Analysis of Four Decades of High Elevation Climate Data

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Abstract: Four decades of instrumented climate records at D1 on Niwot Ridge suggest that high elevation data are an important — and even unique — part of the full climate picture. High elevation data provide information on changing lapse rates as well as model verification for global warming, which is predicted to occur earliest in high latitudes and at high elevations. The D1 records show climatic trends that arguably support global warming, assuming that greater planetary wave amplitude is verification of warming. Lapse rates reflect conditions of air mass stability, atmospheric moisture, and could cover, which contribute to feedback processes involving temperature, precipitation, and snowpack. The D1 record shows a period, 1981-1985, when the lapse rate increased significantly, and this change was not detected by other data.

The D1 climate station is 2.7 kilometers east of the Continental Divide and 34 kilometers west of Boulder, Colorado, at an elevation of 3749 meters. The C1 climate station is 7 kilometers east of D1, at an elevation of 3018 meters. Both sites are on Niwot Ridge; D1 is in the alpine forest and C1 is in the subalpine forest.

Four decades, 1951-1994, of instrumented climate records on Niwot Ridge show:

- A decrease in fall temperatures (–0.044°C/yr), but no significant annual cooling (–0.009°C/yr);
- A daily average maximum:minimum temperature ratio that is relatively constant on a seasonal basis;
- A decreasing trend in the lapse rate (–0.012°C/km/yr) between 3749 and 3018 meters;
- A step-function decrease in winter pressure variability (19%) in the 1991-92 winter;
- A decrease in incident summer solar radiation (3 watts/m^2/yr) between 1971 and 1992, but an increase in 1965-1970 and in 1992-1994; and
- An annual precipitation increase of 11.04 mm/yr at 3749 meters, but no trend in annual precipitation at 3018 meters (Greenland 1994).

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The 1981-1985 "Cold Event"

Although there is no significant long-term trend in the 40-year temperature record at the 3749 meter site (D1), 1981-1985 is a notable cold period, averaging 3°C colder annually than in the rest of the record (Figure 1). This cold period is evident in the record for all seasons as well as in the maximum and minimum average daily values. A lower site, at 3018 meters (C1), also reflects this cold period, but less distinctly. At the lowest sites in the Colorado Front Range, Boulder and Longmont, this cold period is conspicuously absent.

The D1-Longmont lapse rate increased from an average of 6.3 to 7.6°C/km during the 1981-1985 period (Figure 2). The D1-C1 annual lapse rate increased about 1.5°C/km during this same time.

Surface solar insolation at both D1 and C1 declined steadily from 1971 to 1992 (Figure 3). Precipitation was enhanced slightly in the 1981-1985 period but was within the extremes of the 40-year record at both sites.

This cool period is not easily explained by reduced solar radiation nor increased cloudiness (as implied from the precipitation record and the lack of change in the temperature maximum: minimum ratio). A possible explanation may be a change in atmospheric circulation patterns during the 5-year period. Such changes could increase polar air mass frequency during 1981-1985 relative to the remaining record. However, air masses affect regions, and Boulder and Longmont did not cool during this period.

A possible explanation for this condition is that the two areas are dominated by elevationally different circulation patterns. The mountains of the Continental Divide near D1, dominated by west or northwest air flow, encourage a lee-developing cyclonic flow to develop over the eastern plains (Bresch and Reitter 1987), where Longmont and Boulder are located. This cyclonic tendency creates the potential for a southeasterly flow, and possible warm air advection, over the plains and at the same time a northwest flow and cold air advection over the mountains, only a few kilometers to the west.

In summary, the Niwot Ridge data suggest that high elevation climate data are an important part of the complete climate picture, both in model verification and for identification of changes that cannot be measured at low elevations alone.

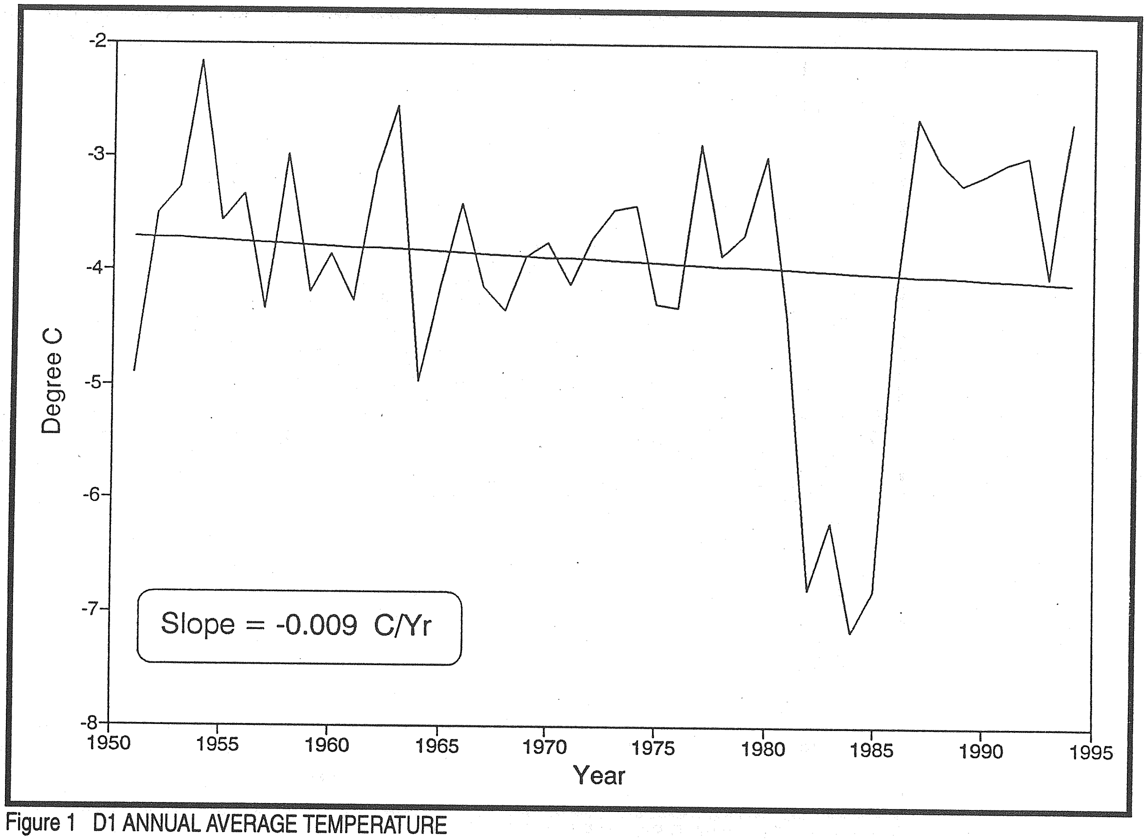

Figure 1 D1 ANNUAL AVERAGE TEMPERATURE

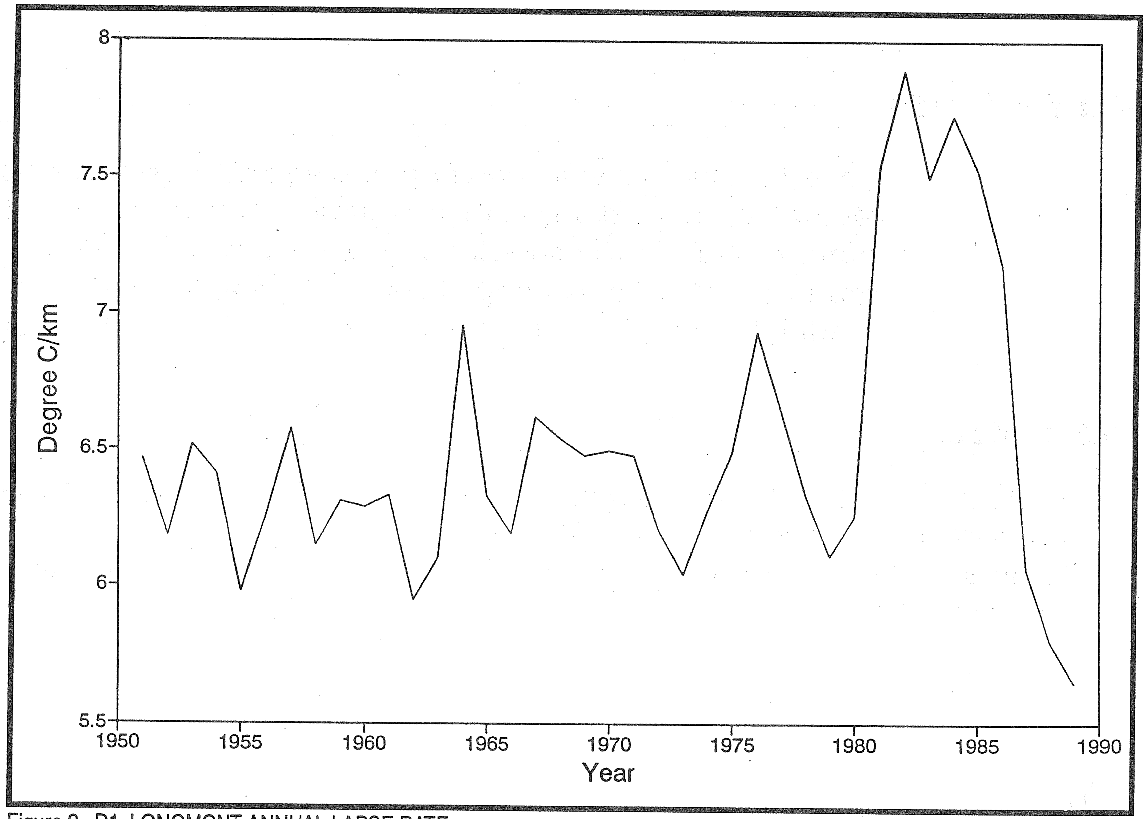

Figure 2 D1, LONGMONT ANNUAL LAPSE RATE

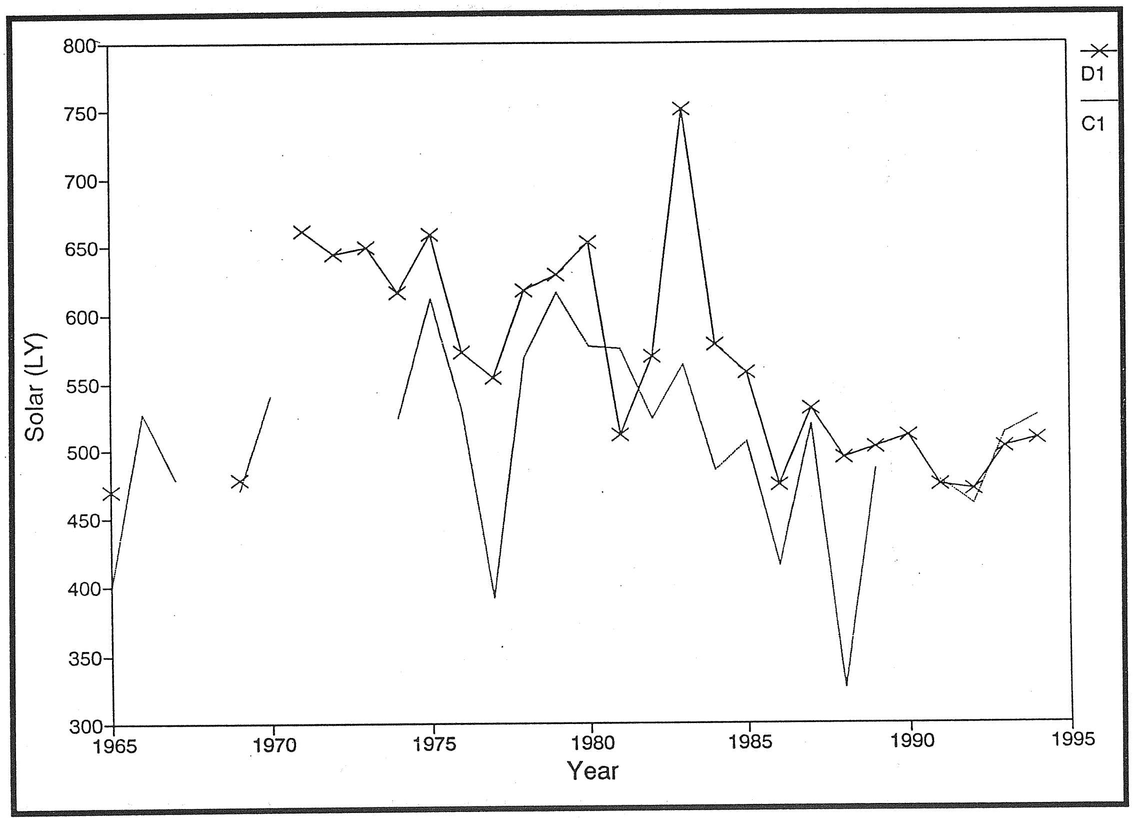

Figure 3 D1,C1 SUMMER SOLAR RADIATION

Future Study

Synoptic-scale classification or pressure grid correlation fields may verify whether or not changes in circulation occurred from 1981 to 1985. Establishment of the correlation between radiosonde and high elevation ground pressure and temperature data might also be valuable in augmenting the relatively few climate records at high elevations.

References

Bresch, J.F., and E.R. Reitter. 1987. Case study of unusual long-range sulfur transport episode. *American Meteorological Society* 26:315-321.

Greenland, D. 1994. A Decrease in Temperatures at High Elevations in the Colorado Front Range, USA. Unpublished report.