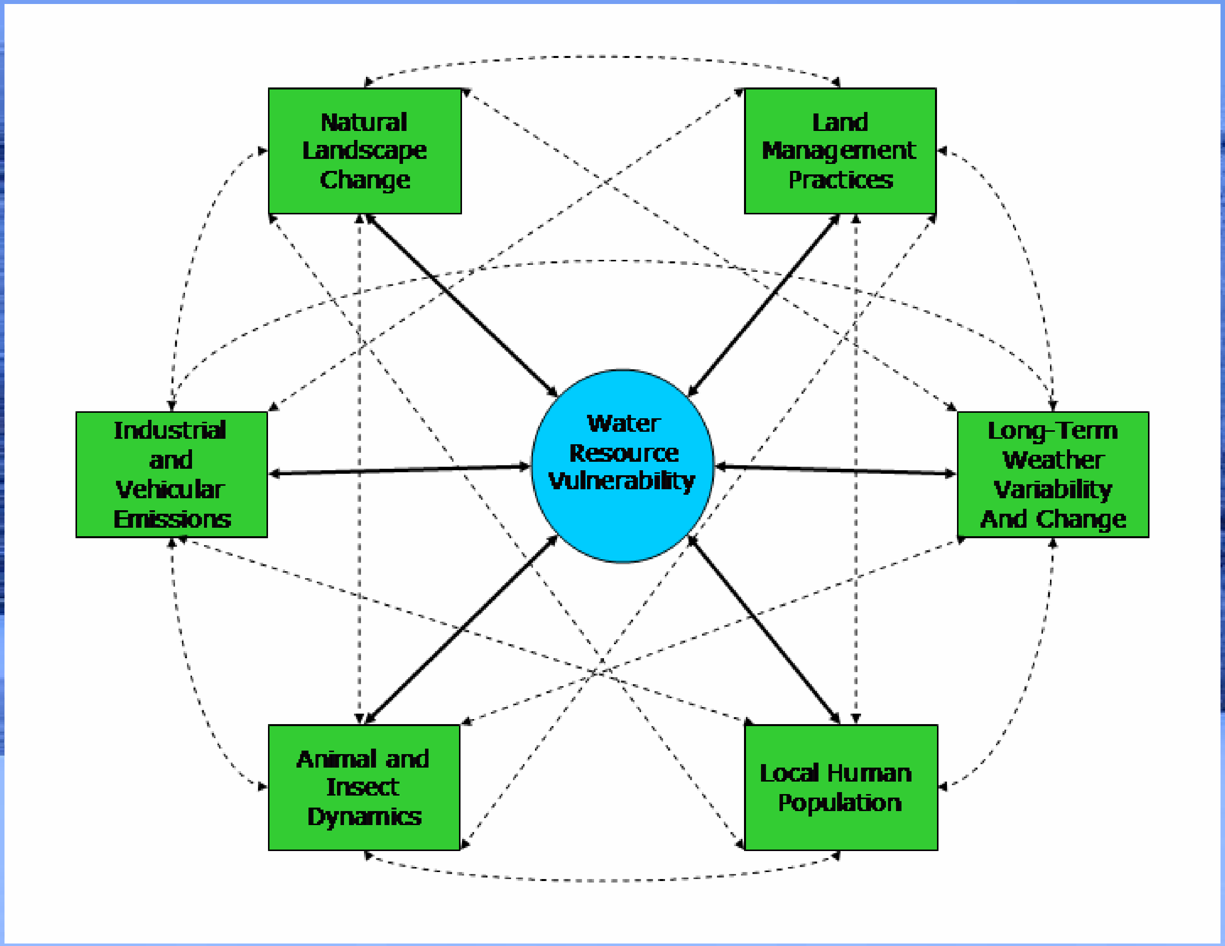
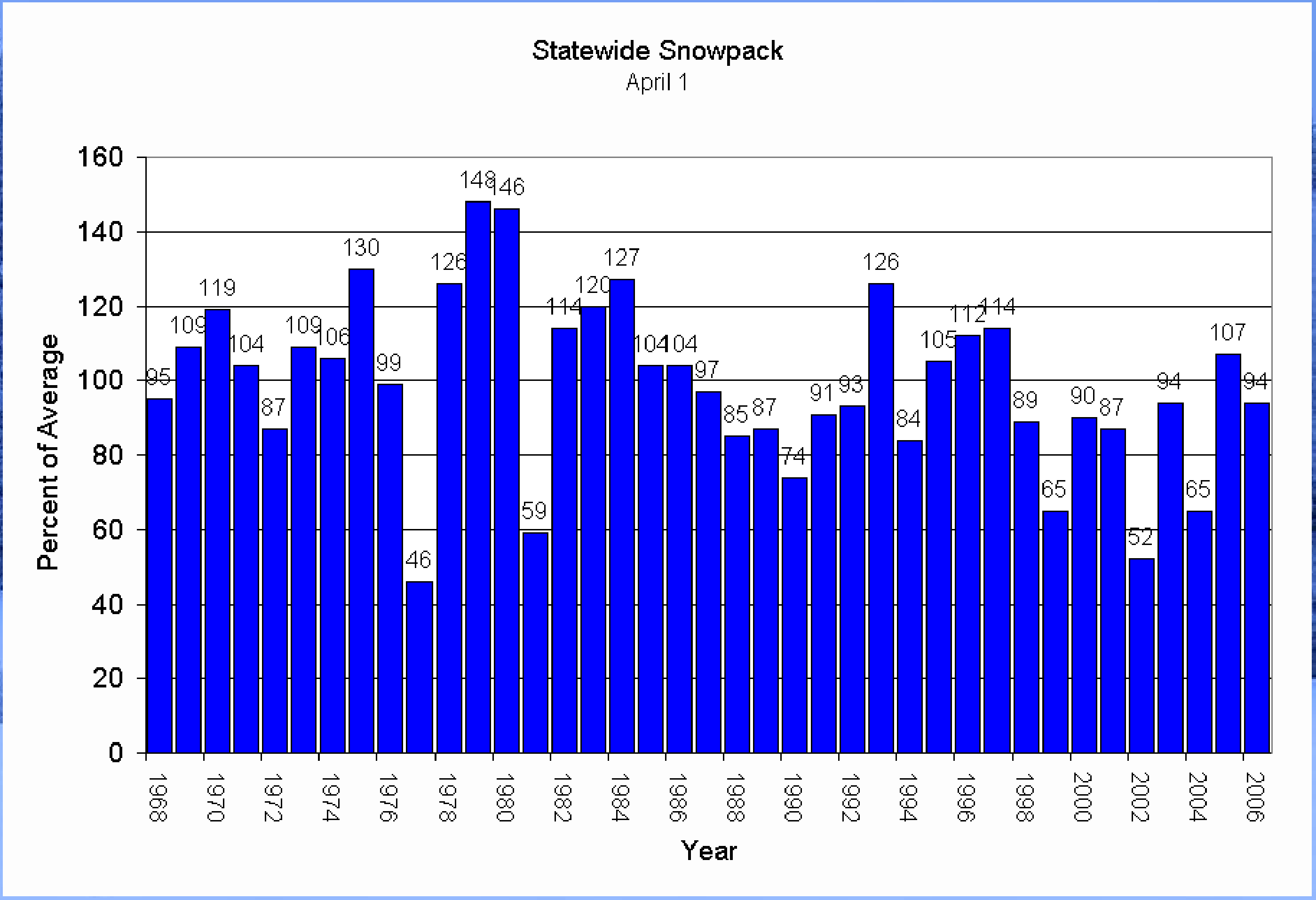


Figure 5. Comparison of the meridional and the zonal component of NGoRF between infrared GRF, shortwave ADRF, and shortwave AIRF for atmosphere and surface. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974.
http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

A Focus on Vulnerability



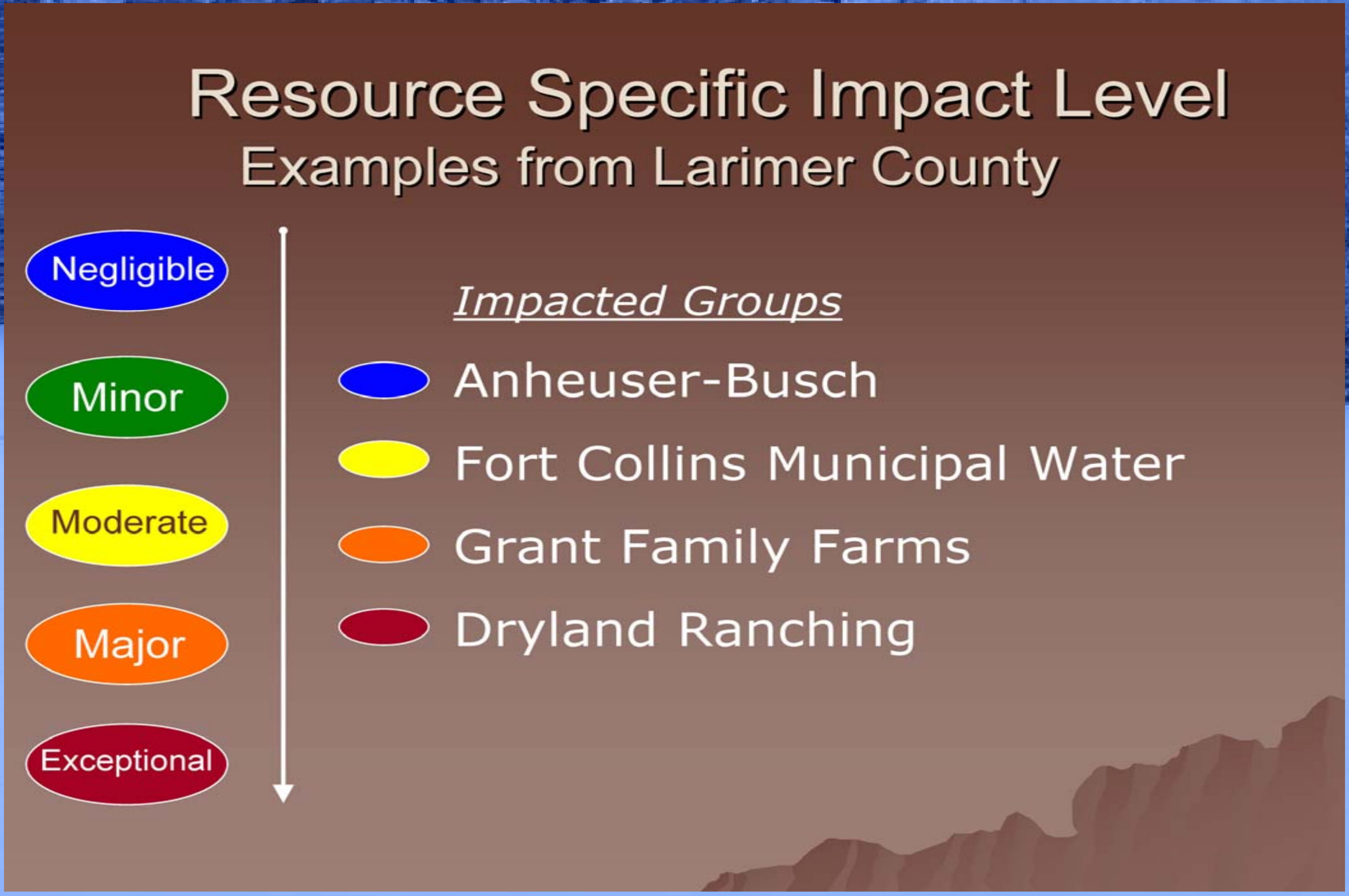
Schematic of the relation of water resource vulnerability to the spectrum of the environmental forcings and feedbacks (adapted from [3]). The arrows denote nonlinear interactions between and within natural and human forcings. From: Pielke, R.A. Sr., 2004: Discussion Forum: A broader perspective on climate 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 2006.

ftp://ftp-fc.sc.egov.usda.gov/CO/Snow/snow/watershed/monthly/aprstatetime.gif

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



Question

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

1. subsidies for alternative energy
2. purchasing wilderness areas (e.g., through the Nature Conservancy)
3. building/enlarging water impoundments
4. building pipelines to transport water over large distances
5. purchasing open spaces in growing urban areas
6. funding additional mass transit

Where Should This Money Come From?

1. carbon usage tax
2. mileage driven tax
3. lottery
4. tax on large private vehicles
5. state income tax increase
6. property tax increase

Conclusions

The needed focus for the study of climate change and variability is on the regional and local scales. Global and zonally-averaged climate metrics would only be important to the extent that they provide useful information on these space scales.

Global warming is not equivalent to climate change. Significant, societally important climate change, due to both natural- and human- climate forcings, can occur without any global warming or cooling.

The spatial pattern of ocean heat content change is the appropriate metric to assess climate system heat changes including global warming and cooling.

Global and zonally-averaged surface temperature trend assessments, besides having major difficulties in terms of how this metric is diagnosed and analyzed, do not provide significant information on climate change and variability on the regional and local scales.

In terms of climate change and variability on the regional and local scale, the IPCC Reports, the CCSP Report on surface and tropospheric temperature trends, and the U.S. National Assessment have overstated the role of the radiative effect of the anthropogenic increase of CO_2 relative to the role of the diversity of other human climate forcing on global warming, and more generally, on climate variability and change.

Global and regional climate models have not demonstrated skill at predicting climate change and variability on multi-decadal time scales.

Attempts to significantly influence regional and local-scale climate based on controlling CO_2 emissions alone is an inadequate policy for this purpose.

A vulnerability paradigm, focused on regional and local societal and environmental resources of importance, is a more inclusive, useful, and scientifically robust framework to interact with policymakers, than is the focus on global multi-decadal climate predictions which are downscaled to the regional and local scales. The vulnerability paradigm permits the evaluation of the entire spectrum of risks associated with different social and environmental threats, including climate variability and change.

Humans are significantly altering the global climate, but in a variety of diverse ways beyond the radiative effect of carbon dioxide. The IPCC assessments have been too conservative in recognizing the importance of these human climate forcings as they alter regional and global climate. These assessments have also not communicated the inability of the models to accurately forecast the spread of possibilities of future climate. The forecasts, therefore, do not provide any skill in quantifying the impact of different mitigation strategies on the actual climate response that would occur.

- The Current IPCC Focus is to Promote Energy Policy Changes, Not to Provide an Effective Climate Policy
- Policymakers Need To Be Informed Of This Very Important Distinction
- We Need To Separate Climate Policy From Energy Policy.

Roger A. Pielke Sr. Research Group Weblog

http://climatesci.colorado.edu

Roger A. Pielke Sr. Website

http://cires.colorado.edu/science/groups/pielke

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