

# Ten Overlooked Issues in Climate Change Science

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# **Policy Statement on Climate Variability and Change by the American Association of State Climatologists**

- 1. Past climate is a useful guide to the future - Assessing past climate conditions provides a very effective analysis tool to assess societal and environmental vulnerability to future climate, regardless of the extent the future climate is altered by human activity. Our current and future vulnerability, however, will be different than in the past, even if climate were not to change, because society and the environment change as well. Decision makers need assessments of how climate vulnerability has changed.**
- 2. Climate prediction is complex with many uncertainties. The AASC recognizes climate prediction is an extremely difficult undertaking. For time scales of a decade or more, understanding the empirical accuracy of such predictions - called “verification” - is simply impossible, since we have to wait a decade or longer to assess the accuracy of the forecasts.**

**Available at: <http://ccc.atmos.colostate.edu/policystatement.php>**



# **Views of Climate Change Science**

- 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.**

# 1

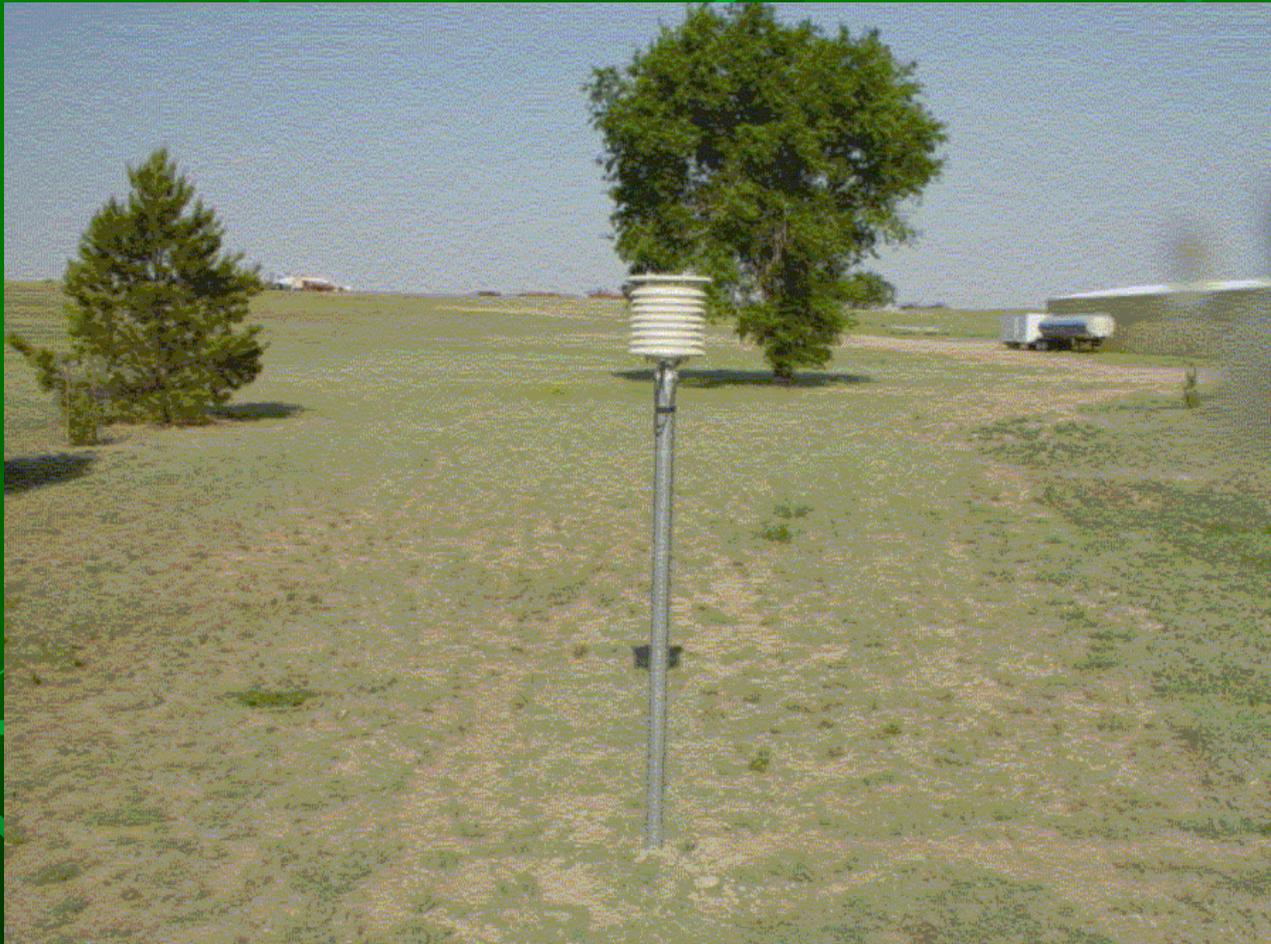
## The Lack of Spatial Representativeness of Surface Temperature

From Davey, C.A., and R.A. Pielke Sr., 2003: Microclimate exposures of surface-based weather stations - implications for the assessment of long-term temperature trends. Bull. Amer. Meteor. Soc., submitted.

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

Hanamean, J.R. Jr., R.A. Pielke Sr., C.L. Castro, D.S. Ojima, B.C. Reed, and Z. Gao, 2003: Vegetation impacts on maximum and minimum temperatures in northeast Colorado. Meteorological Applications, in press.

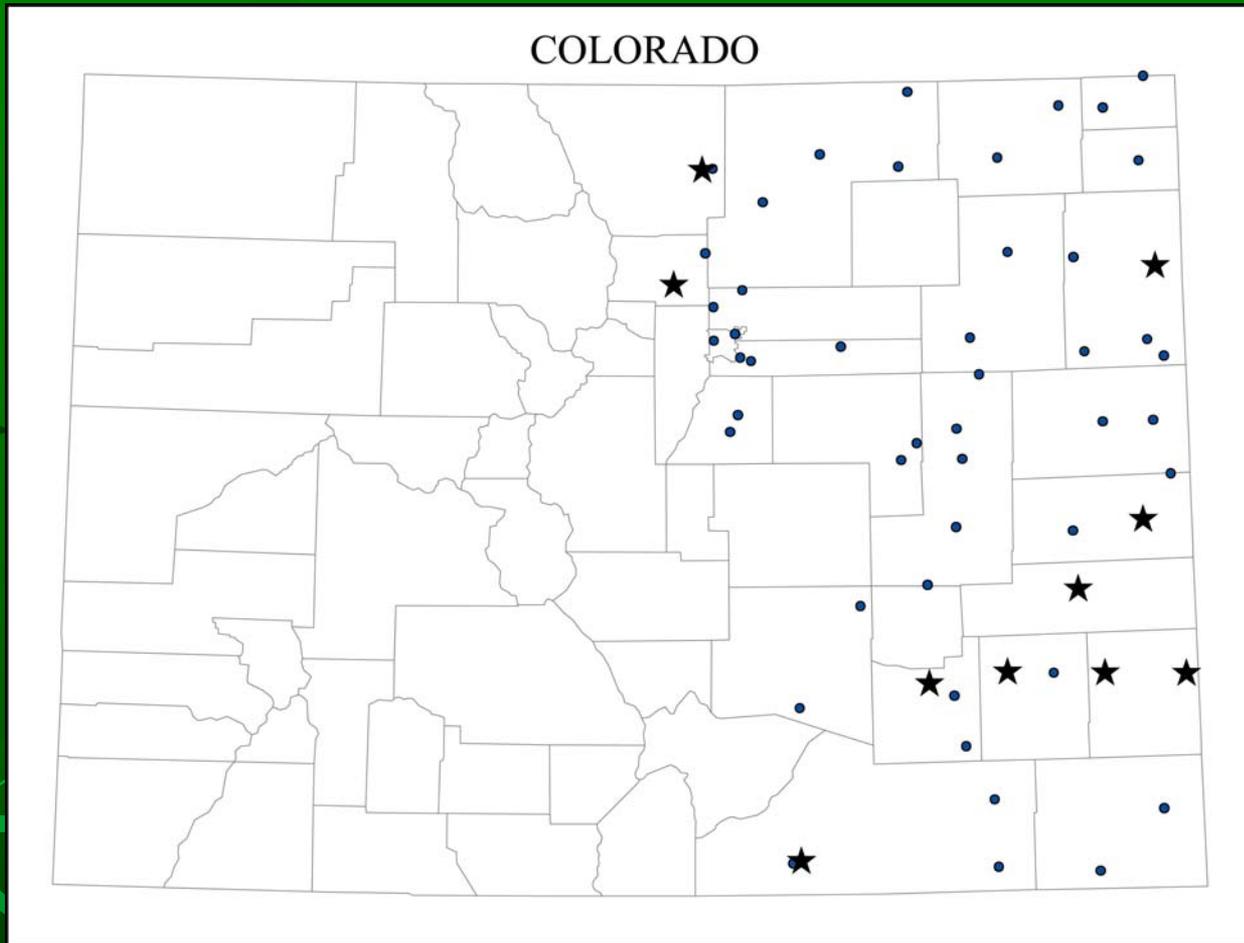
<http://blue.atmos.colostate.edu/publications/pdf/R-254.pdf>



**Maximum-minimum temperature sensor (MMTS) installation near Lindon, Colorado.**

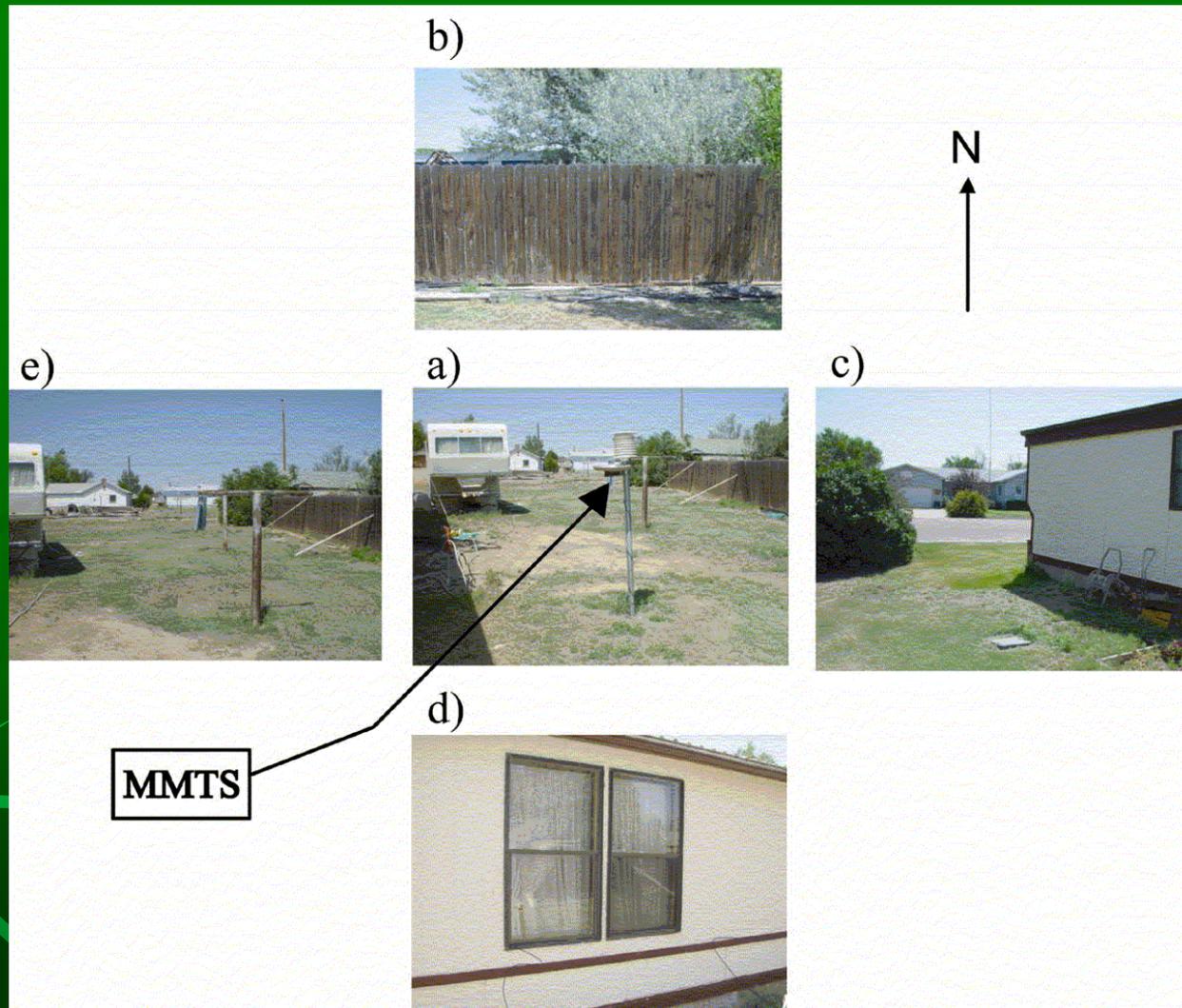


**MMTS installation near John Martin Reservoir, Colorado.**

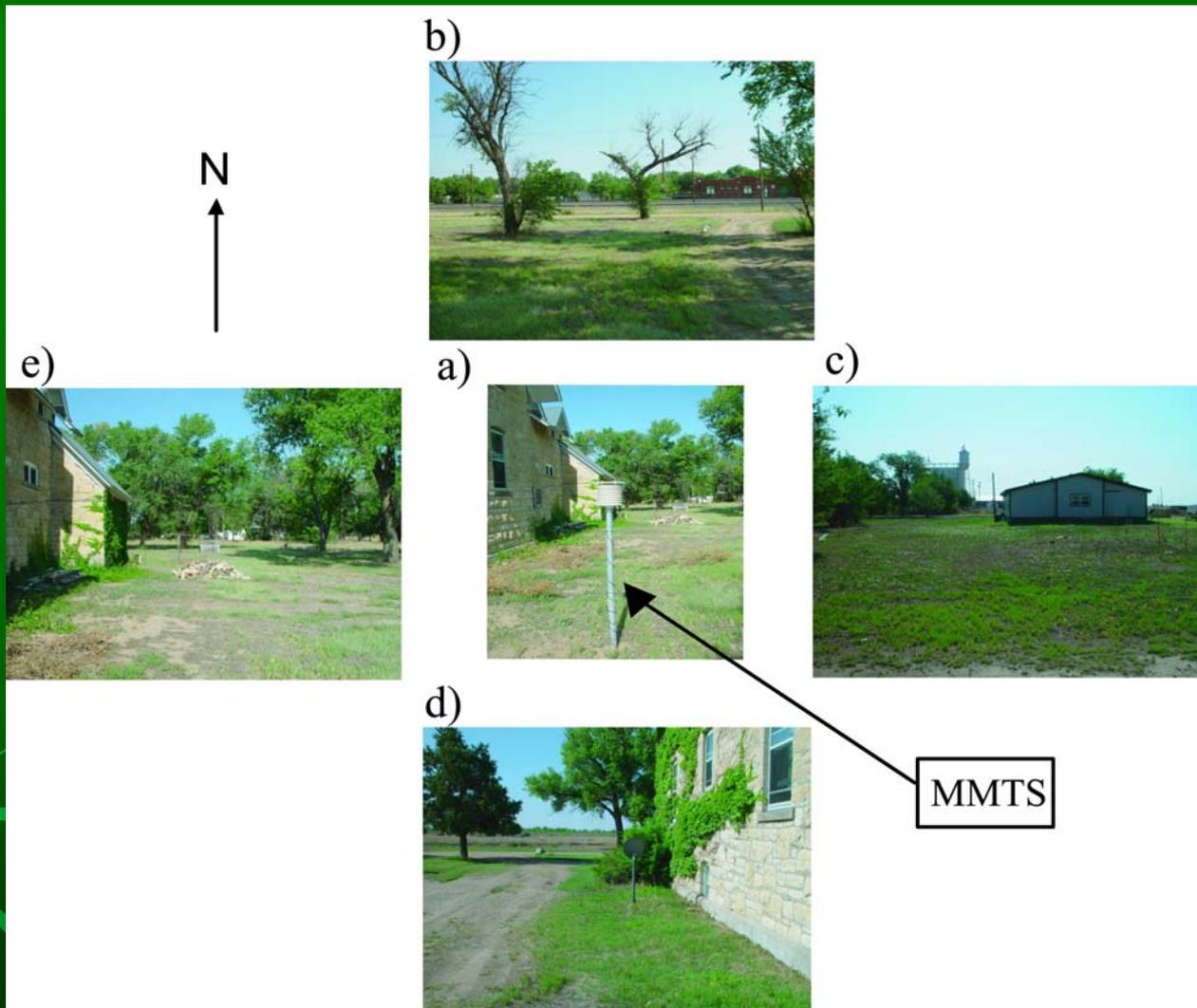


Map of study region, showing all surveyed COOP sites. The USHCN sites are indicated by stars.

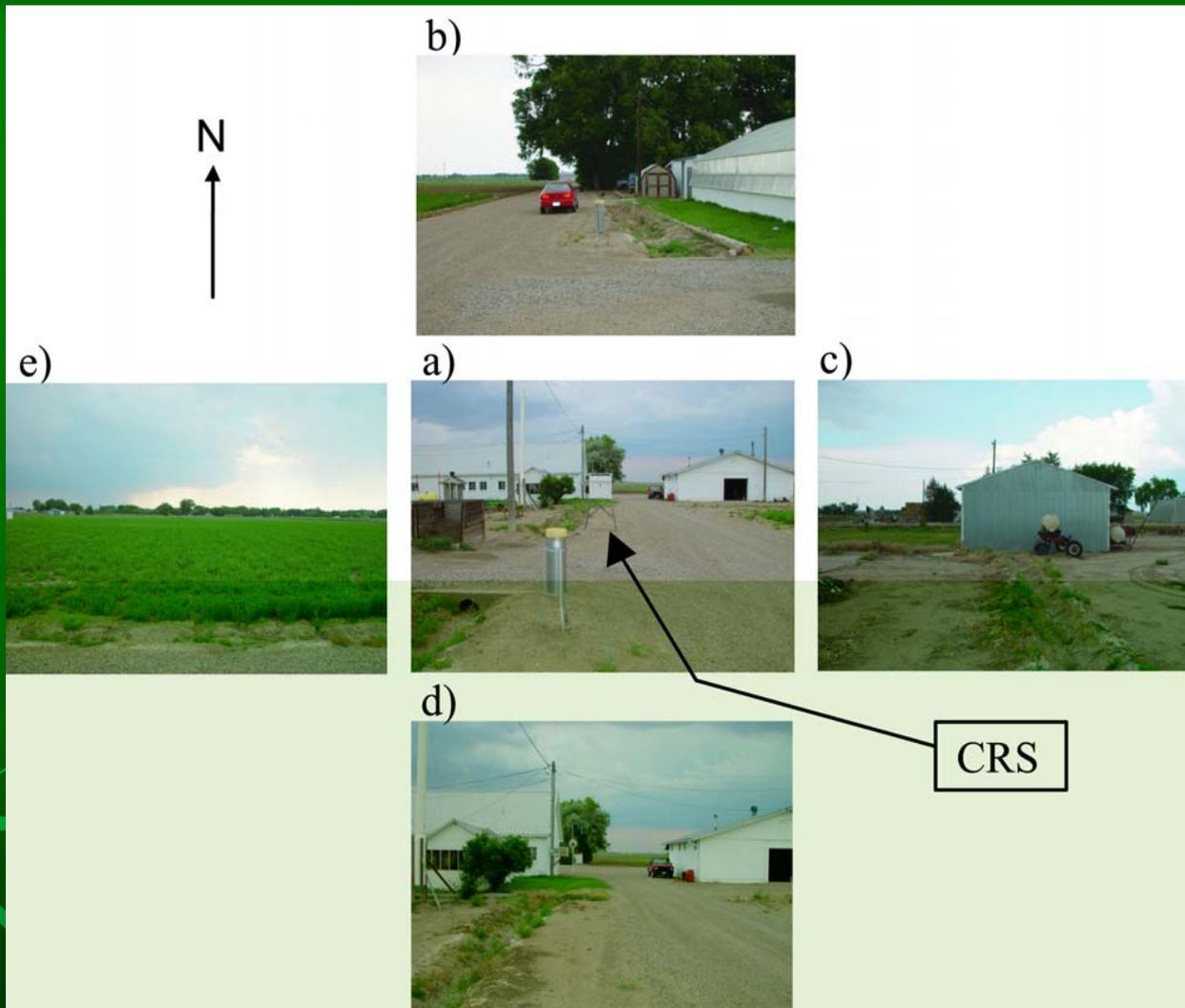
The following photos are for HCN sites.



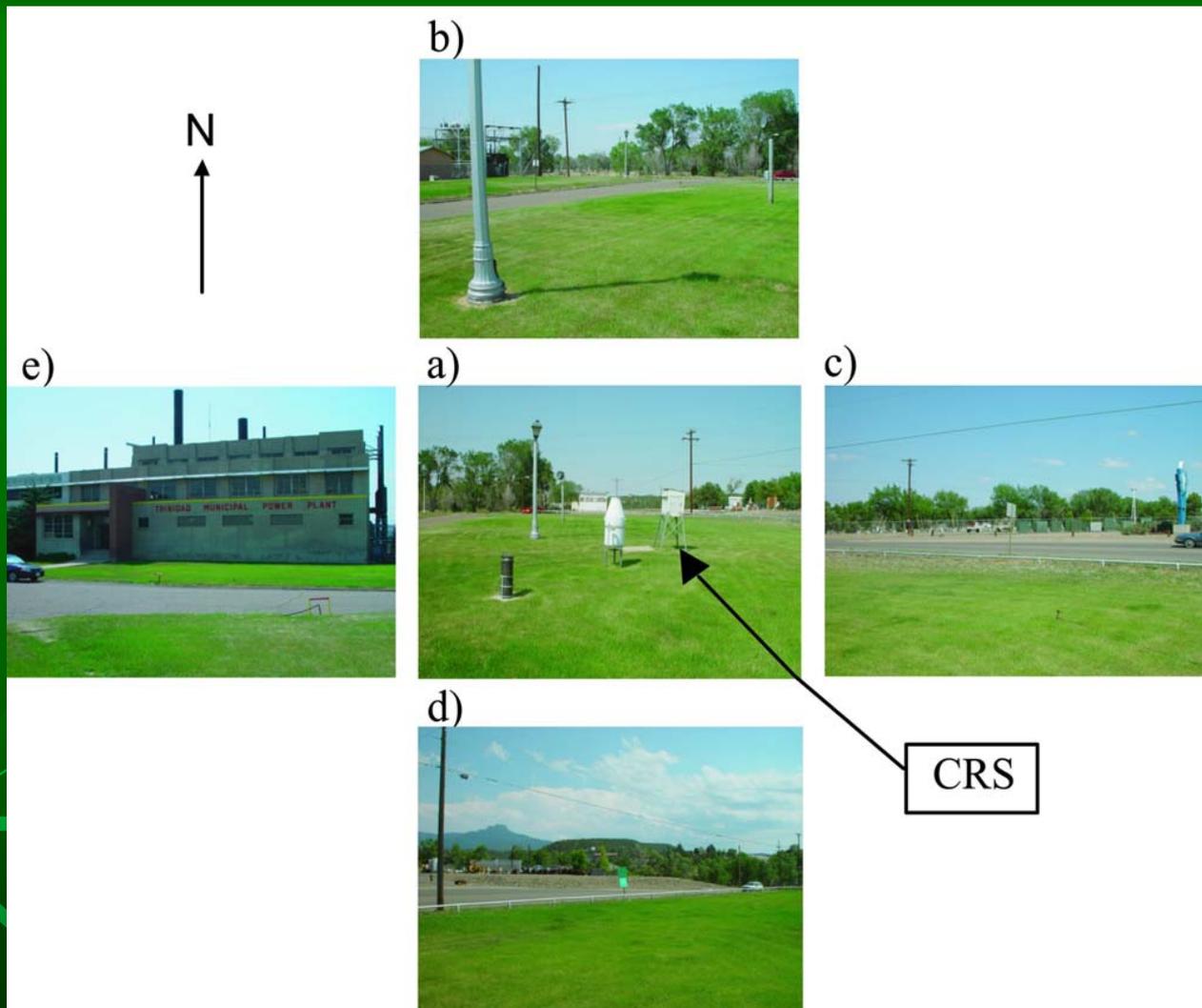
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Eads, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.



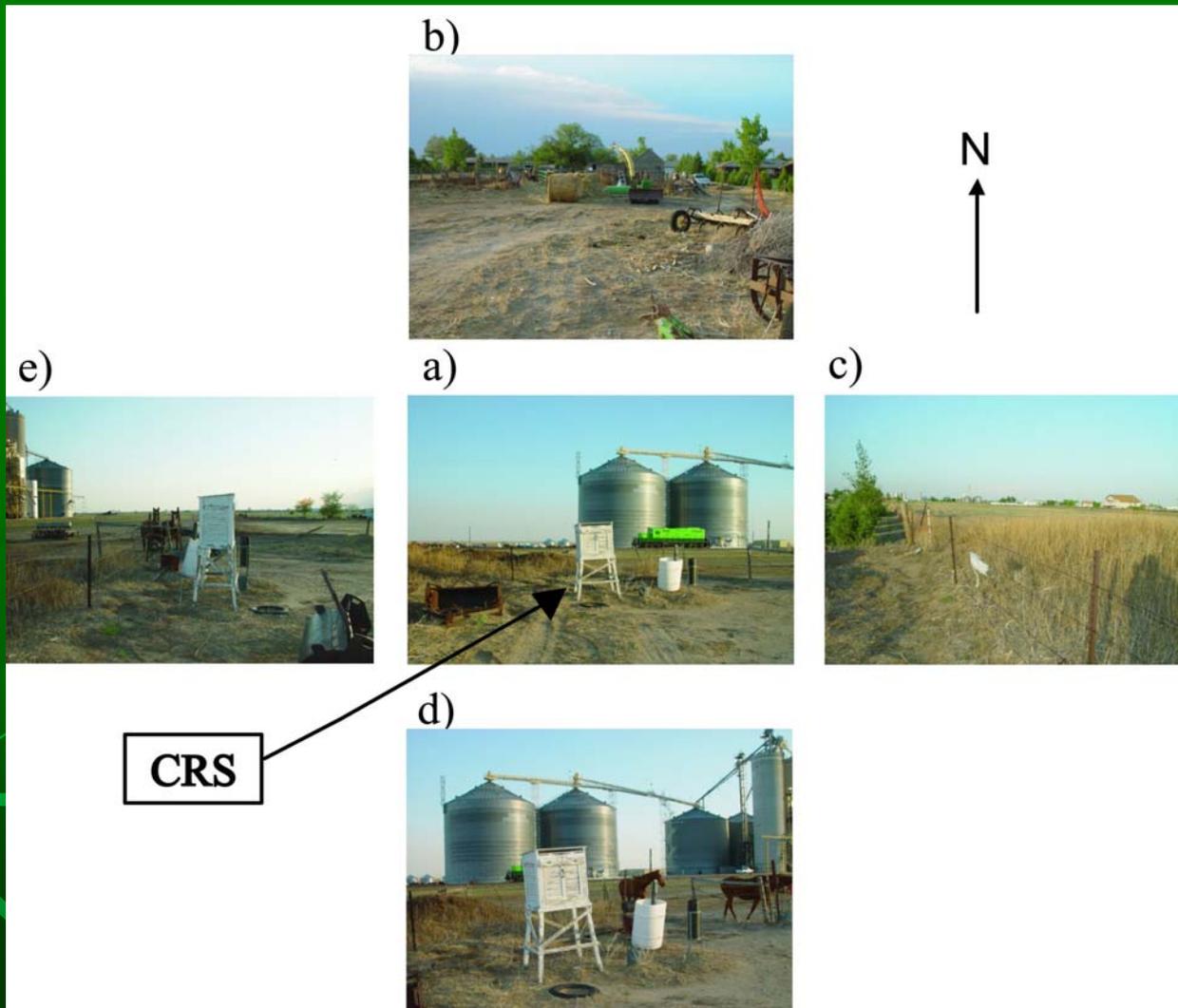
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Holly, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.



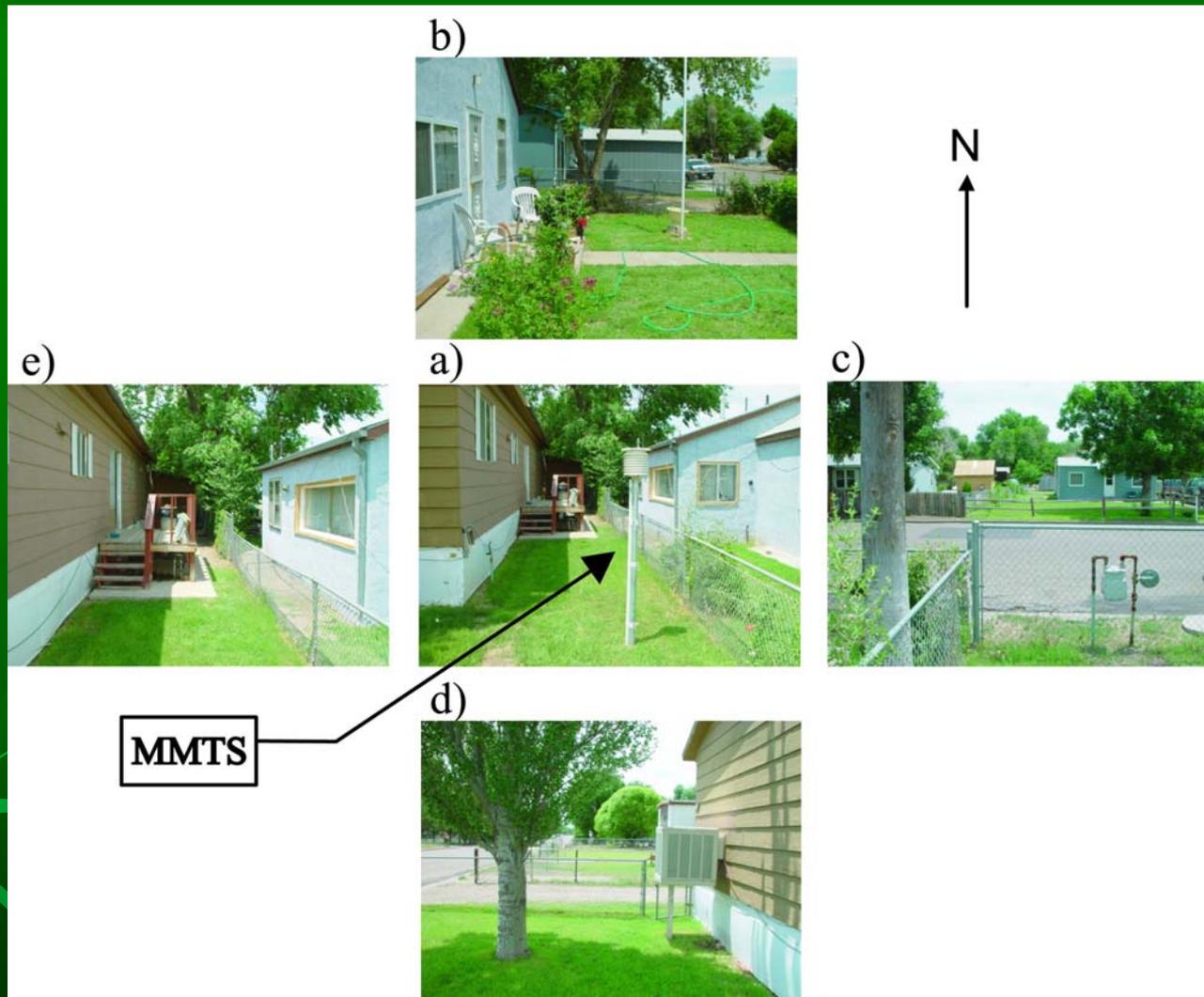
Photographs of the temperature sensor exposure characteristics for the NWS COOP station near Rocky Ford, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively. (CRS-Cotton Region Shelter)



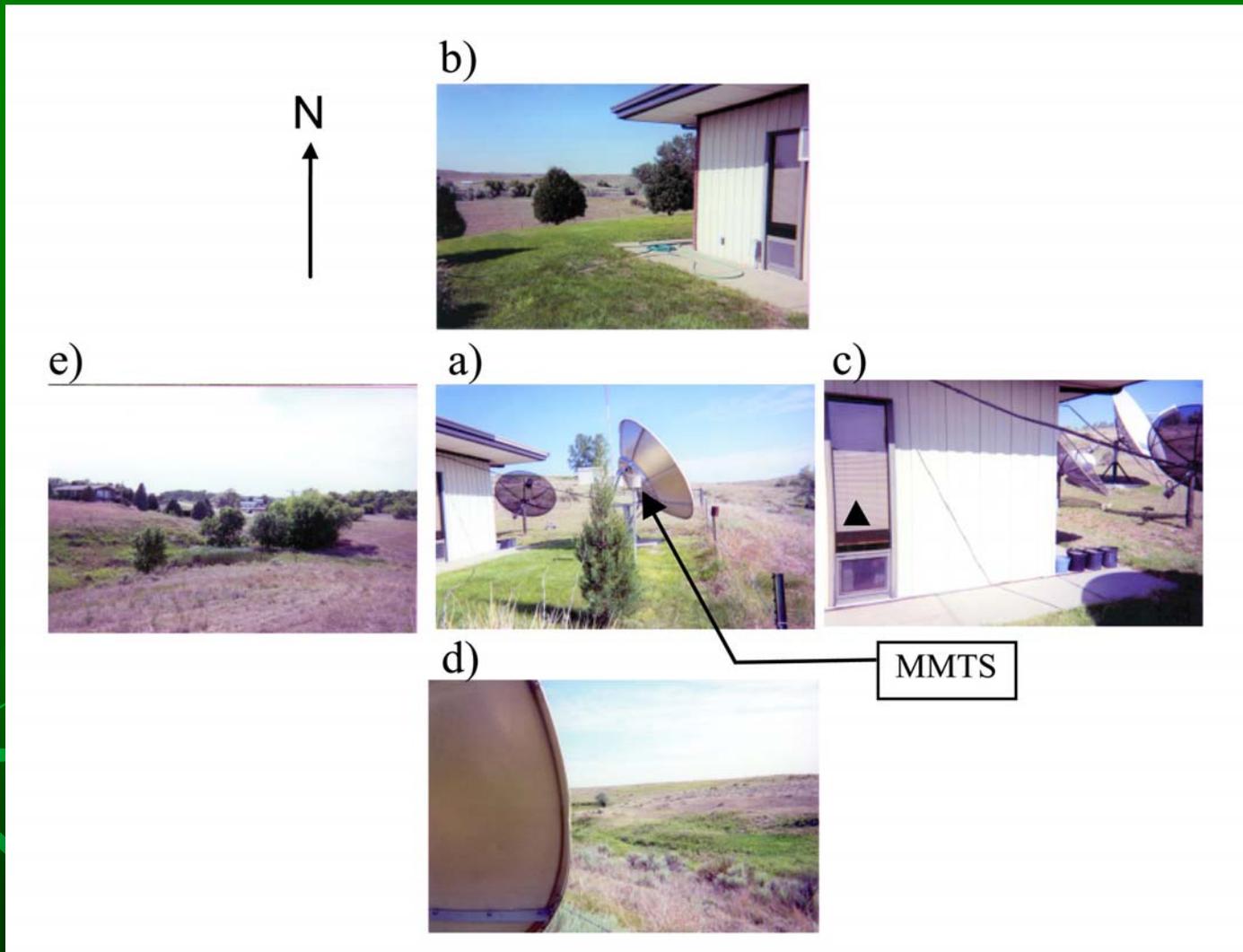
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Trinidad, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.



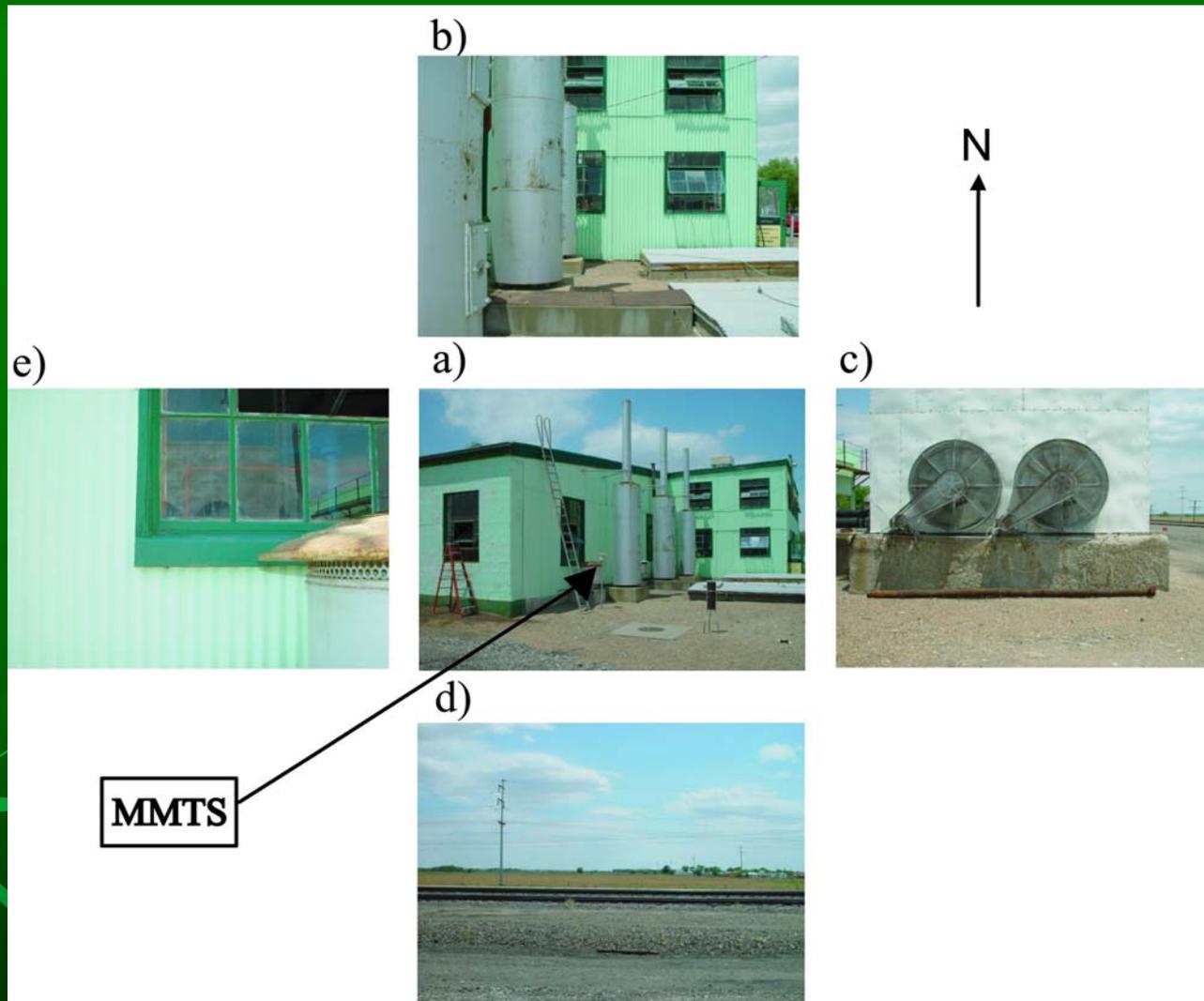
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Cheyenne Wells, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.



Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Lamar, 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.



Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Wray, 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.



Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Las Animas, 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.



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

# 2

## The Lack of Added Regional Simulation Skill By Dynamic Downscaling

From Castro, C.L., and R.A. Pielke Sr., 2003: Dynamical downscaling: An assessment of value added using a regional climate model. *J. Geophys. Res. - Atmospheres*, submitted.

<http://blue.atmos.colostate.edu/publications/pdf/R-276.pdf>

**Table 1: Dependence of regional model on indicated constraints.**

	<b>TYPE I</b>	<b>TYPE II</b>	<b>TYPE III</b>	<b>TYPE IV</b>
<b>Bottom Boundary Conditions</b>	Terrain; LDAS <sup>a</sup> ; Observed SSTs	Terrain; Climatological Vegetation; Observed SSTs	Terrain; Climatological Vegetation; Observed SSTs; Deep Soil Moisture	Terrain; Soils
<b>Initial Conditions</b>	ETA Analysis Field	NONE	NONE	NONE
<b>Lateral Boundary Conditions</b>	Global Forecast System Atmospheric Model <sup>b</sup>	NCEP Reanalysis <sup>c</sup>	Global Model Forced by Observed SSTs	IPCC <sup>d</sup> ; US National Assessment <sup>e</sup>
<b>Regional</b>	ETA <sup>f</sup> MM5 <sup>g</sup> RAMS <sup>h</sup> ARPS <sup>i</sup>	PIRCS <sup>j</sup>	COLA <sup>k</sup> /ETA <sup>l</sup>	RegCM <sup>m</sup>

<sup>a</sup> <http://ldas.gsfc.nasa.gov/>

<sup>b</sup> <http://www.emc.ncep.noaa.gov/gmb/moorthi/gam.html>

<sup>c</sup> Kalnay et al. (1996)

<sup>d</sup> Houghton et al. (2001)

<sup>e</sup> <http://www.gcrio.org/NationalAssessment/>

<sup>f</sup> Black (1994)

<sup>g</sup> Grell et al. (1994)

<sup>h</sup> Pielke et al. (1992)

<sup>i</sup> Xue et al. (2000, 2001)

<sup>j</sup> Takle et al. (1999)

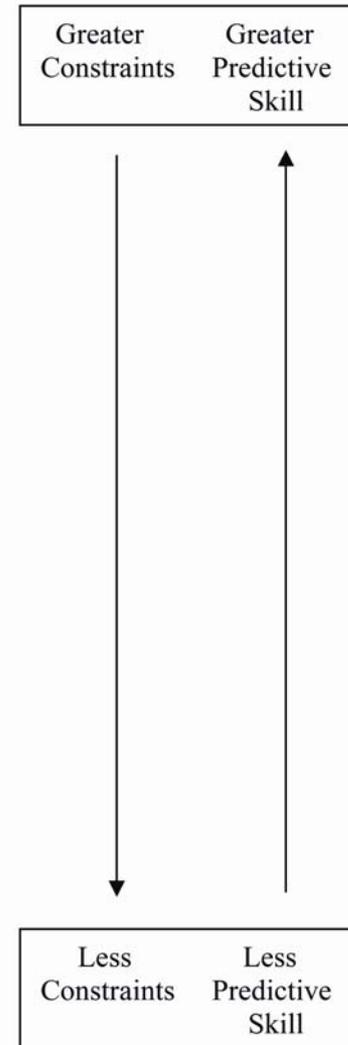
<sup>k</sup> <http://www-pcmdi.llnl.gov/modldoc/amip/14cola.html>

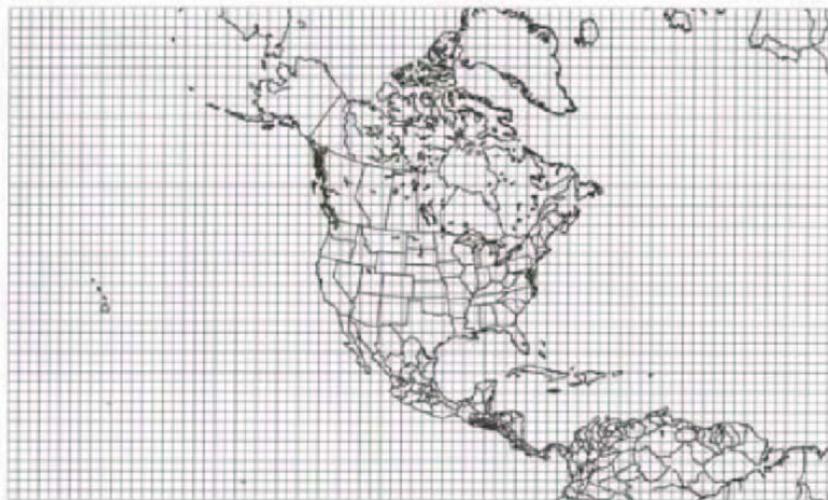
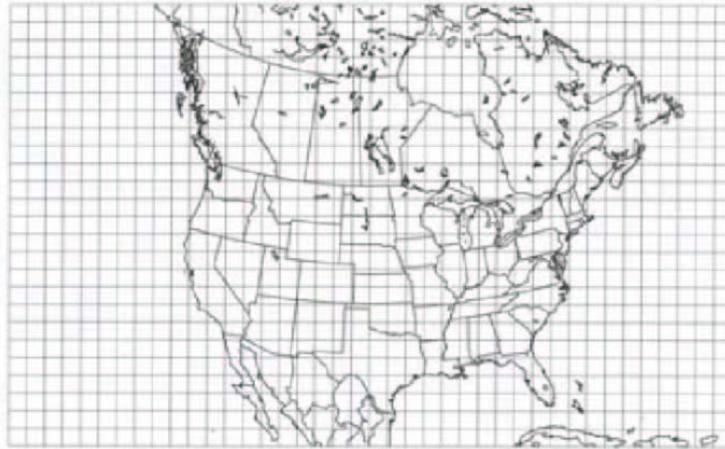
<sup>l</sup> Mesinger et al. (1997)

<sup>m</sup> Giorgi (1993a, b)

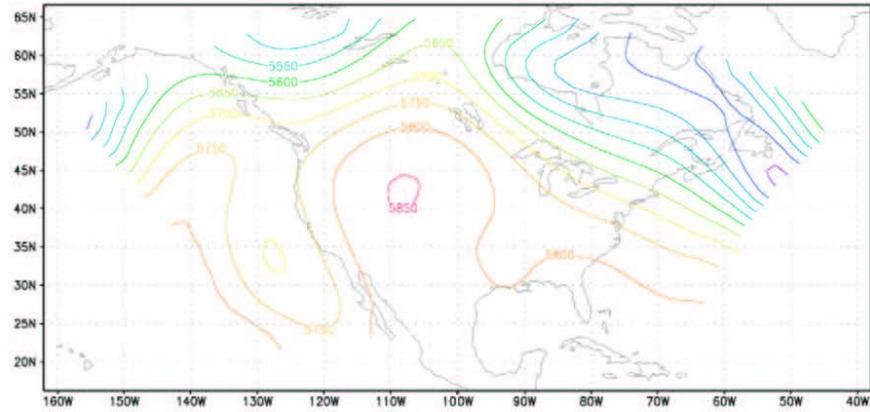
**Table 2: Examples of predictability.**

<b>Constraints</b>		
Day-to-Day Weather Prediction	Type 1	Initial Conditions Lateral Boundary Conditions Topography Other Bottom Land Boundary Conditions Solar Irradiance Well-Mixed Greenhouse Gases
Seasonal Weather Simulation	Type 2	Lateral Boundary Conditions Topography Other Bottom Land Boundary Conditions Solar Irradiance Well-Mixed Greenhouse Gases
Season Weather Prediction	Type 3	Topography Other Bottom Land Boundary Conditions Sea Surface Temperatures Solar Irradiance Well-Mixed Greenhouse Gases
Multiyear Climate Prediction	Type 4	Topography Solar Irradiance Well-Mixed Greenhouse Gases

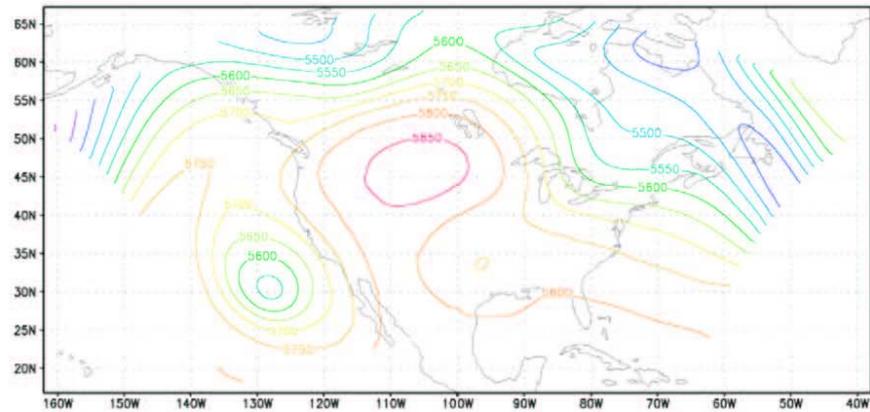




**Figure 1:** RAMS domains for model sensitivity experiments for  $\Delta x = 200$  km.

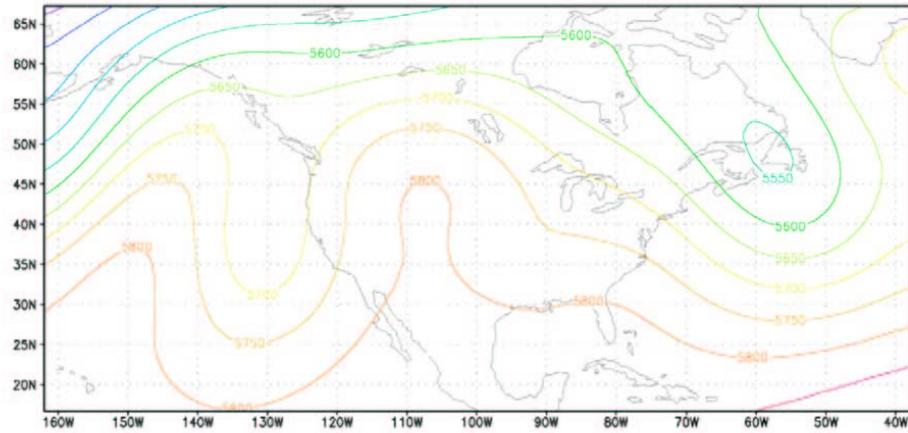


(a)

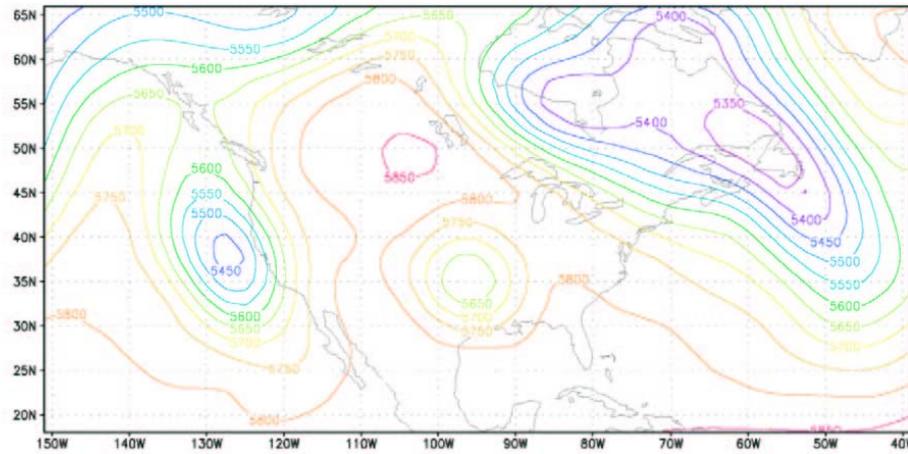


(b)

**Figure 2:** Observed 500-mb height (m) on 0Z UTC, 12 May 1993, for a) basic experiment 1, b) basic experiment 3, c) basic experiment 4, and d) NCEP Reanalysis.

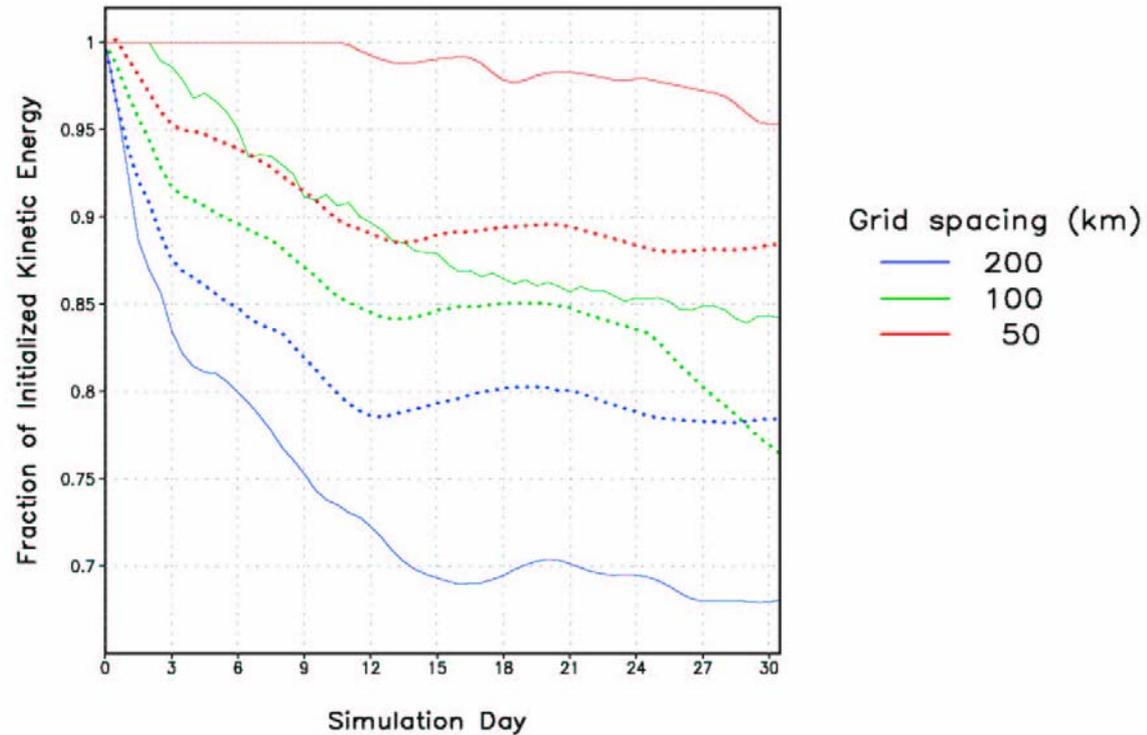


(c)



(d)

**Figure 2 continued**



**Figure 5:** Time evolution of the fraction of model simulated to model initialized domain averaged total kinetic energy for the six basic experiments. The small domain is indicated by a solid line and the large domain is indicated by a dashed line.

**Dynamical downscaling with a RCM never adds more value to predictability of the large-scale over and above that which exists in the larger global model or reanalysis when downscaled from the larger global model or reanalysis using one-dimensional boundary-layer theory to interpolate to higher spatial resolution terrain height, and land and water surface values. The utility of the RCM is to resolve the smaller-scale features which have a greater dependence on the surface boundary.**

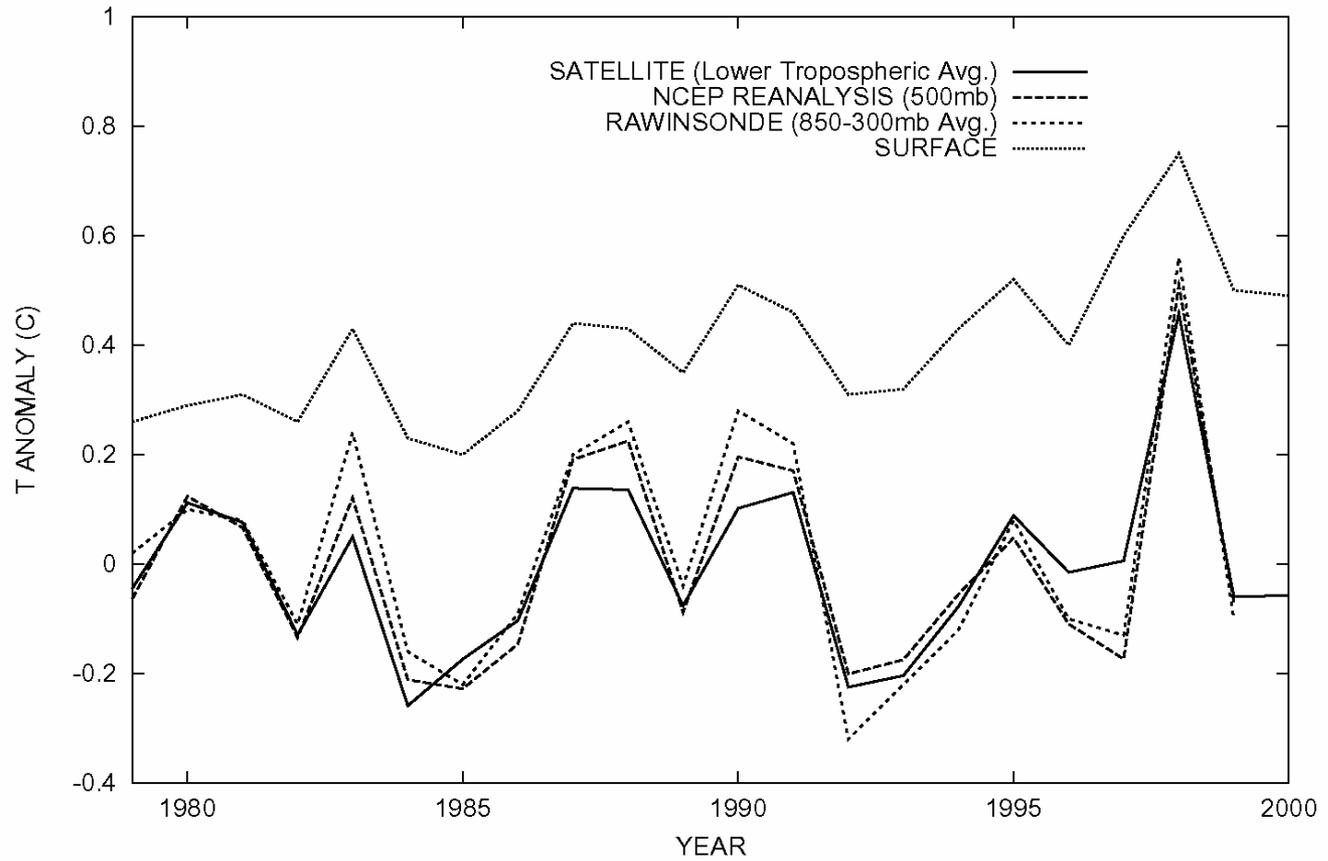
# 3

## GCM Models Have Not Yet Succeeded In Skillfully Predicting 1980-2000 Global Climate

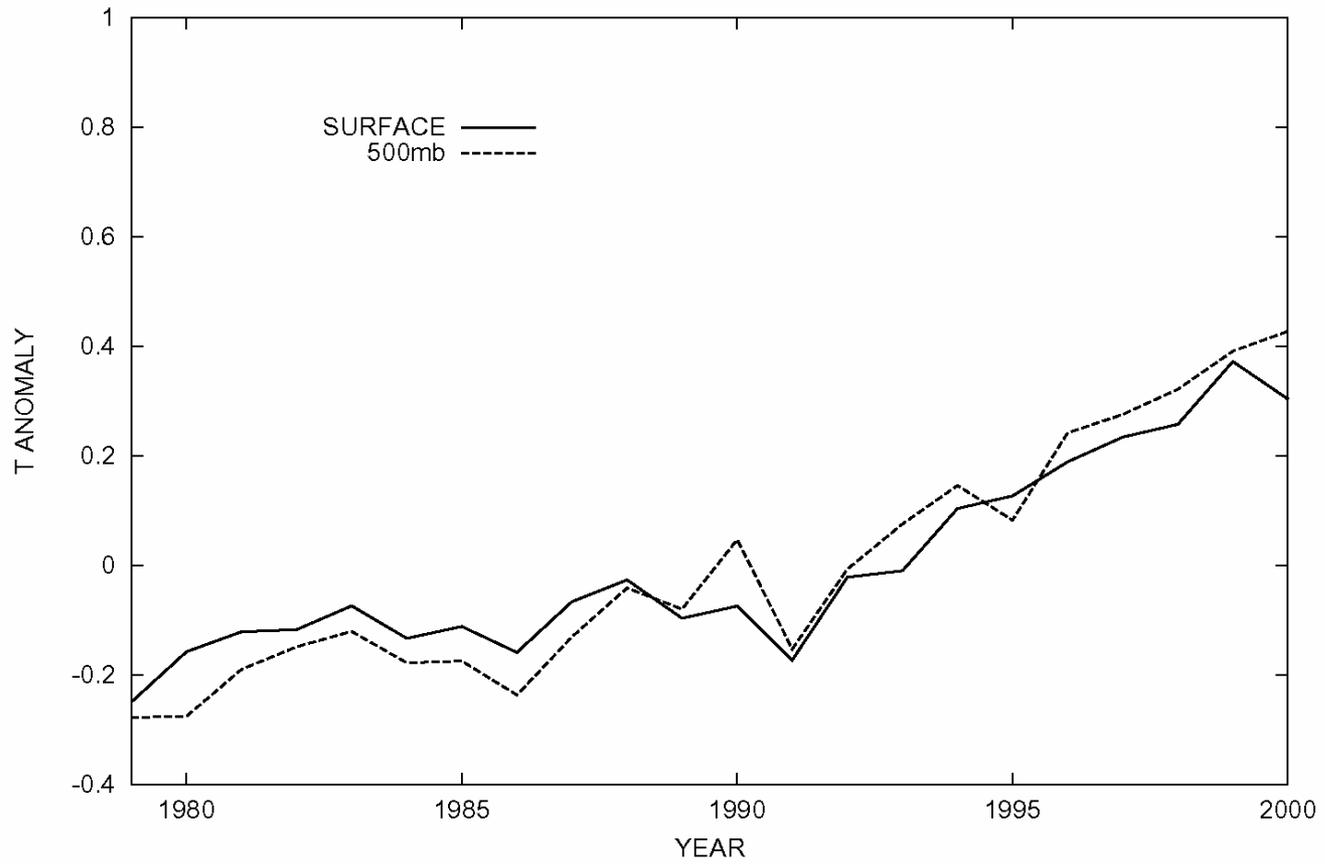
Chase, T.N., R.A. Pielke Sr., B. Herman, and X. Zeng, 2003: Tropospheric temperature structure and the utility of recent climate model configurations for attribution and impact studies. *Climate Res.*, in press.

<http://blue.atmos.colostate.edu/publications/pdf/R-271.pdf>

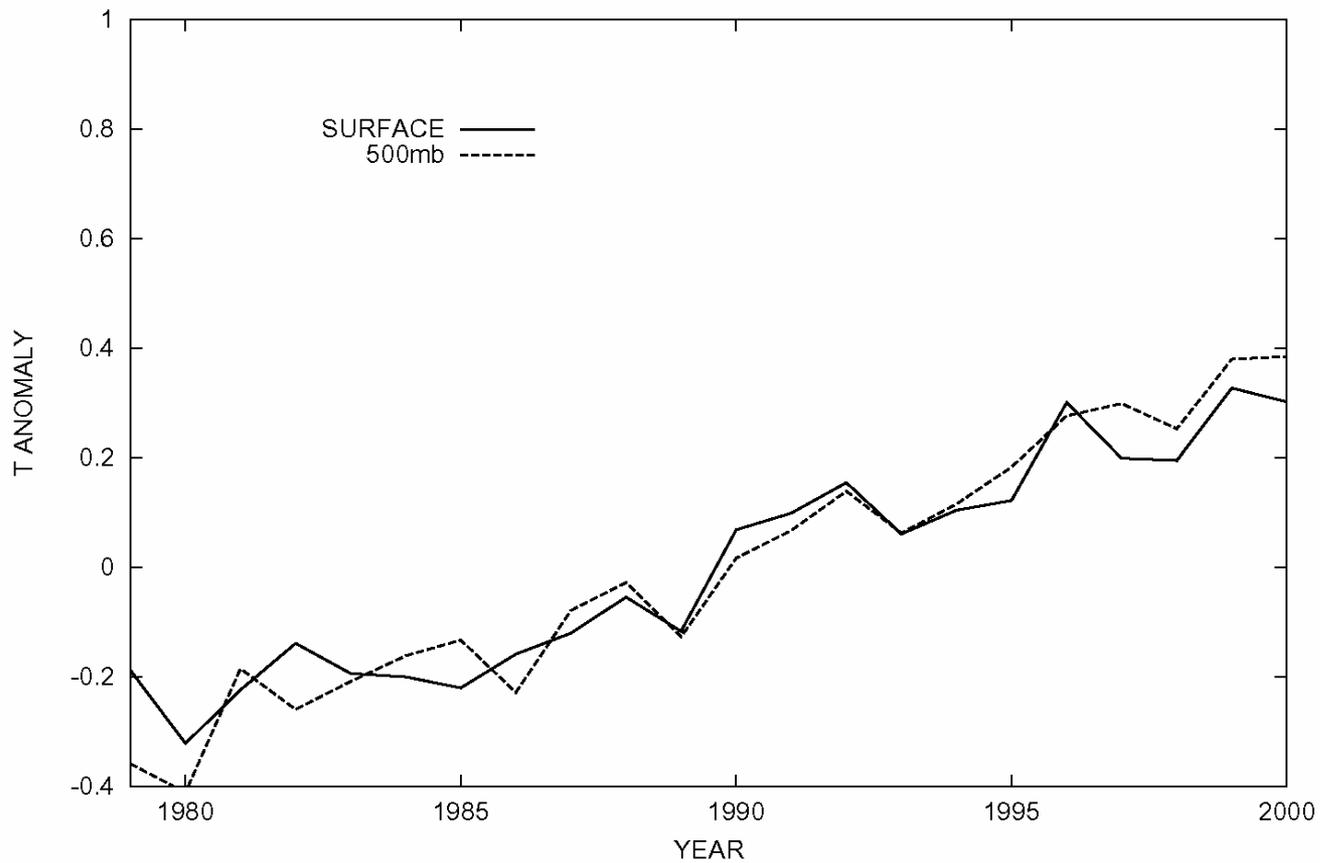
OBSERVATIONS: GLOBAL TEMPERATURE ANOMALY



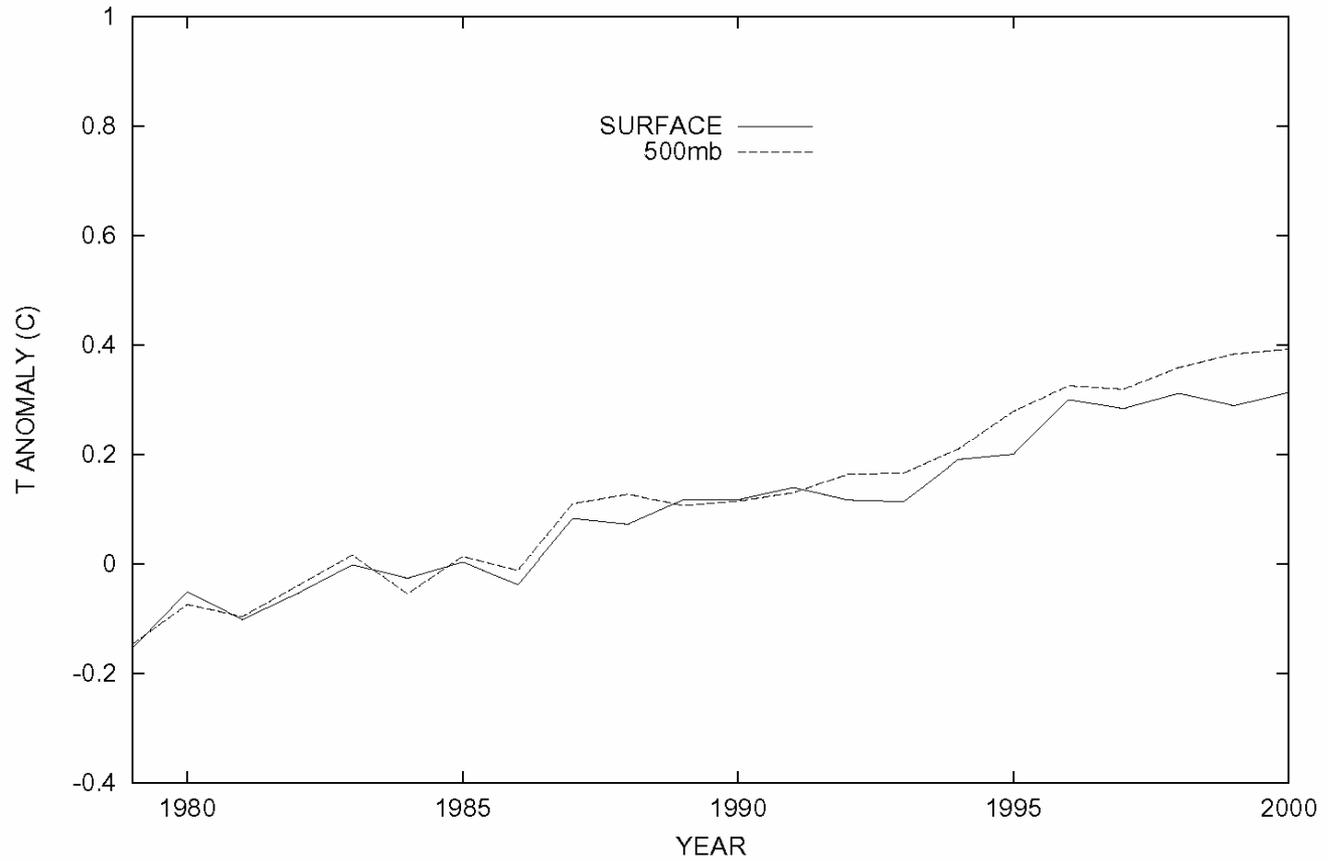
CGCM1: GLOBAL TEMPERATURE ANOMALY



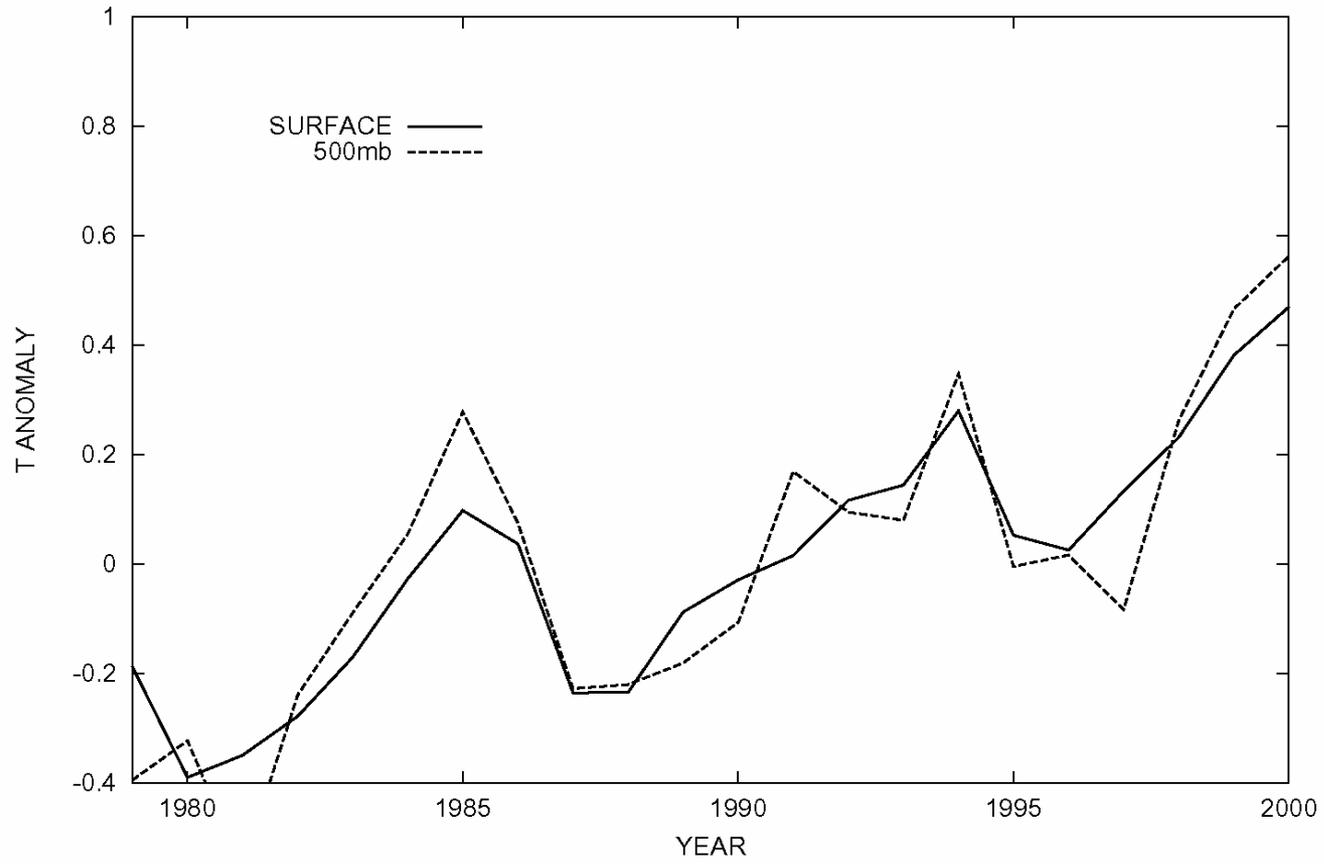
CGCM2: GLOBAL TEMPERATURE ANOMALY



GISS: GLOBAL TEMPERATURE ANOMALY



GFDL: GLOBAL TEMPERATURE ANOMALY



## ANNUAL TRENDS MSU 2r and 1000–500 NCEP

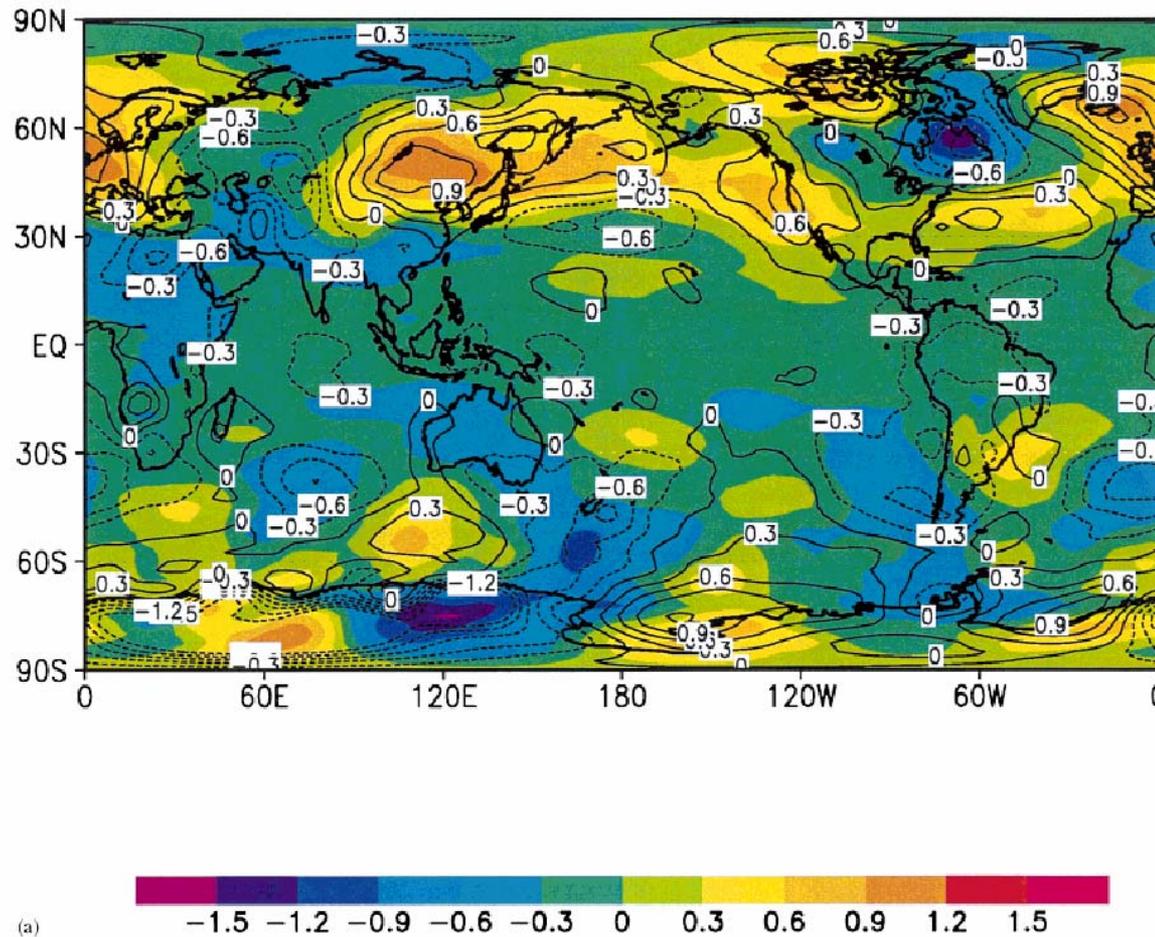


Plate 1. MSU (coloured) and NCEP 1000–500 mb (contoured) trends in °C/19 years for (a) annual average, (b) DJF average and (c) JJA average

From: Chase, T.N., R.A. Pielke, J.A. Knaff, T.G.F. Kittel, and J.L. Eastman, 2000: A comparison of regional trends in 1979-1997 depth-averaged tropospheric temperatures. *Int. J. Climatology*, 20, 503-518.  
<http://blue.atmos.colostate.edu/publications/pdf/R-224.pdf>

# 4

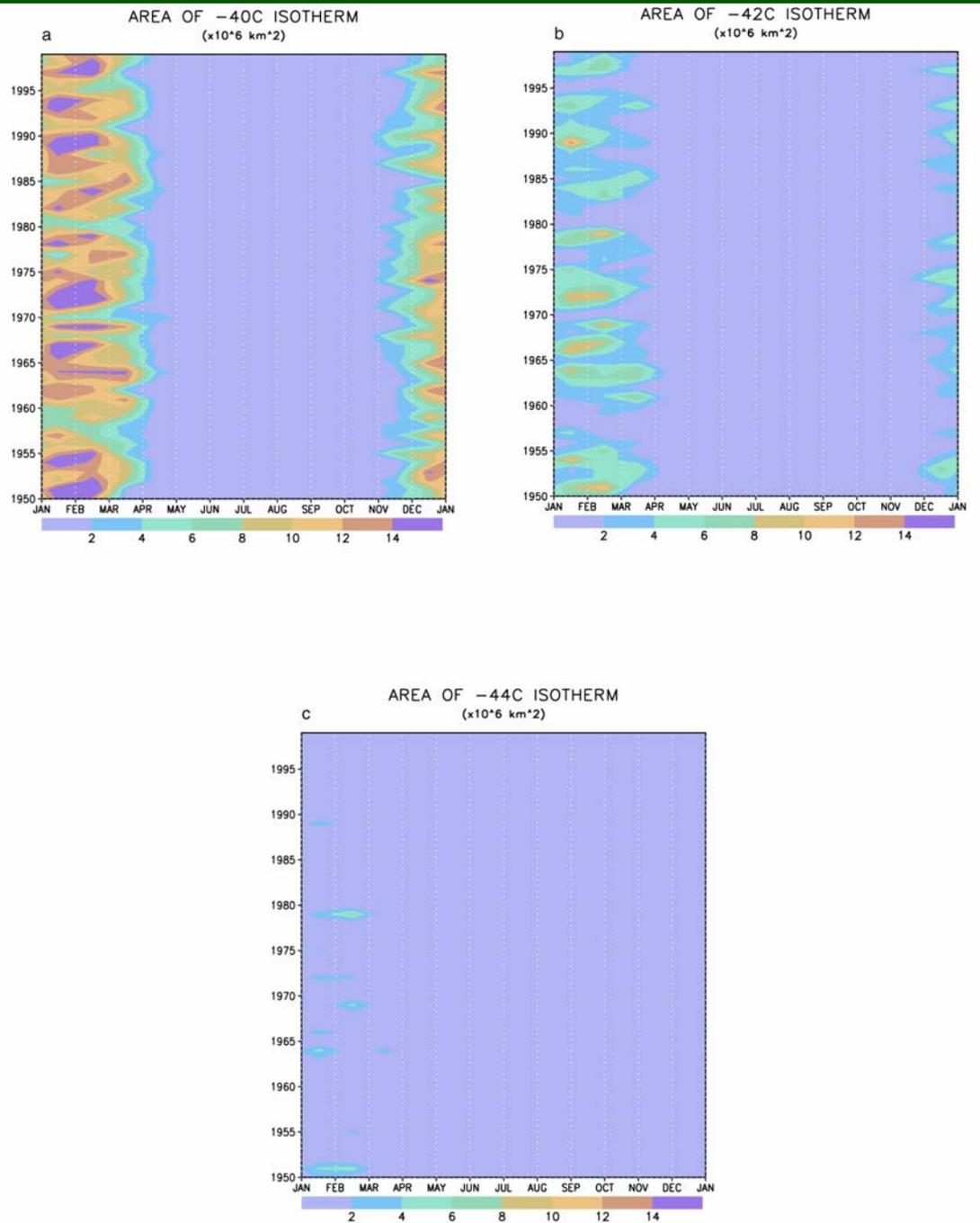
## The Lack of Warming in the Arctic Troposphere

From Chase, T.N., B. Herman, R.A. Pielke Sr., X. Zeng, and M. Leuthold, 2002: A proposed mechanism for the regulation of minimum midtropospheric temperatures in the Arctic. *J. Geophys. Res.*, 107(D14), 10.10291/ 2001JD001425.

<http://blue.atmos.colostate.edu/publications/pdf/R-246.pdf>

[http://www.atmo.arizona.edu/gifs/500mb\\_t.gif](http://www.atmo.arizona.edu/gifs/500mb_t.gif)

Reanalysis monthly-averaged area enclosed by indicated isotherm during the period 1950-1998 north of 60°N. (a) -40°C isotherm, (b) -42°C isotherm, and -44°C isotherm.



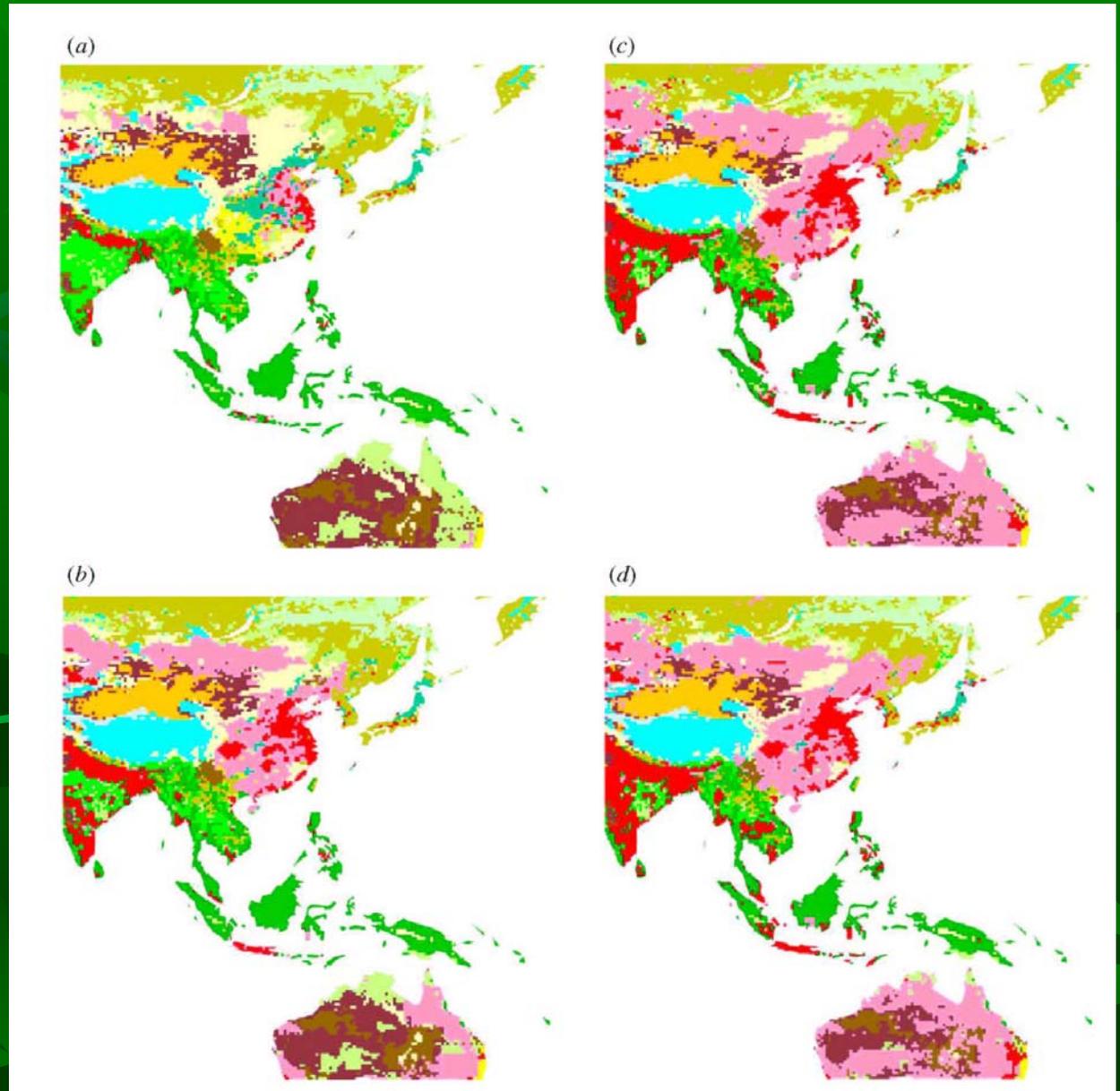
# 5

## The Global Spatial Redistribution of Energy by Human-Caused Landscape Change

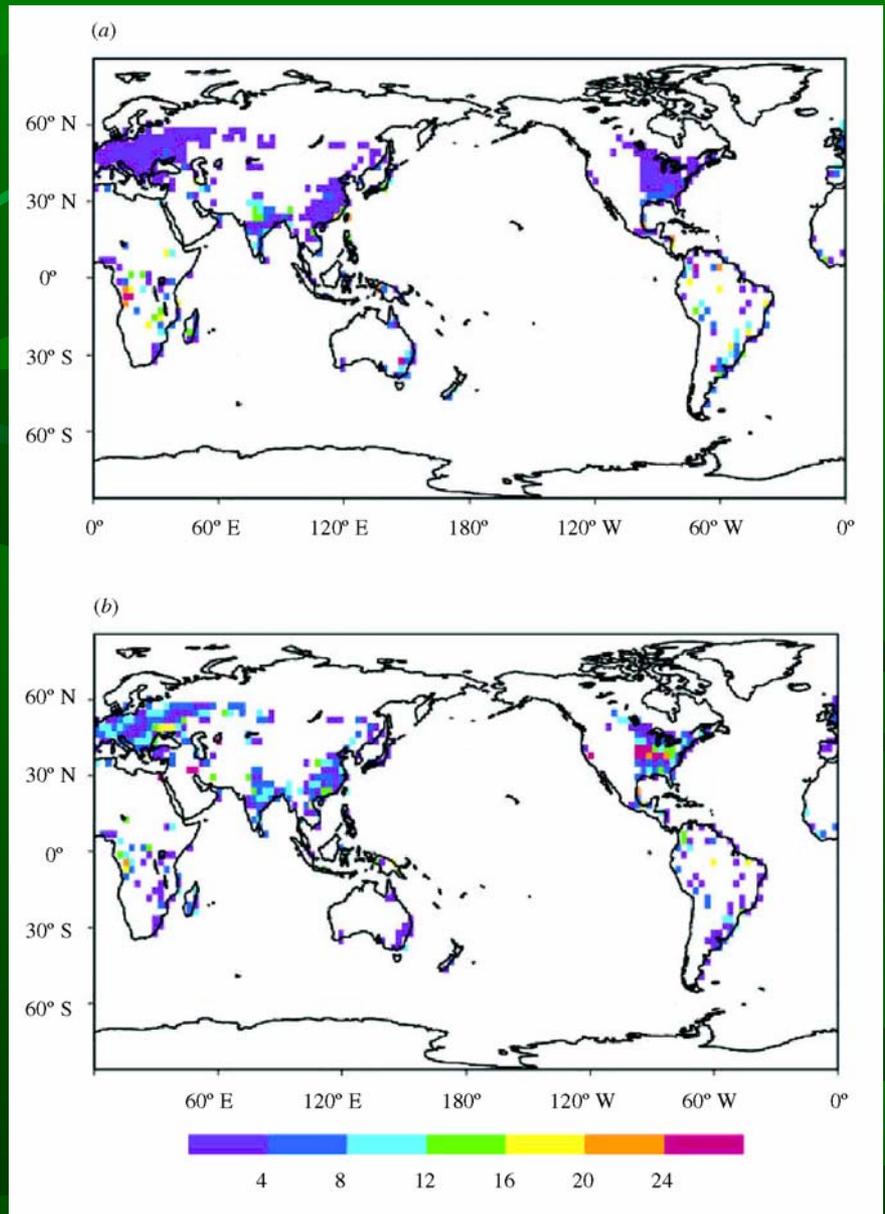
From Pielke Sr., R.A., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D. Niyogi, and S. Running, 2002: The influence of land-use change and landscape dynamics on the climate system- relevance to climate change policy beyond the radiative effect of greenhouse gases. *Phil. Trans. A. Special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

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

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.)

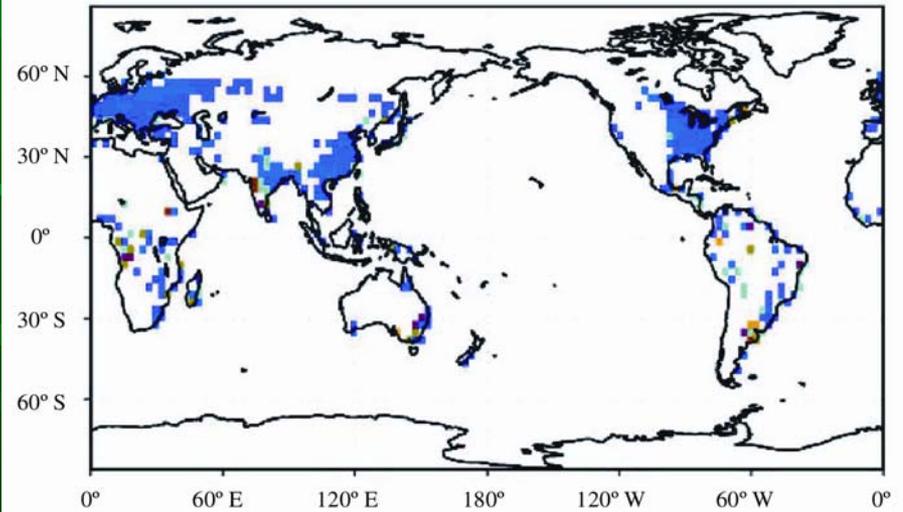


The ten-year average absolute-value change in surface latent turbulent heat flux in  $\text{W m}^{-2}$  at the locations where land-use change occurred for (a) January, and (b) July. (Adapted from Chase et al. 2000.)

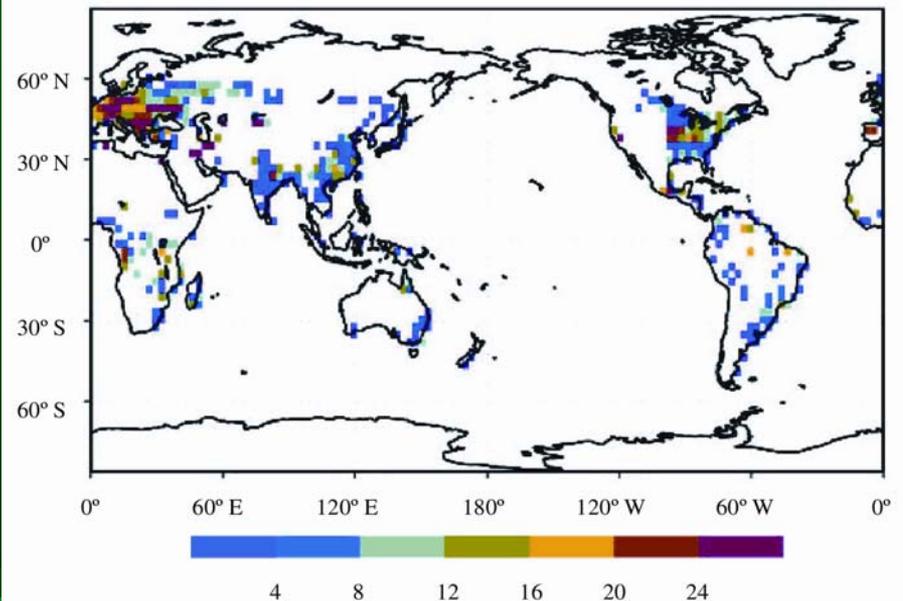


The ten-year average absolute-value change in surface sensible heat flux in  $W m^{-2}$  at the locations where land-use change occurred for (c) January, and (d) July. (Adapted from Chase et al. 2000.)

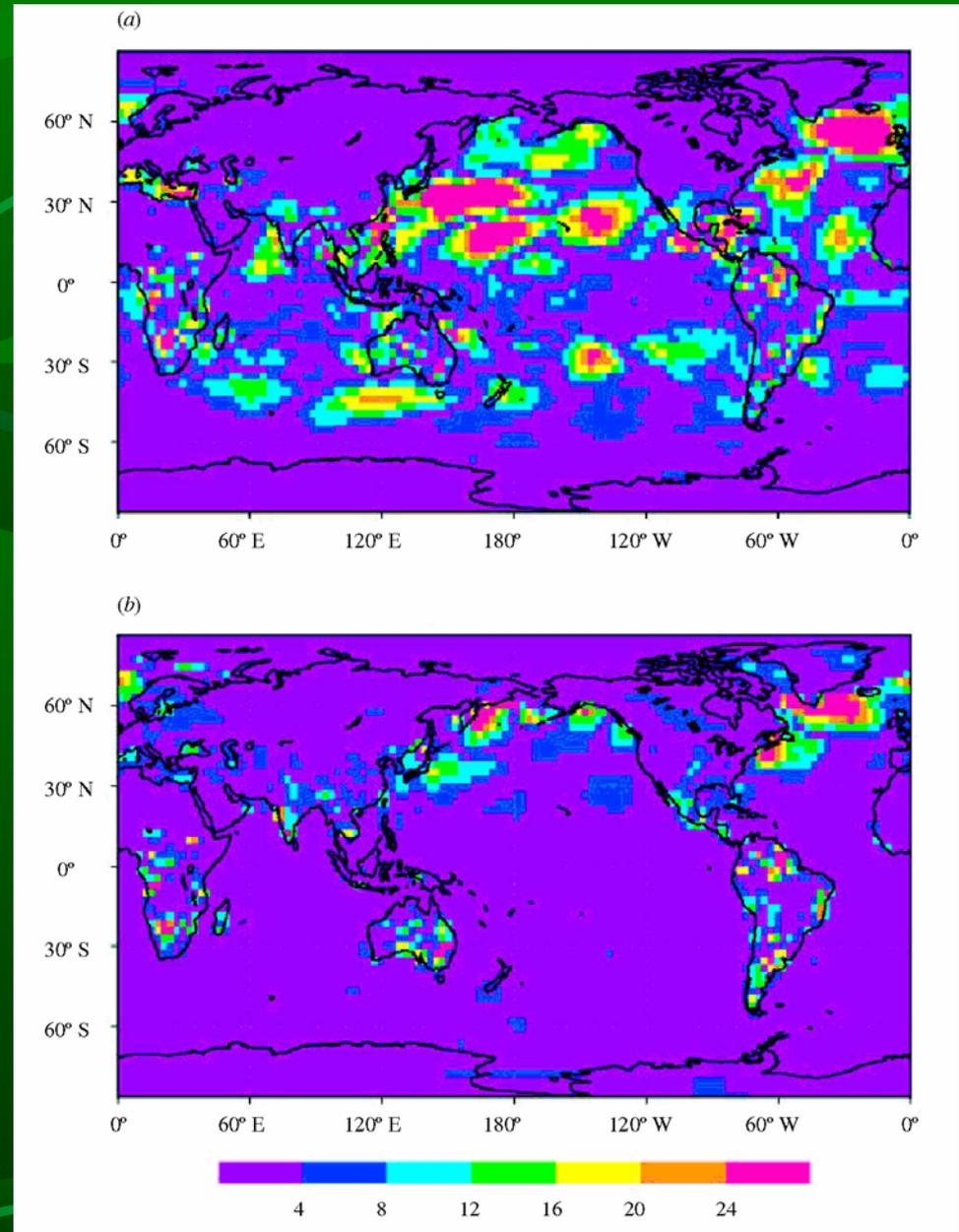
(c)



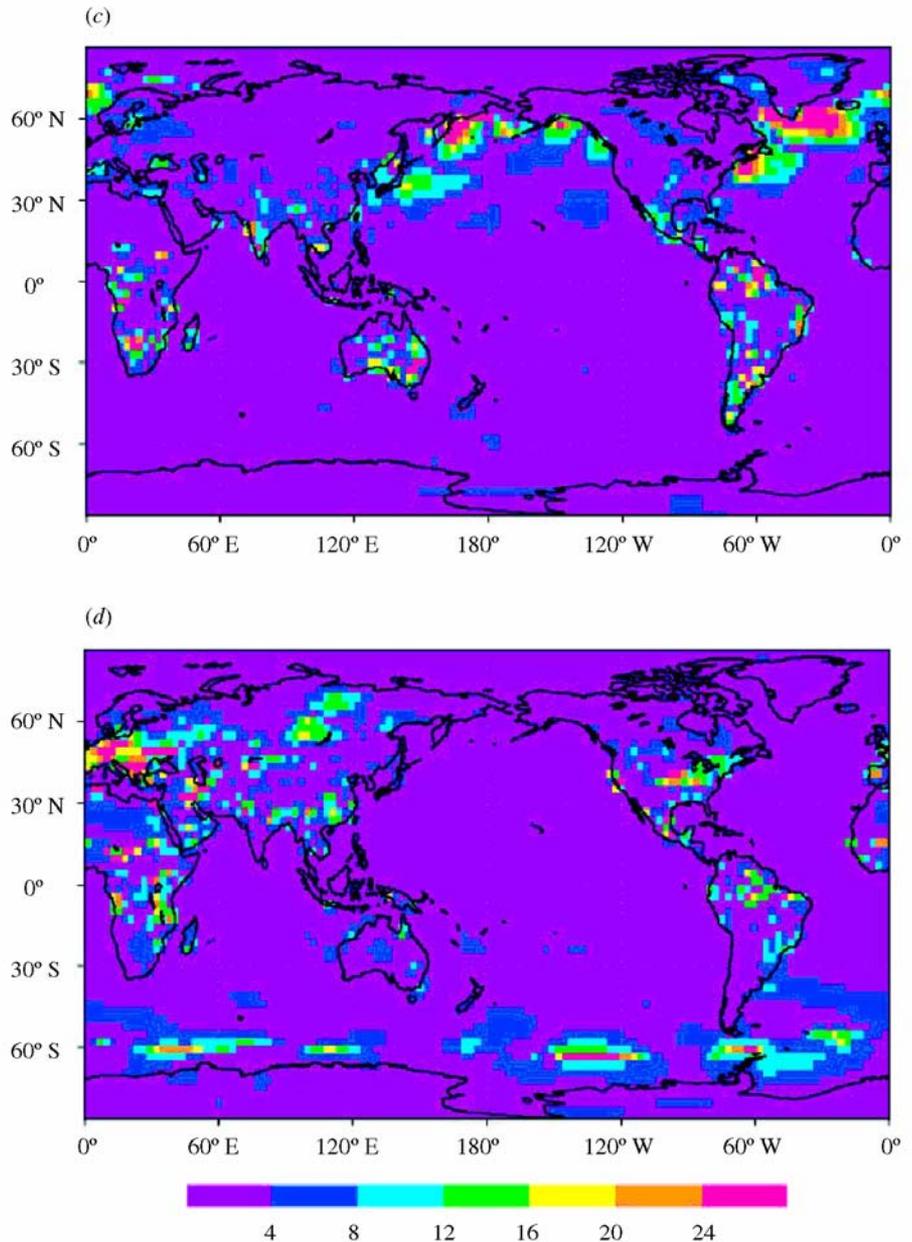
(d)



The ten-year average absolute-value change in surface latent turbulent heat flux in  $\text{W m}^{-2}$  worldwide as a result of the land-use changes for (a) January, and (b) July. (Adapted from Chase et al. 2000.)



The ten-year average absolute-value change in sensible turbulent heat flux in  $W m^{-2}$  worldwide as a result of the land-use changes for (c) January, and (d) July. (Adapted from Chase et al. 2000.)



# A Change In Any Single Term In The Surface Heat Budget Will Result In a Spatial Redistribution Of Energy

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

where

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

# 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	1.08 Watts m <sup>-2</sup>
	January	0.7 Watts m <sup>-2</sup>
Teleconnections Included	July	8.90 Watts m <sup>-2</sup>
	January	9.477 Watts m <sup>-2</sup>

# 6

## The Adoption of a More Appropriate Metric to Monitor “Global Warming (or Cooling)”

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>

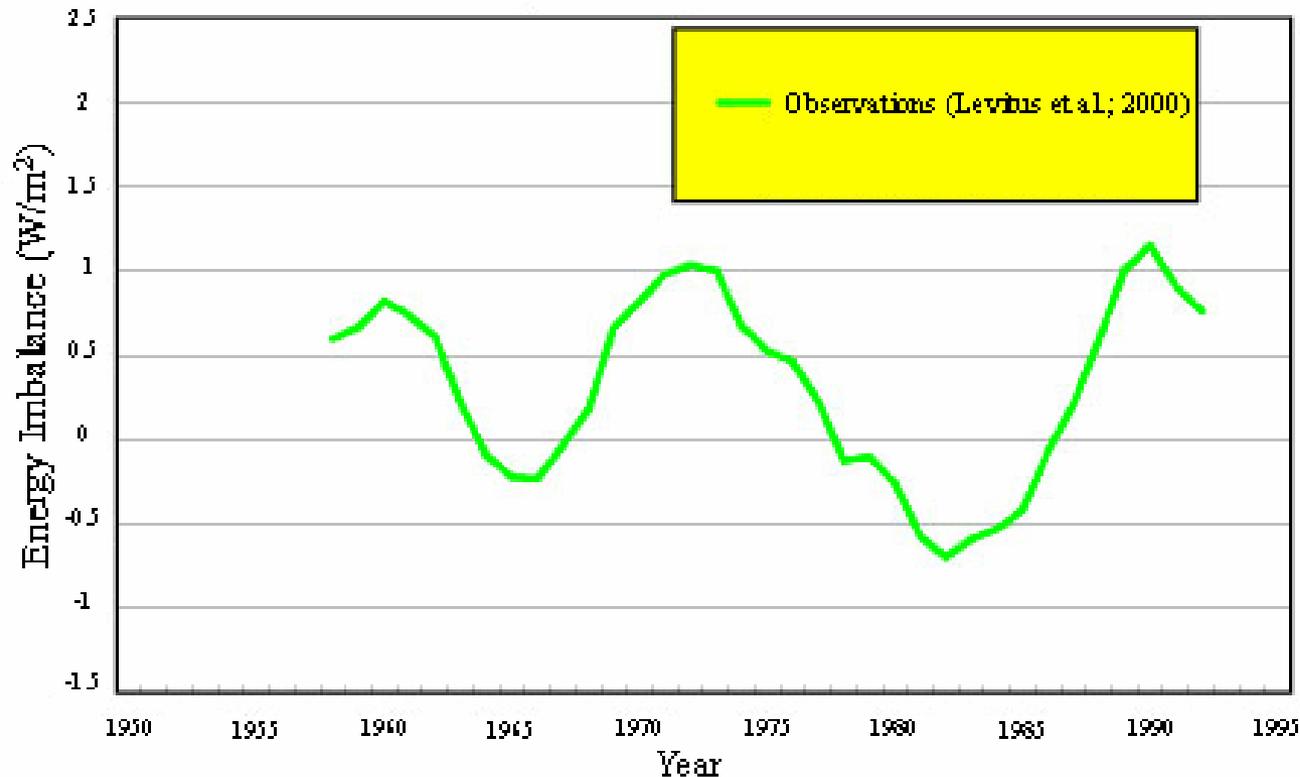
The heat budget for the earth system can be expressed as

$$\iint_{t, A_{\text{Earth}}} R_N dA dt = \iint_{t, V_{\text{atmos}}} Q dV dt + \iint_{t, V_{\text{ocean}}} Q dV dt \quad (1)$$

+ other heat reservoirs,

where  $R_N$  is the global mean nonequilibrium radiative forcing,  $A_{\text{Earth}}$  is the area of the earth,  $Q$  is the heating rate,  $V_{\text{atmos}}$  is the volume of the atmosphere, and  $V_{\text{ocean}}$  is the volume of the ocean.

Annual Planetary Energy Imbalance (Heat Input to Oceans)  
[5-year running mean]



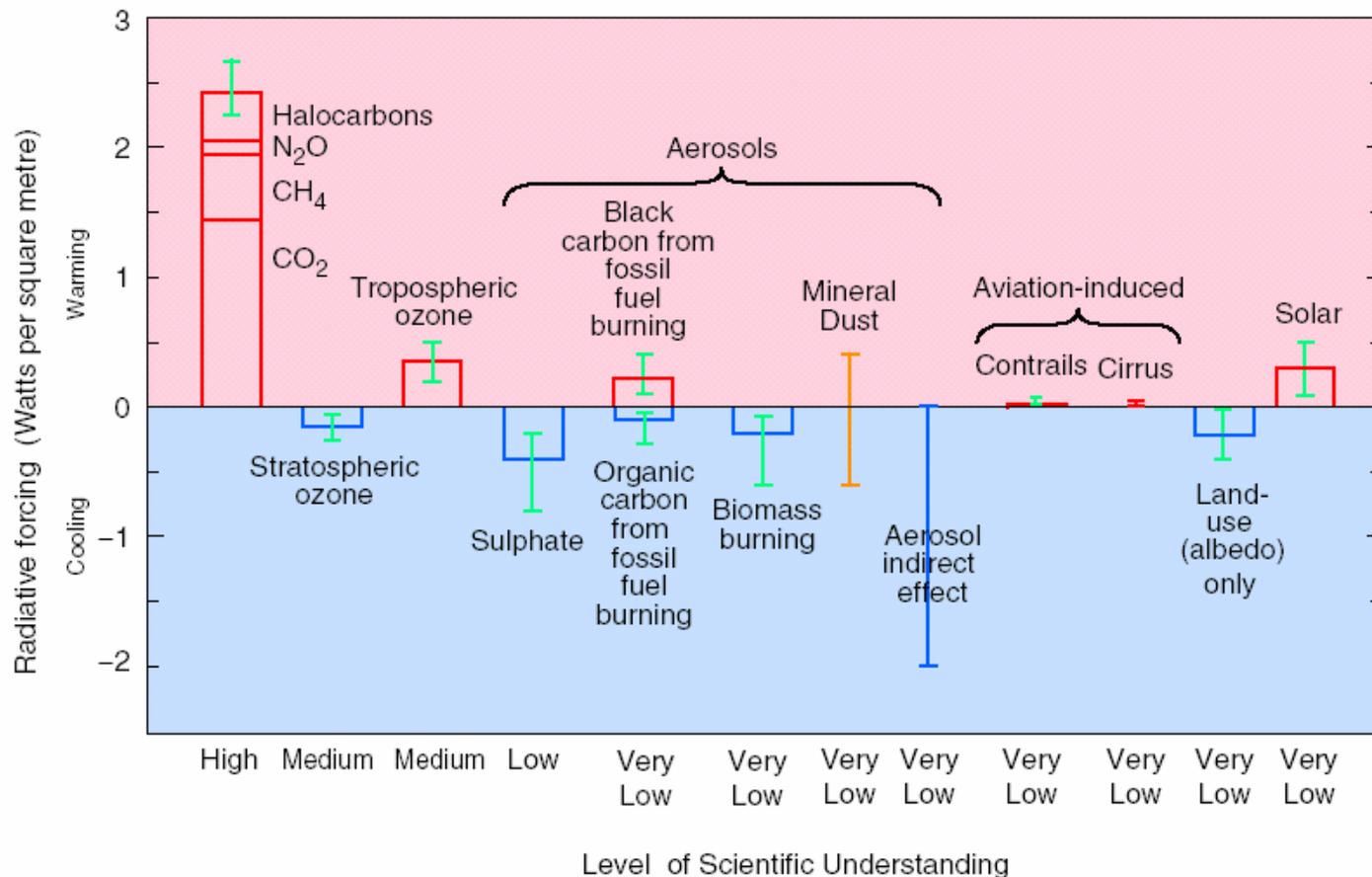
Planetary energy imbalance (heat storage in the upper 3 km of the world ocean) observations expressed in units of watts m<sup>-2</sup> (adapted from Levitus et al. 2001). (Figure prepared by Alan Robock, Rutgers University, 2001, personal communication.)

**Mid 1950s to Mid-1990s**

**~ 0.15 Watts m<sup>-2</sup> surface - 300 meters**

**~ 0.15 Watts m<sup>-2</sup> 300 meters – 3 km**

## The global mean radiative forcing of the climate system for the year 2000, relative to 1750



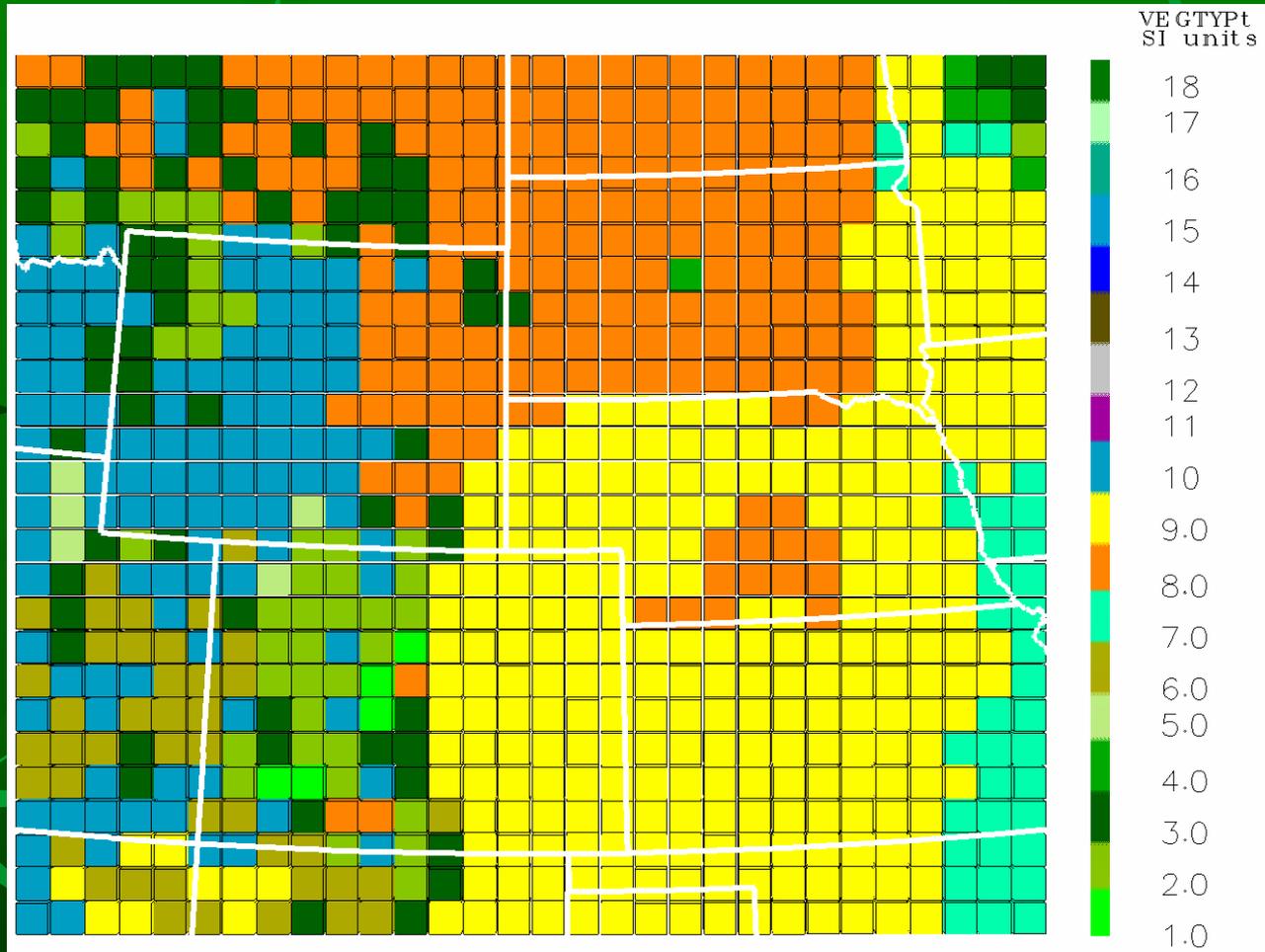
Estimate of actual climate system heat change from the early 1950s-1995 is 0.3 Watts per meter squared (Pielke 2003) based on ocean heat storage changes (Levitus et al. 2000). Figure from Houghton et al. Eds., 2001: Summary for Policymakers: <http://www.ipcc.ch>

# 7

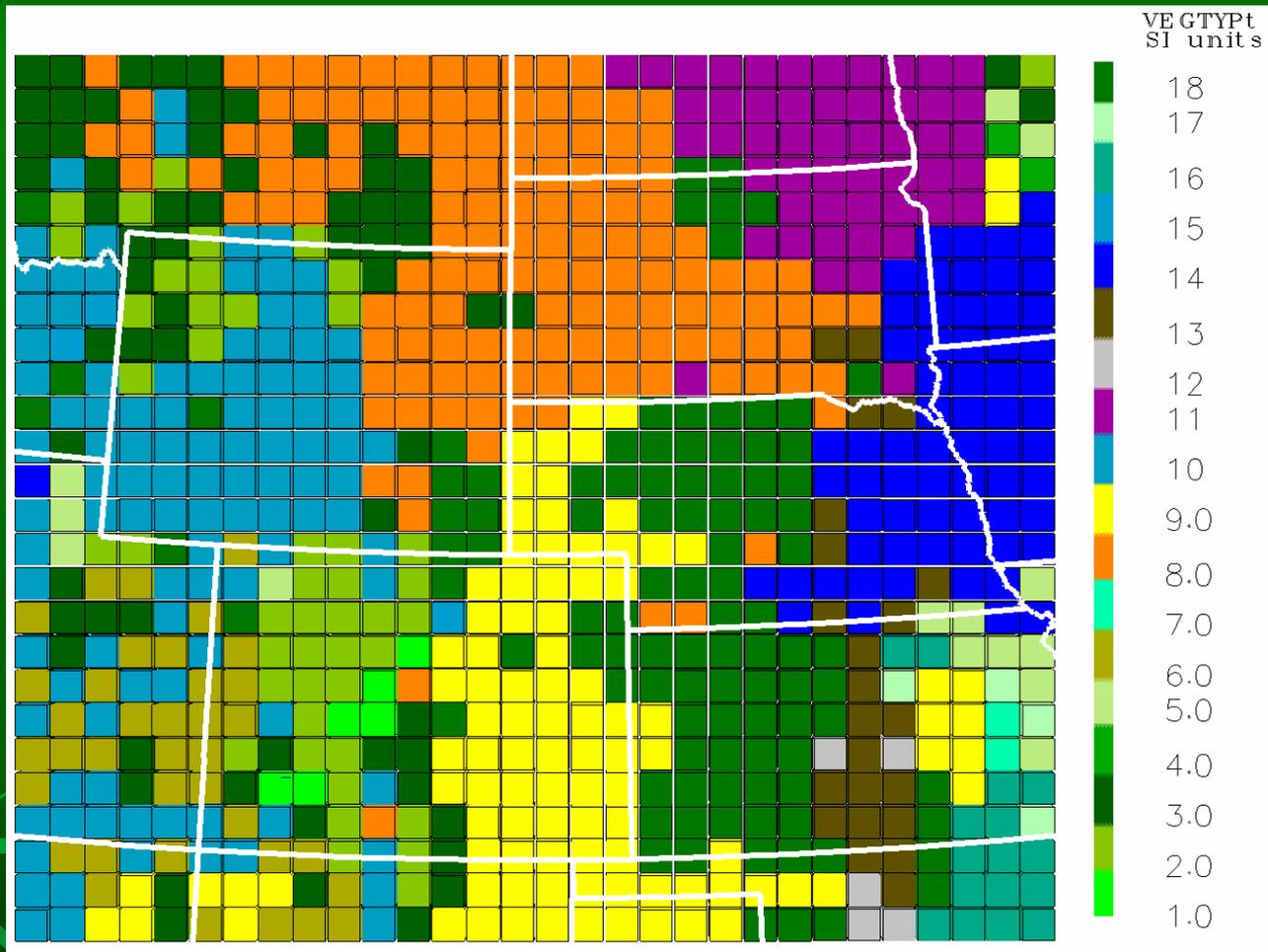
## The Importance of the Biological Effect of Enhanced CO<sup>2</sup>

Eastman, J.L., M.B. Coughenour, and R.A. Pielke Sr., 2001: The effects of CO<sup>2</sup> and landscape change using a coupled plant and meteorological model. *Global Change Biology*, 7, 797-815.

<http://blue.atmos.colostate.edu/publications/pdf/R-229.pdf>



**Modeling domain and natural vegetation distribution. Classes represent: 1-tundra; 2-subalpine; 3-temperate conifer; 4-temperate deciduous; 5-temperate xeromorphic; 6-temperate coniferous xeromorphic; 7-savanna and deciduous; 8-C3 shortgrass 9- C4 tall grass; 10- temperate arid shrub; 11-spring wheat/small grass; 12-small grains; 13-winter wheat; 14-corn; 15-irrigated crop; 16-deciduous forest crop; 17-subtropical mixed forest; and 18-grassland and grain. From Eastman et al. (2001).**



**Modeling domain and current vegetation distribution. Classes represent: 1-tundra; 2-subalpine; 3-temperate conifer; 4-temperate deciduous; 5-temperate xeromorphic; 6-temperate coniferous xeromorphic; 7-savanna and deciduous; 8-C3 shortgrass 9- C4 tall grass; 10- temperate arid shrub; 11-spring wheat/small grass; 12-small grains; 13-winter wheat; 14-corn; 15-irrigated crop; 16-deciduous forest crop; 17-subtropical mixed forest; and 18-grassland and grain. From Eastman et al. (2001).**

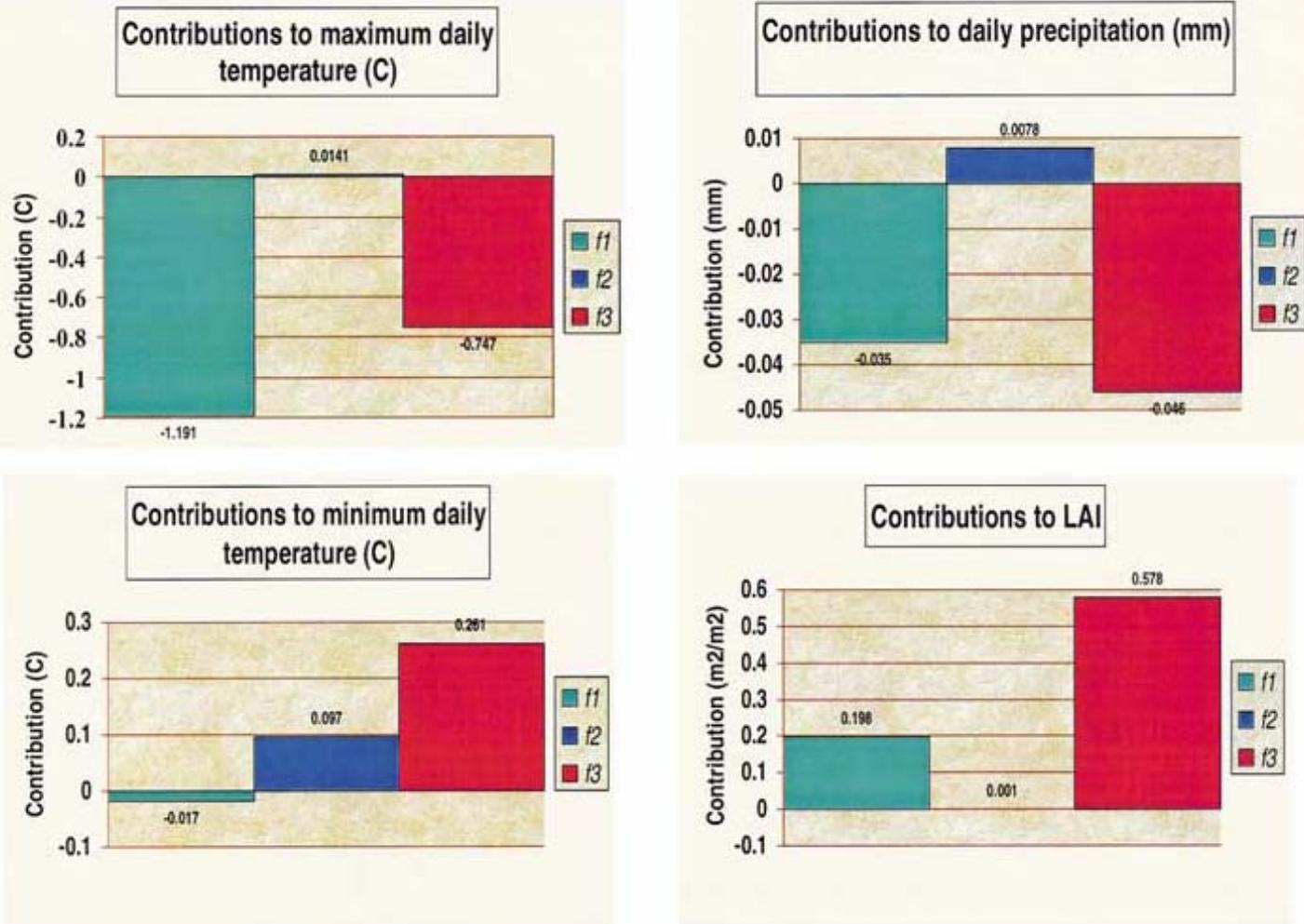


Figure 4. RAMS/GEMTM coupled model results – the seasonal domain-averaged (central Great Plains) for 210 days during the growing season, contributions to maximum daily temperature, minimum daily temperature, precipitation, and leaf area index (LAI) due to: f1 = natural vegetation, f2 =  $2 \times \text{CO}_2$  radiation, and f3 =  $2 \times \text{CO}_2$  biology (adapted from Eastman et al., 2001).

**Table 5** Domain and seasonally-averaged mean and standard deviation for the control simulation, and mean contributions and standard deviation of contributions owing to natural vegetation,  $2 \times \text{CO}_2$  radiation, and  $2 \times \text{CO}_2$  biology

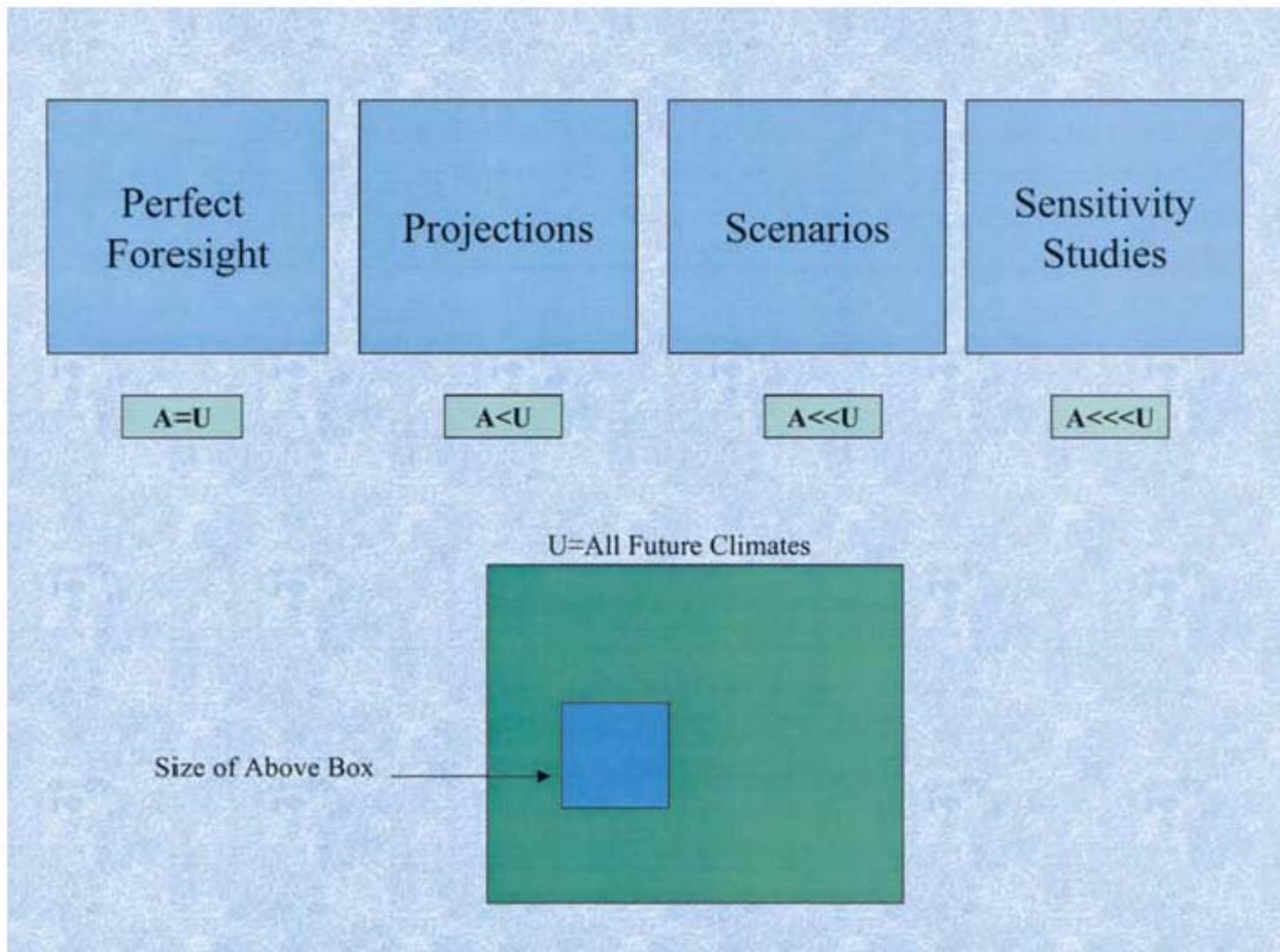
Variable	Current Vegetation $1 \times \text{CO}_2$		Natural Vegetation		$2 \times \text{CO}_2$ radiation		$2 \times \text{CO}_2$ biology	
	Mean	$\sigma$	Mean	$\sigma$	Mean	$\sigma$	mean	$\sigma$
TMAX ( $^{\circ}\text{C}$ )	23.13	4.52	- 1.191	1.77	0.014	0.159	- 0.747	0.639
TMIN ( $^{\circ}\text{C}$ )	7.299	2.78	- 0.017	0.531	0.097	0.041	0.261	0.365
PPT (mm)	0.889	0.34	- 0.035	0.088	0.008	0.011	- 0.046	0.030
LAI	2.663	3.402	0.198	0.783	0.001	0.071	0.578	0.621

# 8

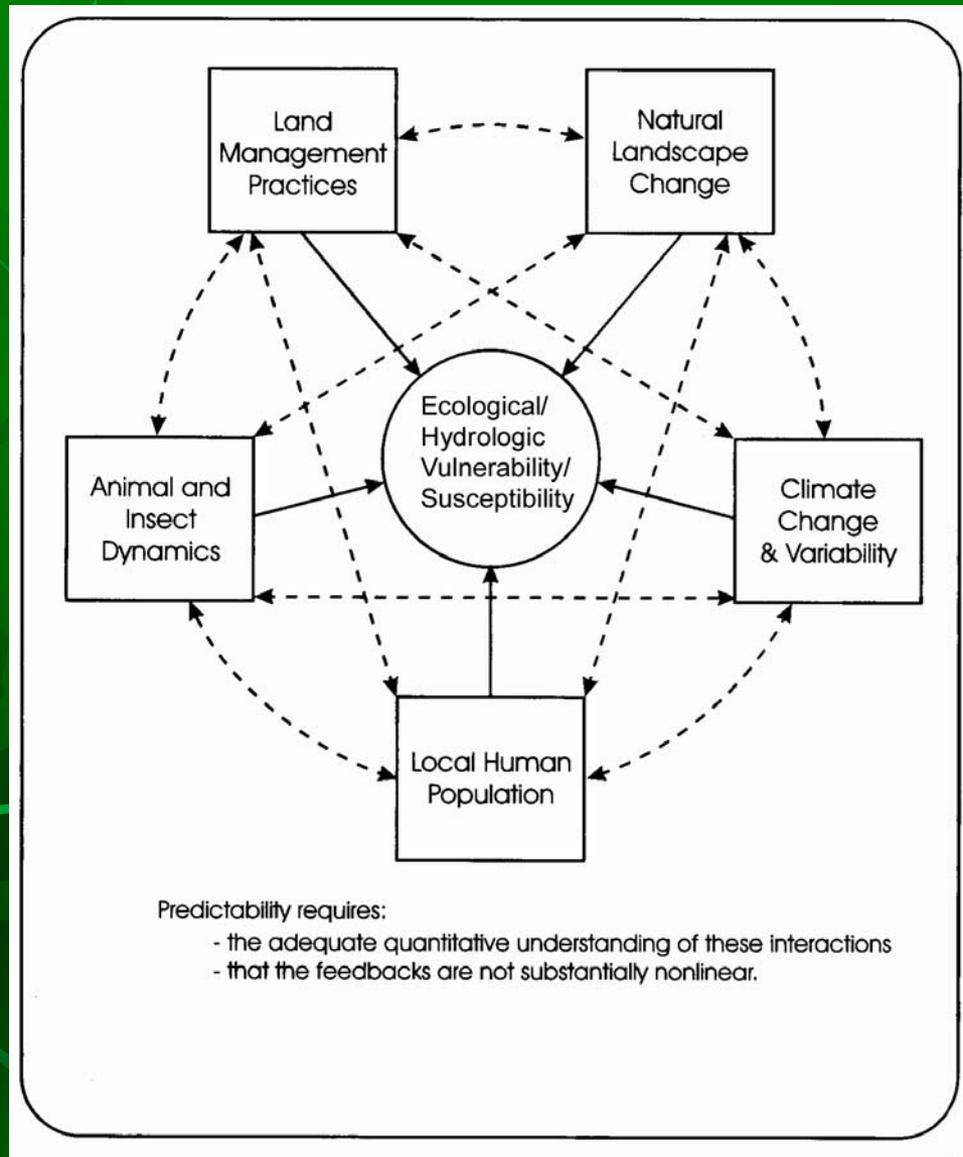
## Climate as an Initial Value Problem

Pielke, R.A. Sr., 2002: Overlooked issues in the U.S. National Climate and IPCC assessments. *Climatic Change*, 52, 1-11.

<http://blue.atmos.colostate.edu/publications/pdf/R-225.pdf>



*Figure 6. Schematic of different classes of prediction. The size of the box labeled 'U' represents the range of future climate, while the box labeled 'A' indicates the relative subset of possible future climate that are estimated using the different classes of prediction, (adapted from Pielke Sr., 2001).*



\* Note that more appropriately, it is weather change and variability

9a

# 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*, in press.

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

Marshall, C.H., R.A. Pielke Sr., and L.T. Steyaert, 2003: 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>

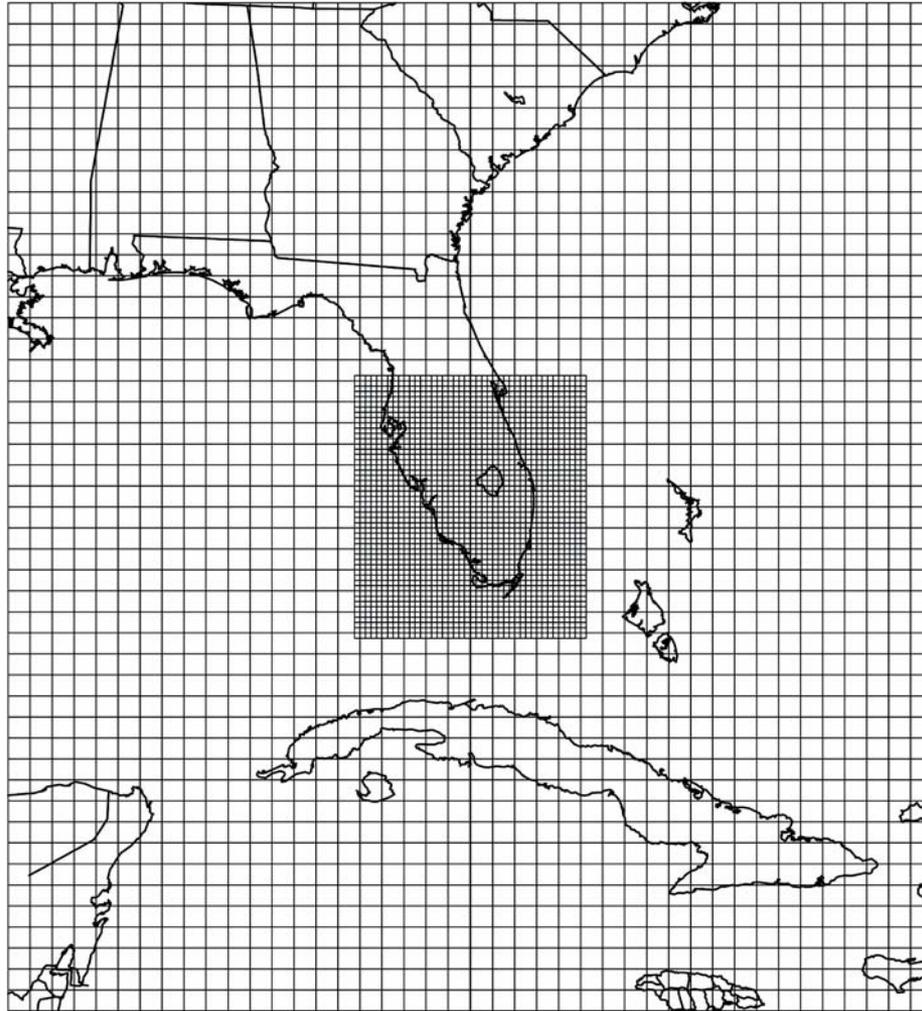
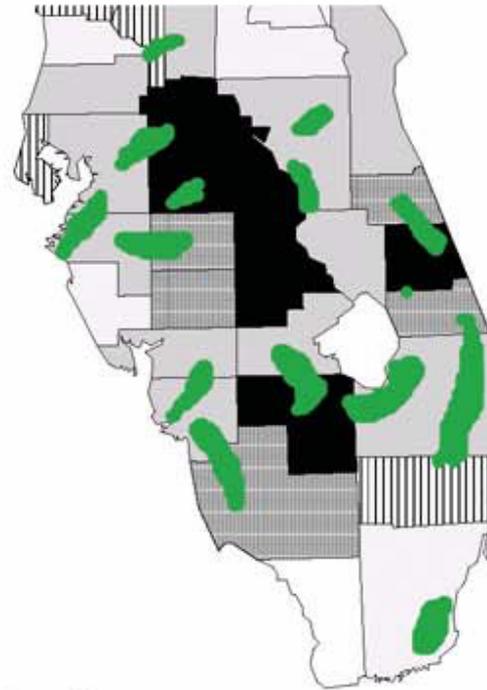


Fig. 2. Outer and inner grid configurations for RAMS domain centered on south Florida.

 Principle areas of winter fresh vegetables



Number of Citrus Trees by County

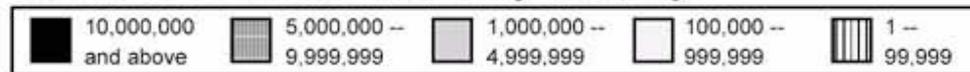


Fig. 1. Number of citrus trees per county and principle areas of winter fresh vegetable production. Figure adapted from Florida Agriculture Facts Directory 2002.

## Observed Minimum Temp (°C) 19970119

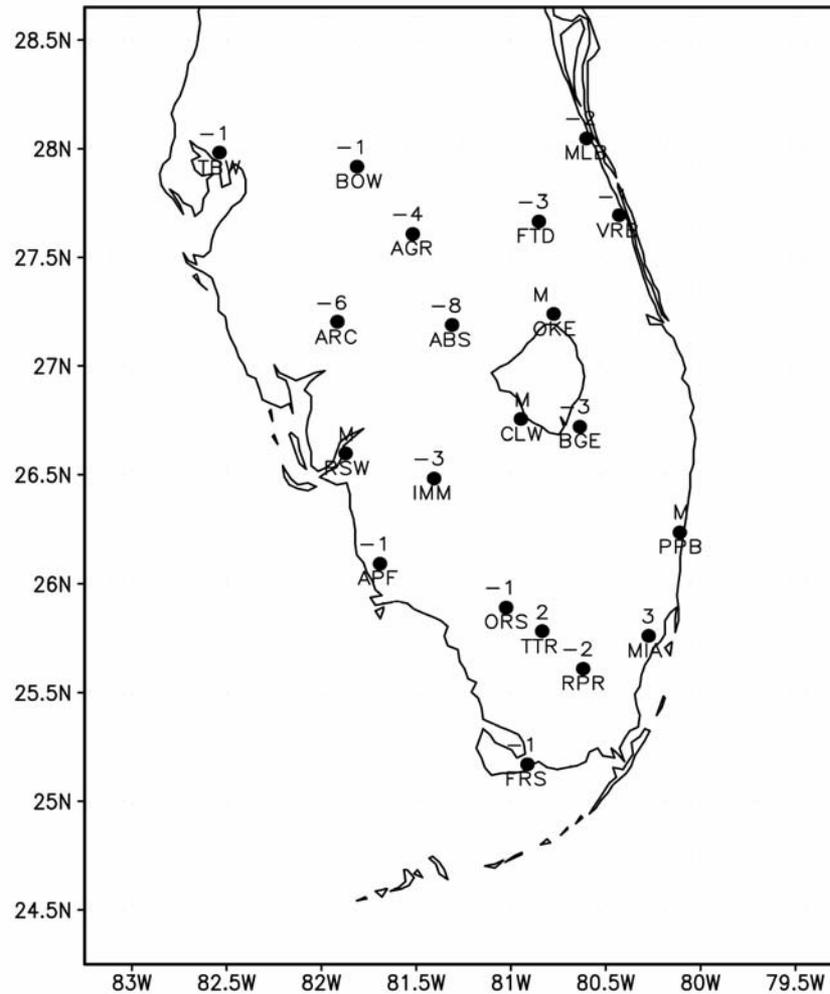


Fig. 2. Observations of minimum temperature from the National Weather Service Cooperative Observer Network on the morning of January 19, 1997.

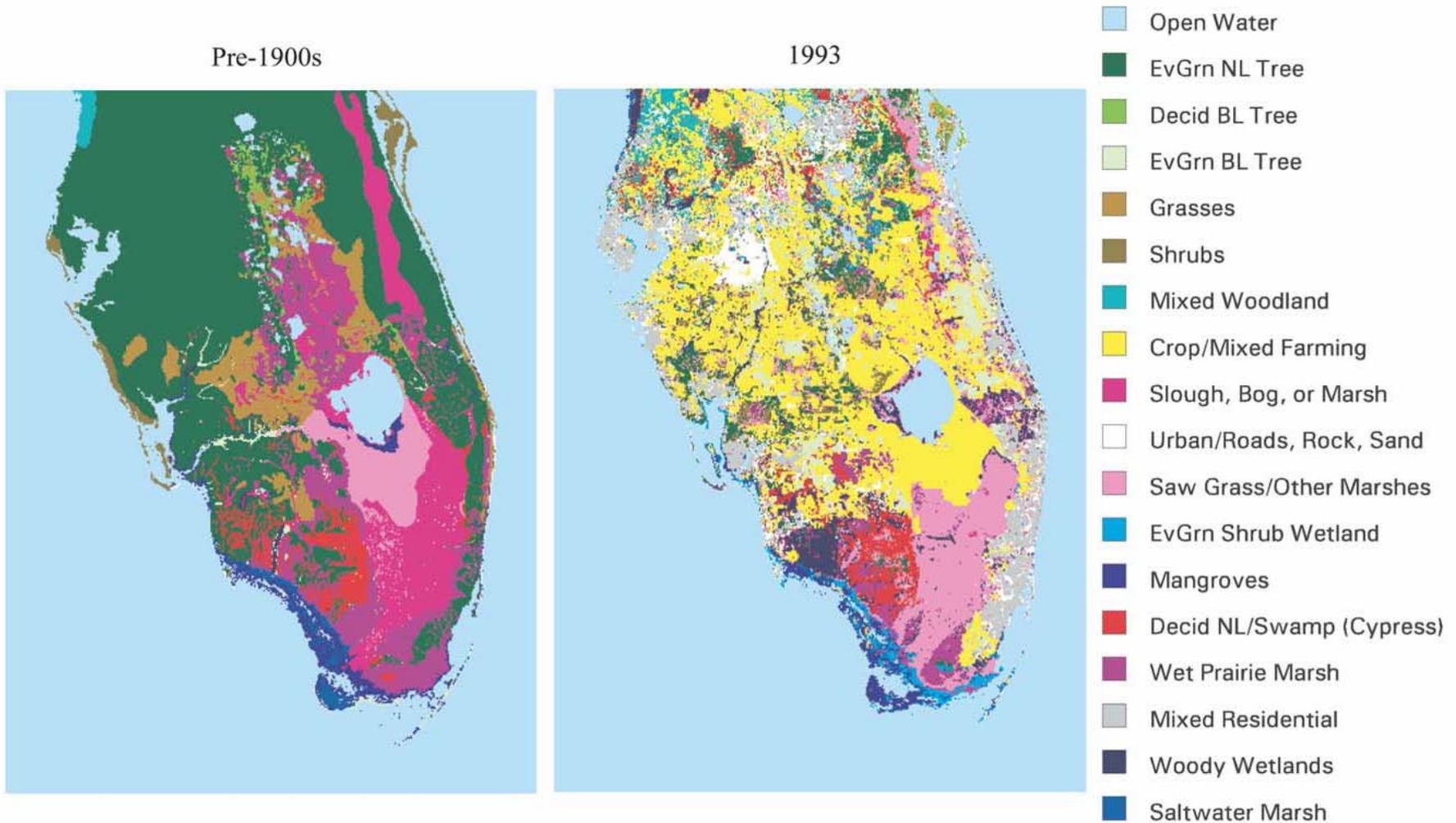


Fig. 3. U.S. Geological Survey land cover classes for pre-1900s natural conditions (left) and 1993 land use patterns.

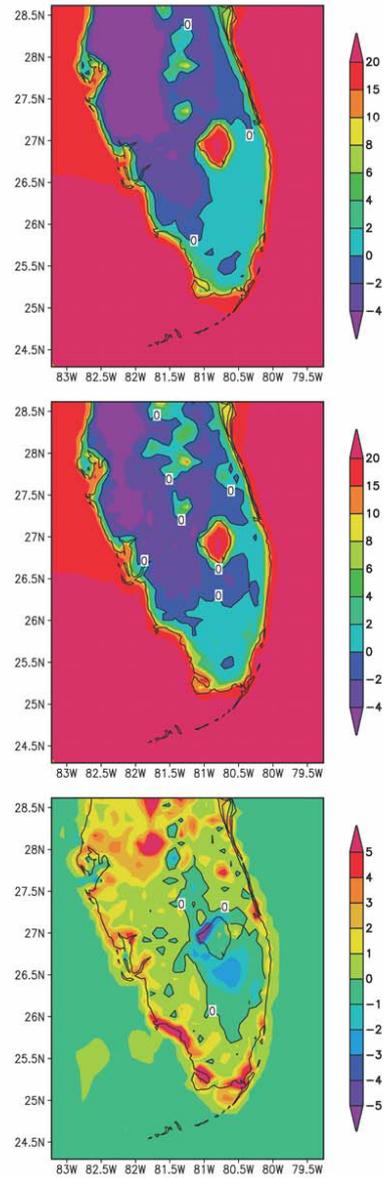


Fig. 4. Model simulated 2 meter minimum temperatures on the morning of January 19, 1997 for the pre-1900s scenario (top panel), the 1993 scenario (middle panel), and the difference of the two (1993 minus pre-1900s scenario; bottom panel).

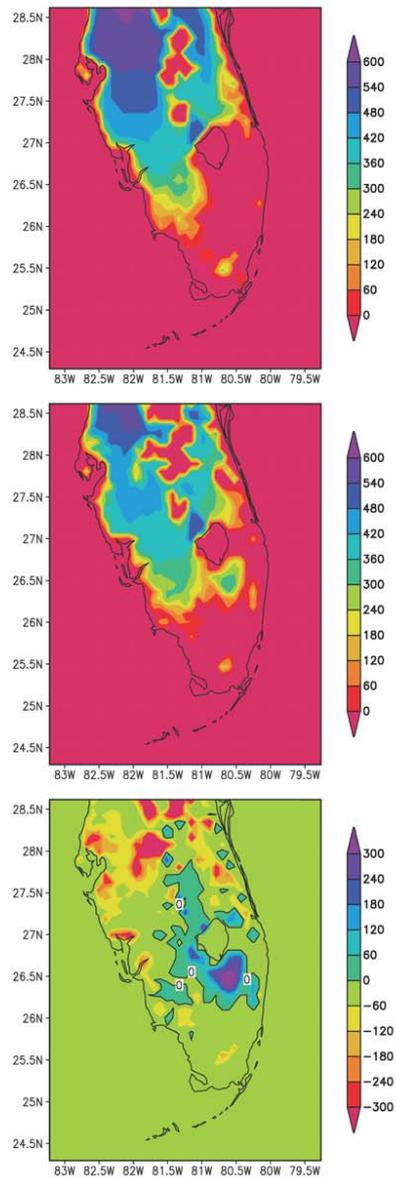


Fig. 5. Time spent below freezing (minutes) for the night prior to the morning of January 19, 1997, for the pre-1900s land cover scenario (top), the 1993 land cover scenario (middle) and the difference of the two (bottom).

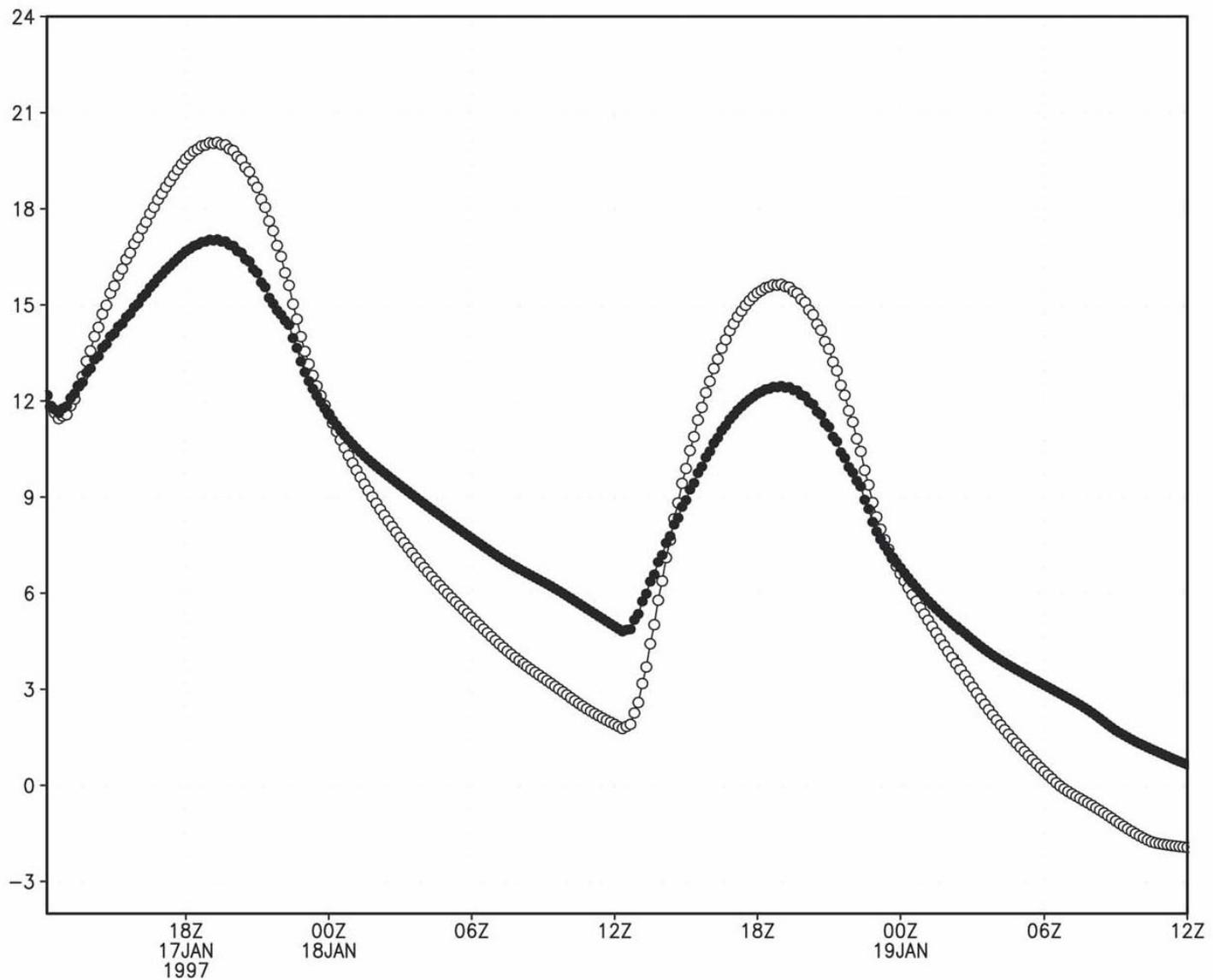


Fig. 7. Time series of 2 meter temperature for a model grid point located just south of Lake Okeechobee for the pre-1900s land cover scenario (filled circles) and the 1993 land cover scenario (open circles).

# 9b

## 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, 2003: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. *Mon. Wea Rev.*, in press

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

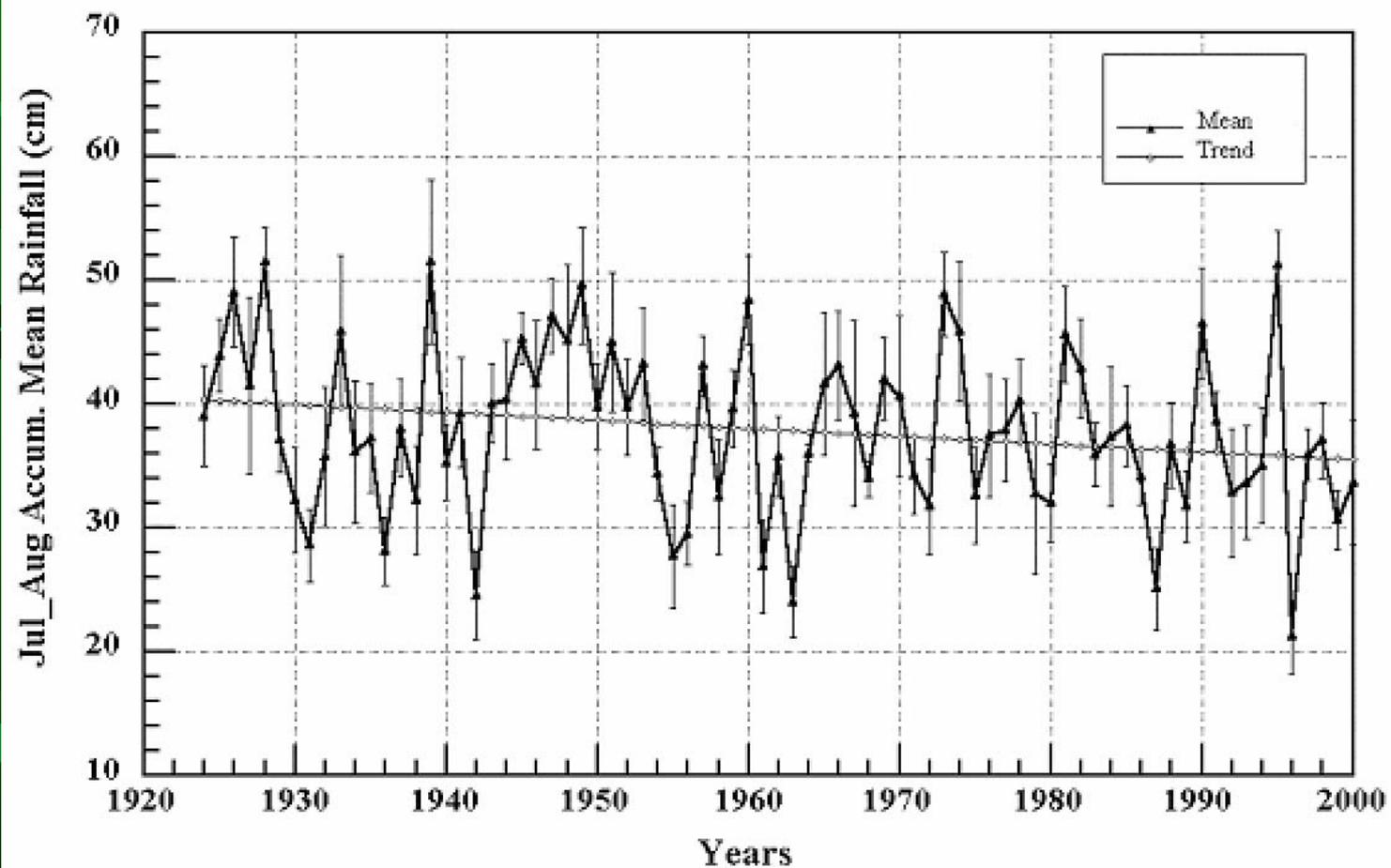


FIG. 25. Regional average time series of accumulated convective rainfall (cm) from 1924 to 2000, with corresponding trend based on linear regression of all July-August amounts. The vertical bars overlain on the raw time series indicate the value of the standard error of the July-August regional mean.

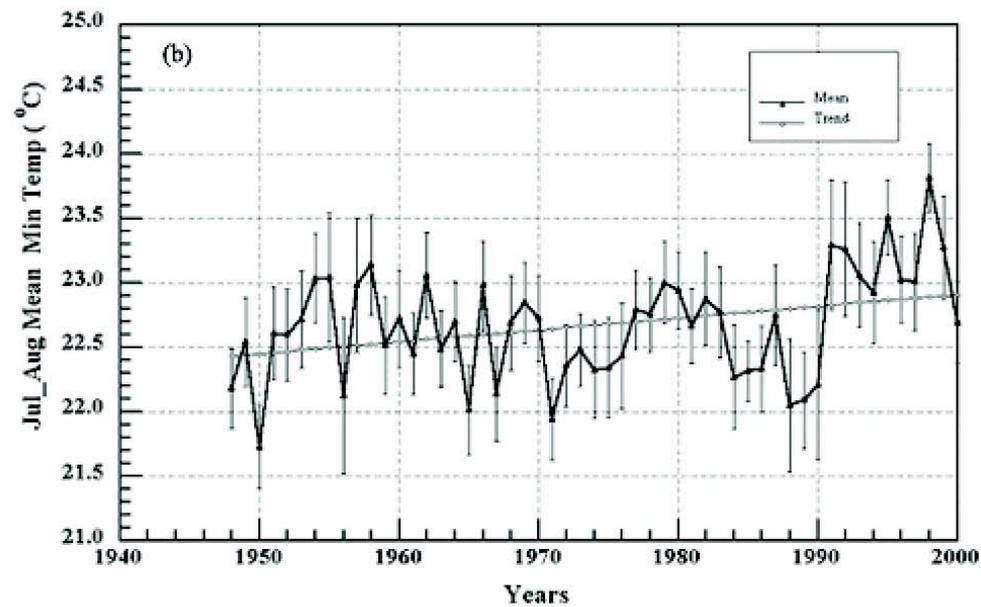
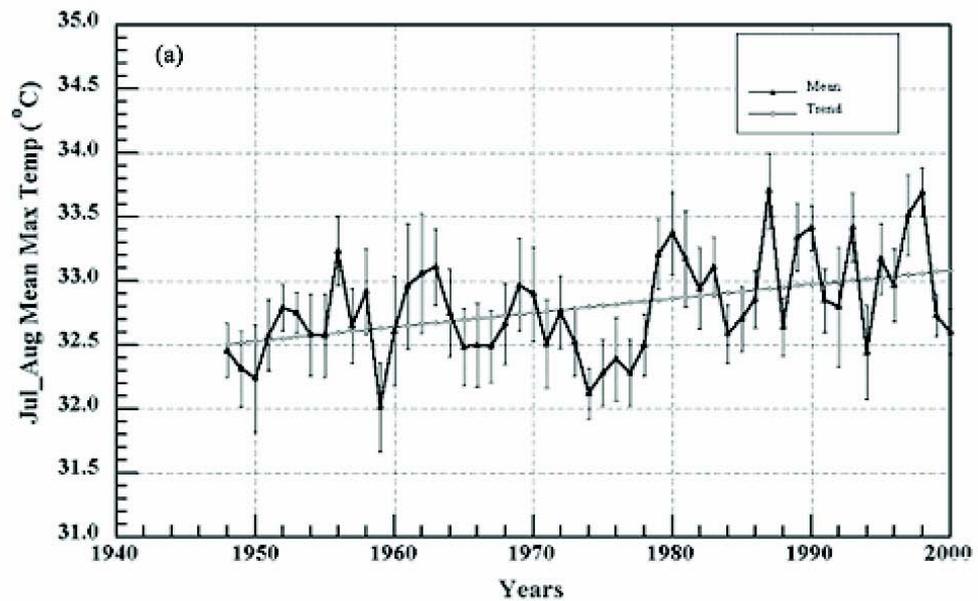


FIG. 26. Same as in Figure 25, except for daily (a) maximum and (b) minimum shelter-level temperature ( $^{\circ}\text{C}$ )

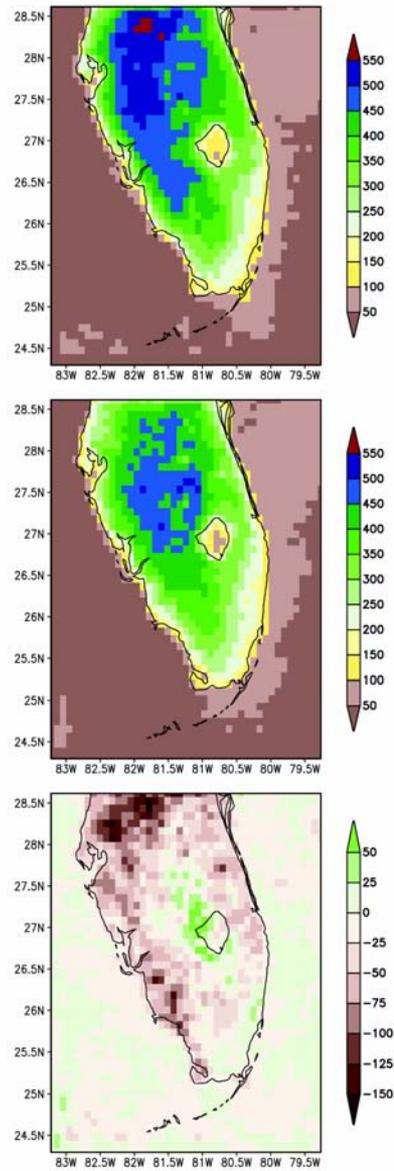


FIG. 4. Accumulated convective rainfall (mm) from the model simulations of July-August 1973 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).

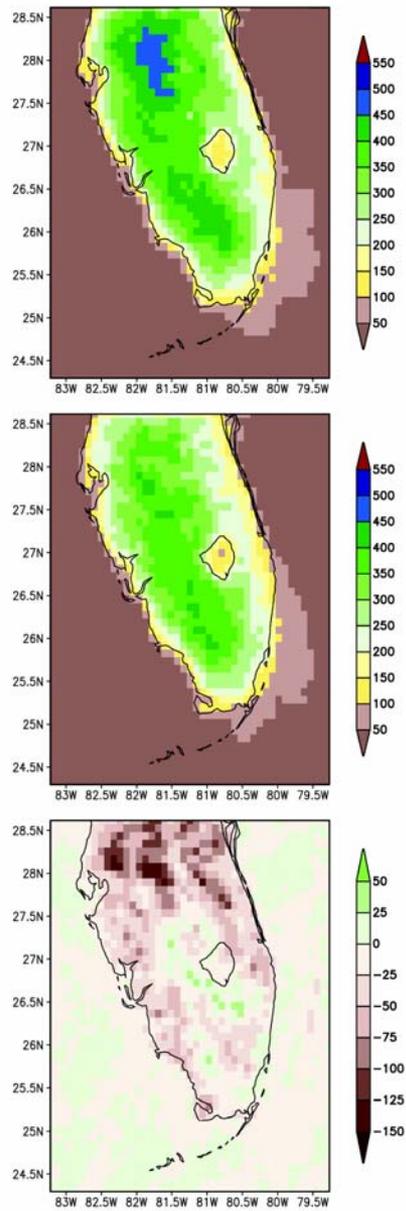


FIG. 5. Same as in Figure 4, except for July-August 1989.

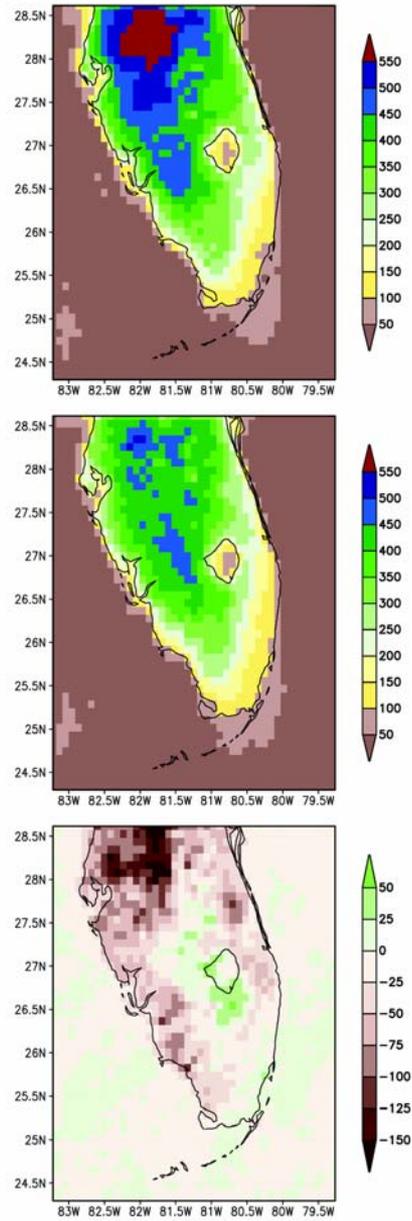
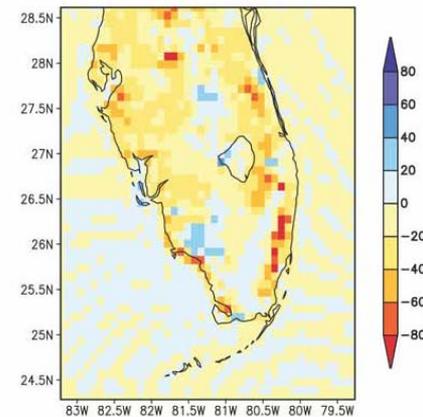
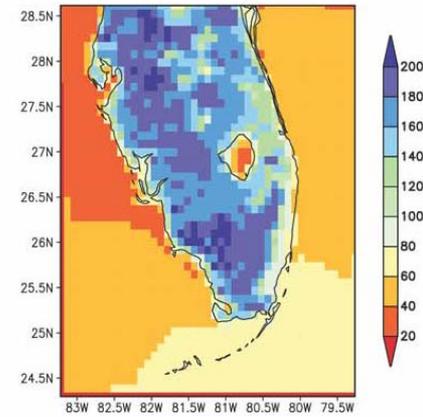
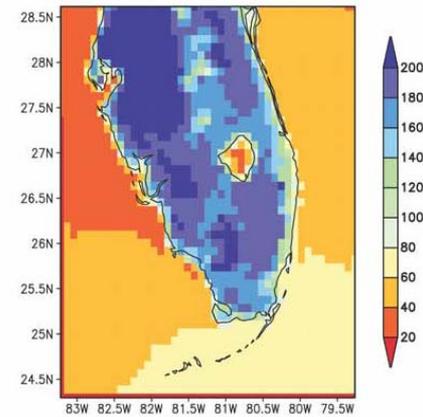


FIG. 6. Same as in Figure 4, except for July-August 1994.

Two-month average of the surface latent heat flux ( $\text{W m}^{-2}$ ) from the model simulations of July and August 1994 with pre-1900s land cover (top), 1994 land use (middle), and the difference field for the two (bottom; 1994 minus pre-1900s case).



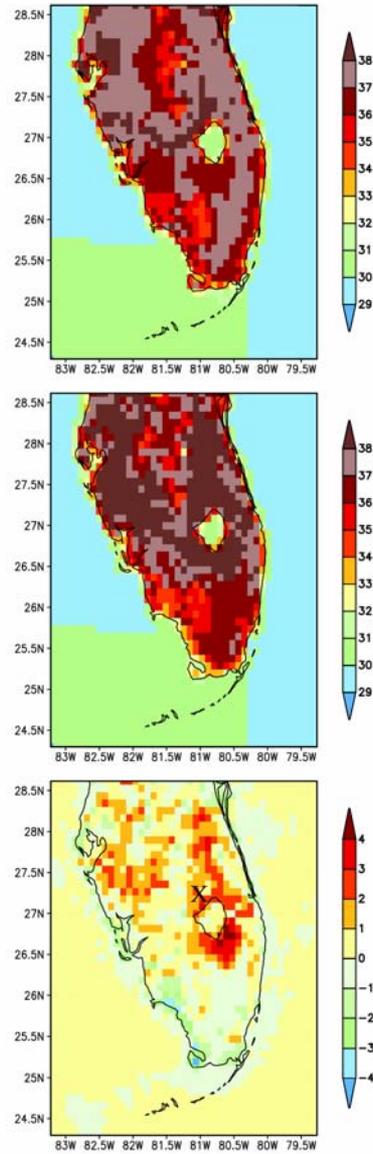


FIG. 13. Two-month average of the daily maximum shelter-level temperature from the model simulations of July-August 1989 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).

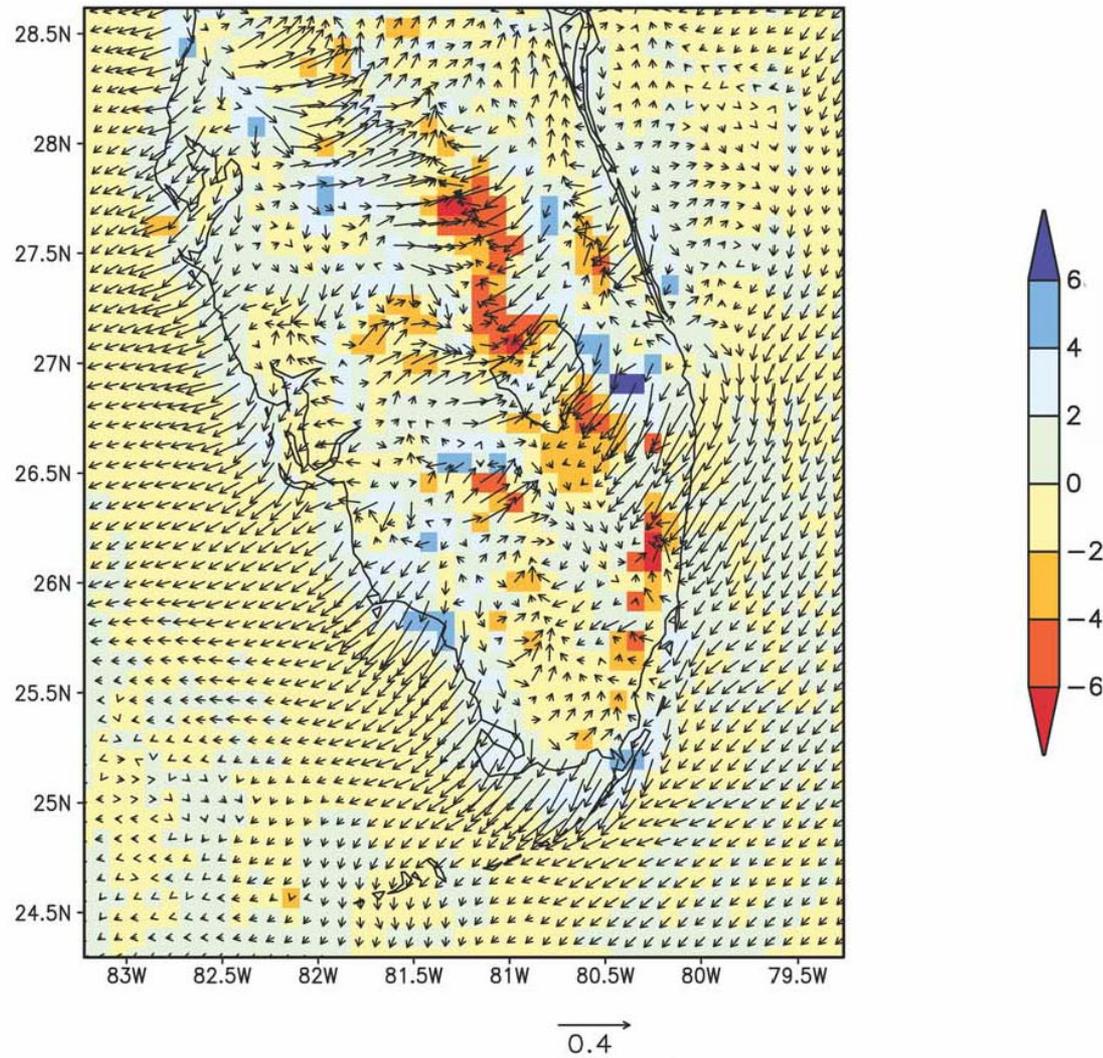


FIG. 17. Difference (1993 minus pre-1900s case) of the fields shown in Figure 16.

# 10

## Arctic Sea Ice and Northern Hemispheric Snow-Cover Changes

Pielke Sr., R.A., G.E. Liston, W.L. Chapman, and D.A. Robinson, 2003: Actual and insolation-weighted Northern Hemisphere snow cover and sea ice -- 1974-2002. *Climate Dynamics*, submitted.

<http://blue.atmos.colostate.edu/publications/pdf/R-256.pdf>

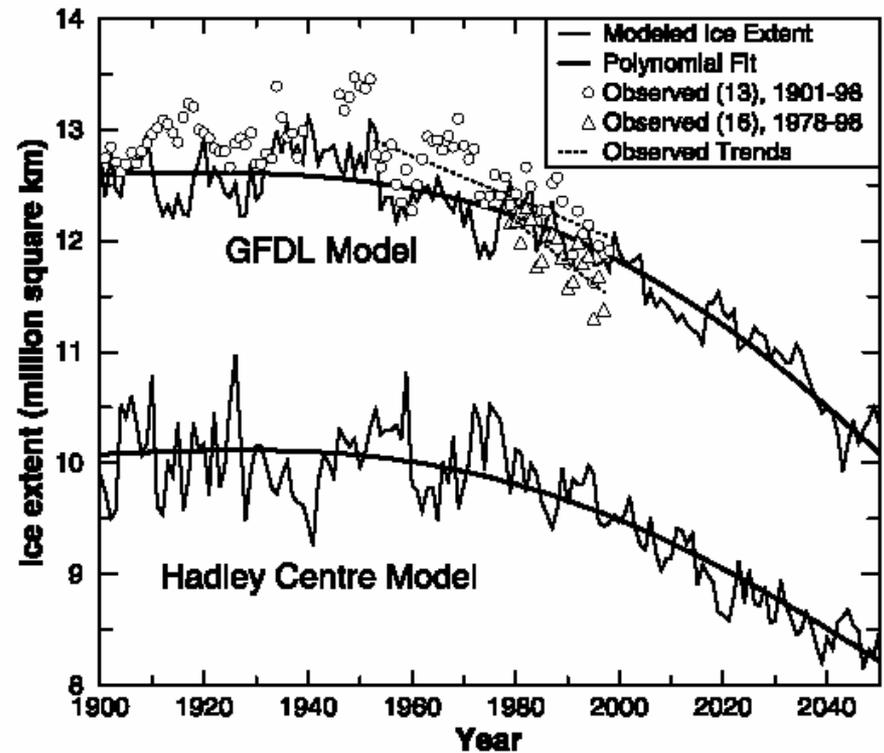
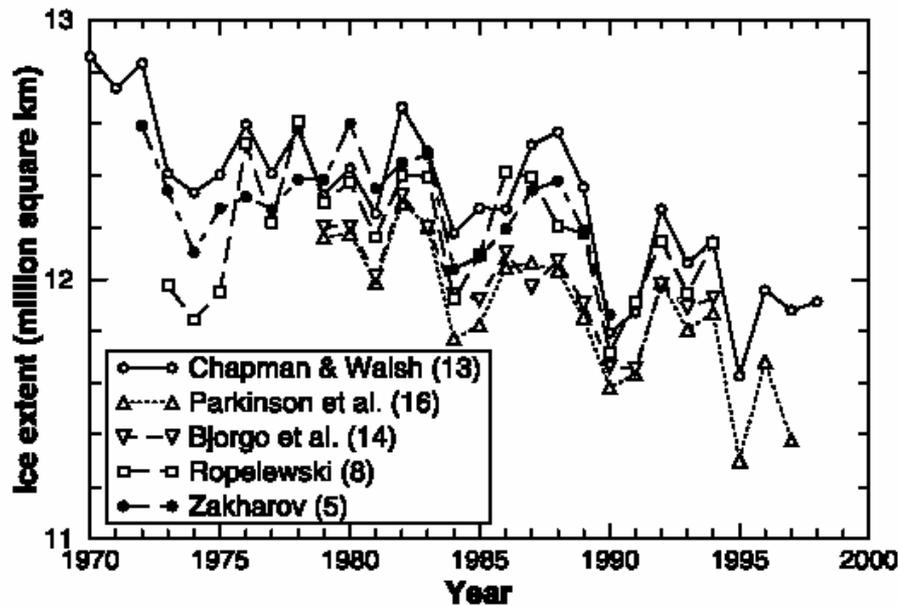
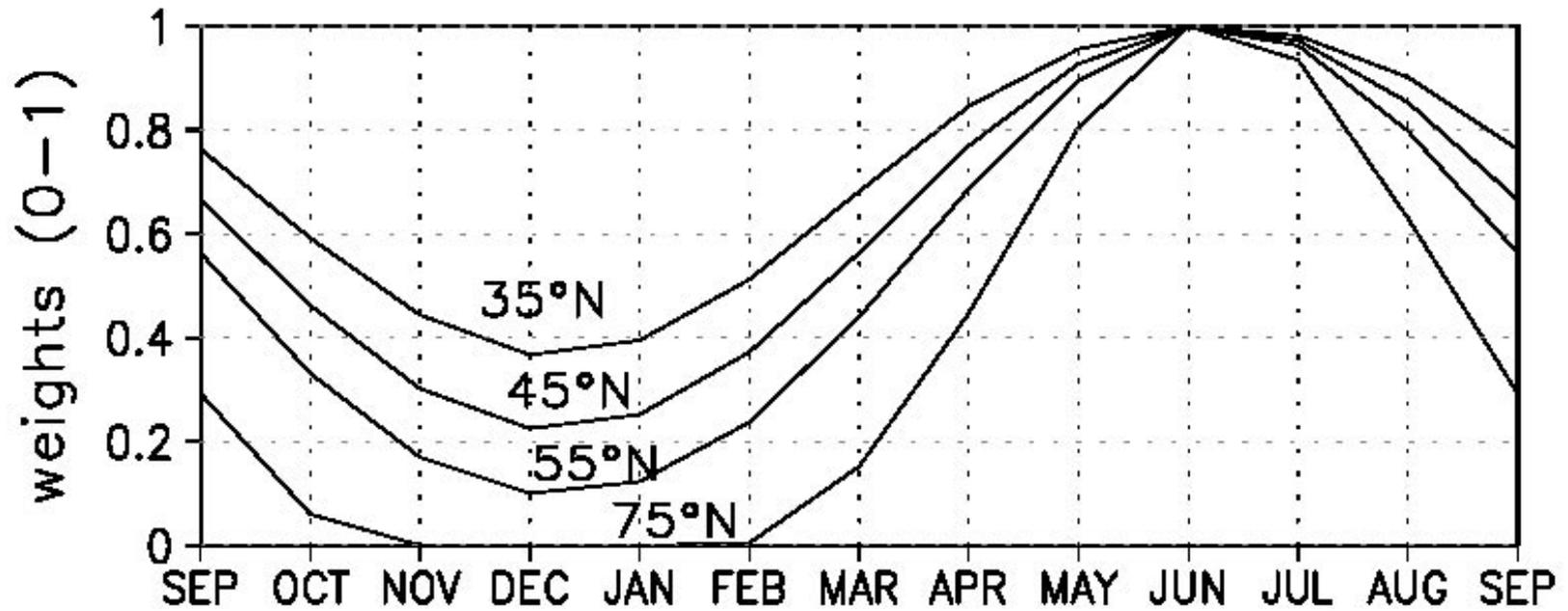


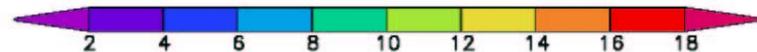
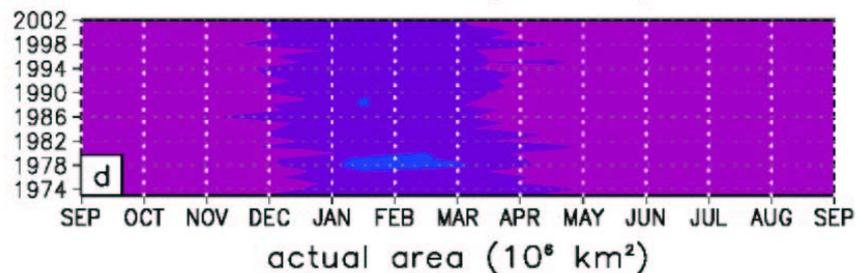
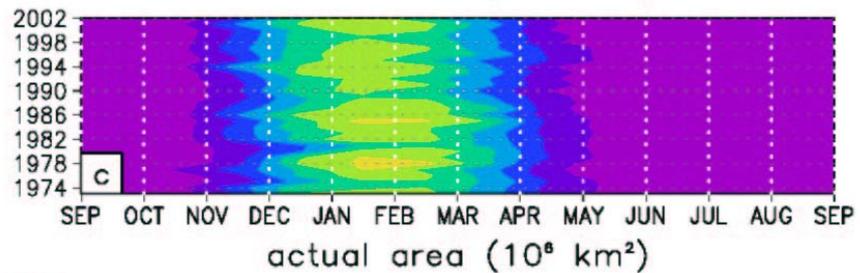
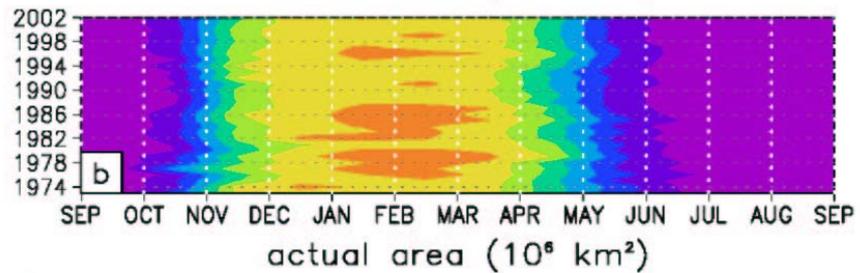
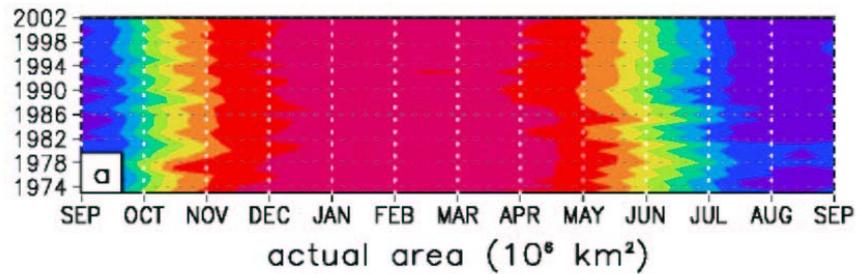
Fig. 1 (left). Observed decrease of NH sea ice extent during the past 25 years.

Fig. 2 (right). Observed and modeled variations of annual averages of NH sea ice extent. Observed data for 1901–98 are from Chapman and Walsh (13). Observed data for 1978–98 are from Parkinson *et al.* (16). The modeled sea ice extents are from the GFDL and Hadley Centre climate model runs forced by observed CO<sub>2</sub> and aerosols. Modeled data for ~250 years are smoothed by polynomials of degree 10 to estimate nonlinear trends caused by a change of external radiative forcing.

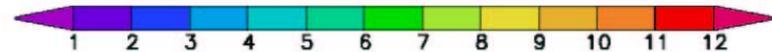
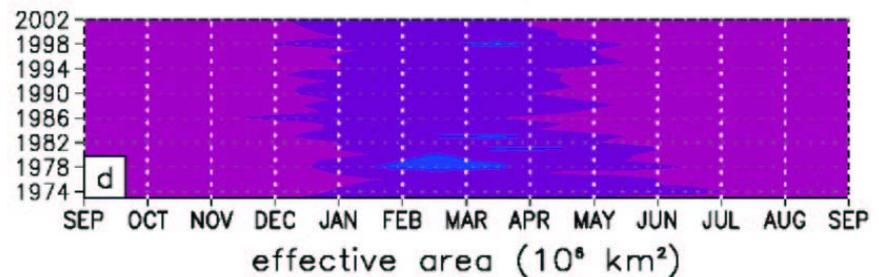
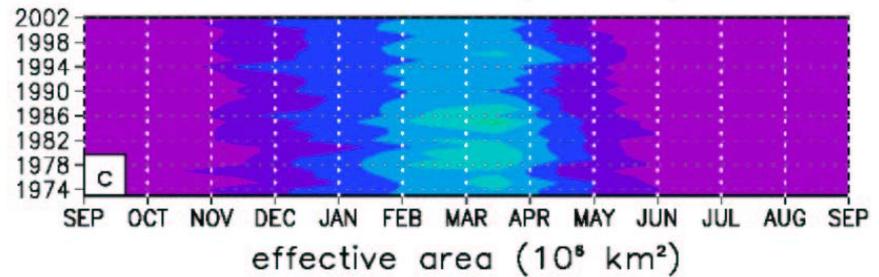
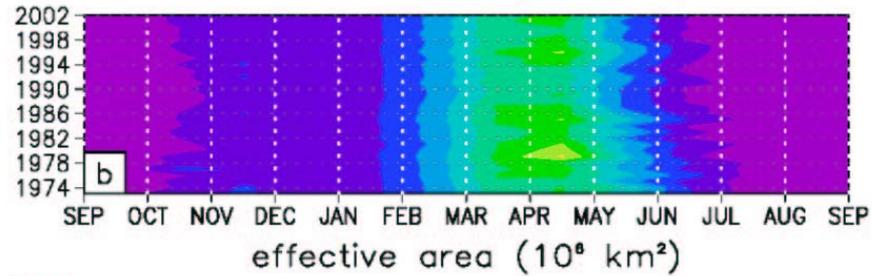
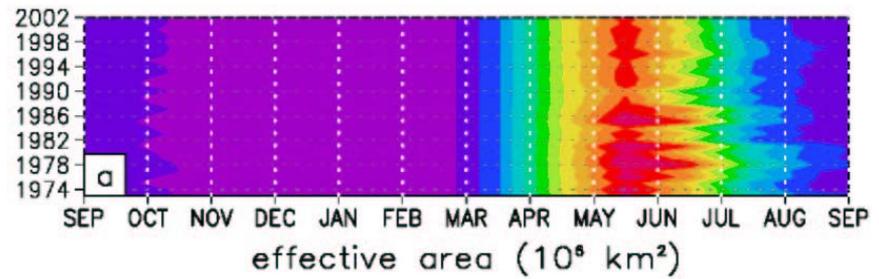


Weighting function values applied to the snow-cover latitude bands: 35°N for the 30-40, 45°N for 40-50, 55°N for 50-60, and 75°N for 60-90°N. The 75°N weights were also used for the sea-ice data.

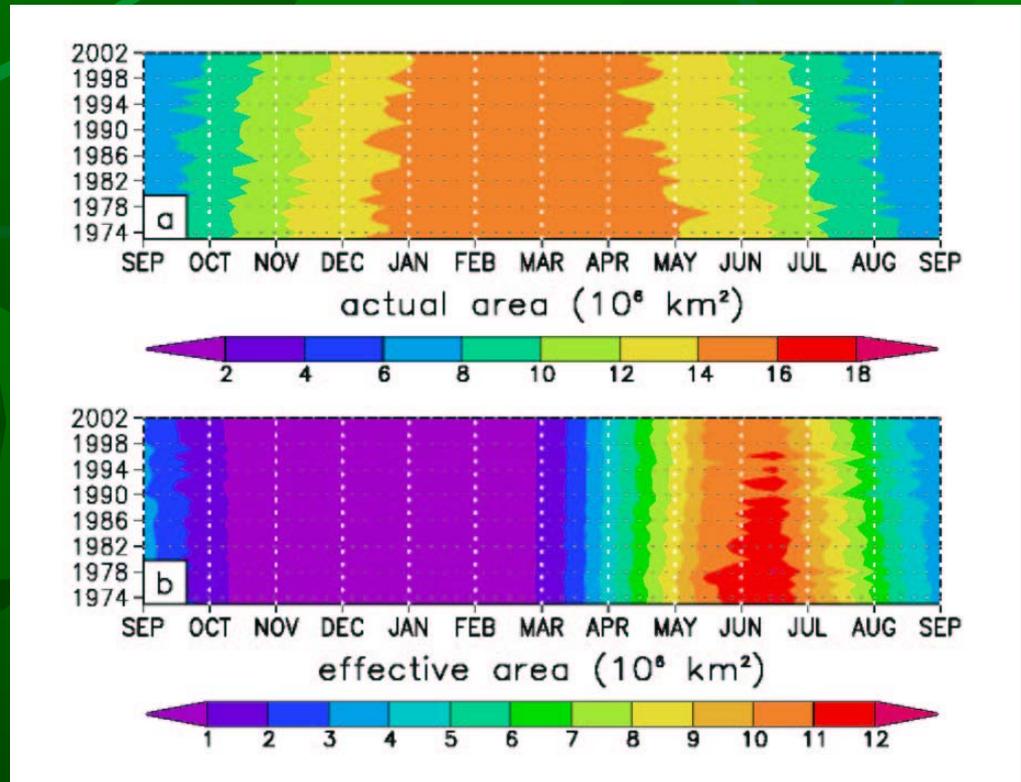
**Actual snow cover  
by latitude bands  
(a) 60-90°N; (b)  
50-60°N; (c) 40-  
50°N; and (d) 30-  
40°N.**



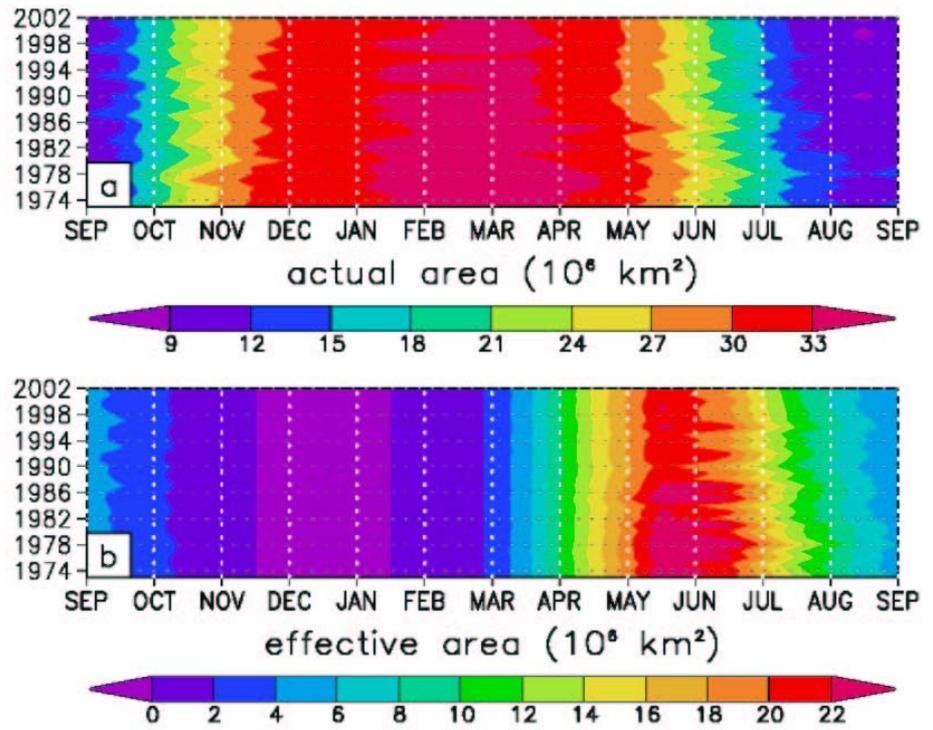
Same as previous figure but for the insolation weighted values.



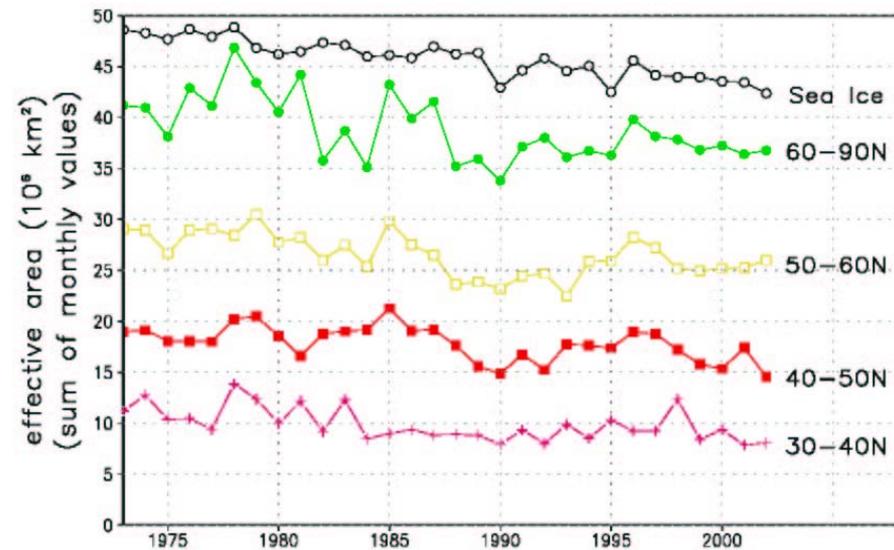
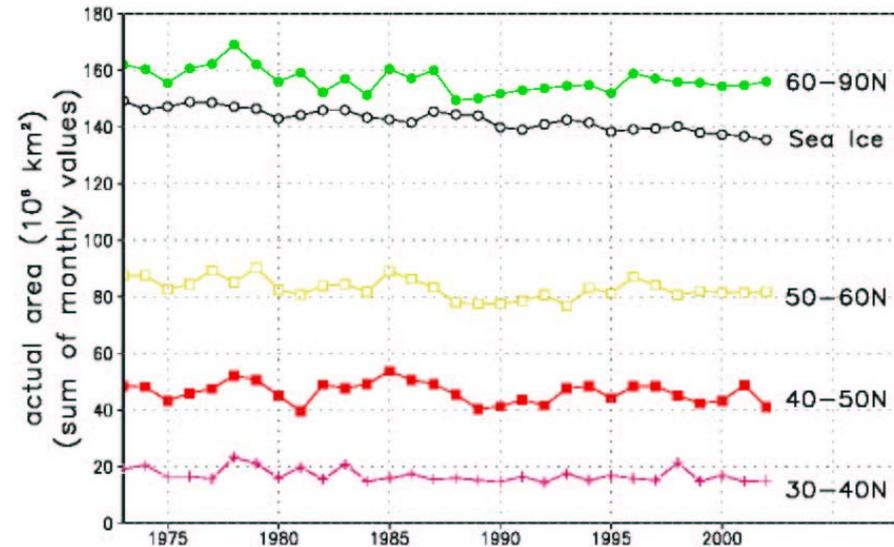
**Actual and  
insolation  
weighted values  
for Arctic sea ice.**



Actual and insolation weighted values with Arctic sea ice and snow (60-90°N) included together.



The sum of monthly values of actual area and insolation weighted areas for the period 1973-2003.



# ***CONCLUSION***

**The earth's climate system and human disturbance of the climate system is more complicated and multi-dimensional than commonly assumed. This may make skillful prediction of the future climate impossible!**

**There is a new direction emerging.**

**Kabat, P., M. Claussen, P.A. Dirmeyer, 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, 2003: *Vegetation, water, humans and the climate: A new perspective on an interactive system*. Global Change - The IGBP Series, Springer, in press.**