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Elevation Correction and Interpolation Bias in Regional Climate Data Analysis

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NARCCAP

ABSTRACT

The analysis of regional climate model (RCM) outputs frequently requires spatial interpolation of the data from the model's native grid to another set of locations: a different grid for intermodel comparison, a set of station locations for modeling of dependent processes or comparison with raw observations, specific points of interest for impacts studies, and so on. Elevation is sometimes neglected during interpolation, even though it has a major influence on climate, with an increase of 1000 meters in altitude giving temperature changes equivalent to a shift in latitude of around 7.5 degrees poleward. The spatial scale over which elevation varies significantly is often much smaller than the scale at which RCMs are typically run (tens of kilometers), and thus the difference in elevation from one set of locations to another can be quite large, even if the locations come from two grids with comparable resolutions. Consequently, the results obtained by interpolation can, in principle, be significantly different depending on whether or not one corrects for elevation.

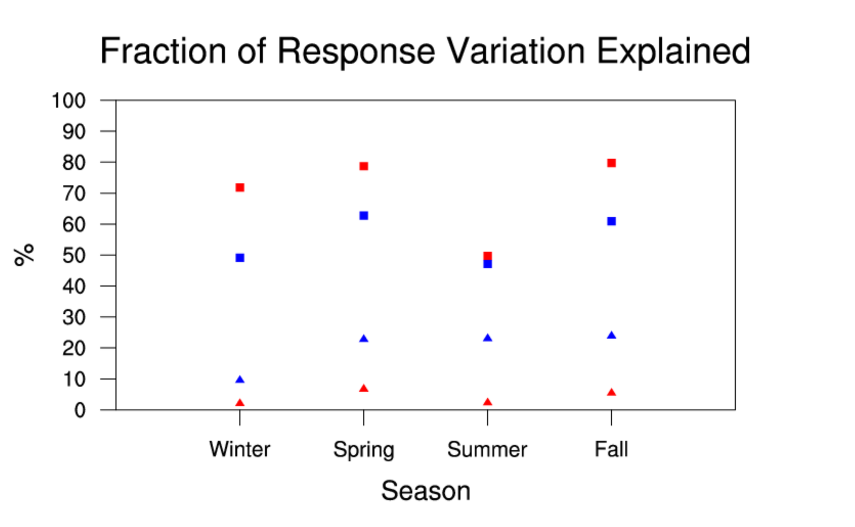
We examine the relevance and characteristics of changes due to elevation correction to determine whether it is important to users of NARCCAP data. Elevation correction in this case is performed by interpolating the data using a thin plate spline algorithm (a type of kriging) with elevation provided as a covariate field.

We compare the bias against observations of data regridded with and without elevation correction for the six NARCCAP RCMs using gridded observational datasets with comparable spatial resolution (CRU and UDEL, at 1/2-degree grid spacing) and at much higher resolution (PRISM, at 4 -km grid spacing). We also consider the spatial distribution of bias and changes in bias due to elevation correction, the statistical characteristics of bias reduction, and the relationships of bias to elevation and to the observables in question. These results are evaluated in the context of intermodel comparison, impacts modeling and analysis, and other uses popular in the NARCCAP community.

BACKGROUND AND MOTIVATION

- **Elevation Affects Climate**

This is expected based solely on physics, and is borne out in observations. We performed multiple linear regression on seasonal climatology data from the NWS COOP Network using latitude and elevation as explanatory variables. The results are summarized in this figure, which shows that the contribution of elevation to the temperature signal is substantial:

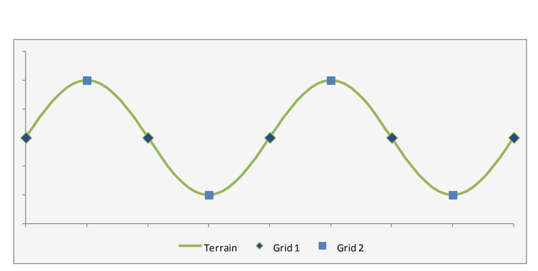


- **Elevation Varies Significantly from Gridcell to Gridcell**

Let's say that we consider temperature variations of less than roughly half a degree Fahrenheit or a quarter-degree Celsius to be negligible. Assuming an adiabatic lapse rate of 6.5 K per 1000 m and slopes of up to 45°, at any spatial resolution less than approximately 100 meters (a *much* higher resolution than the typical resolution for regional modeling) the difference in temperature between adjacent model gridcells due solely to difference in elevation will exceed the threshold of negligibility.

- **Grid-Point Placement Is Not Based On Elevation**

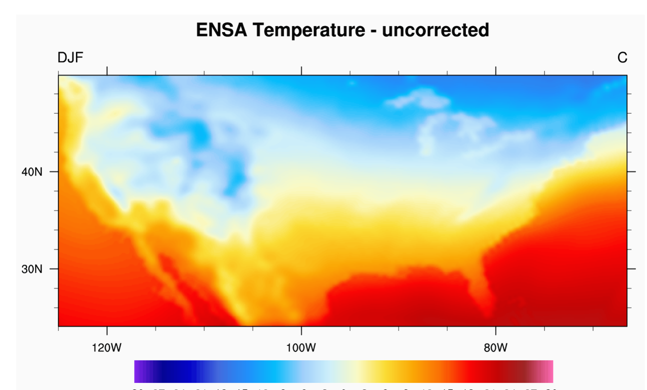
Grid points can be placed optimally in one dataset and pessimally in another relative to hills and valleys. Interpolating a variable influenced by elevation to intermediate points in the hypothetical example at right would produce very different results depending on which grid was used.

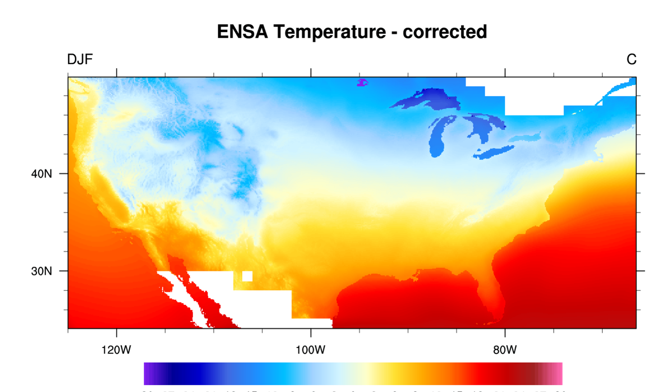


ELEVATION CORRECTION

We correct for elevation by supplying it as a covariate to the thin-plate spline algorithm (TPS). Given a covariate on both input and output grids, TPS adjusts the interpolation based on the statistical correlation between the variable being interpolated and the covariate.

These figures show the results of interpolating temperature data from half-degree resolution down to a 4-km grid. The temperature field is the seasonal climatology for an ensemble average (ENSA) of five NARCCAP models driven by NCEP. The "uncorrected" interpolation uses no covariate; the "corrected" interpolation uses elevation as a covariate and interpolates data separately over land and over water. (Missing data is due to gaps in the elevation dataset.)



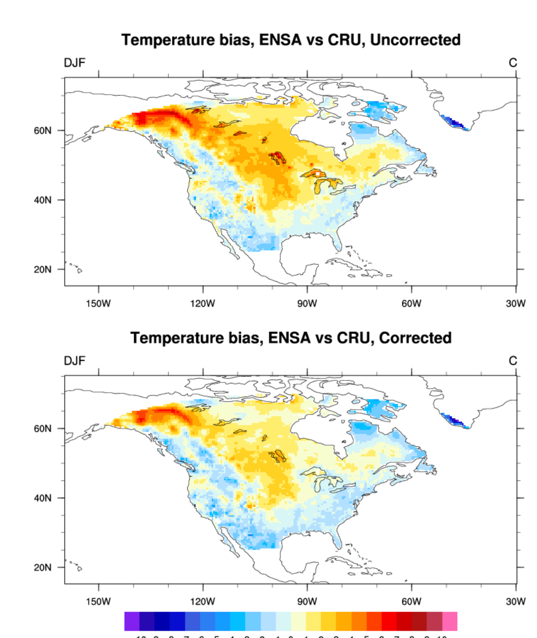


The corrected interpolation certainly *looks* better, but the question remains:

DOES IT ACTUALLY MATTER?

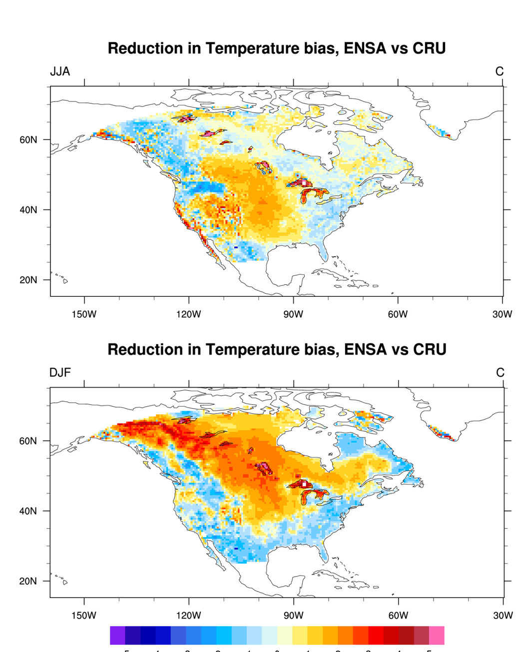
BIAS REDUCTION vs CRU / UDEL

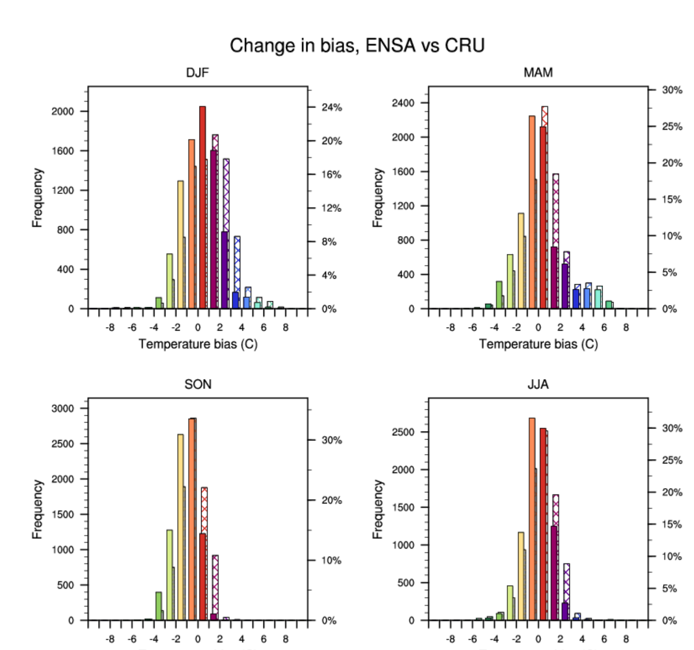
The figures at right show the bias against the CRU dataset of winter average temperatures for the five-member NARCCAP ensemble. Results for bias vs UDEL are similar. CRU and UDEL have a half-degree spatial resolution, while the NARCCAP RCMs are comparable, at 50 km resolution.



The figures below left show the reduction in bias due to elevation correction for winter and summer. Bias reduction is calculated as the difference in the square of the biases, divided by the square root of said difference.

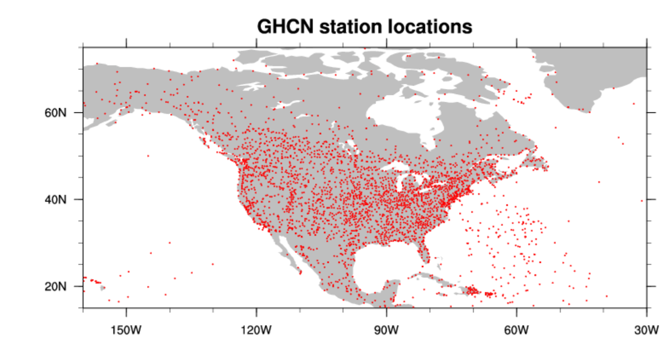
The figures at bottom right show changes in the distribution of bias due to correction. The rear (hatched) histograms show bias for the uncorrected interpolation, while the front (solid) histograms show bias with correction. The corrected-bias histograms show a shift toward zero and a tightening of the peak. This effect is more prominent in the ensemble (shown) than in any individual RCM, and appears to be associated at least in part with improvements near Canadian lakes due to separate land/water interpolation.





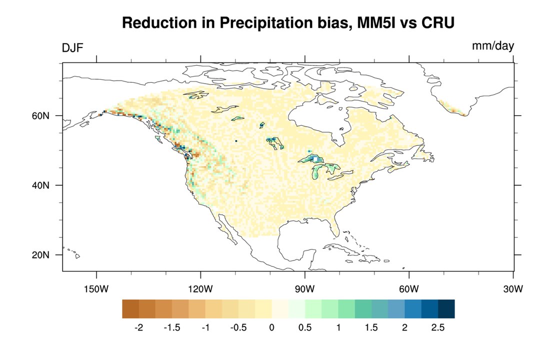
OBSERVATION DENSITY

The CRU/UDEL biases are especially high in the Yukon and Northwest Territories. Although it is likely that RCM performance in Arctic regions is poor because key processes are not well represented, it is also true that observations are very sparse in the far north. We have eliminated points north of 55° in the following analyses.



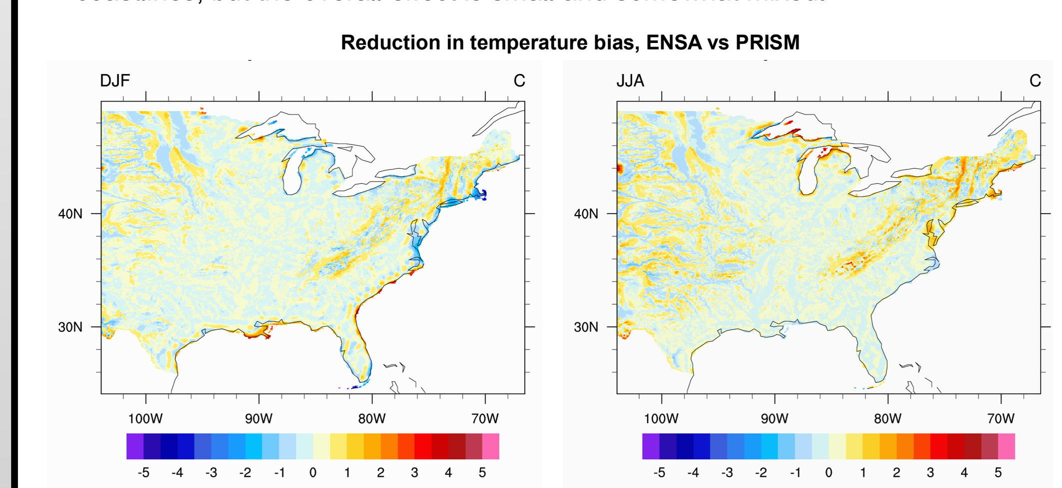
PRECIPITATION

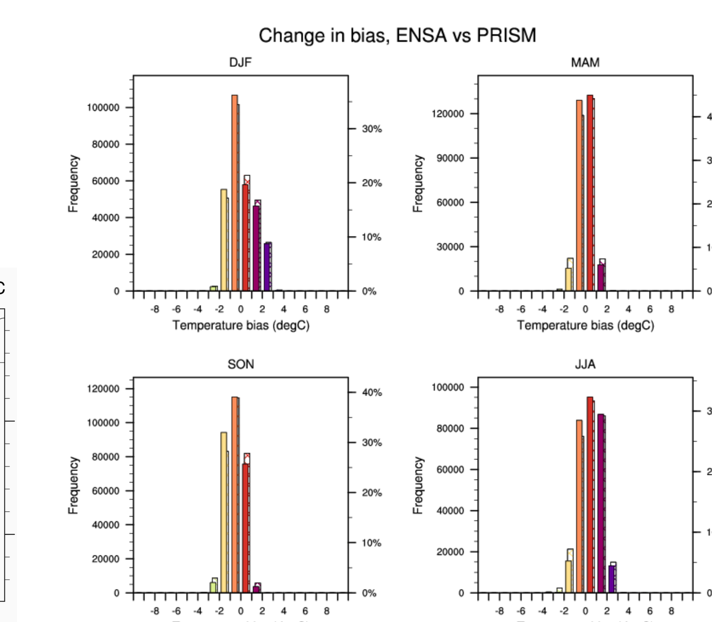
Although precipitation is indirectly influenced by elevation, interpolation with correction shows no appreciable improvement. The figure at right is typical of the effects for all models and seasons.



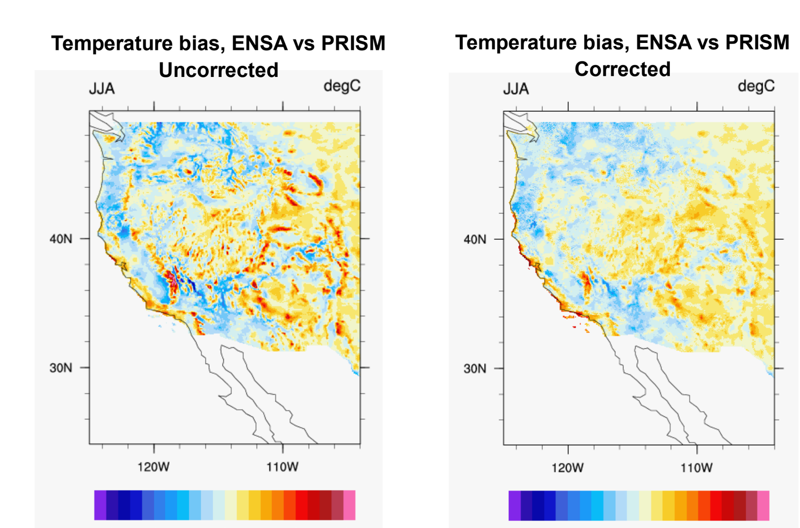
BIAS REDUCTION vs PRISM—PLAINS

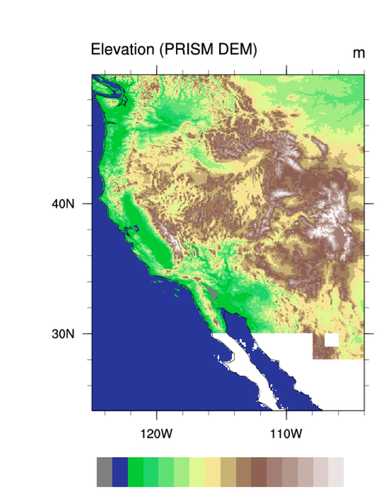
Reduction in bias against the PRISM observational dataset due to correction is considerably different west and east of longitude 104W. These figures show seasonal bias reduction over the comparatively flat eastern U.S.. There are some improvements, attributable to better resolution of the Appalachians and coastlines, but the overall effect is small and somewhat mixed.

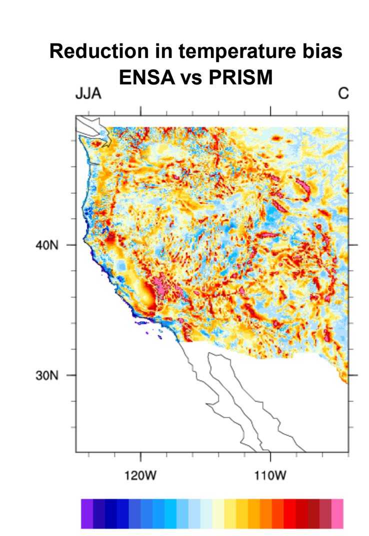




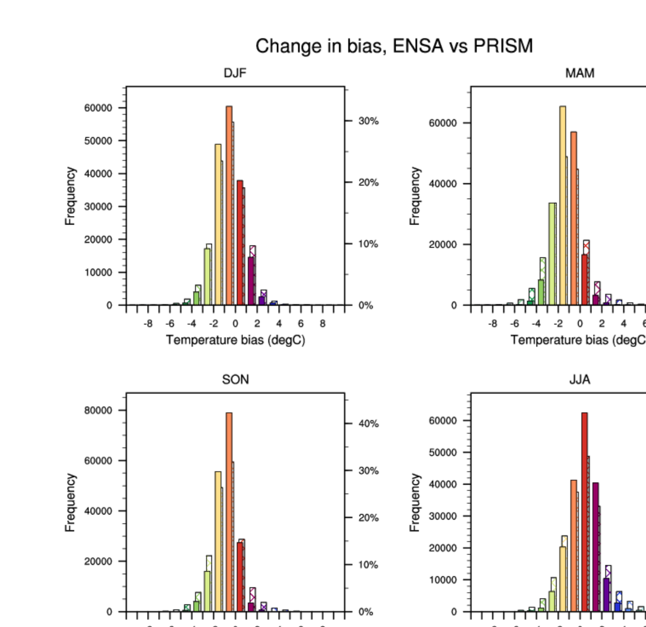
BIAS REDUCTION vs PRISM—MOUNTAINS







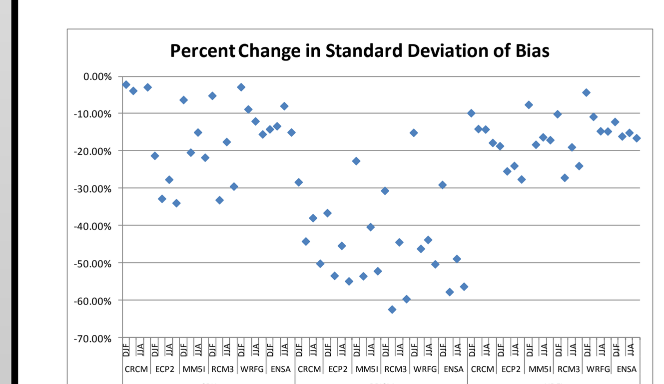
In the mountainous western U.S., bias reduction due to elevation correction when interpolating to higher resolution (50 km to 4 km) is clear. The figures at left show bias and bias reduction for summer; the reduction of bias in other seasons is comparable. Elevation is also shown. Note that improvements occur both at high and low elevations, and for both under- and over-estimates. The mean bias across the region (i.e., location of the histogram peak) does not always shift closer to zero, but in all cases the spread decreases (i.e., the histogram narrows).

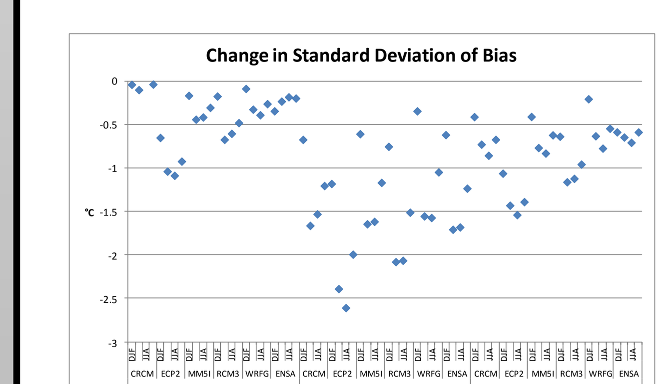


CONCLUSION: YES, IT MATTERS*

(*For temperature, but not precipitation, and more in the mountains than in the plains.)

Elevation correction produces small but noticeable improvements when interpolating between grids at the same scale, and more significant improvements when interpolating to higher resolution. The figures below show the changes due to correction for the western subdomain. The CRU/UDEL bias standard deviations drop by 0.5–1°C, around 15% on average, while PRISM bias standard deviations drop on average by nearly 1.5 °C, around 44%.





CITATIONS

CRU: Mitchell, T.D., 2004: *CRU TS 2.10*, Climatic Research Unit, University of East Anglia. Downloaded August 2008. http://www.cru.uea.ac.uk/cru/data/hrg/cru_ts_2.10

NARCCAP: Mearns, L.O., et al., 2007, updated 2011. *The North American Regional Climate Change Assessment Program dataset*, National Center for Atmospheric Research Earth System Grid data portal, Boulder, CO. Data accessed 2011-01-07. http://www.earthsystemgrid.org/project/NARCCAP.html

PRISM: Daly, Chris, Wayne Gibson, and George Taylor, 2002, updated 2011: *103-Year High-Resolution Precipitation Climate Data Set for the Conterminous United States*, The PRISM Climate Group. Downloaded July 2011. ftp://ftp.ncdc.noaa.gov/pub/data/prism100

TPS interpolation: Furrer, Reinhard, Douglas Nychka, and Stephen Sain, 2011: *fields: Tools for spatial data*, R package version 6.5.2. http://www.image.ucar.edu/Software/Fields

UDEL: Matsuura, K. , and C. Willmott, 2009: *Terrestrial Air Temperature and Precipitation: 1900-2008 Gridded Monthly Time Series (V 2.01)*, Center for Climatic Research, Department of Geography, University of Delaware. Downloaded April 2010. http://climate.geog.udel.edu/~climate/html_pages/archive.html