Unanswered Questions

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Vertical Temperature Trends
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Is the Surface Temperature Data Spatially Representative?

Use of Photographs to Document the Microclimate Environment

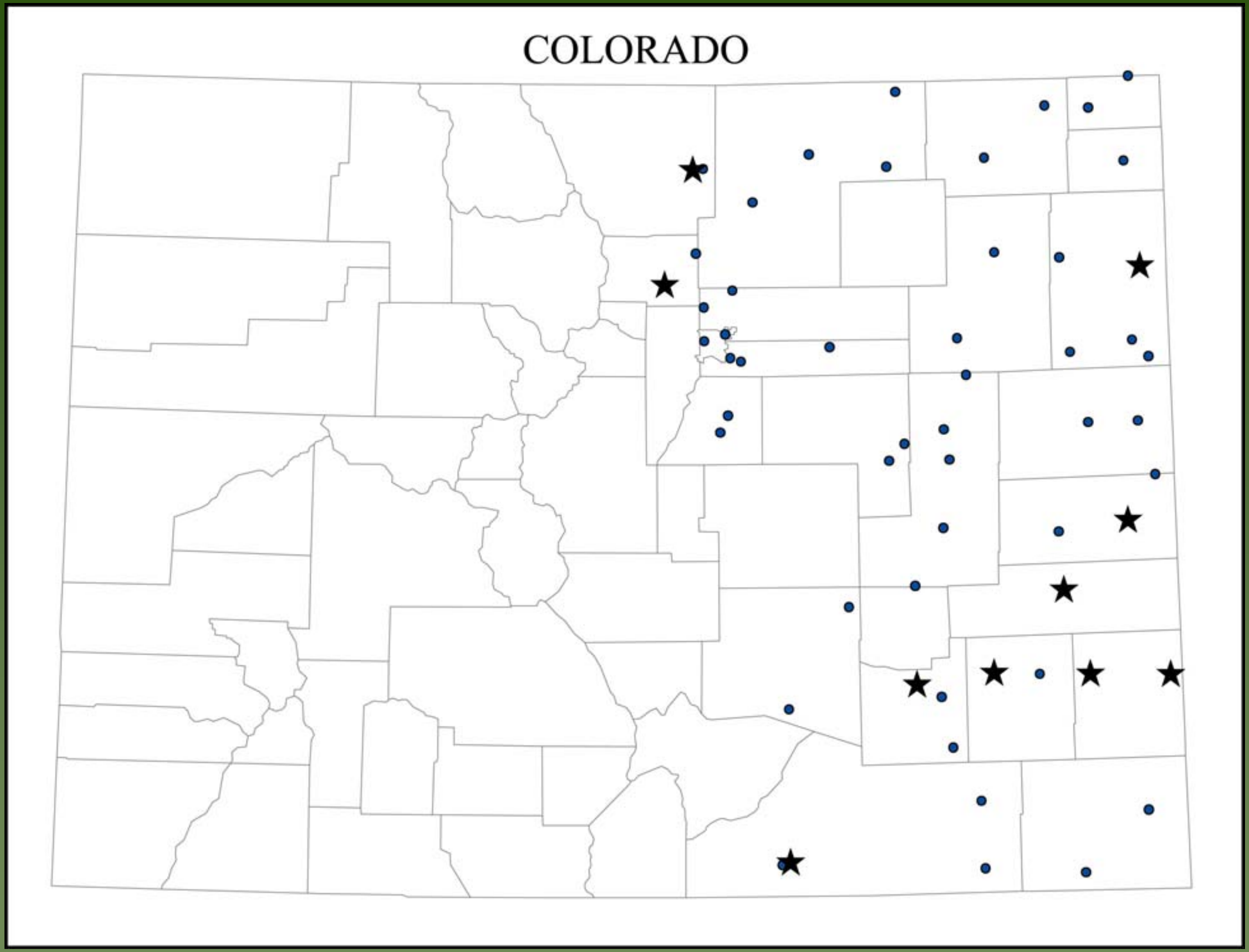
The Lack of Spatial Representativeness of Surface Temperature

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

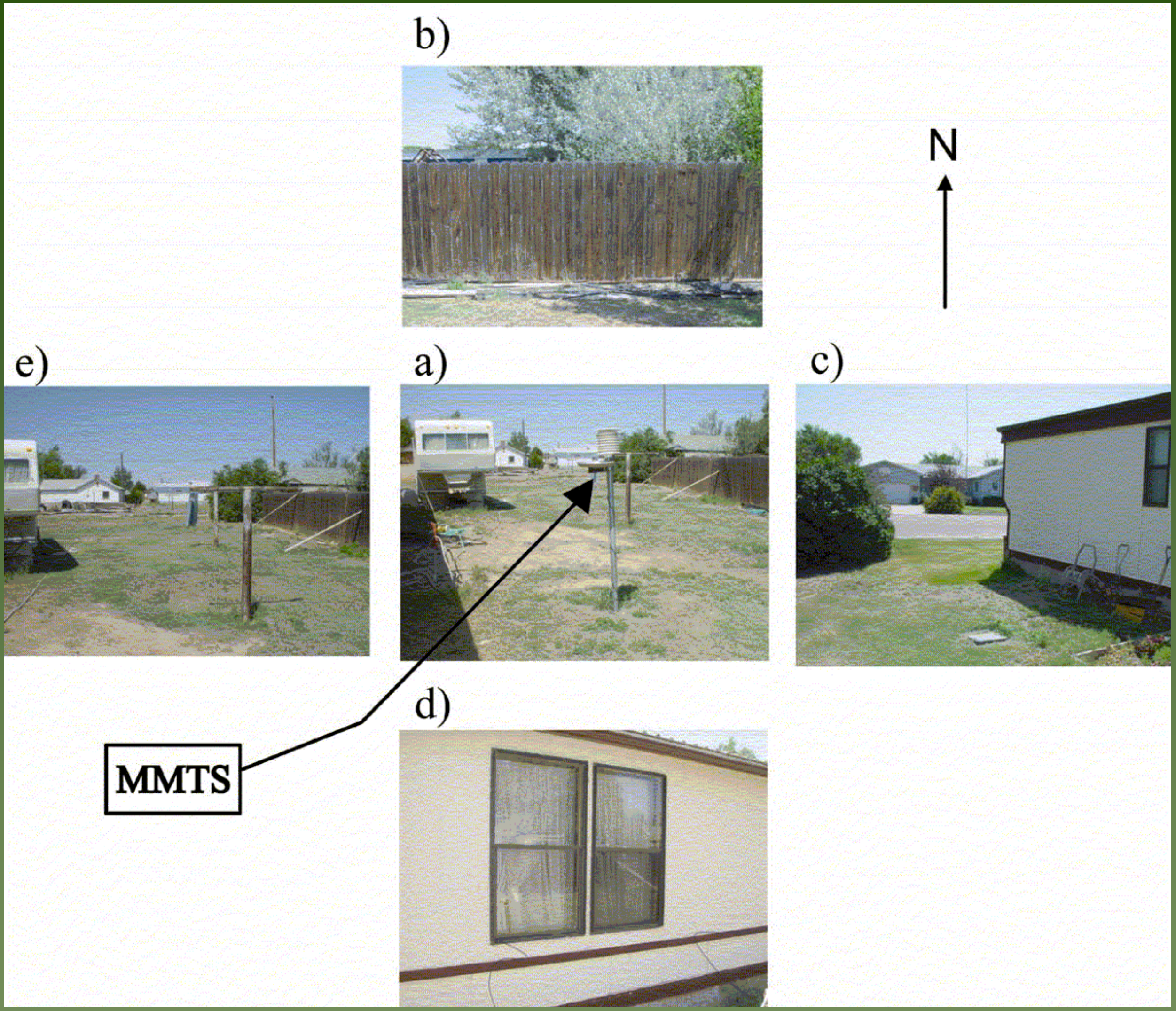
Maximum-minimum temperature sensor (MMTS) installation near Lindon, Colorado.

MMTS installation near John Martin Reservoir, Colorado.

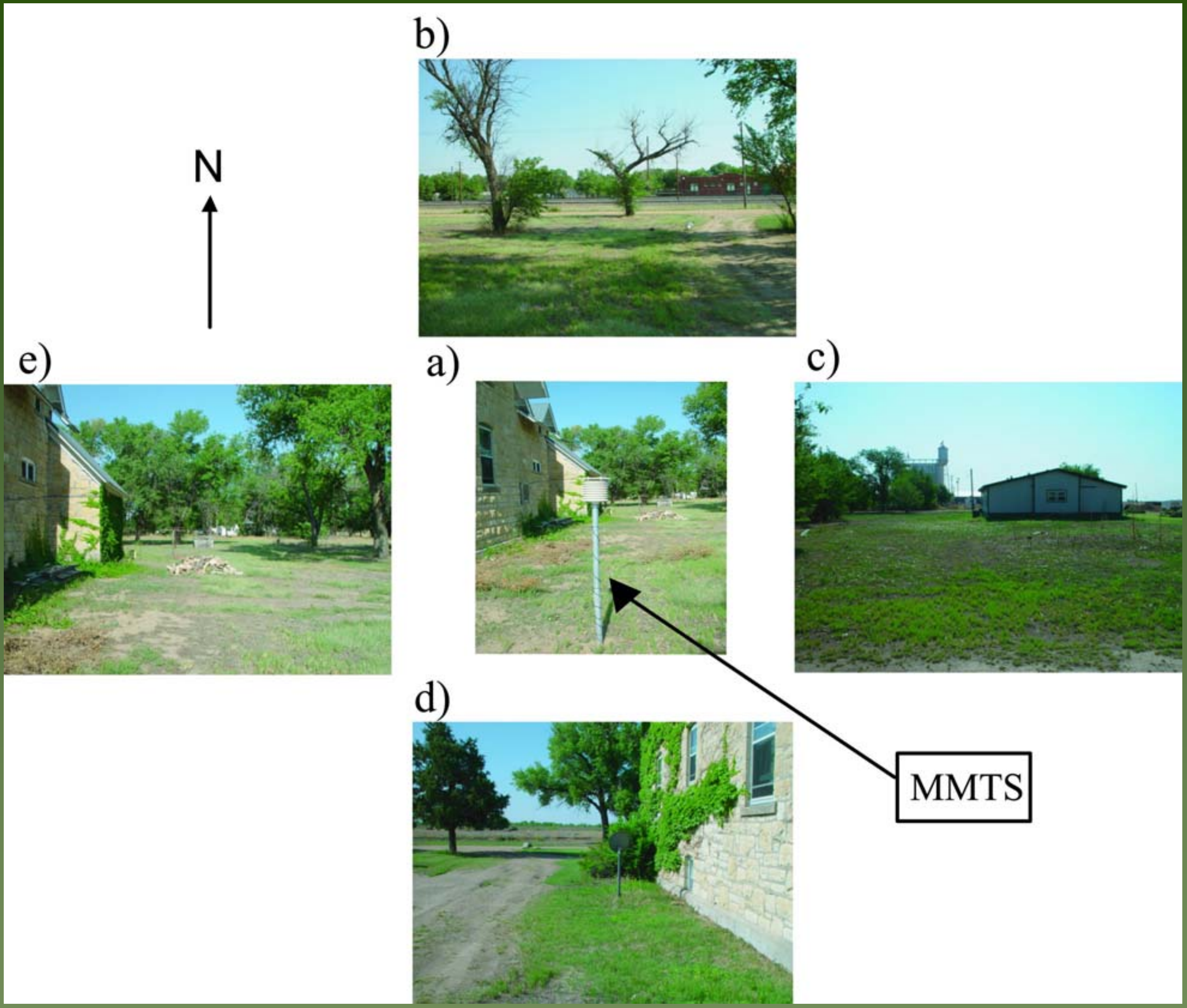


Map of study region, showing all surveyed COOP sites. The USHCN sites are indicated by stars.

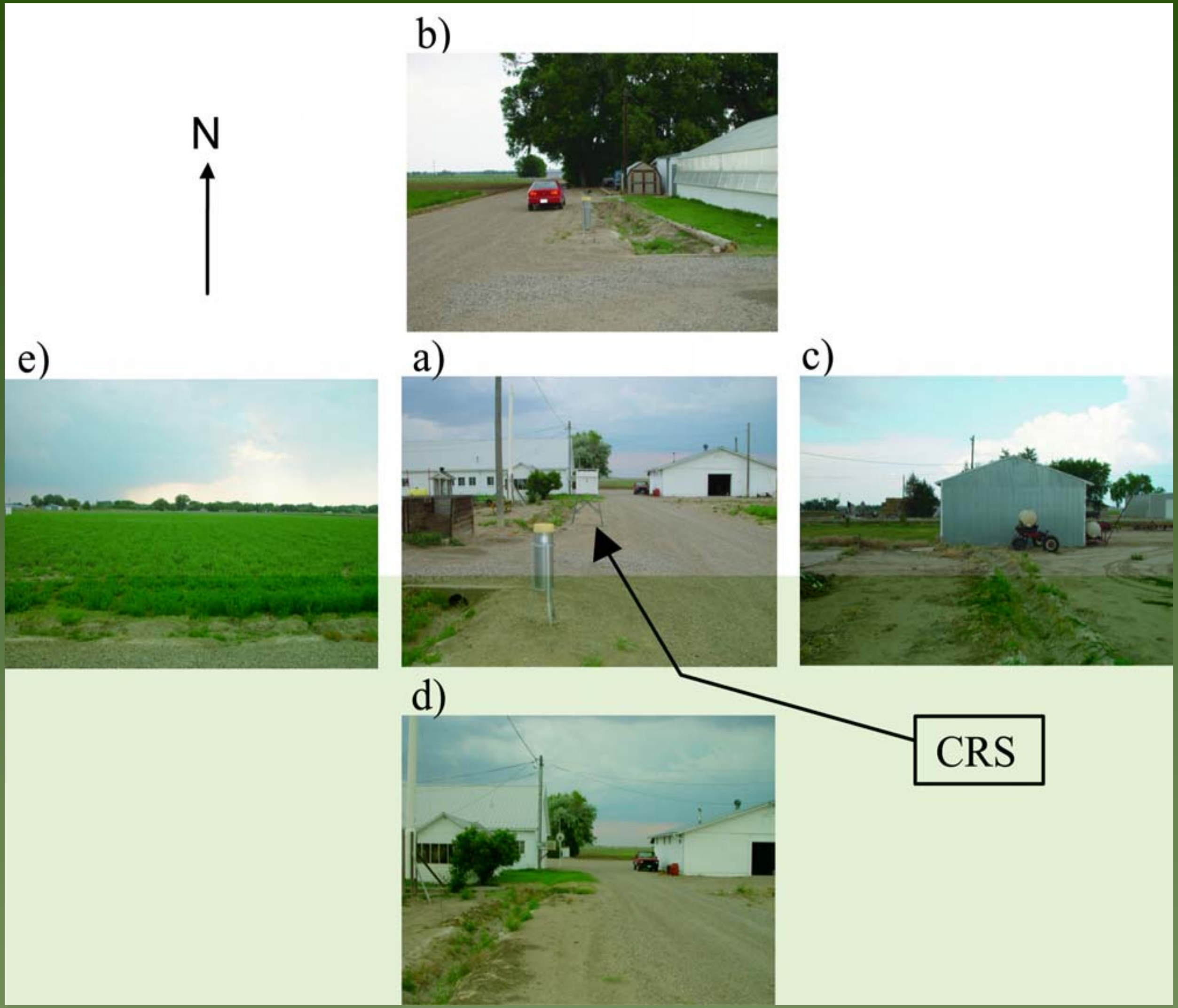
The following photos are for HCN sites.



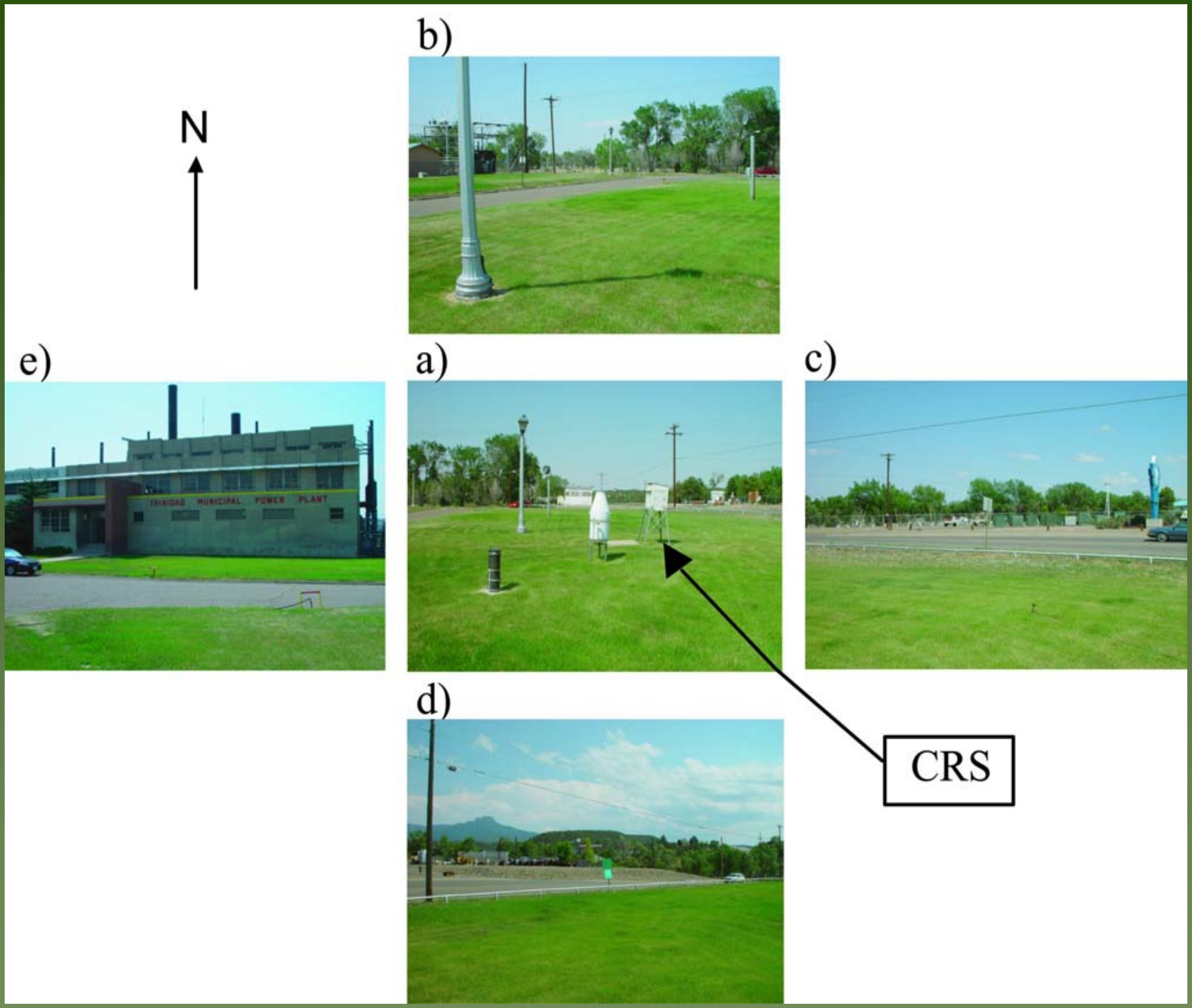
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Eads, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.



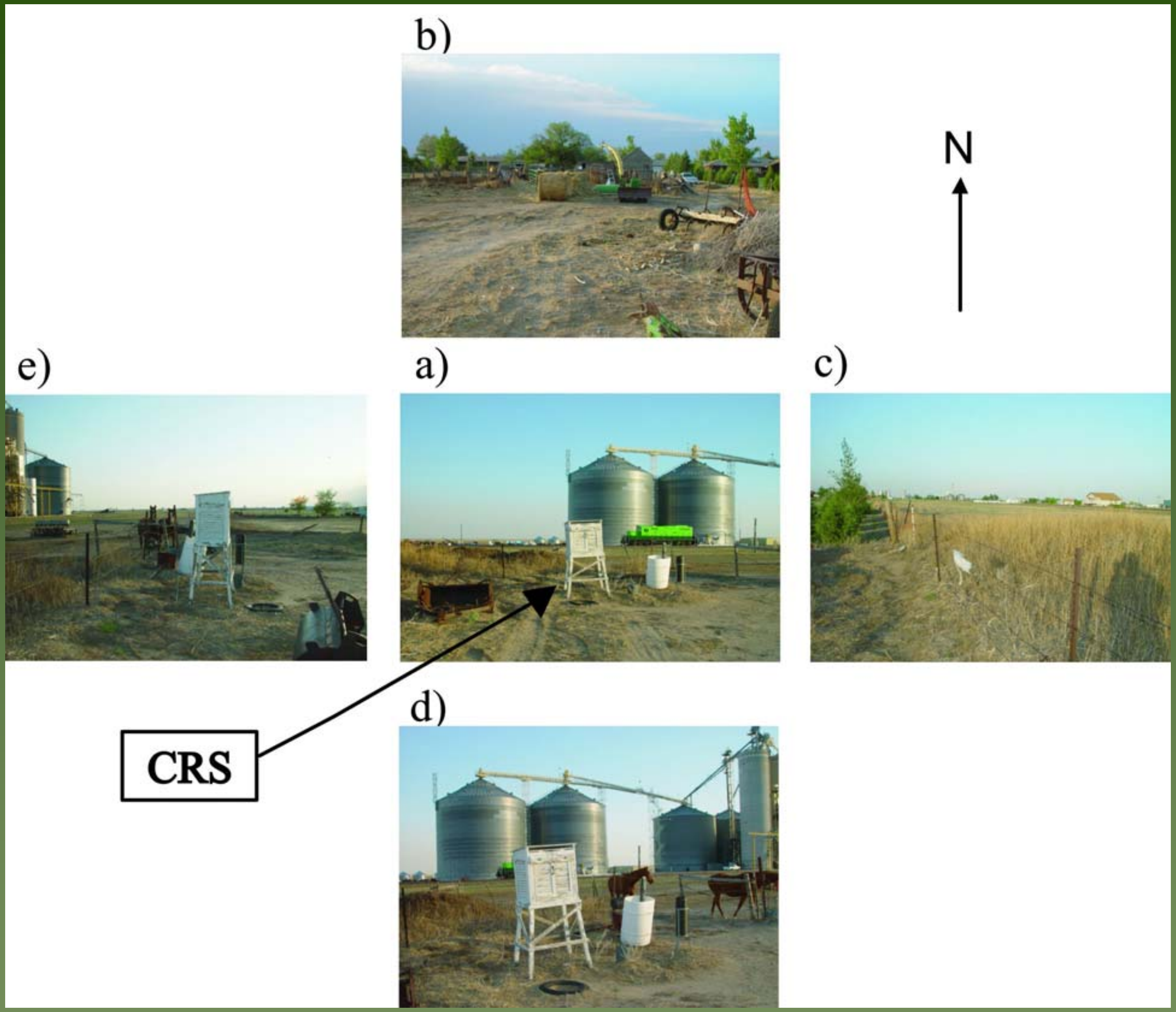
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Holly, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.



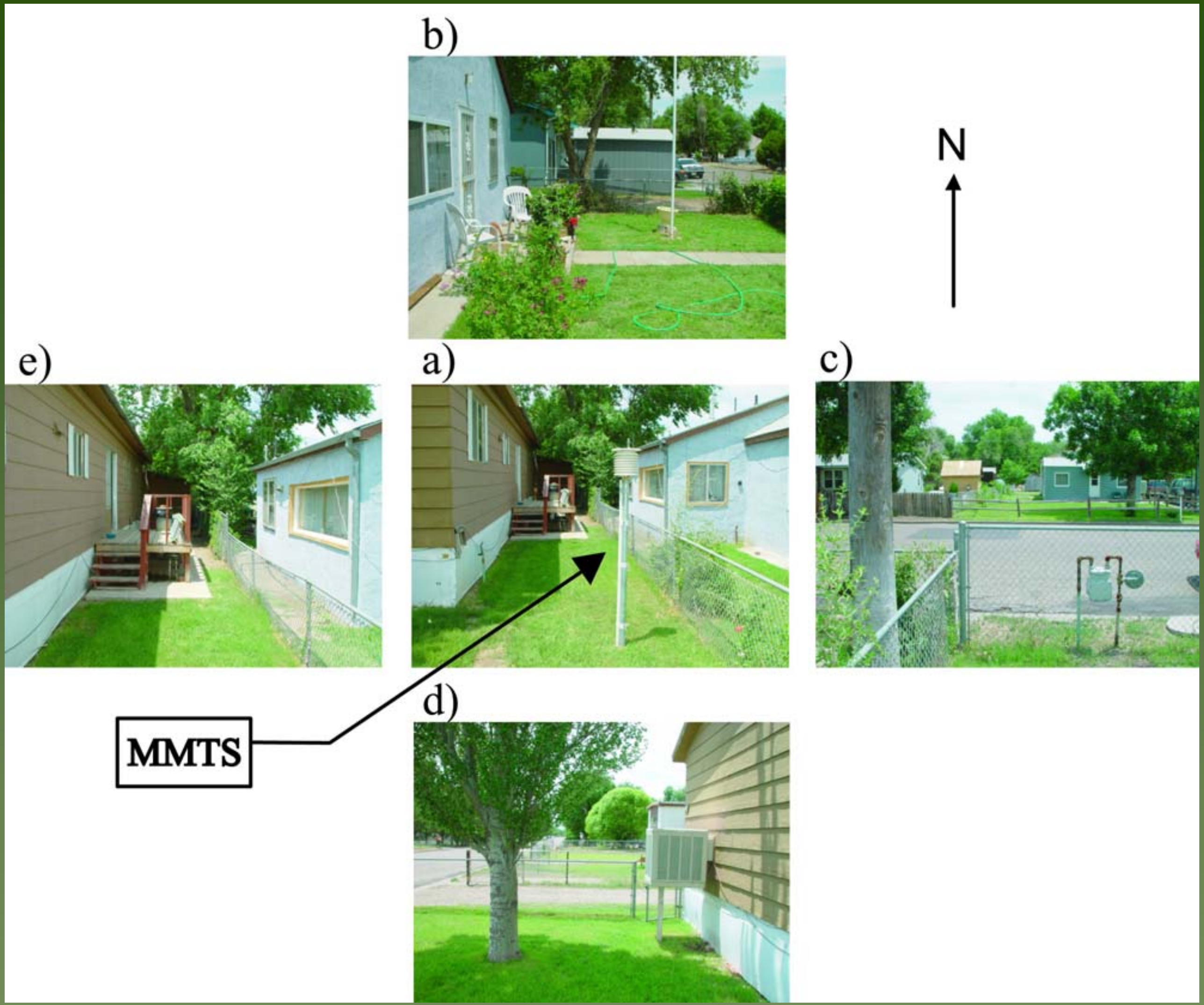
Photographs of the temperature sensor exposure characteristics for the NWS COOP station near Rocky Ford, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively. (CRS-Cotton Region Shelter)



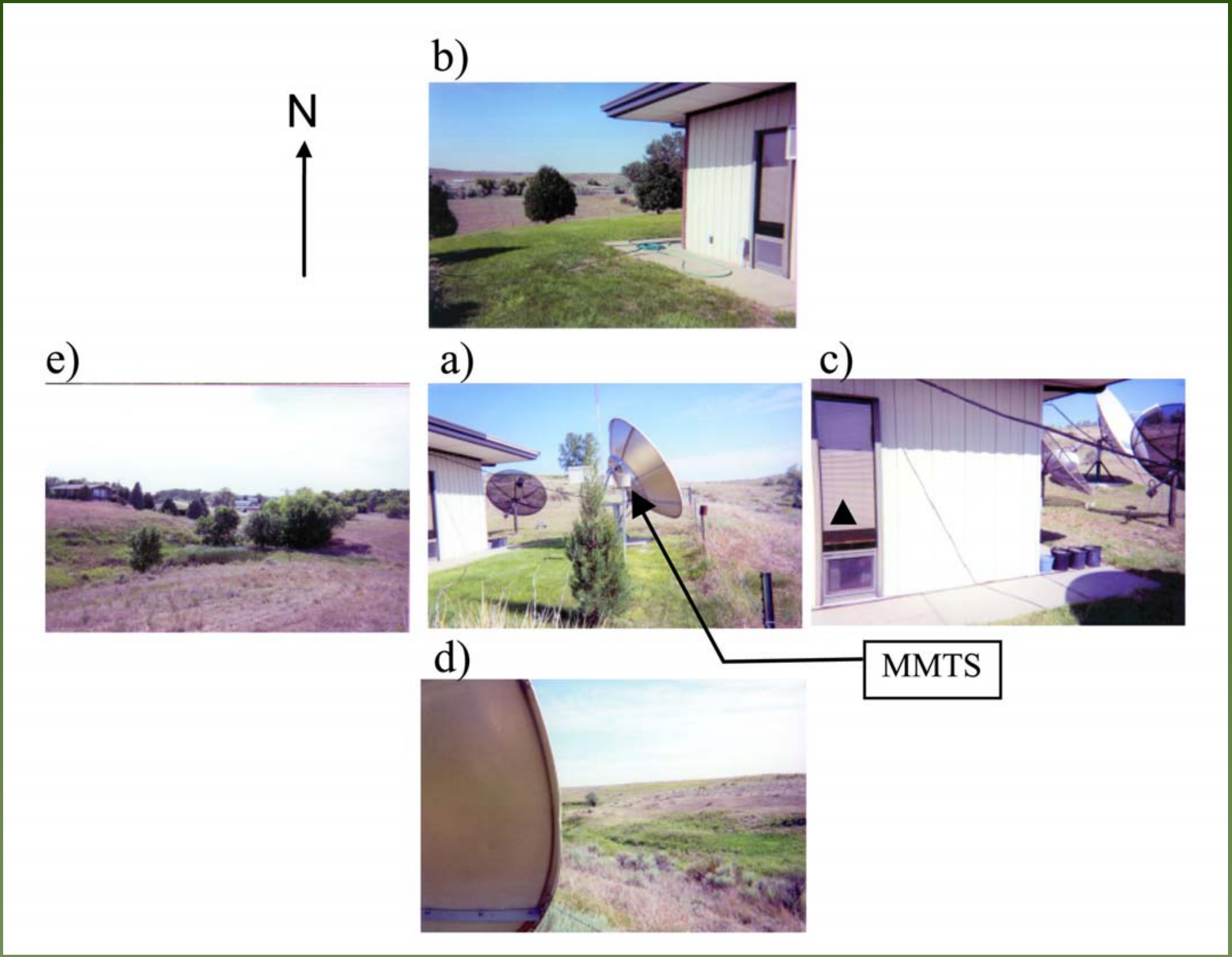
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Trinidad, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.



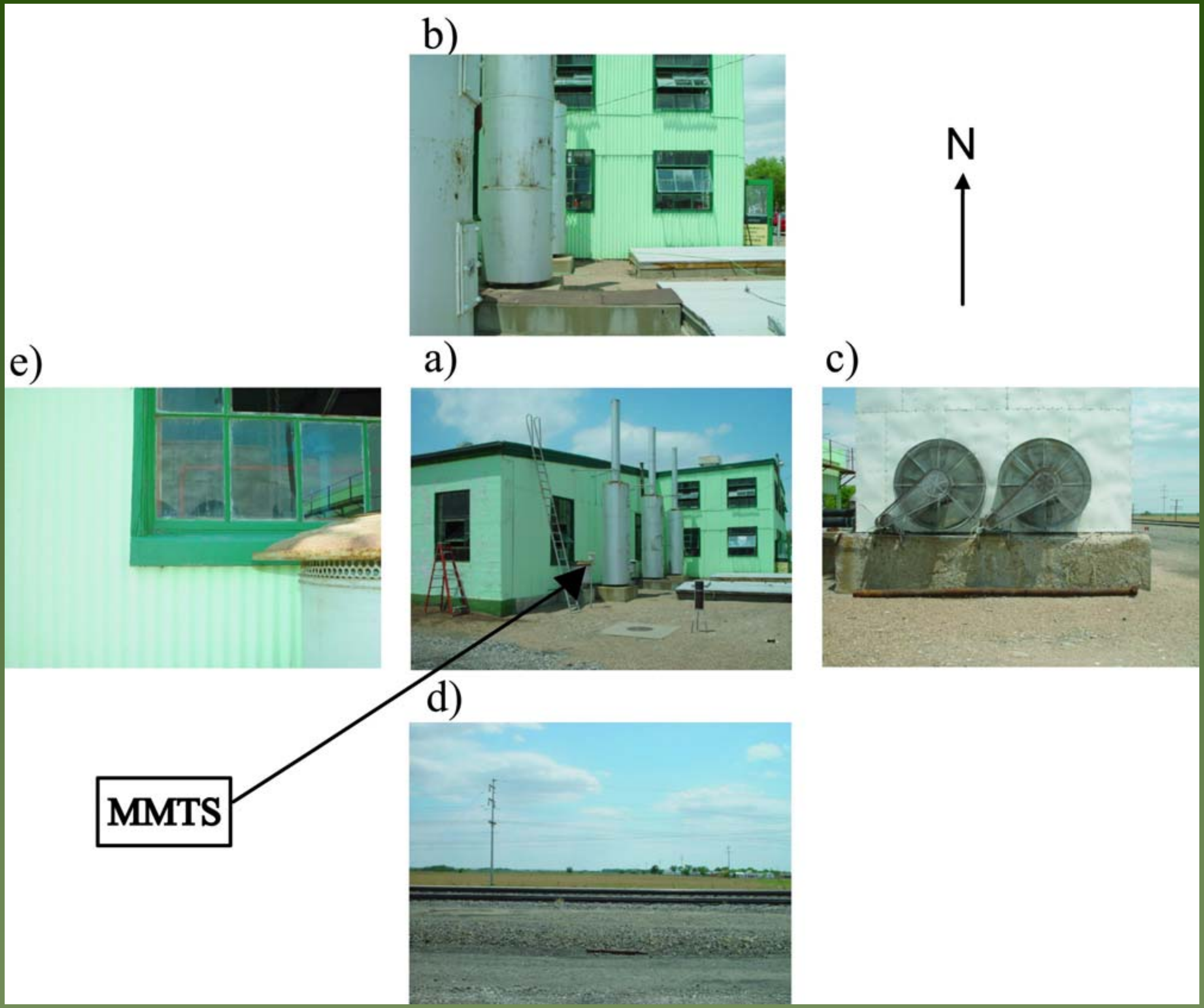
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Cheyenne Wells, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.



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.

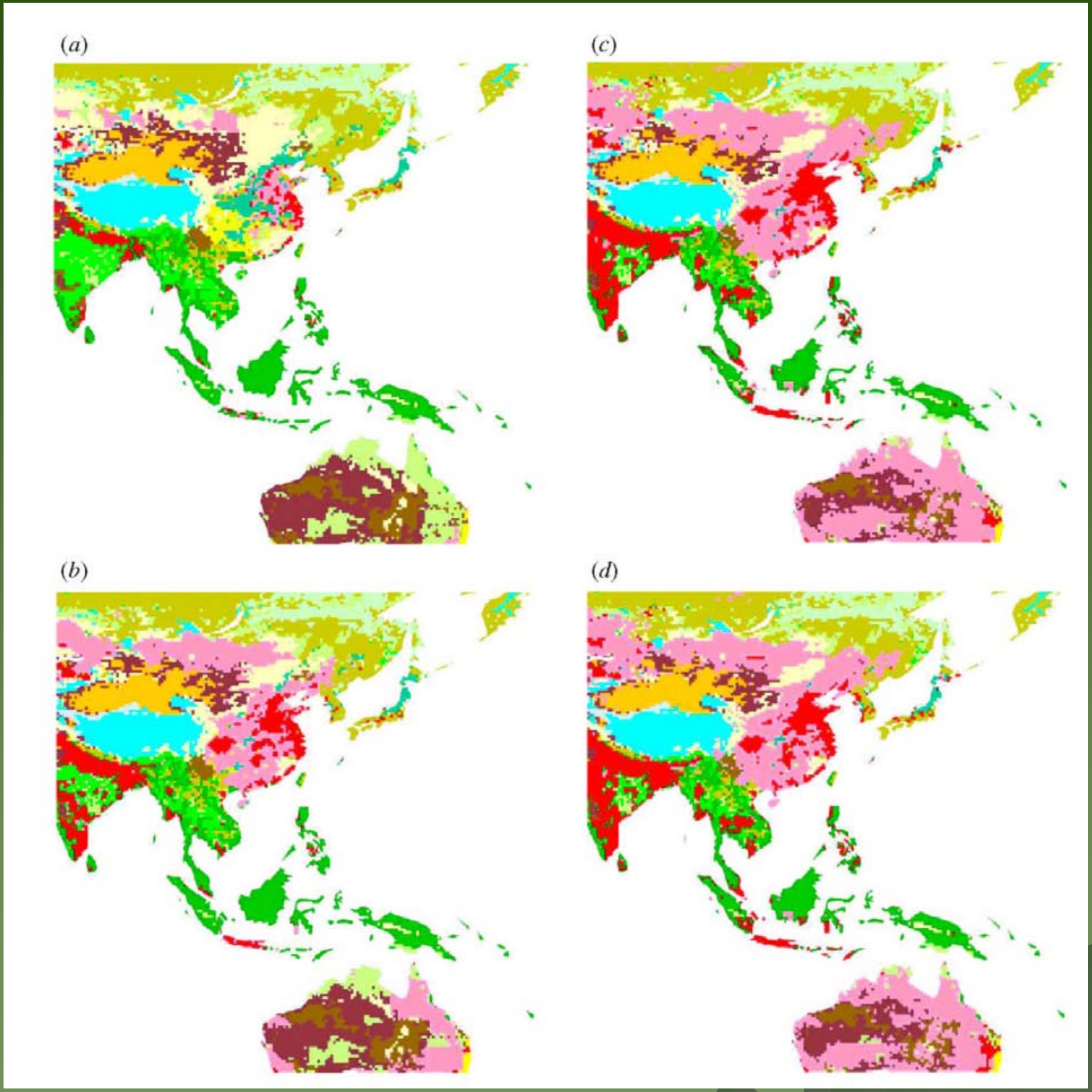


Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Las Animas, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.

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

Has Land-Use Change Altered the Surface Temperature Trends?

Examples of land-use change from (a) 1700, (b) 1900, (c) 1970, and (d) 1990. The human-disturbed landscape includes intensive cropland (red) and marginal cropland used for grazing (pink). Other landscape includes tropical evergreen forest and deciduous forest (dark green), savannah (light green), grassland and steppe (yellow), open shrubland (maroon), temperate deciduous forest (blue), temperate needleleaf evergreen forest (light yellow) and hot desert (orange). Note the expansion of cropland and grazed land between 1700 and 1900. (Reproduced with permission from Klein Goldewijk 2001.)



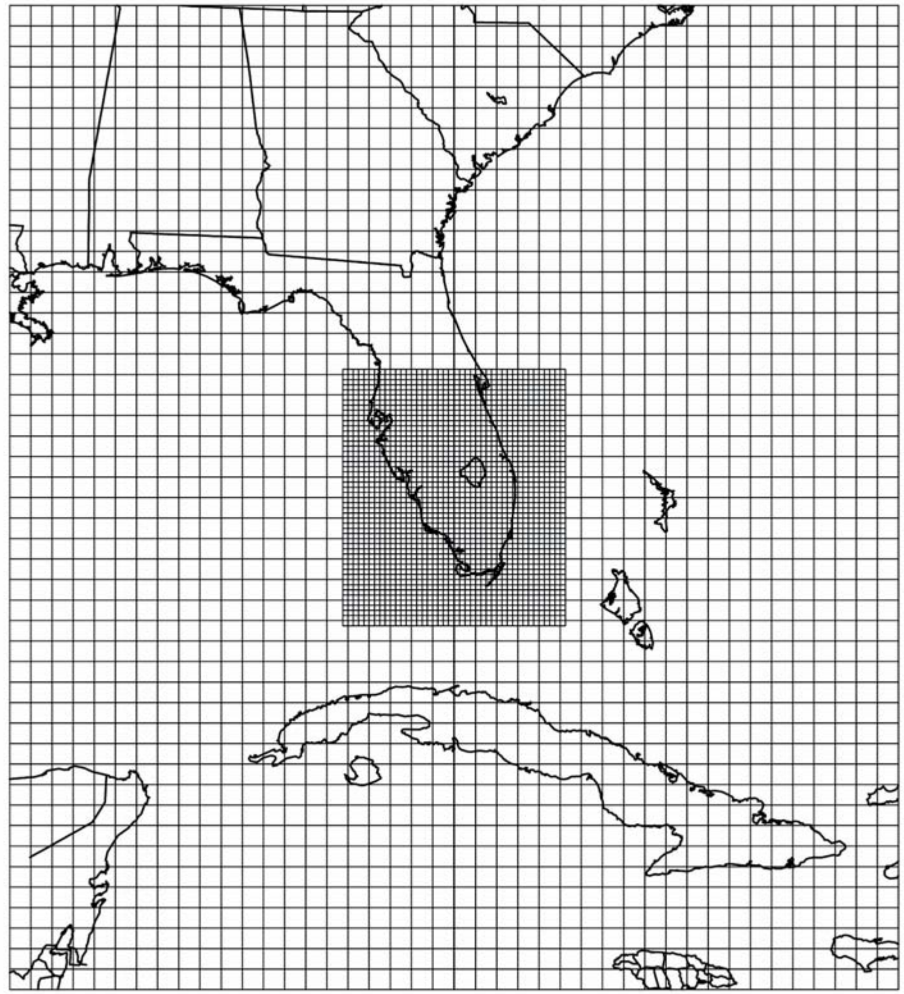


Fig. 2. Outer and inner grid configurations for RAMS domain centered on south Florida.

Following figures are from: 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

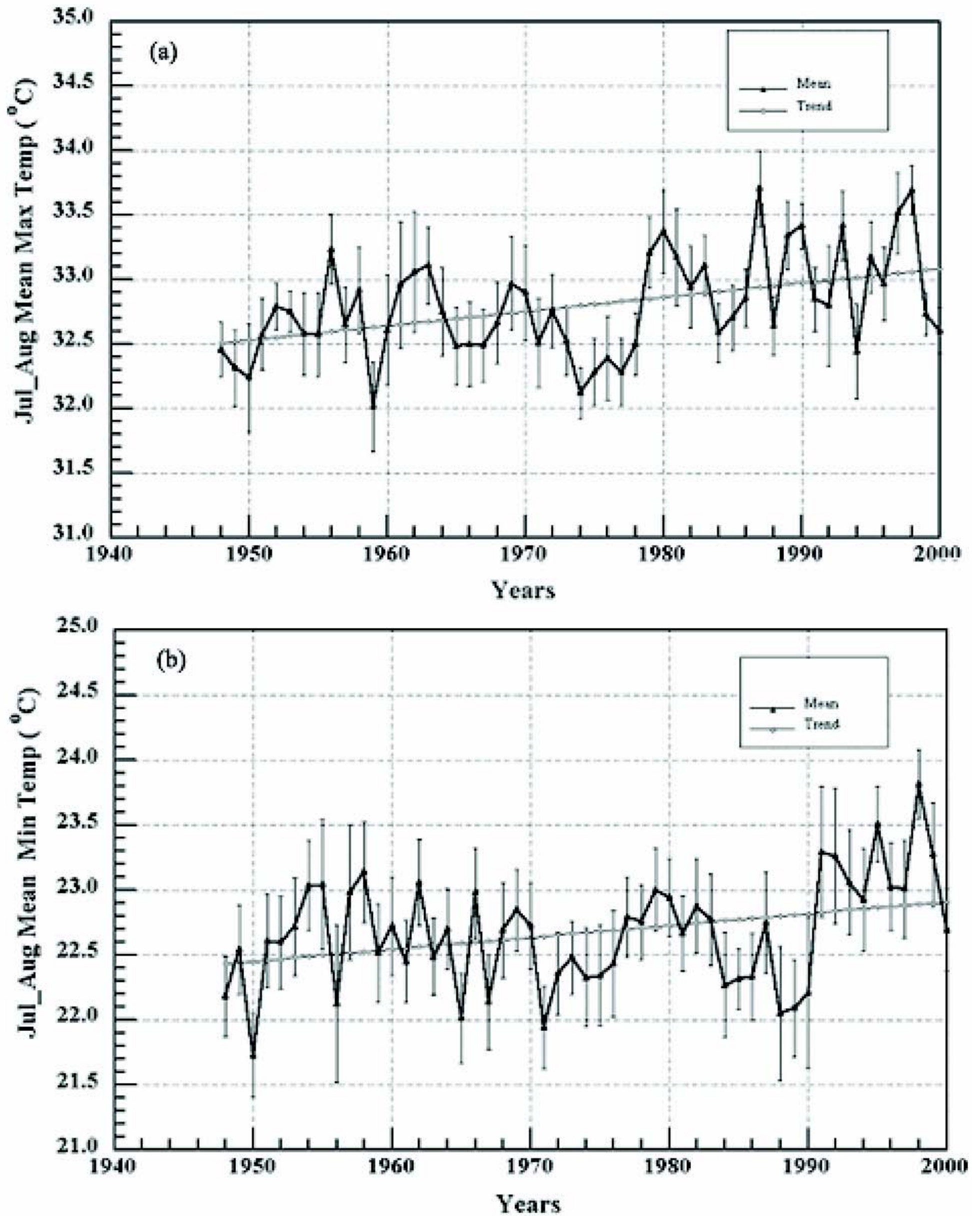


FIG. 26. Same as in Figure 25, except for daily (a) maximum and (b) minimum shelter-level temperature (°C)

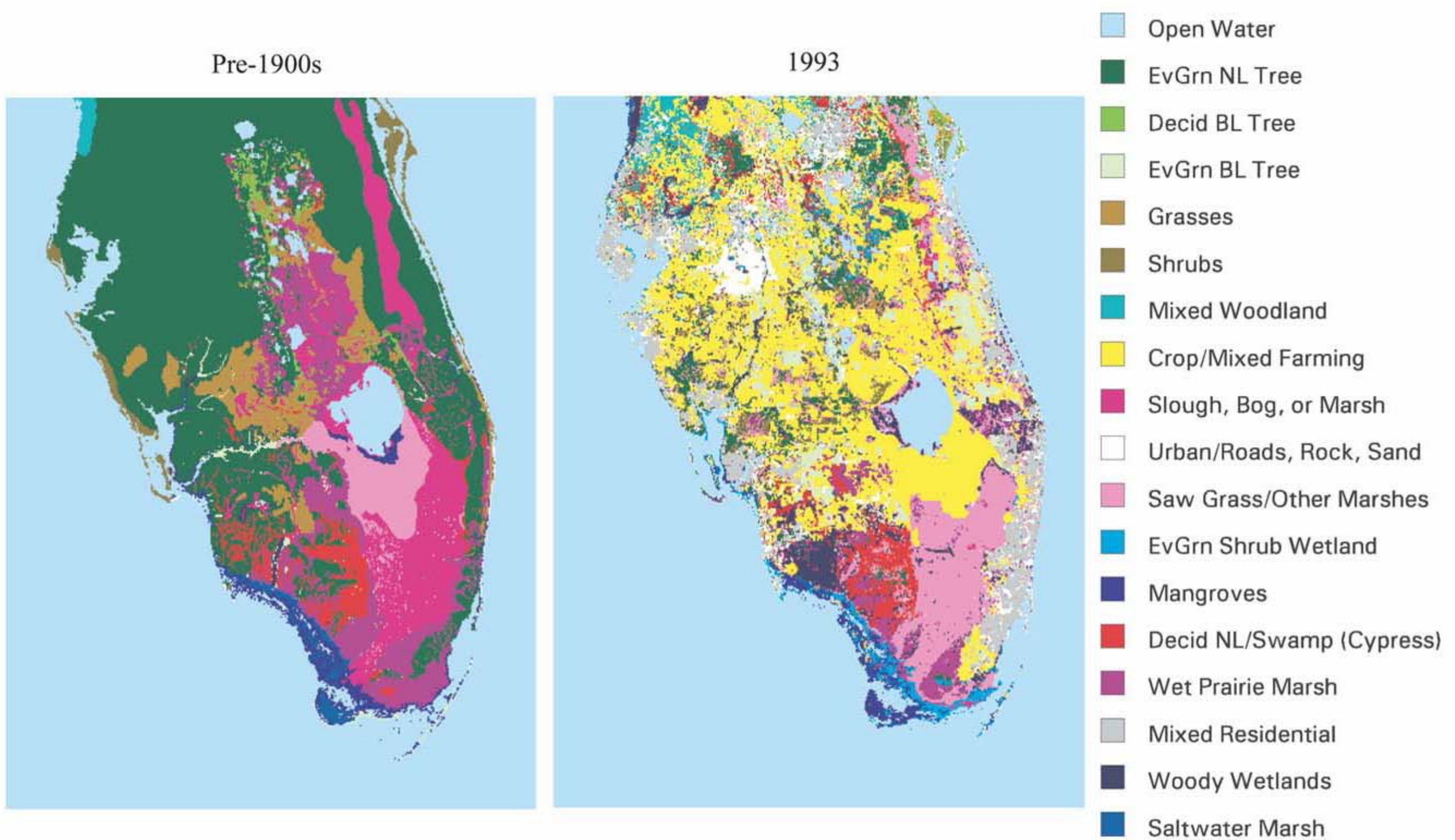


Fig. 3. U.S. Geological Survey land cover classes for pre-1900s natural conditions (left) and 1993 land use patterns.

The following figures are from: 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

1989

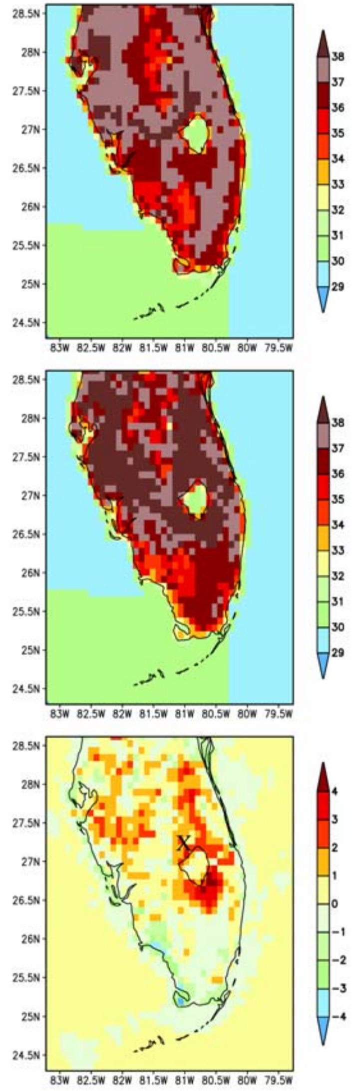


FIG. 13. Two-month average of the daily maximum shelter-level temperature from the model simulations of July-August 1989 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).

1989

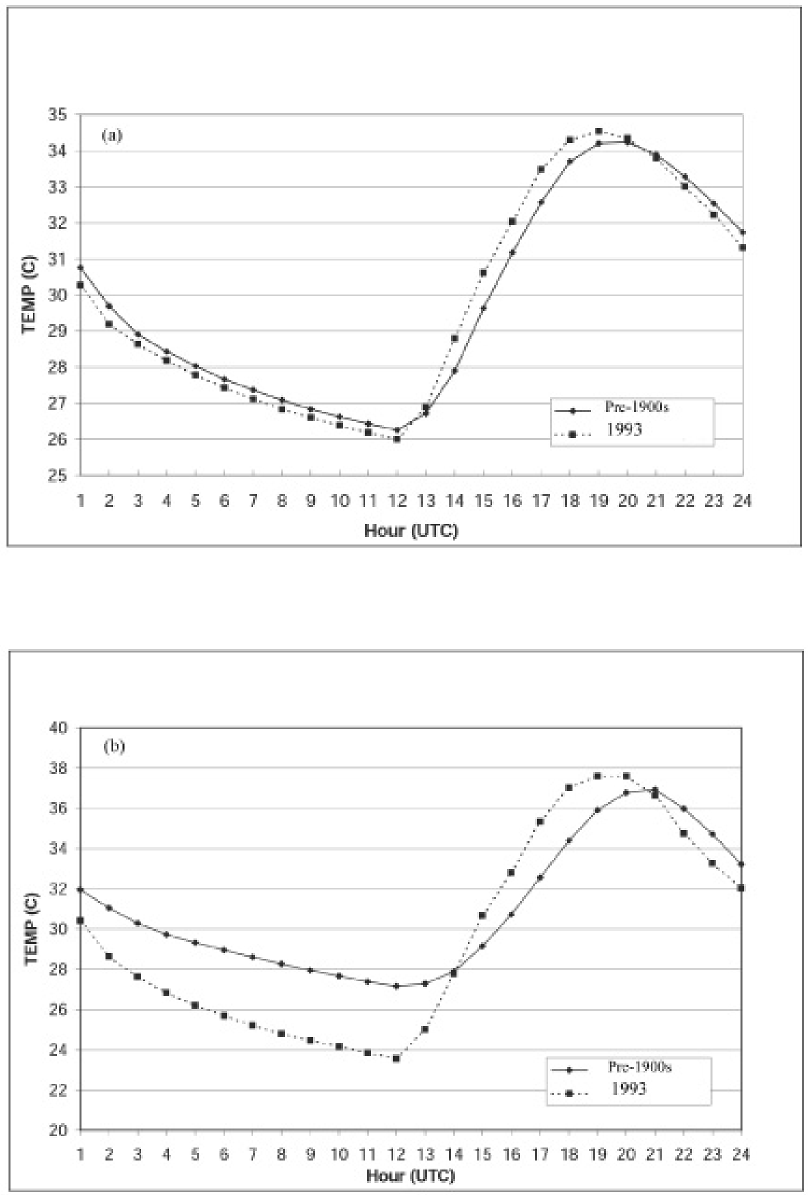


FIG. 15. Two-month average of the diurnal cycle of shelter-level temperature from the model simulations for July-August 1989 (a) averaged over all land grid points in the domain, and (b) for a grid point in the Kissimmee River valley that is indicated by the "X" on Figures 13 and 14.

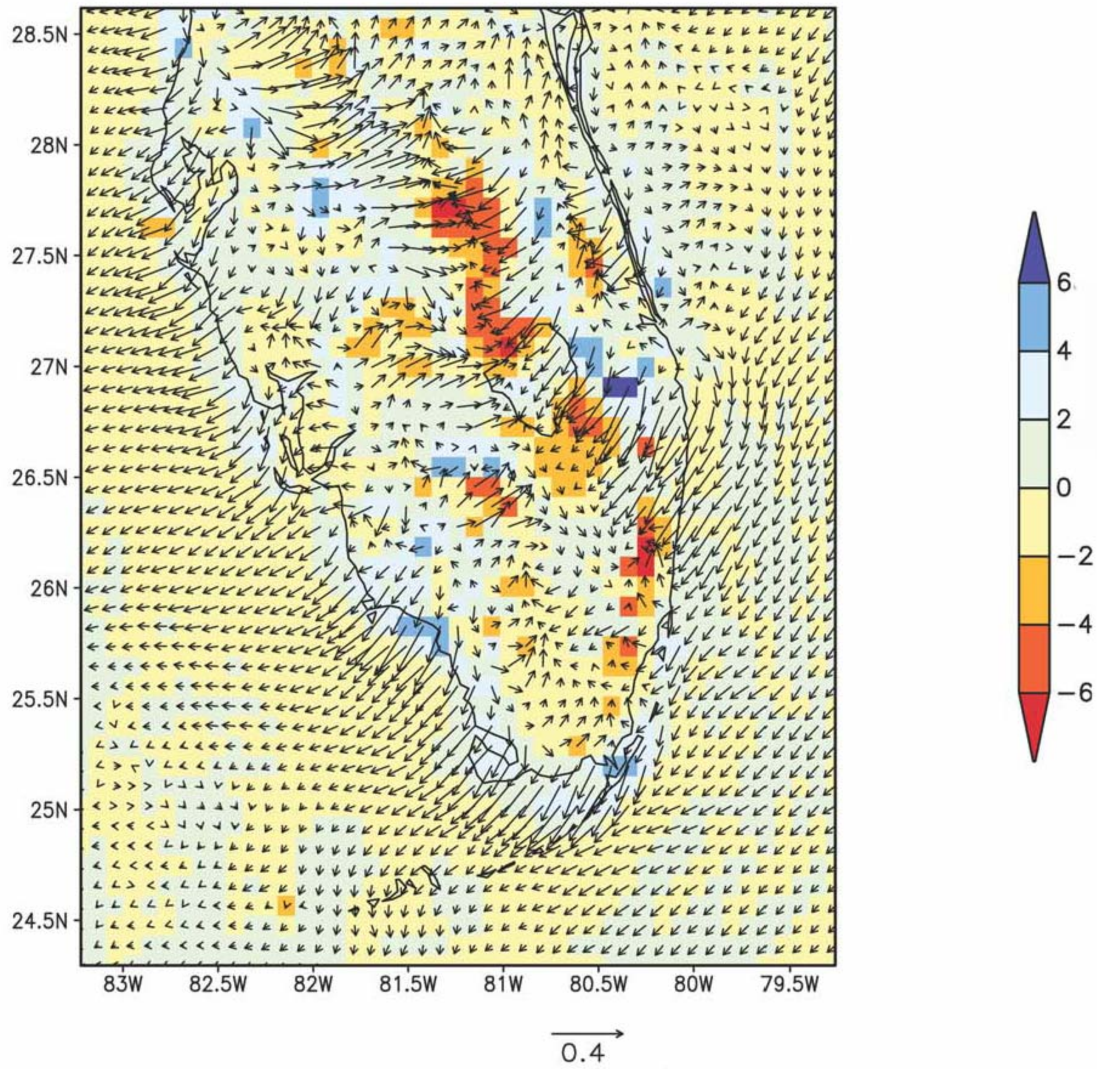


FIG. 17. Difference (1993 minus pre-1900s case) of the fields shown in Figure 16.

Do Vegetation Dynamics and Snow Cover Affect Surface Temperature?

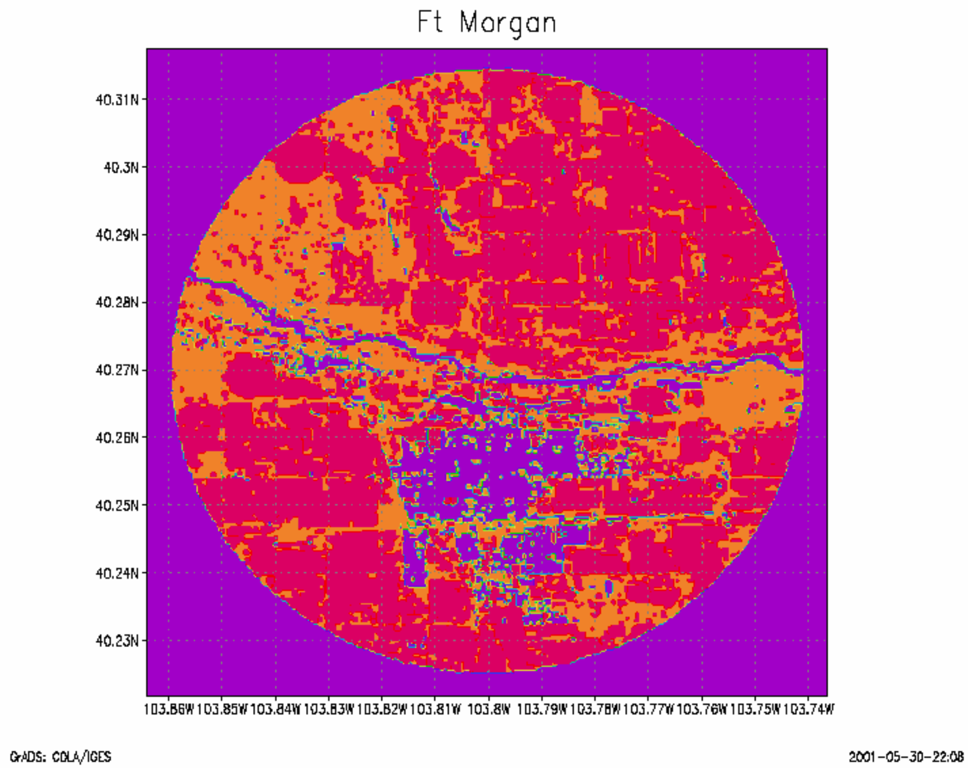


Figure 10: 5 km radius circle of 30 m resolution land-use data for Fort Morgan. The color scales represent: purple - low and high intensity residential/commercial/industrial/transportation; orange - grasslands/herbaceous; and dark red - herbaceous planted/cultivated. Other land-use covers an area of less than 1%.

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

From: Segal, M., R. Avissar, M.C. McCumber, and R.A. Pielke, 1988: Evaluation of vegetation effects on the generation and modification of mesoscale circulations. J. Atmos. Sci., 45, 2268-2292.

http://blue.atmos.colostate.edu/publications/pdf/R-84.pdf

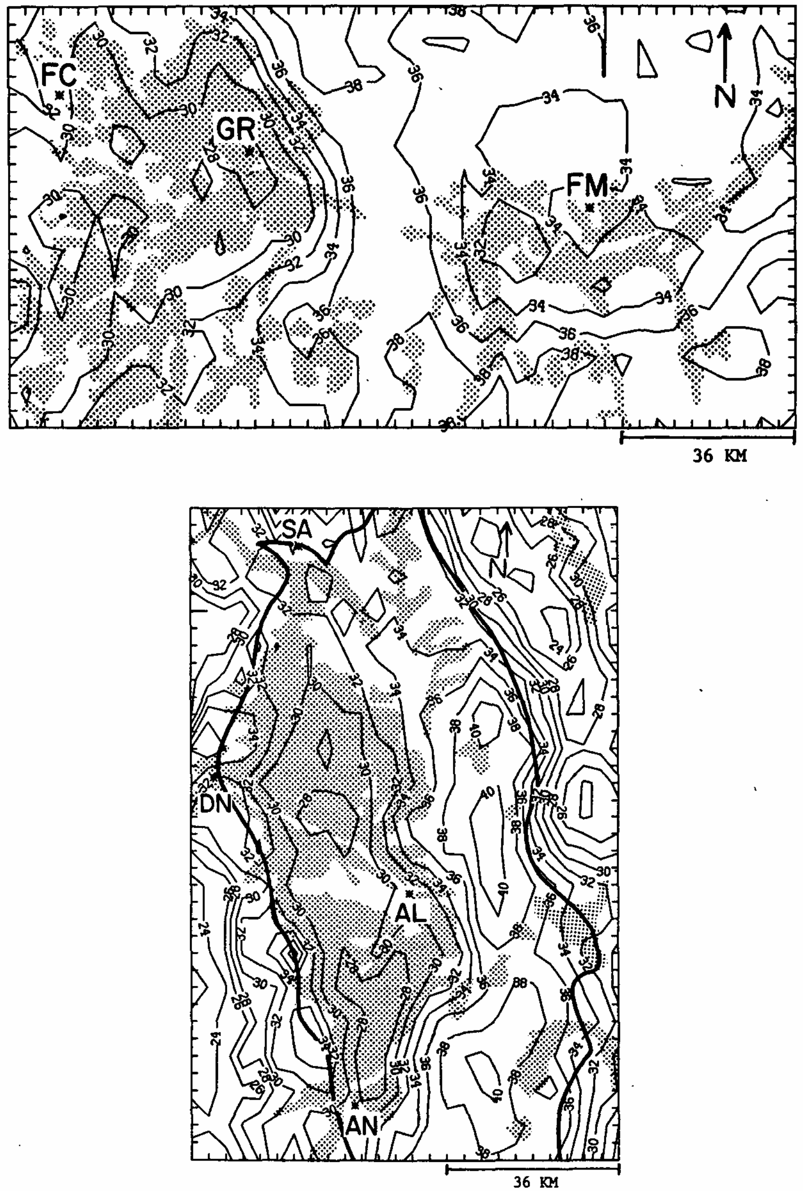


FIG. 11. Composite of GOES derived surface temperature at 1300 LST for the period 1 August 1986 to 15 August 1986 (a) for northeast Colorado (FC—Fort Collins; FM—Fort Morgan; GR—Greeley), (b) for the San Luis Valley in Colorado (AL—Alamosa; AN—Antonito; DN—Del Norte; SA—Saguache). The lower valley is outlined by a dark line separating it from significant elevated terrain. Irrigated areas are shaded.

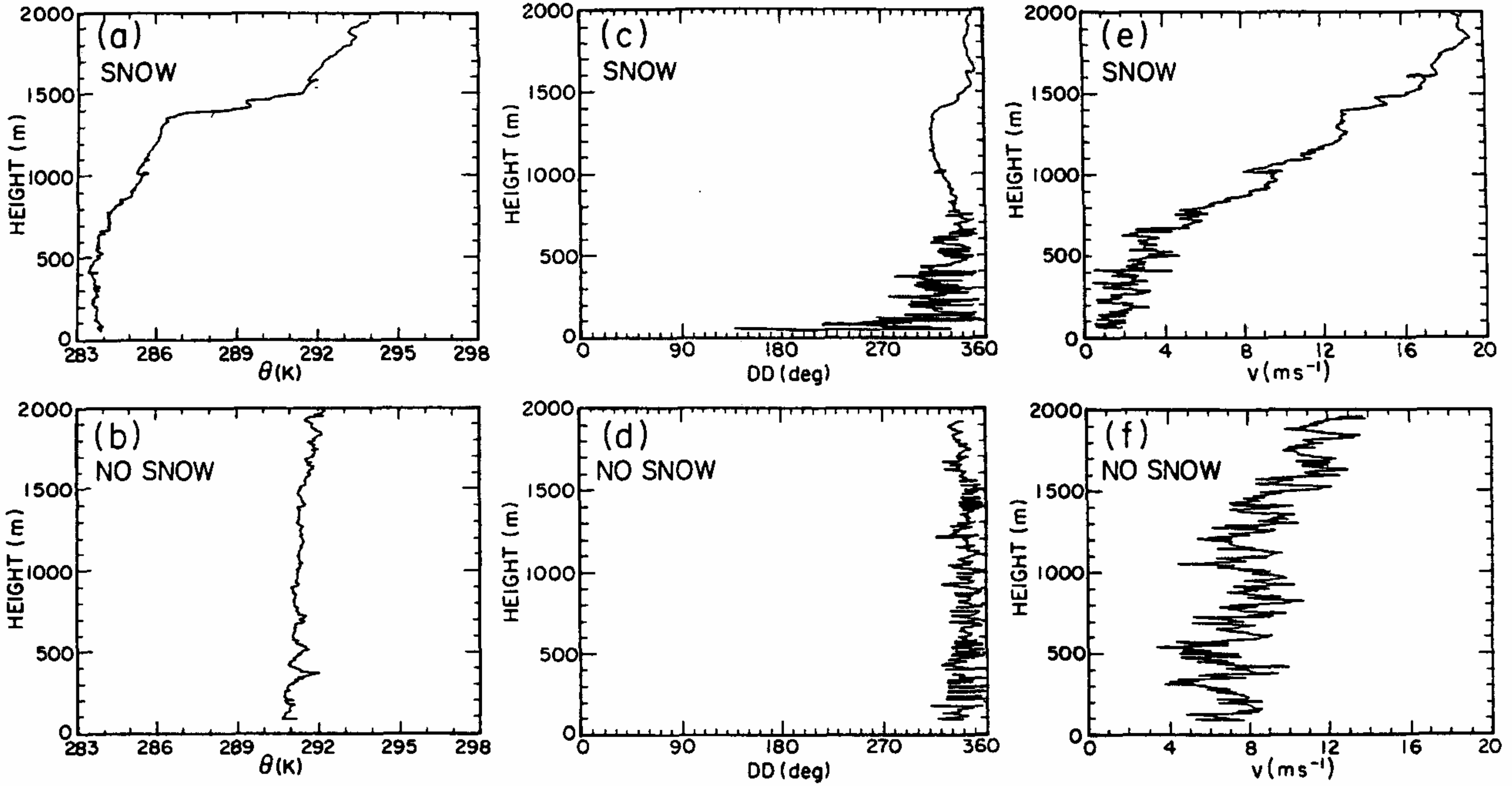
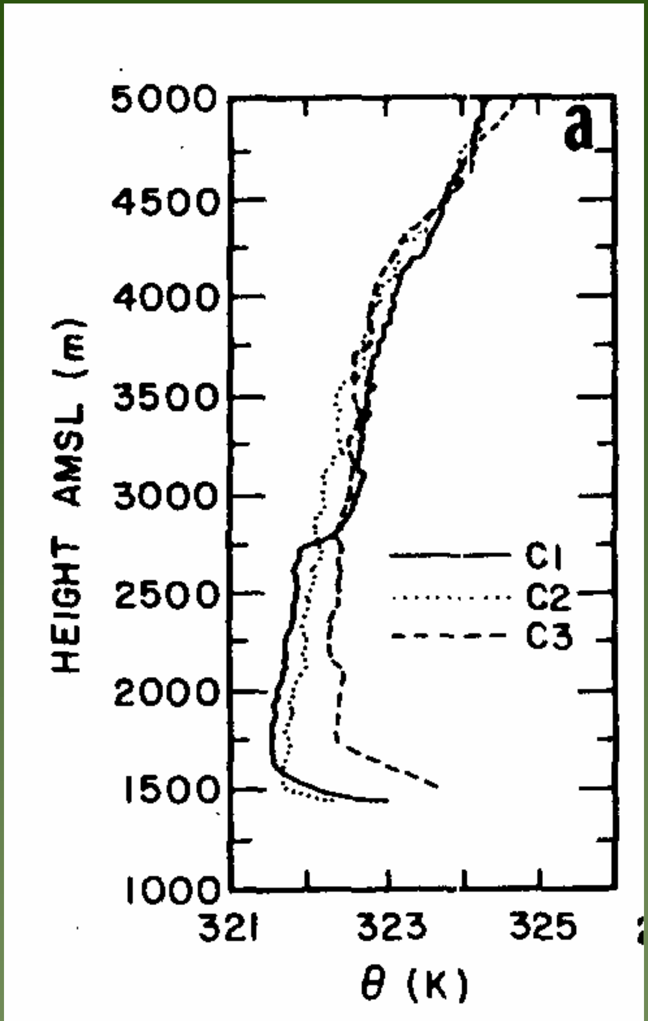


FIG. 11. Vertical profiles of several variables from Flight No. 2 at the locations indicated by Fig. 9a. Snow measurements were made from 1355:40–1413:17 CST; bare ground measurements were made from 1536:23–1547:00 CST; (a–b) potential temperature; (c–d) wind direction, *DD*; and (e–f) wind speed, *V*.

From: Segal, M., J.H. Cramer, R.A. Pielke, J.R. Garratt, and P. Hildebrand, 1991: Observational evaluation of the snow-breeze. Mon. Wea. Rev., 119, 412-424. http://blue.atmos.colostate.edu/publications/pdf/R-113.pdf



Segal, M., W. Schreiber, G. Kallos, R.A. Pielke, J.R. Garratt, J. Weaver, A. Rodi, and J. Wilson, 1989: The impact of crop areas in northeast Colorado on midsummer mesoscale thermal circulations. Mon. Wea. Rev., 117, 809-825. From: http://blue.atmos.colostate.edu/publications/pdf/R-88.pdf C1:over irrigated crops; C2:over the boundary between the crops and short grass prairie; C3:over short grass prairie

Can The Atmosphere Itself Be Used to Integrate Temperature?

Use of the Concept of "Thickness"

$$(z_2 - z_1) = \Delta z = \frac{R_d \overline{T}_v}{g} \ln\left(P_1/P_2\right).$$

Thickness provides the layer mean temperature between two pressure surfaces

Use of the Concept of “Thermal Wind”

$$\Delta\vec{V}_g = \frac{g\vec{k}}{f} \times \vec{\nabla}_p(\Delta z)$$

The Thermal Wind Provides an Estimate of the Layer-Averaged Horizontal Temperature Gradient

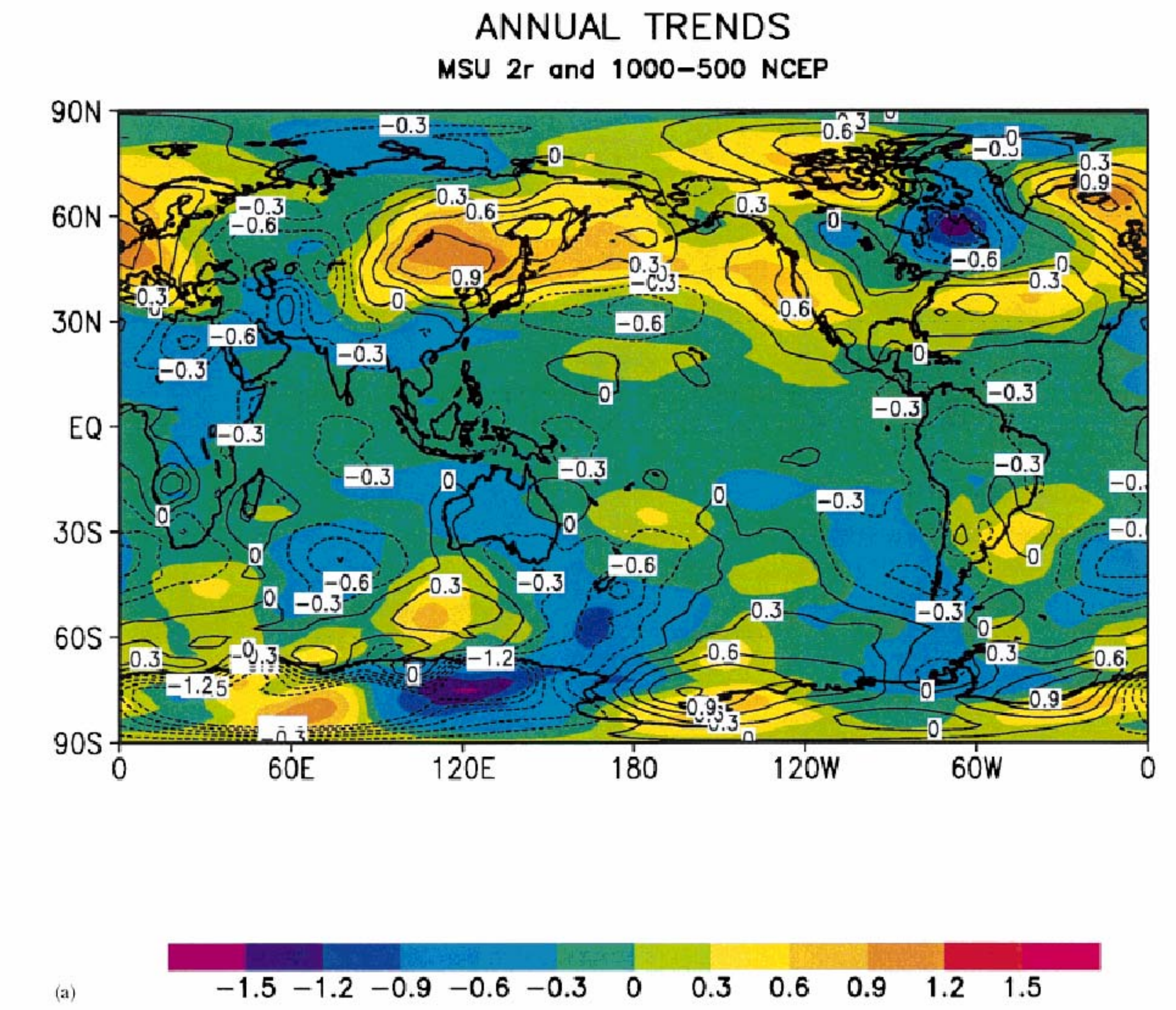
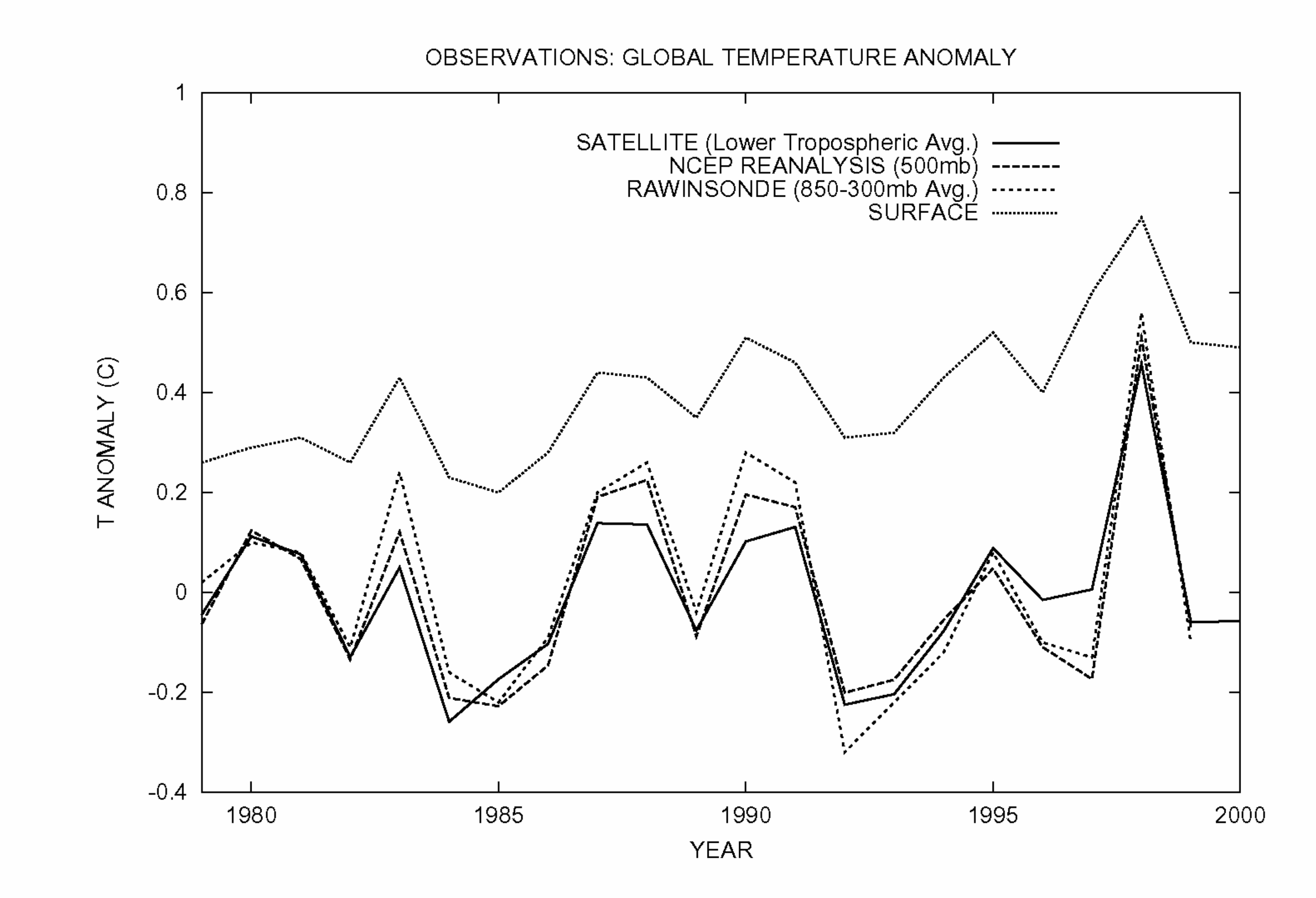
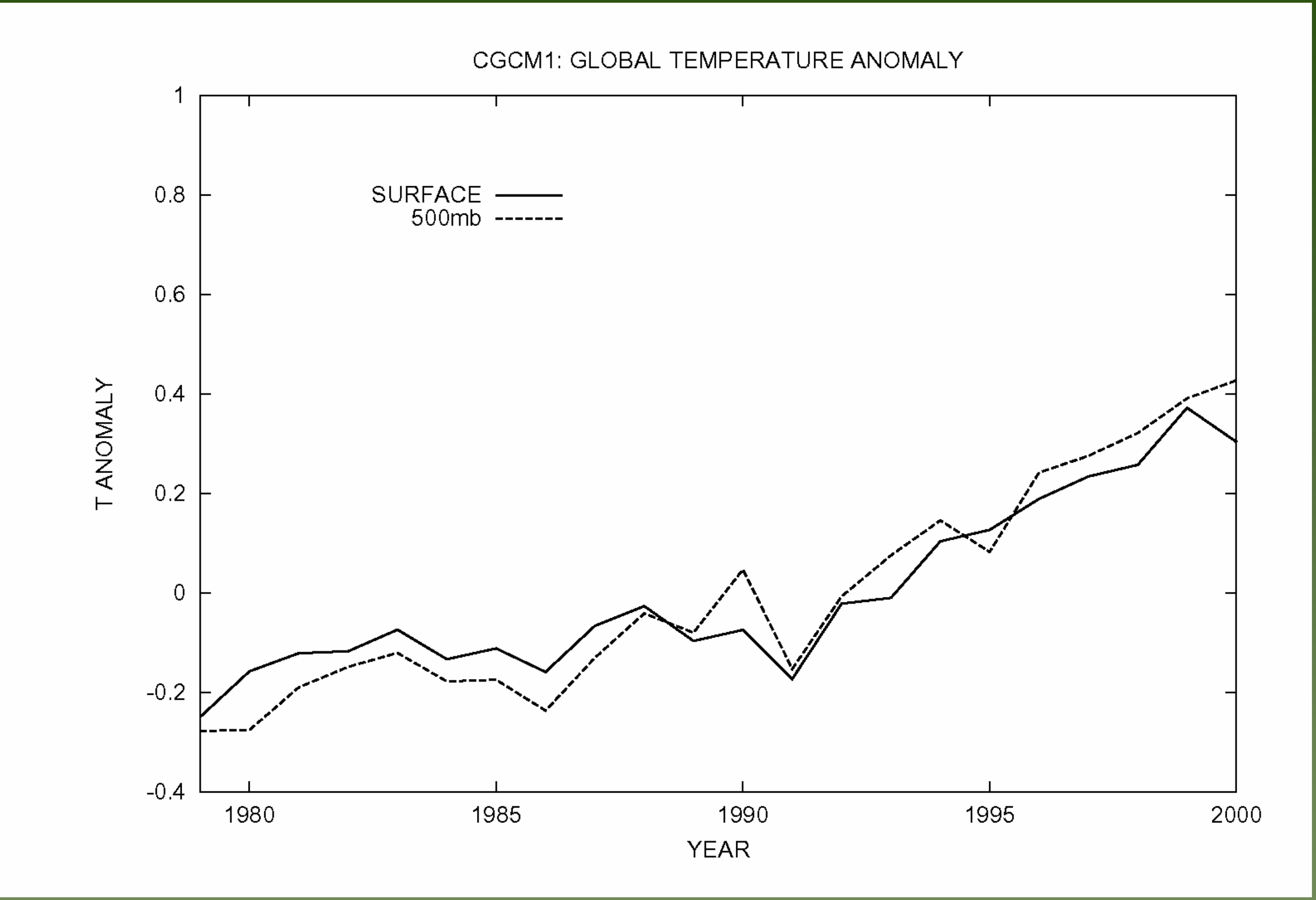


Plate 1. MSU (coloured) and NCEP 1000–500 mb (contoured) trends in °C/19 years for (a) annual average, (b) DJF average and (c) JJA average

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



There is excellent correlation between the MSU and NCEP Reanalysis data. We have examined the statistical robustness of these correlations in Chase et al. (2000). From: 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



From: 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

From: Pielke, R.A. Sr., T.N. Chase, T.G.F. Kittel, J. Knaff, and J. Eastman, 2001: Analysis of 200 mbar zonal wind for the period 1958-1997. J. Geophys. Res., 106, D21, 27287-27290. http://blue.atmos.colostate.edu/publications/pdf/R-211.pdf

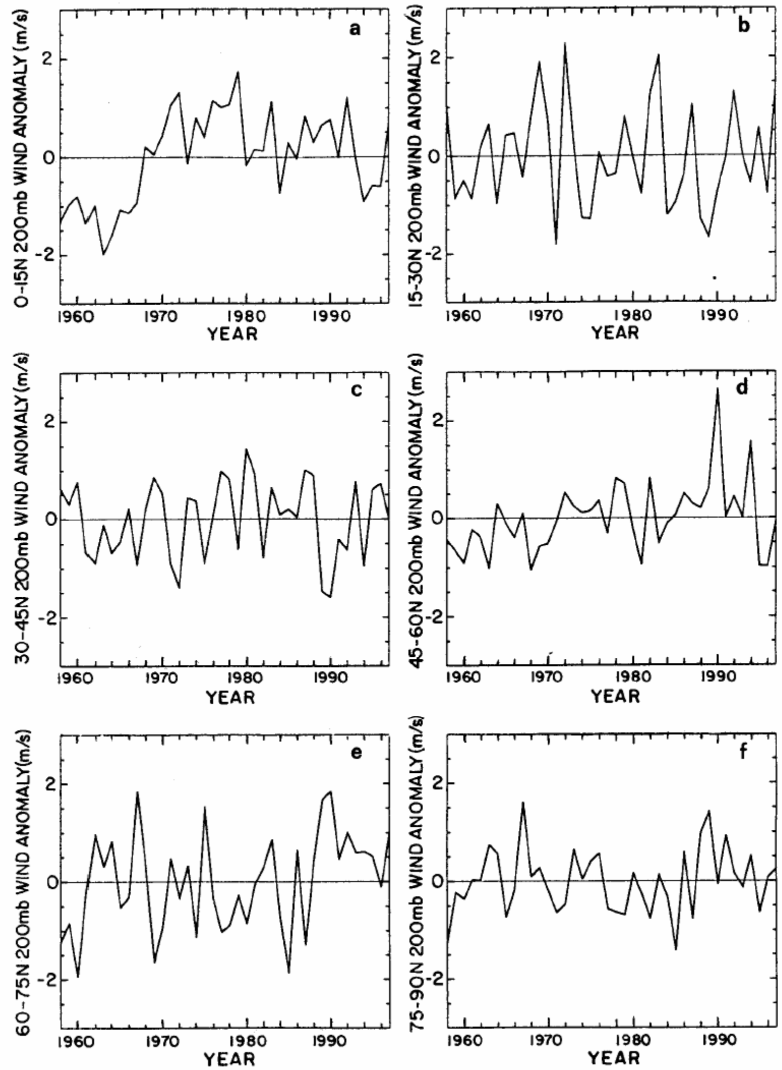


Figure 1. The 200 mbar westerly wind anomaly from the NCEP Reanalysis for 1958–1997. (a) 0°–15°N, (b) 15°–30°N, (c) 30°–45°N, (d) 45°–60°N, (e) 60°–75°N, (f) 75°–90°N, (g) 0°–15°S, (h) 15°–30°S, (i) 30°–45°S, (j) 45°–60°S, (k) 60°–75°S, and (l) 75°–90°S. Equation (1) can be used to convert these values to north-south temperature gradients. A value of 1 m s^{-1} corresponds to a difference in temperature across a distance of 1000 km of 0.04°C, 0.12°C, 0.19°C, 0.25°C, 0.29°C, and 0.31°C for the latitudes of 7.5°, 22.5°, 37.5°, 52.5°, 67.5°, and 82.5°, respectively.

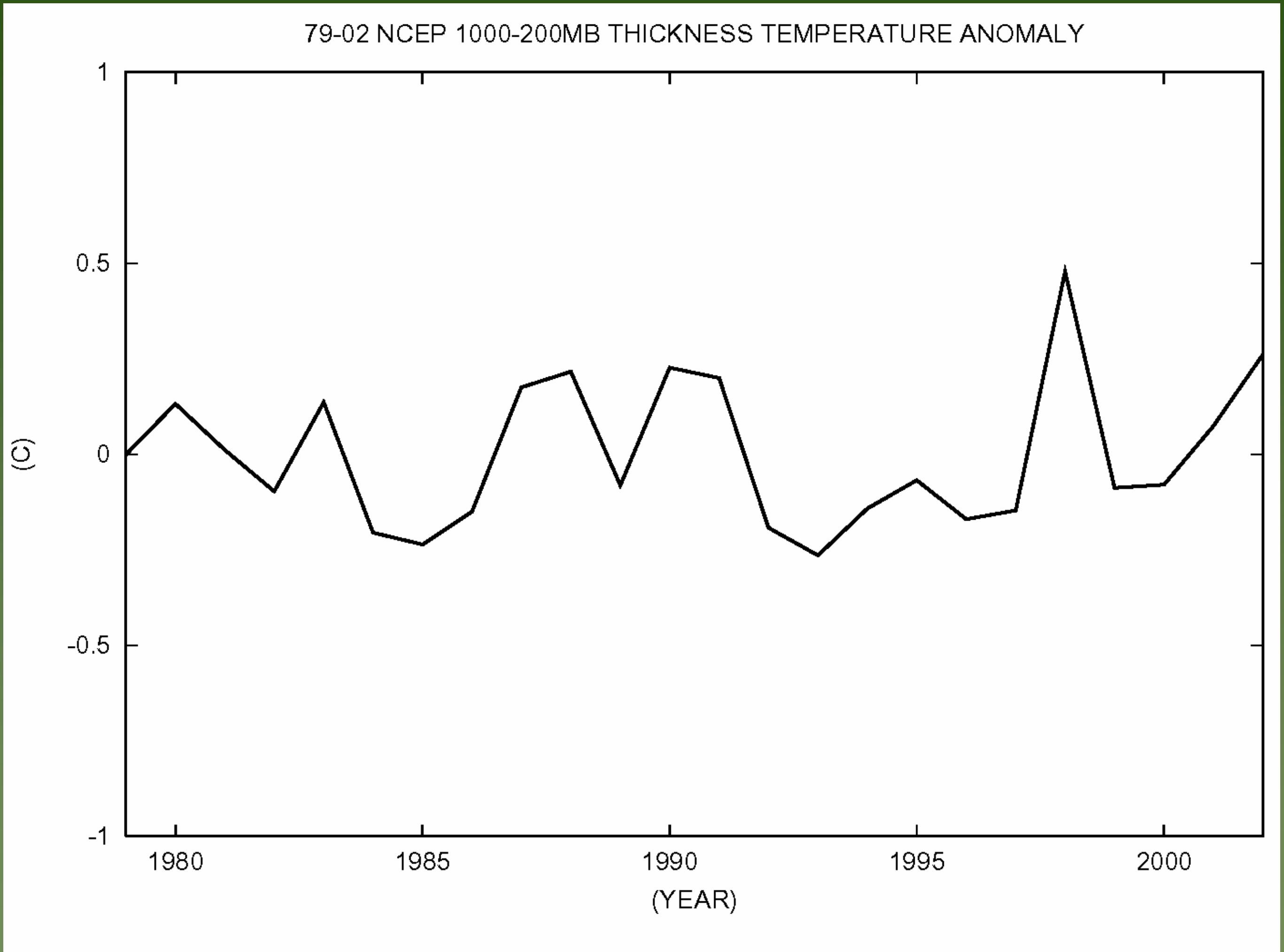
Table 1. The 1958–1997 200 mbar Observed Westerly Wind Trends and Significance Level p From NCEP Reanalysis[a]

	Observed	
	Trend	p
Globe	0.03	0.58
0°–15°N	0.35	<0.01
15°–30°N	−0.03	0.86
30°–45°N	0.03	0.82
45°–60°N	0.22	0.02
60°–75°N	0.27	0.05
75°–90°N	0.06	0.50
0°–15°S	0.41	<0.01
15°–30°S	−0.72	<0.01
30°–45°S	−0.76	<0.01
45°–60°S	0.38	<0.01
60°–75°S	0.59	<0.01
75°–90°S	0.11	0.09

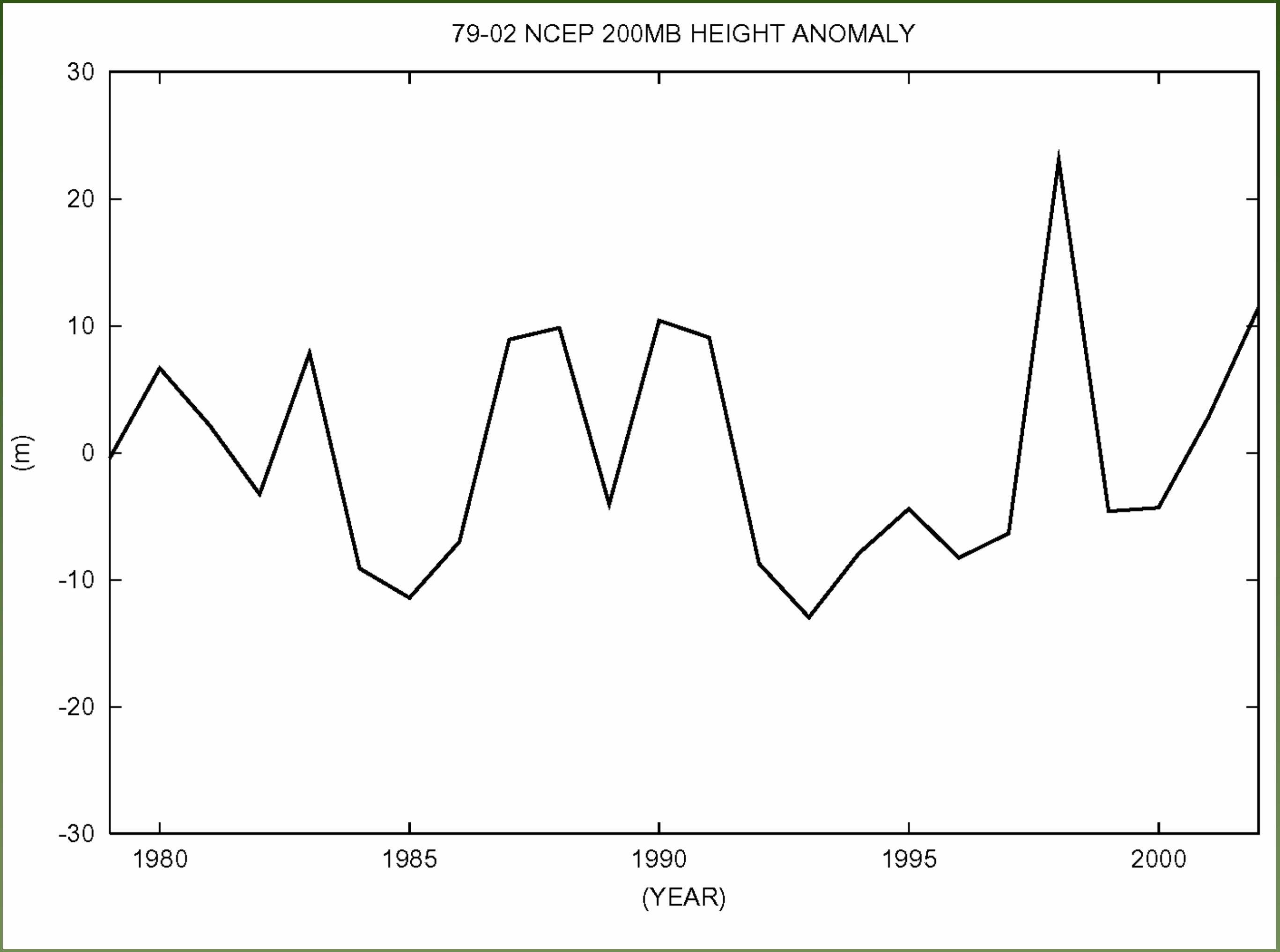
[a]Units of trends are in m s^{-1} $decade^{-1}$.

From: Pielke, R.A. Sr., T.N. Chase, T.G.F. Kittel, J. Knaff, and J. Eastman, 2001: Analysis of 200 mbar zonal wind for the period 1958-1997. J. Geophys. Res., 106, D21, 27287-27290. http://blue.atmos.colostate.edu/publications/pdf/R-211.pdf

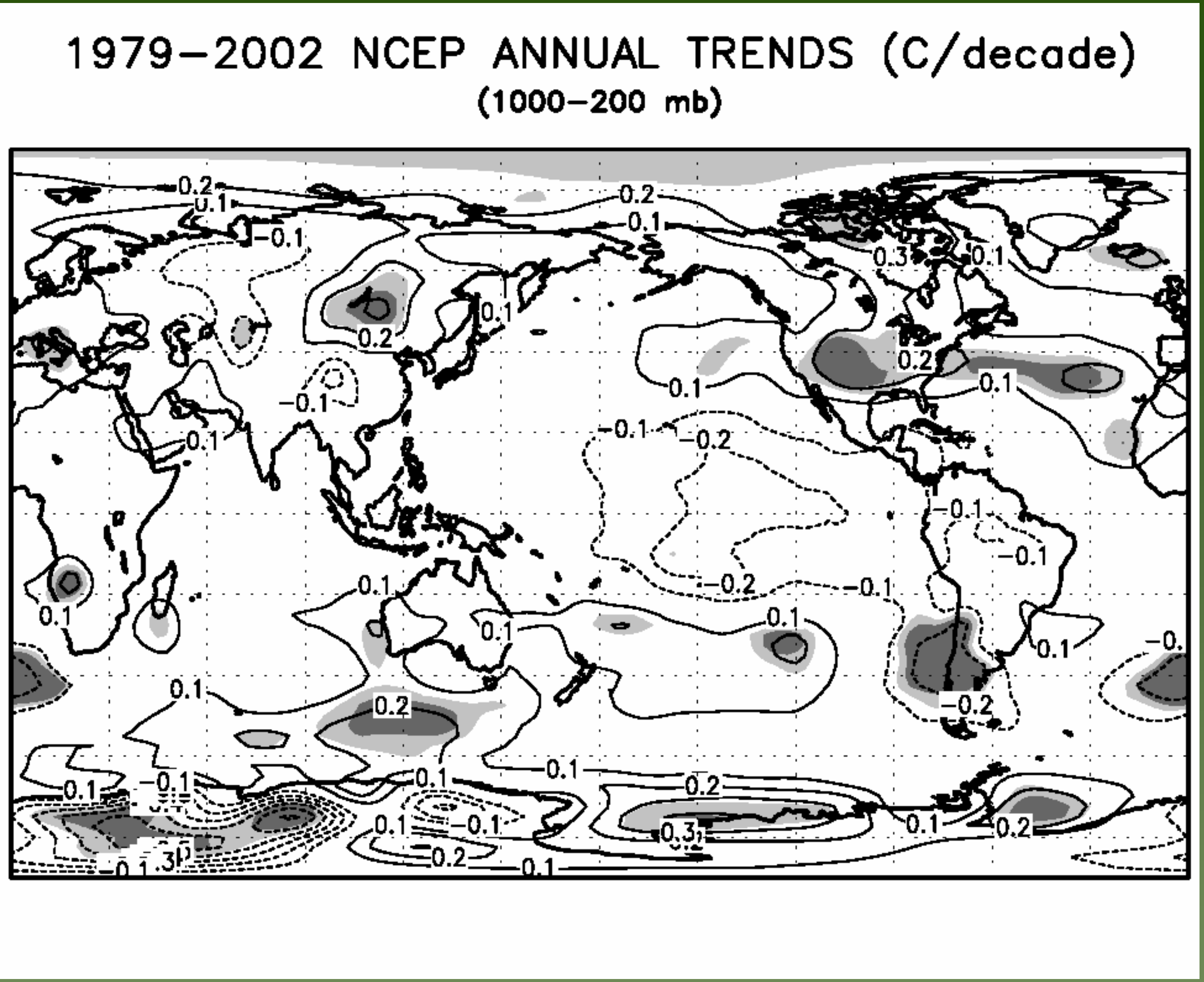
Can The Concept of Thickness Be Used to Help Interpret Tropopause Changes?



1979-2002 NCEP Reanalysis 1000-200 mb layer mean temperature anomaly, and (b) the same but for the 200 mb height anomaly. From: Pielke Sr., R.A., and T.N. Chase, 2003: Technical comment on "Contributions of anthropogenic and natural forcing to recent tropopause height changes". Science, submitted.

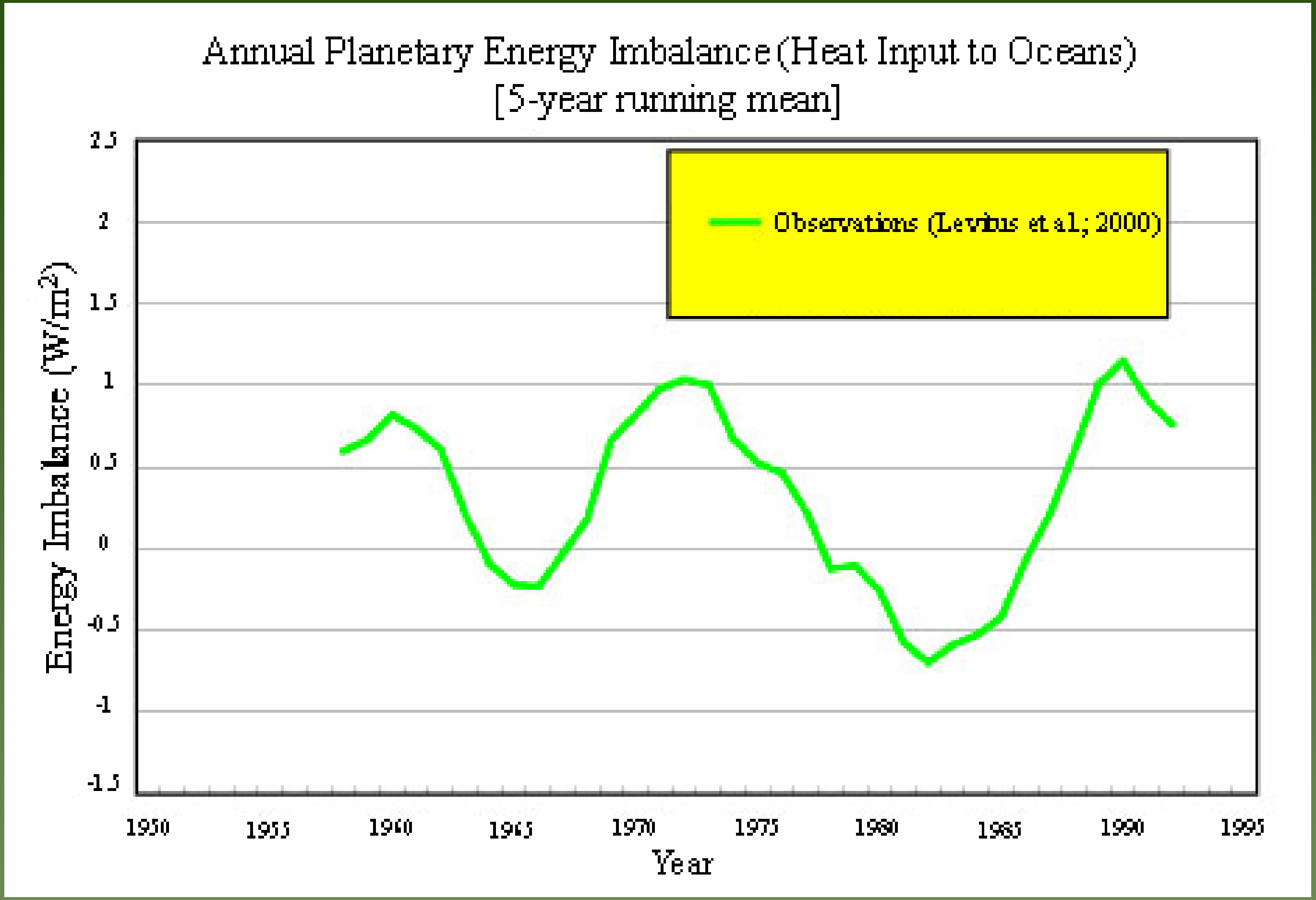


1979-2002 NCEP Reanalysis for the 200 mb height anomaly. From: Pielke Sr., R.A., and T.N. Chase, 2003: Technical comment on "Contributions of anthropogenic and natural forcing to recent tropopause height changes". Science, submitted.



Spatial map of the 1979-2002 NCEP Reanalysis trends of the 1000-200 mb mean layer temperature in units of degrees C per decade. From: Pielke Sr., R.A., and T.N. Chase, 2003: Technical comment on "Contributions of anthropogenic and natural forcing to recent tropopause height changes". Science, submitted.

Can The Ocean Be Used to Assess Global Heat Changes?



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

The heat budget for the earth system can be expressed as

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

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

From: 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

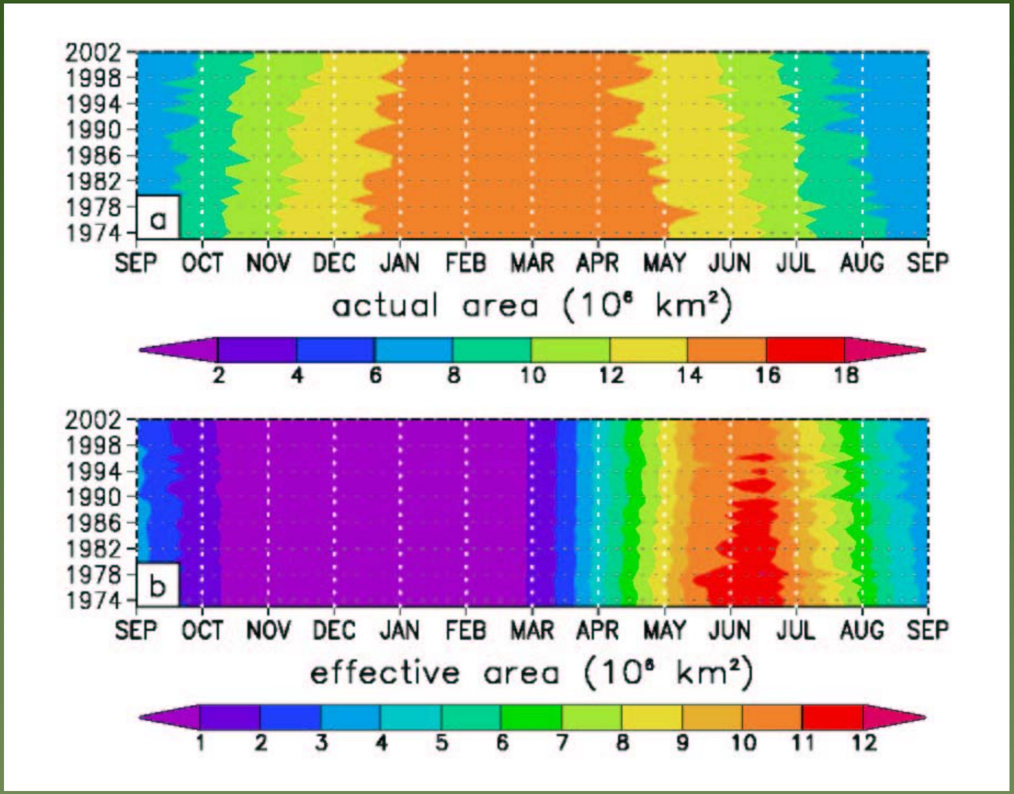
Mid 1950s	to	Mid-1990s
~ 0.15 Watts m^{-2}		surface - 300 meters
~ 0.15 Watts m^{-2}		300 meters – 3 km

Can Data Assimilation Be Used to Assess the Spatial Representativeness of Surface Temperature Data?

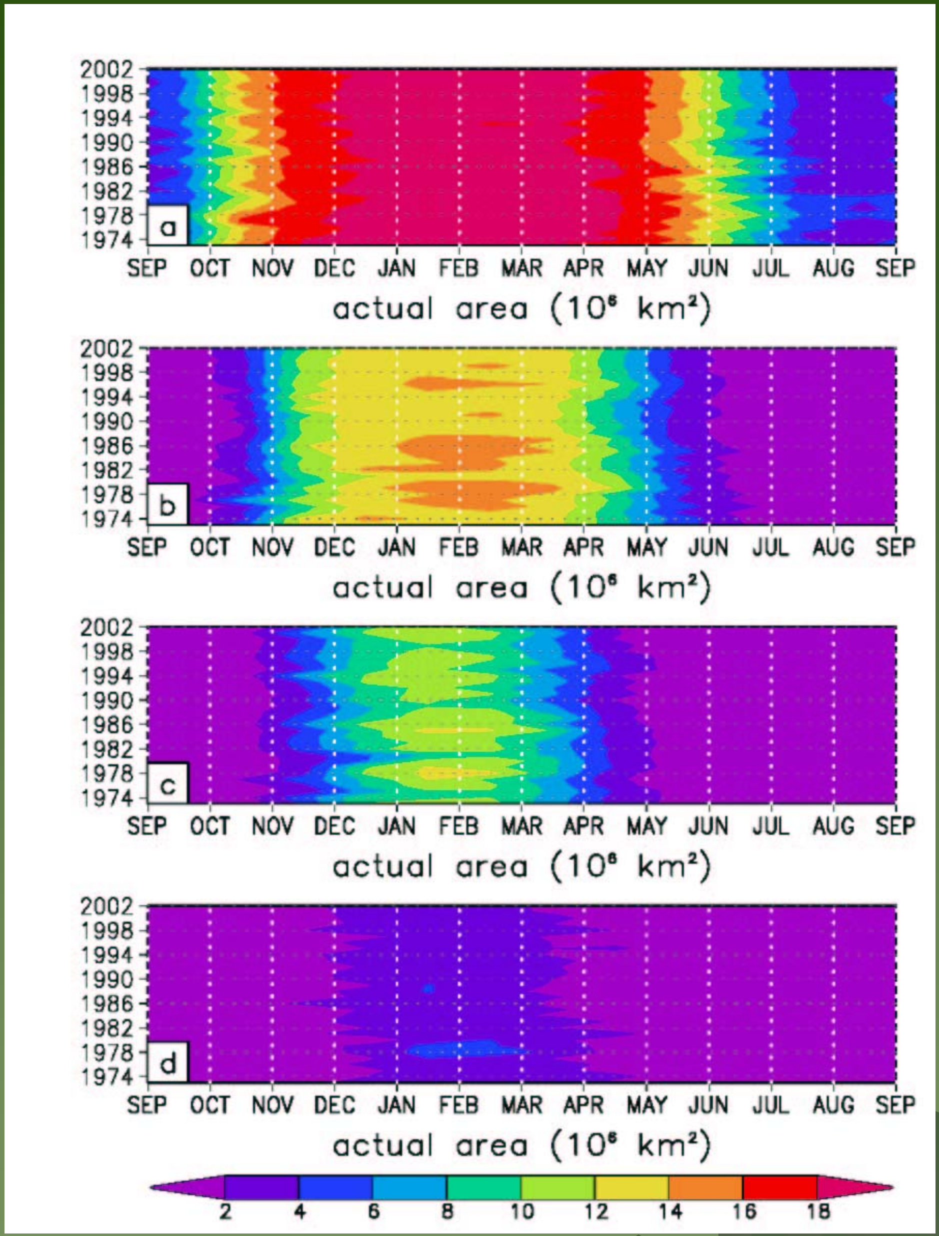
“In regional reanalysis, all of a sudden, we could not reproduce very ‘nice’ results you can see on our reanalysis web page. ‘Nice’ means regional reanalysis clearly fitting raobs, both analysis and the first guess, better than the global reanalysis. The reason was that we started assimilating surface 2 m temperatures, which we believed we were doing all the time, but in fact we were not. Assimilating 2 m temperatures was harming the results dramatically, all the way to the tropopause. We have recovered our ‘nice’ results by discontinuing the assimilation of 2 m temperatures over land. This was implemented also in the operational Eta recently. Today's state-of-the-art data assimilation systems seem unable to do well with land-surface data, which is most of what is fine scale.” (Fedor Mesinger, NOAA, 10/19/03)

What Have Been the Arctic Surface and Tropospheric Trends?

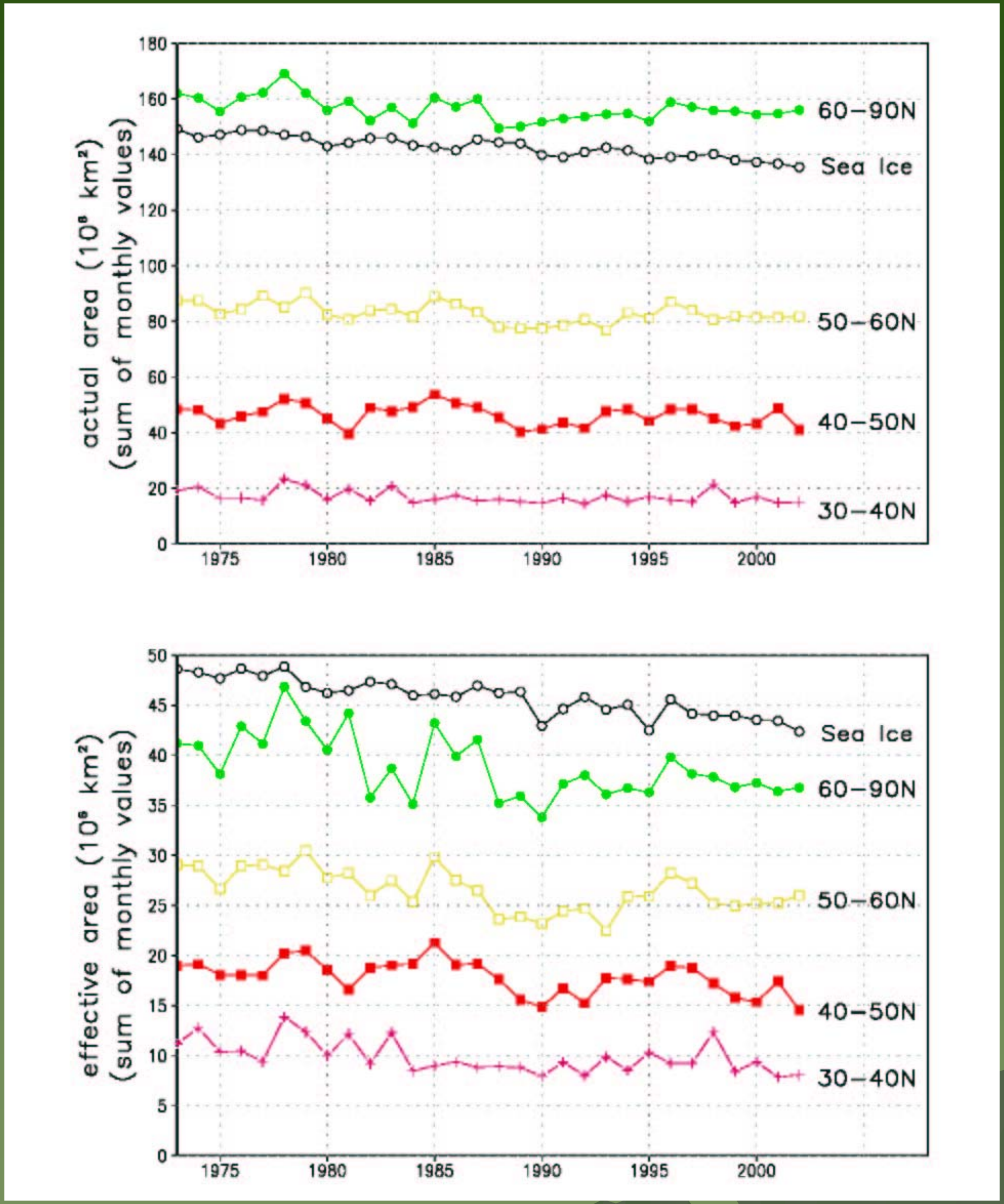
Actual and insolation-weighted values for Arctic sea ice.



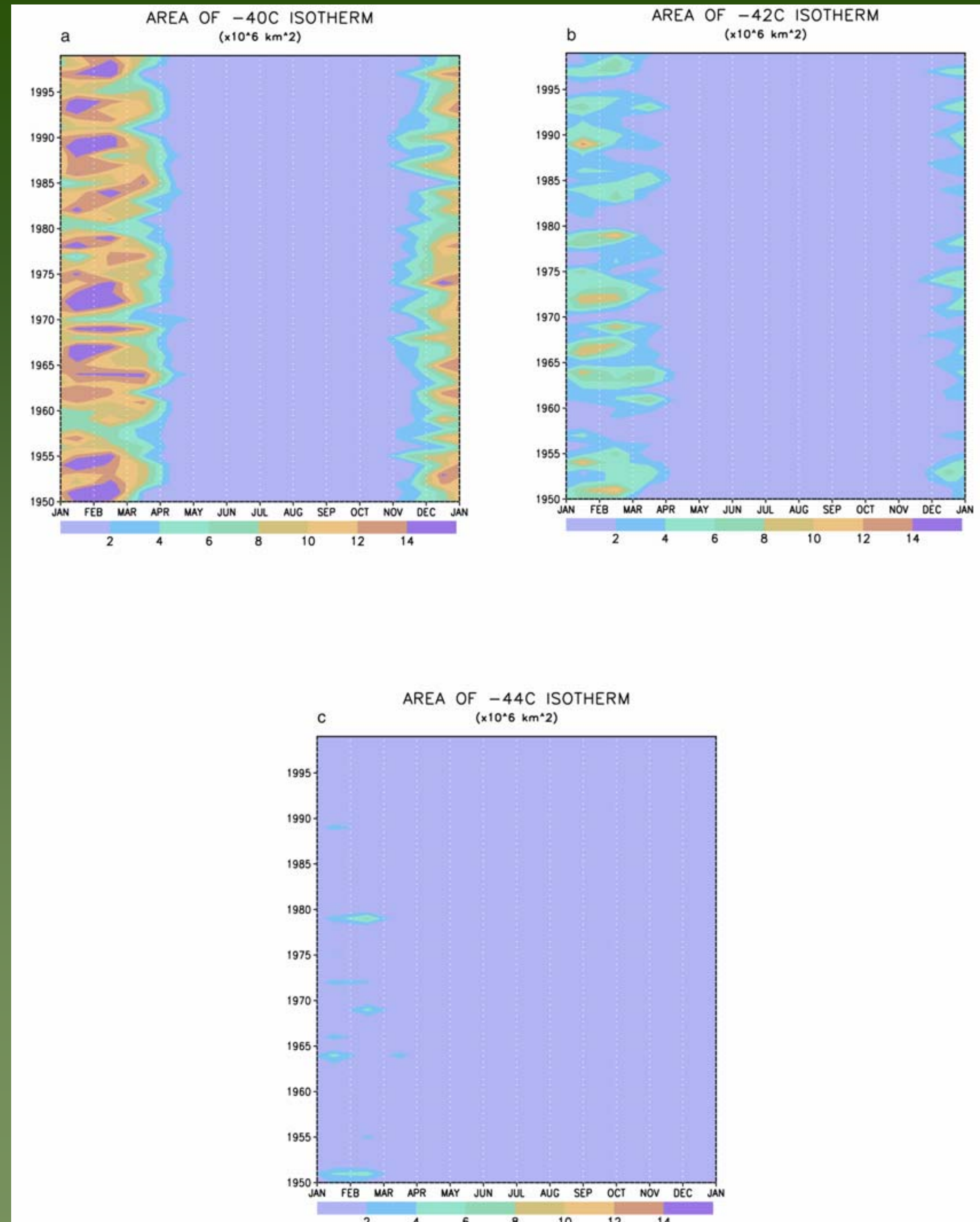
Actual snow cover by latitude bands (a) 60-90°N; (b) 50-60°N; (c) 40-50°N; and (d) 30-40°N.



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



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, (c) and -44°C isotherm.



RECOMMENDATIONS

- All locations used to monitor temperature trends should be photographed
- The land-use history of the local and surrounding region needs to be documented
- The influence of vegetation and soil changes, and snow cover needs to be considered in interpreting the temperature data
- The concepts of thickness, thermal wind, and earth system heat content should be used to assist in the interpretation of the surface and tropospheric temperature data
- Use data assimilation techniques to assess the spatial representativeness of the surface data used in climate reconstructions
- Use surface heat content changes, ($C_pT + Lq$), in addition to temperature to assess trends