

GRASS Geographic Information Systems and climate modeling in the Southwest United States

By Aaron Goldner

SURE undergraduate research

GCEP

Why do this research?

- To use model simulations from IPCC in order to create climate maps that could implicate future climate for the Southwest United States.
- Illustrating that GRASS is an effective way to gather a lot of climate data for quick analysis.
- Hydrology groups, energy consulting firms, and other environmental agencies already use GIS, so creating available map sets with climate data increases efficiency.

Using GRASS and UNIX command line

■ GRASS GIS

- Geographical information systems(GIS). Raster, topological vector, and graphics production.
- I was introduced UNIX c-shell to command the GRASS program for my data manipulation.

```

Terminal - csh - 80x
00035.ppm 3d00036.tif 3d00117.tif
00036.ppm 3d00037.tif 3d00118.tif
00037.ppm 3d00038.tif 3d00119.tif
00038.ppm 3d00039.tif Desktop
00039.ppm 3d00040.tif Documents
00040.ppm 3d00041.tif Library
00041.ppm 3d00042.tif Movies
00042.ppm 3d00043.tif Music
00043.ppm 3d00044.tif Pictures
00044.ppm 3d00045.tif Public
00045.ppm 3d00046.tif Sites
00046.ppm 3d00047.tif ar4
00047.ppm 3d00048.tif globe_setenv.grc
00048.ppm 3d00049.tif grd3
00049.ppm 3d00050.tif help
00050.ppm 3d00051.tif q
00051.ppm 3d00052.tif spgrass6 notes.pdf
00052.ppm 3d00053.tif sw_final.png
00053.ppm 3d00054.tif typescript
00054.ppm 3d00055.tif
3d00000.ppm 3d00056.tif

Mapset <-PERMANENT> in Location <-Final_GLOBE>
GRASS 6.3.cvs >

```

File Config Raster Vector Imagery Grid3D Databases Help

Map Layers for Display 1

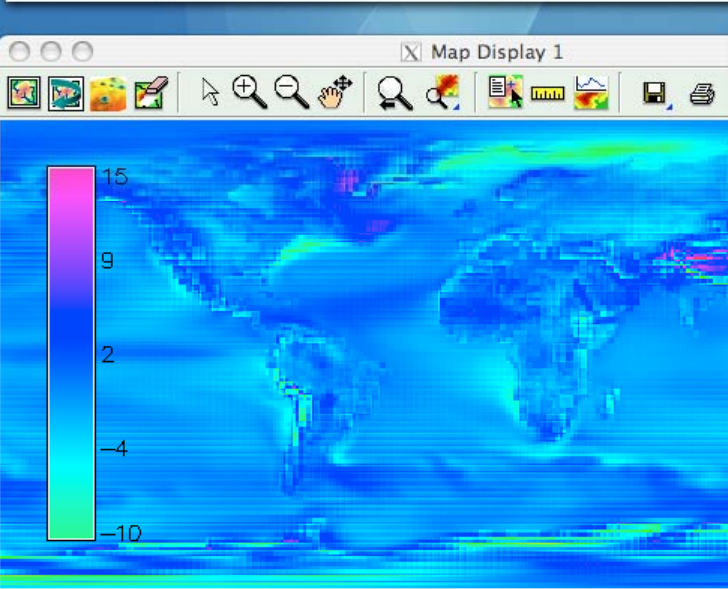
- legend for era_ncartemp_eratemp_1958_1972@PERMANENT
- era_ncartemp_eratemp_1958_1972@PERMANENT

109245-tele_area...amer.kmz

Macintosh HD

gis

workspace



number of lines (U=display all): |U| invert legend

interval between categories (integer maps) 1

draw smooth gradient (fp maps) with maximum of 5

Display legend for subset of raster values

skip categories with no labels

legend for only these categories

legend for only this range of values -10,15

xterm

-rw-r--r--	1	aaron	aaron	640404	Jul	6	09:38	3d00113.tif
-rw-r--r--	1	aaron	aaron	640404	Jul	6	09:38	3d00114.tif
-rw-r--r--	1	aaron	aaron	640404	Jul	6	09:38	3d00115.tif
-rw-r--r--	1	aaron	aaron	640404	Jul	6	09:38	3d00116.tif
-rw-r--r--	1	aaron	aaron	640404	Jul	6	09:38	3d00117.tif
-rw-r--r--	1	aaron	aaron	640404	Jul	6	09:38	3d00118.tif
-rw-r--r--	1	aaron	aaron	640404	Jul	6	09:38	3d00119.tif
drwxr-xr-x	15	aaron	aaron	510	Aug	1	08:06	Desktop/
drwxr-xr-x	5	aaron	aaron	170	Jun	27	11:59	Documents/
drwxr-xr-x	32	aaron	aaron	1088	Jul	17	12:27	Library/
drwxr-xr-x	3	aaron	aaron	102	Dec	31	1969	Movies/
drwxr-xr-x	3	aaron	aaron	102	Dec	31	1969	Music/
drwxr-xr-x	5	aaron	aaron	170	Jul	16	12:16	Pictures/
drwxr-xr-x	4	aaron	aaron	136	Dec	31	1969	Public/
drwxr-xr-x	5	aaron	aaron	170	Dec	31	1969	Sites/
-rw-r--r--	1	aaron	aaron	0	Jun	19	10:33	ar4
-rw-r--r--	1	aaron	aaron	632	Jul	2	13:32	globe_setenv.grc
-rw-r--r--	1	aaron	aaron	131327	Jun	28	12:21	grd3
-rw-r--r--	1	aaron	aaron	1142	Jul	11	16:35	help
-rw-r--r--	1	aaron	aaron	1142	Jul	11	16:35	q
-rw-r--r--	1	aaron	aaron	1142	Jul	11	16:35	spgrass6 notes.pdf*
-rw-r--r--	1	aaron	aaron	1142	Jul	10	15:15	sw_final.png
-rw-r--r--	1	aaron	aaron	1142	Jul	11	16:35	typescript

Output - GIS.m

d.legend map=era_ncartemp_eratemp_1958_1972@PERMANENT color=black lines=0 thin=1 labelnum=5 at=10,90,5,10 range=-10,15

! PNG: GRASS_TRUECOLOR status: TRUE

! PNG: collecting to file: /Volumes/ar4/gis/Final_GLOBE/PERMANENT/.tmp/moraine.lanl.gov/2369.0.ppm.

! GRASS_WIDTH=642, GRASS_HEIGHT=321

g.pnmcomp in=2369.2.ppm,2369.3.ppm mask=2369.2.pgm,2369.3.pgm opacity=1.0,1.0 background=255:255:255 width=642 height=321 output=2369.1.ppm

Save Clear

lesstif-0.93.91

r.info.webloc

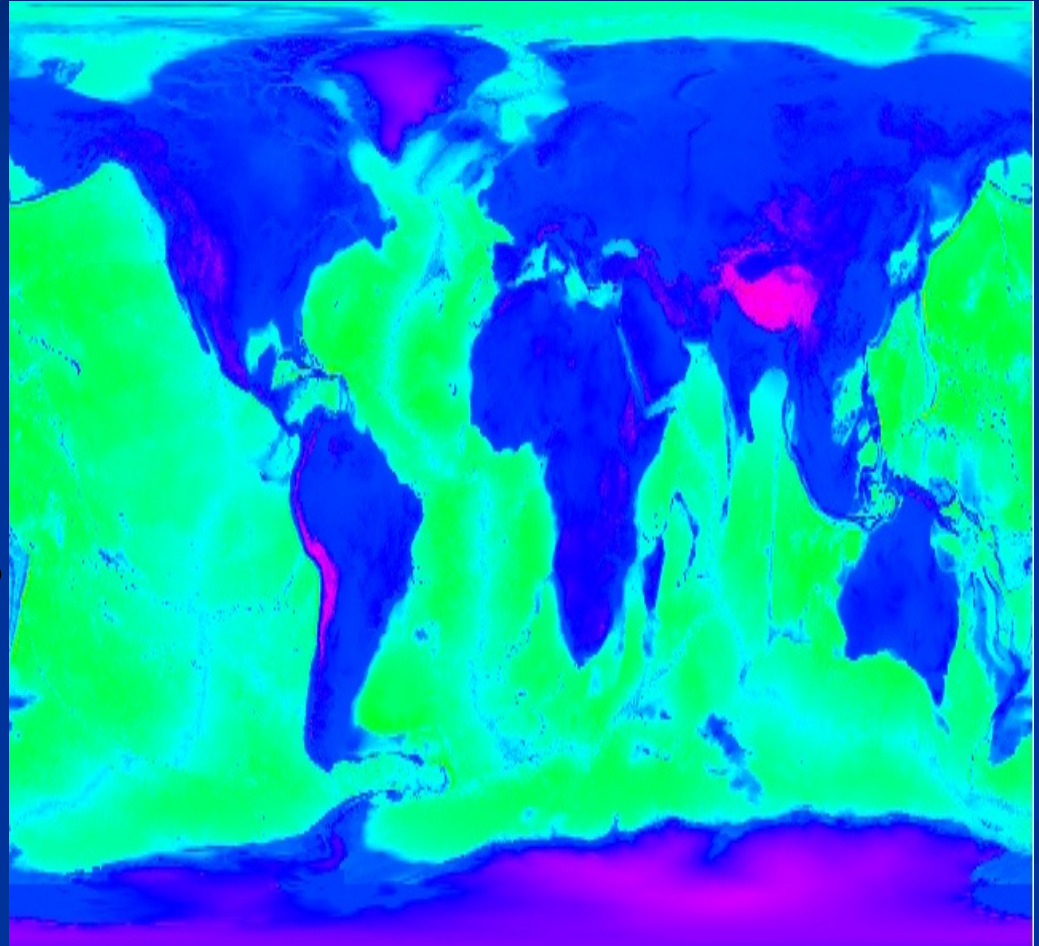
109245-tele_area...er-1.kmz

Picture 1

How to take a screenshot on Mac OS X

Georeferencing in GRASS

- The data came without a projection.
- I used netcdf conversion formulas and projection programs within grass to give my data a projection.



Example script for c-shell

```
r.in.gdal -o input=/Volumes/ar4/ERA_TEST/Dec.tif output=winter2
r.in.gdal -o input=/Volumes/ar4/ERA_TEST/Dec1.tif output=winter3
r.in.gdal -o input=/Volumes/ar4/ERA_TEST/Dec2.tif output=winter4
r.in.gdal -o input=/Volumes/ar4/ERA_TEST/Feb1.tif output=winter5
r.in.gdal -o input=/Volumes/ar4/ERA_TEST/Feb2.tif output=winter6
r.in.gdal -o input=/Volumes/ar4/ERA_TEST/jan.tif output=winter7
r.in.gdal -o input=/Volumes/ar4/ERA_TEST/jan1.tif output=winter8
r.in.gdal -o input=/Volumes/ar4/ERA_TEST/jan3.tif output=winter9
r.in.gdal -o input=/Volumes/ar4/ERA_TEST/Feb.tif output=winter10
```

```
foreach raster ( "`g.mlist rast pattern='winter*' sep=,`" )
r.series input=$raster output=era_djf method=average
g.mremove -f ("winter*")
r.mapcalc era_djf_2mtemp="era_djf"/132
```

!!Spring Average!!

```
ncks -F -d initial_time3,3,,12 -v 2T_GDS0_SFC_123 sfc.1958-1972.nc 58.nc
ncks -F -d initial_time3,3,,12 -v 2T_GDS0_SFC_123 sfc.1973-1987.nc 73.nc
ncks -F -d initial_time3,3,,12 -v 2T_GDS0_SFC_123 sfc.1988-2001.nc 88.nc
```

```
gdal_translate NETCDF:"58.nc":2T_GDS0_SFC_123 Mar.tif -a_srs WGS84 -a_ullr -180 90 180 -90
rm 58.nc
```

```
gdal_translate NETCDF:"73.nc":2T_GDS0_SFC_123 Mar1.tif -a_srs WGS84 -a_ullr -180 90 180 -90
rm 73.nc
```

```
gdal_translate NETCDF:"88.nc":2T_GDS0_SFC_123 Mar2.tif -a_srs WGS84 -a_ullr -180 90 180 -90
rm 88.nc
```

```
ncks -F -d initial_time3,4,,12 -v 2T_GDS0_SFC_123 sfc.1958-1972.nc 4.nc
ncks -F -d initial_time3,4,,12 -v 2T_GDS0_SFC_123 sfc.1973-1987.nc 5.nc
ncks -F -d initial_time3,4,,12 -v 2T_GDS0_SFC_123 sfc.1988-2001.nc 6.nc
```

```
gdal_translate NETCDF:"4.nc":2T_GDS0_SFC_123 Apr.tif -a_srs WGS84 -a_ullr -180 90 180 -90
```

IPCC simulations used

A1B

- Has increasing greenhouse gas concentrations up to 720 ppm. Time scale 2000-2099.

20c3M

- Simulates 19th and 20th century temperature data from 1870-1999.

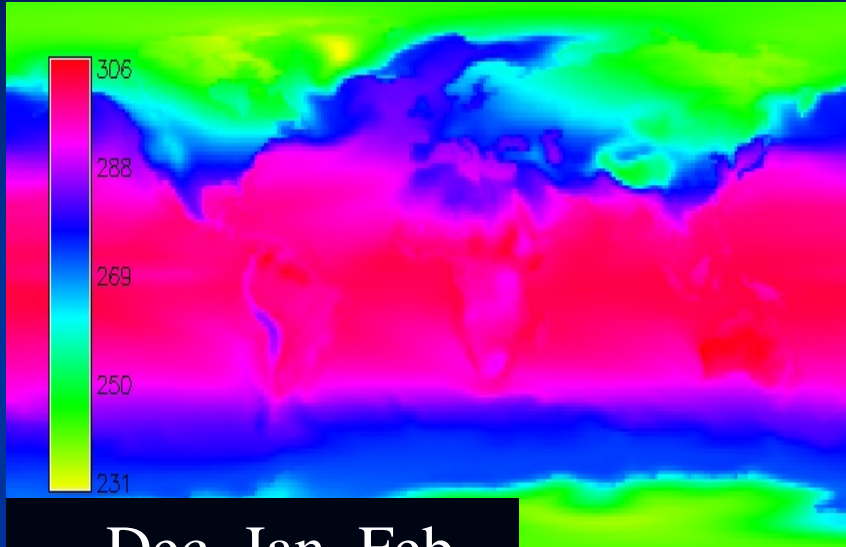
Picntrl

- Pre-industrial data simulation, that uses fixed levels of greenhouse gases and natural amounts of sulfate.

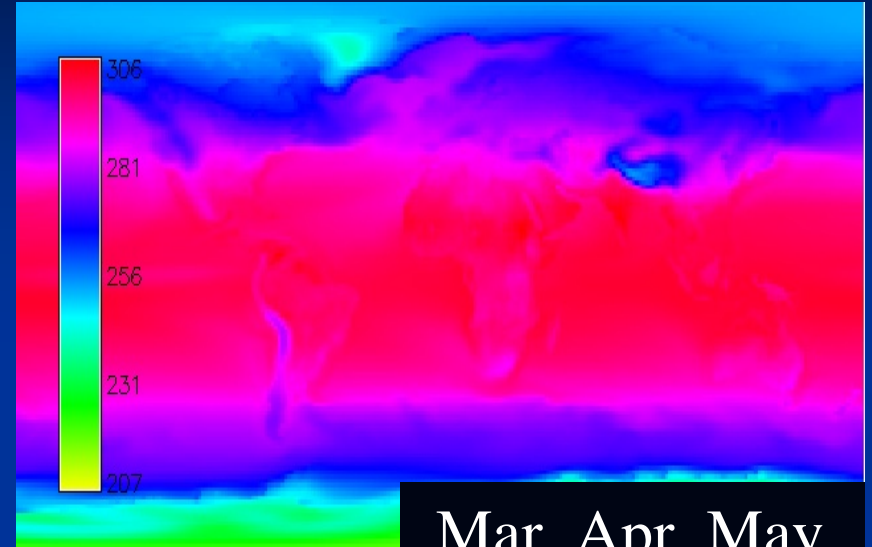
IPCC Models

- Ncar
 - National Center Atmospheric Research. The majority of my maps are based off of the NCAR model.
- Ukmo_hadcm3
 - I created a couple maps based off the ukmo_hadcm3 model to compare and contrast results. Created by the Hadley Research Center.

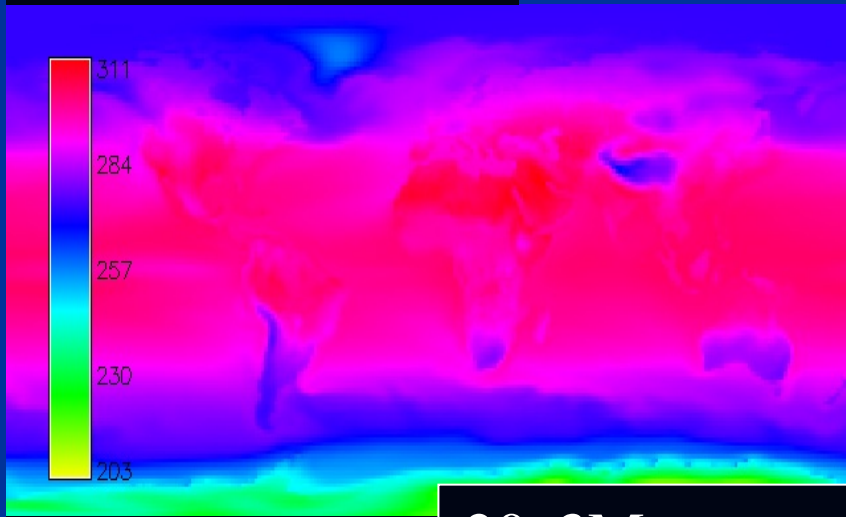
My climate maps started global Seasonal Maps 1870-1999



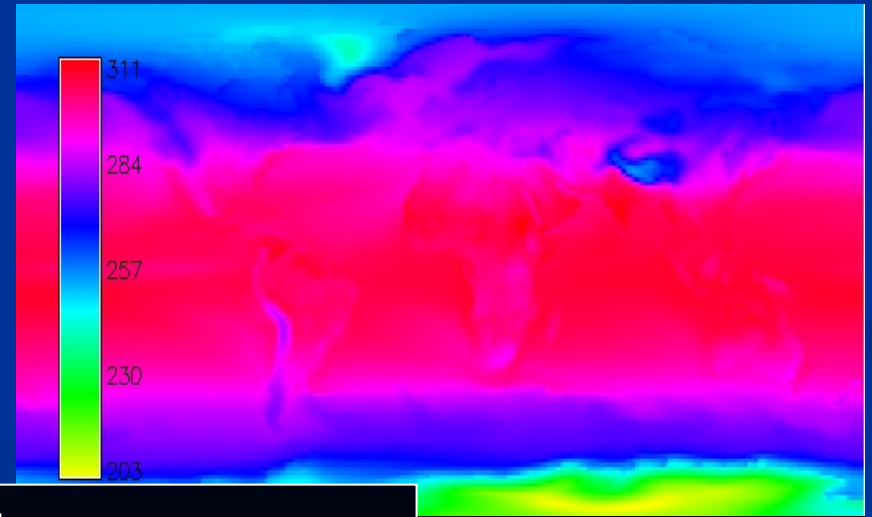
Dec, Jan, Feb



Mar, Apr, May



Jun, Jul, Aug

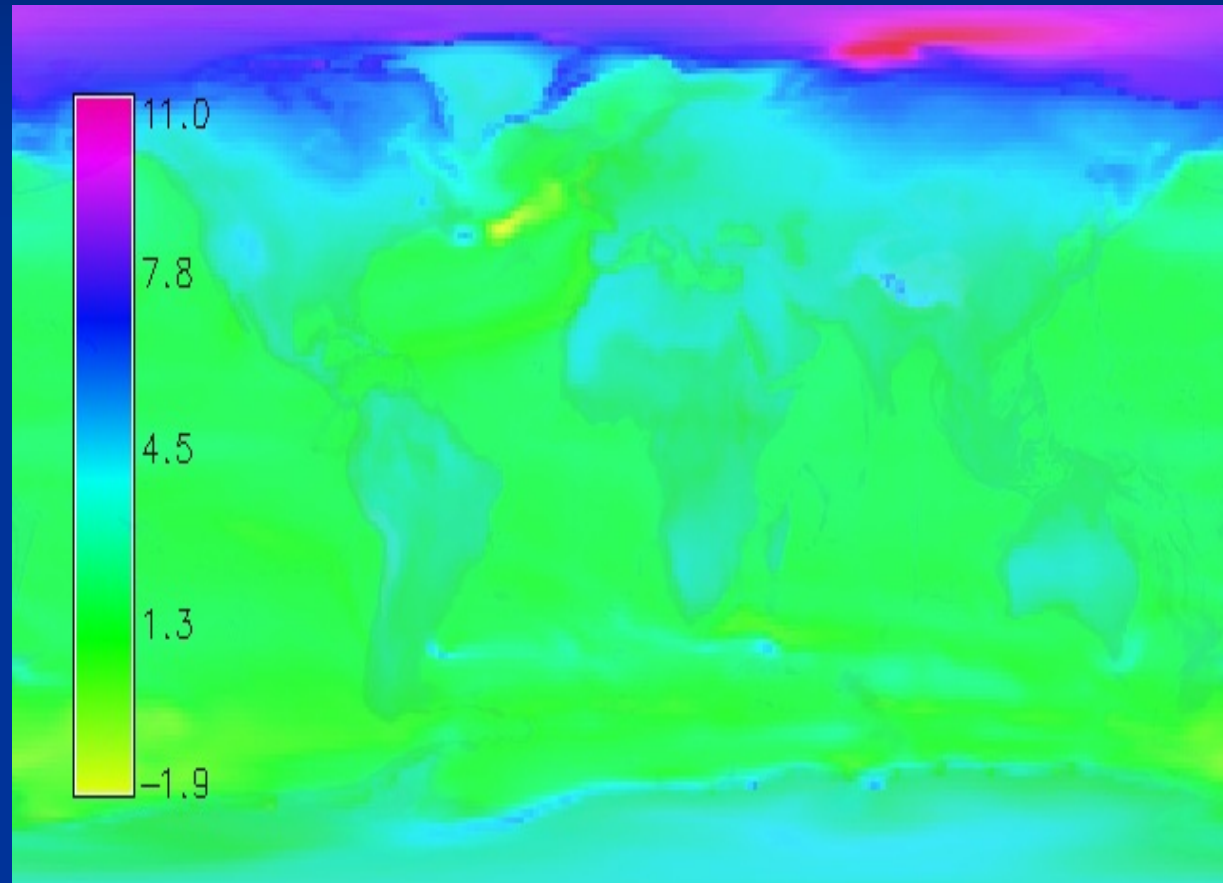


Sept, Oct, Nov

20c3M seasonal temp averages

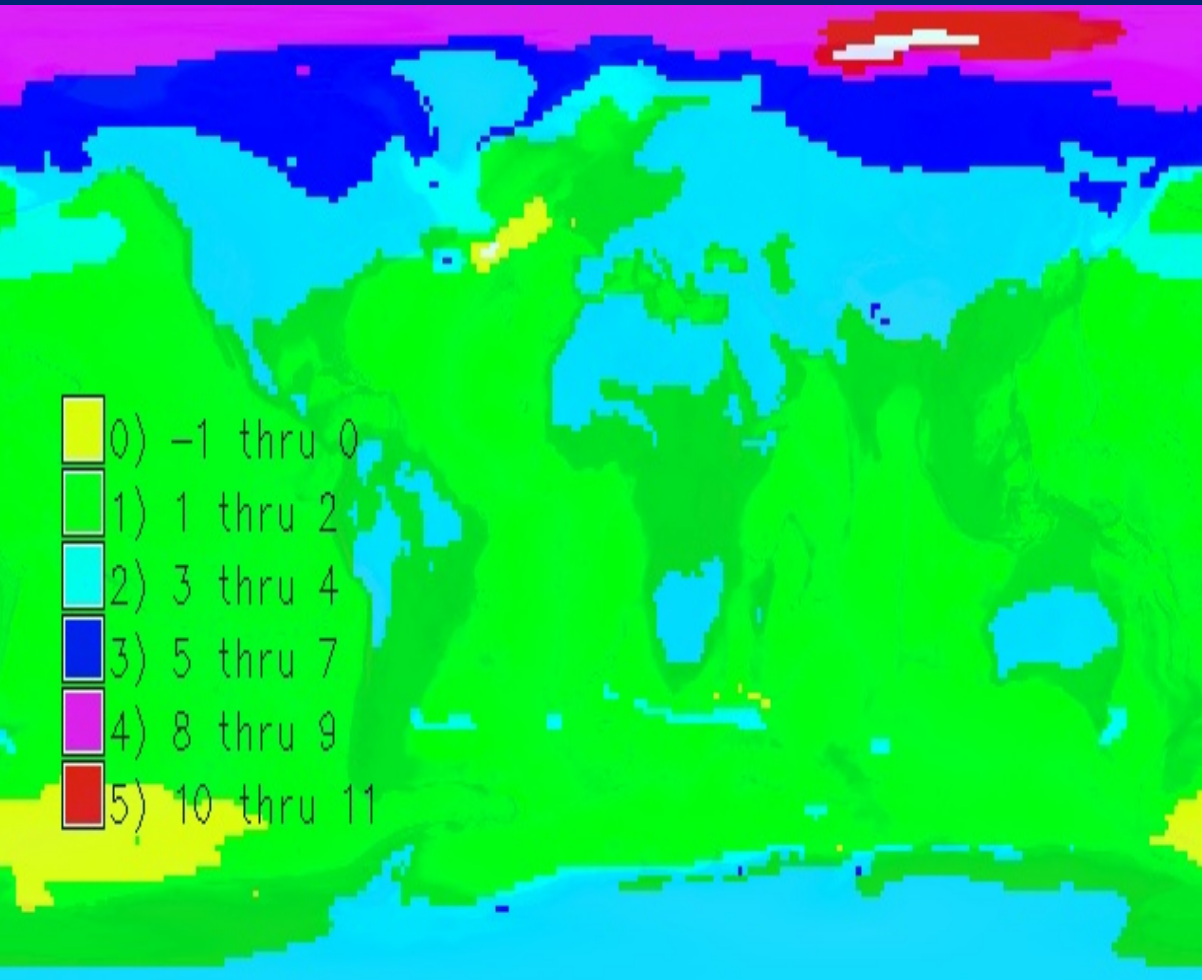
Creating mean temperature differences between 2069-2099 and Pre-Industrial

global change	Temperature change
min	-1.9454 k
max	12.6693 k
range	14.6429 k
mean	2.7266 k



(A1B 2m-temp 2069-2099)- (Picntrl 2m-temp simulation)

Rescaling and Picture Development

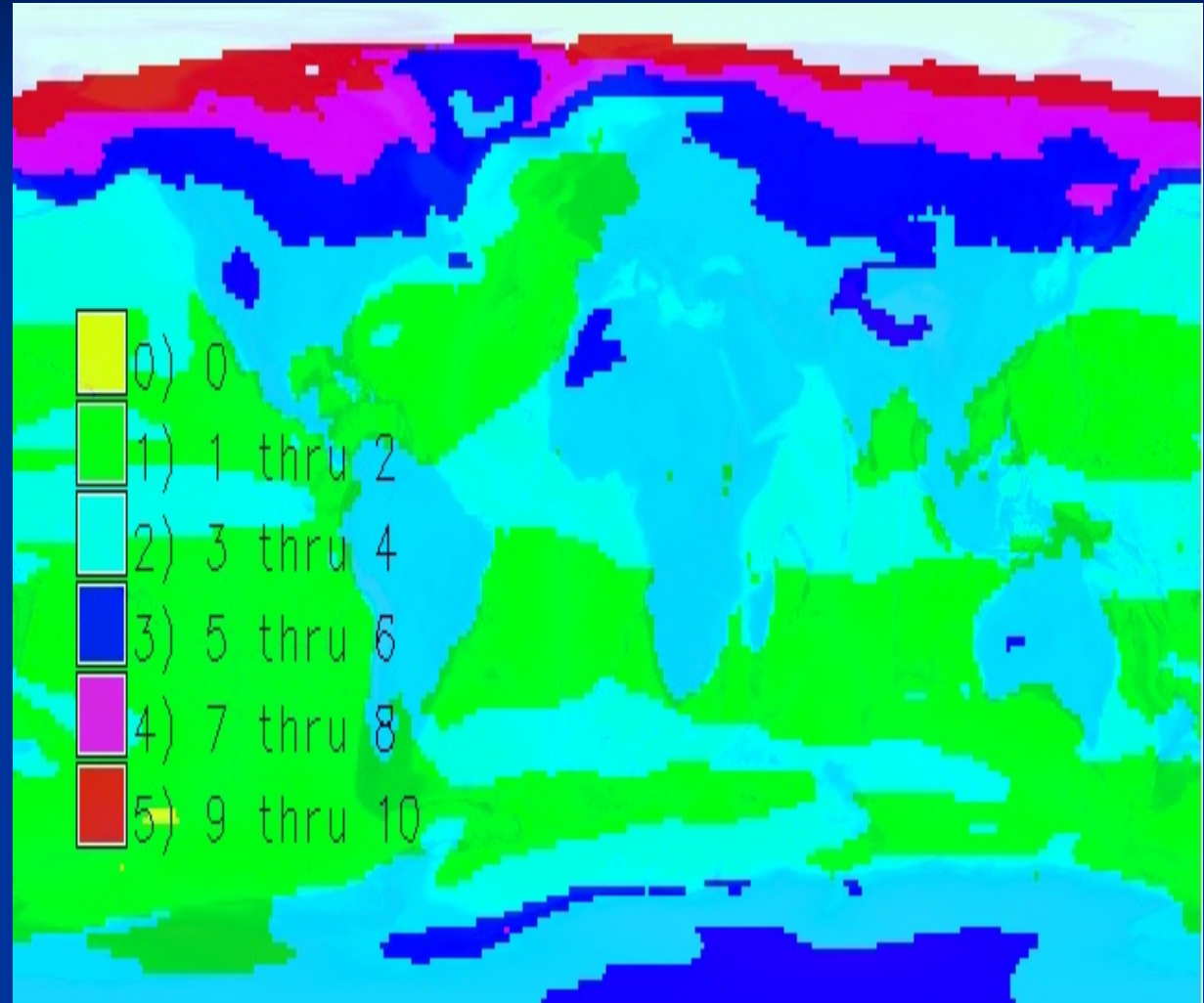


- Shows averages over areas of the globe. Using a rescale technique
- This is SRES a1b (2069-2099) subtracted from the Pre-industrial temperature averages

Units in Kelvin

But that is just one Model!

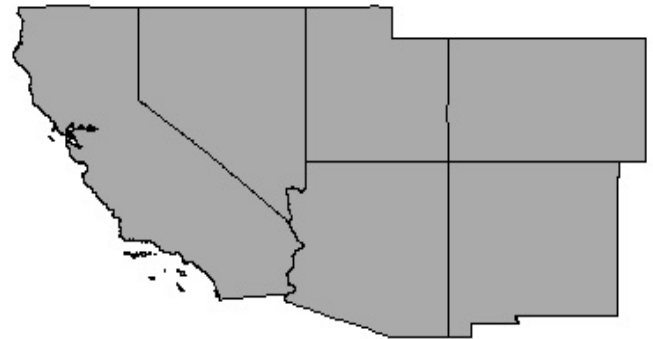
- Using the ukmo_hadcm3 model (1870-1999). Global mean temperature could change from **3.3964** degrees Kelvin in 2099.



(Sres a1b)-(ukmo_hadcm3) units in Kelvin

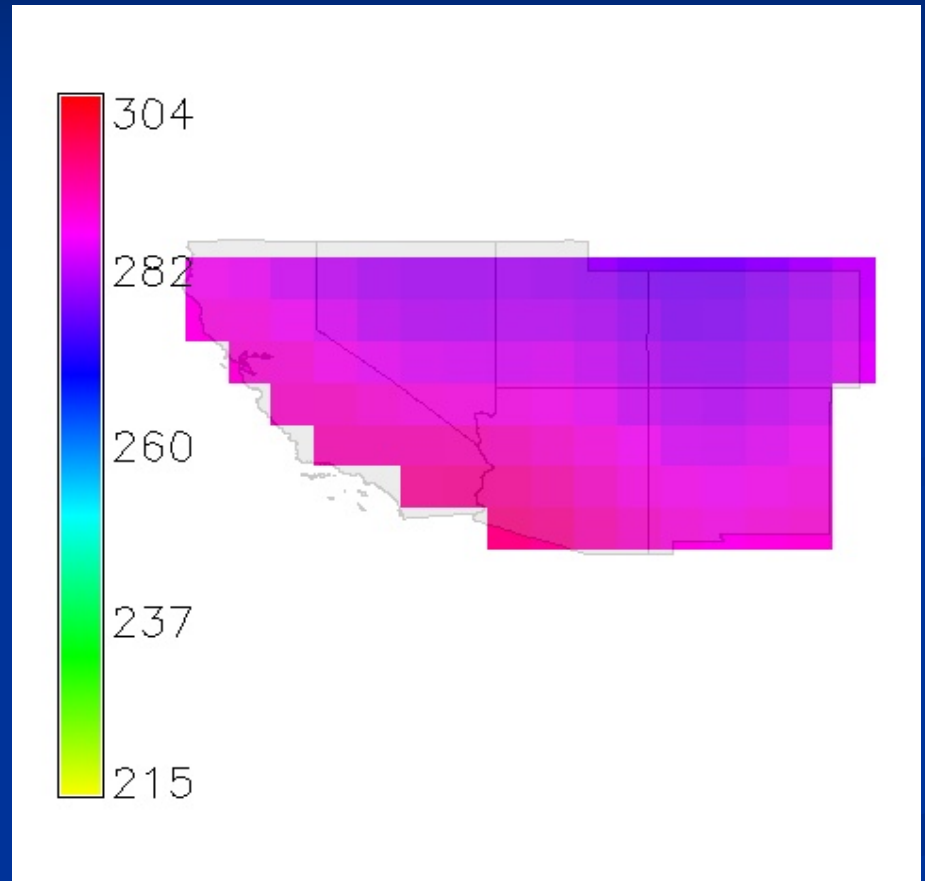
Greater Southwest United States

- Next I began analysis on the Southwest United States.
- This is a vector map of the greater Southwest United States.
- I used a program called r.mask inside of grass to create my climate maps.



Creating basic temperature and precipitation maps of the Southwest

- This is a raster map of the greater southwest representing mean temperature between 1870-1999.
- Now lets see what happens when we take this mean temperature map and subtract them from the possible SRES 1AB data.



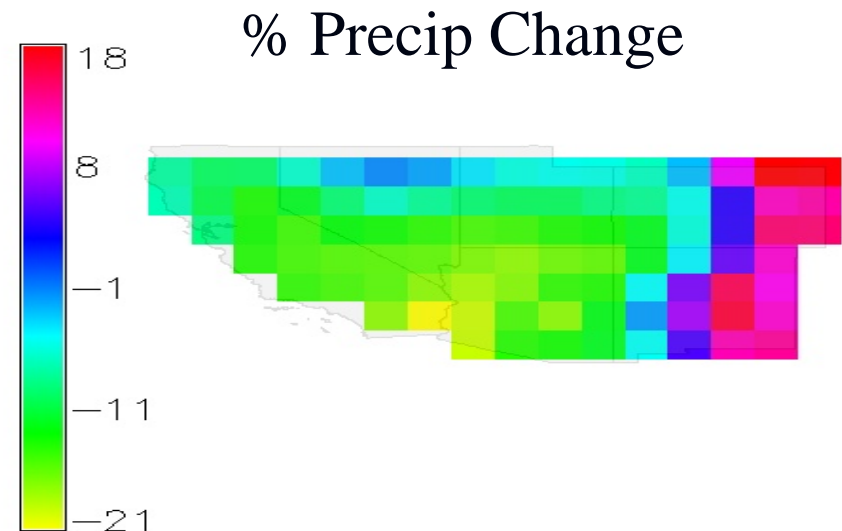
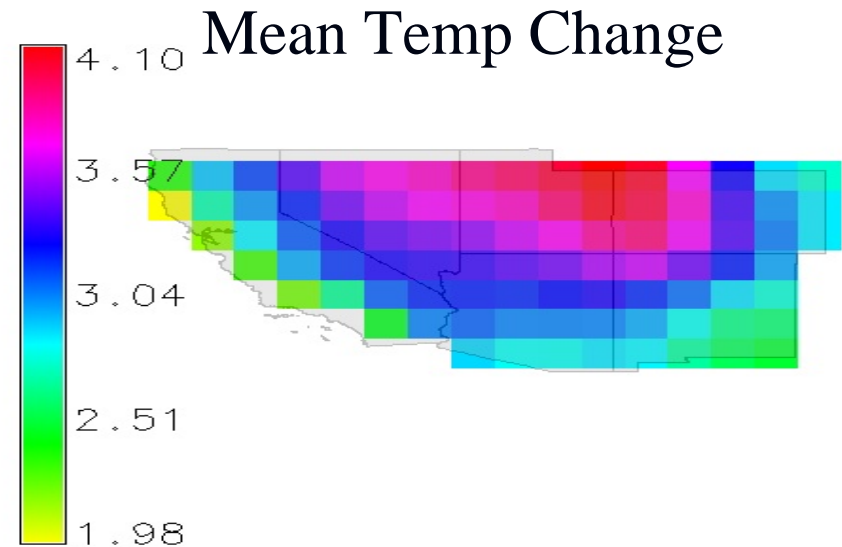
Mean temperature map degrees Kelvin from near model 1870-1999

What could be in 2099

2 m surface temp (sres 1ba)-(pre_industrial temp)	
minimum	1.98 k
maximum	4.09 k
range	2.115 k
mean	3.19693 k

	Mean Precip (Sres a1b)-(pre_indst
Fractional Change	
mean %	-6.25%
range %	38.57%

Near simulation used (SRES1AB 2069-2099) subtracted by (the pre-industrial averages).



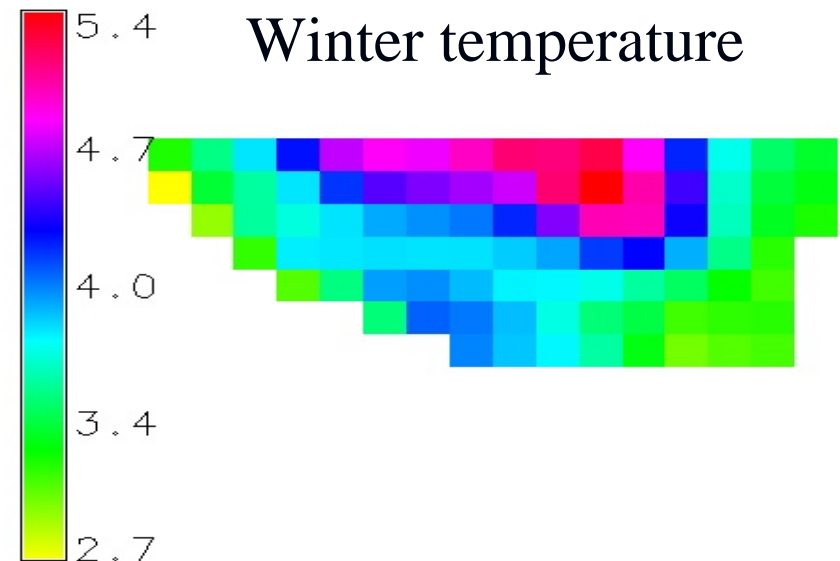
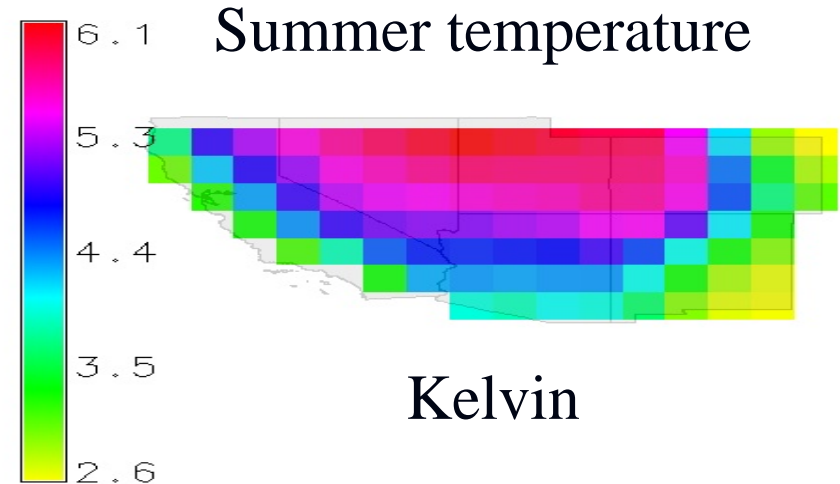
Summer/Winter Differences

2 meter temperature	Summer temperature SW
min	2.57593 k
max	6.14993 k
range	3.57401 k
mean	4.55739 k

2 meter temperature	Summer temperature SW
min	2.57593 k
max	6.14993 k
range	3.57401 k
mean	4.55739 k

(A1B 2069-2099)-(Pre_indust)

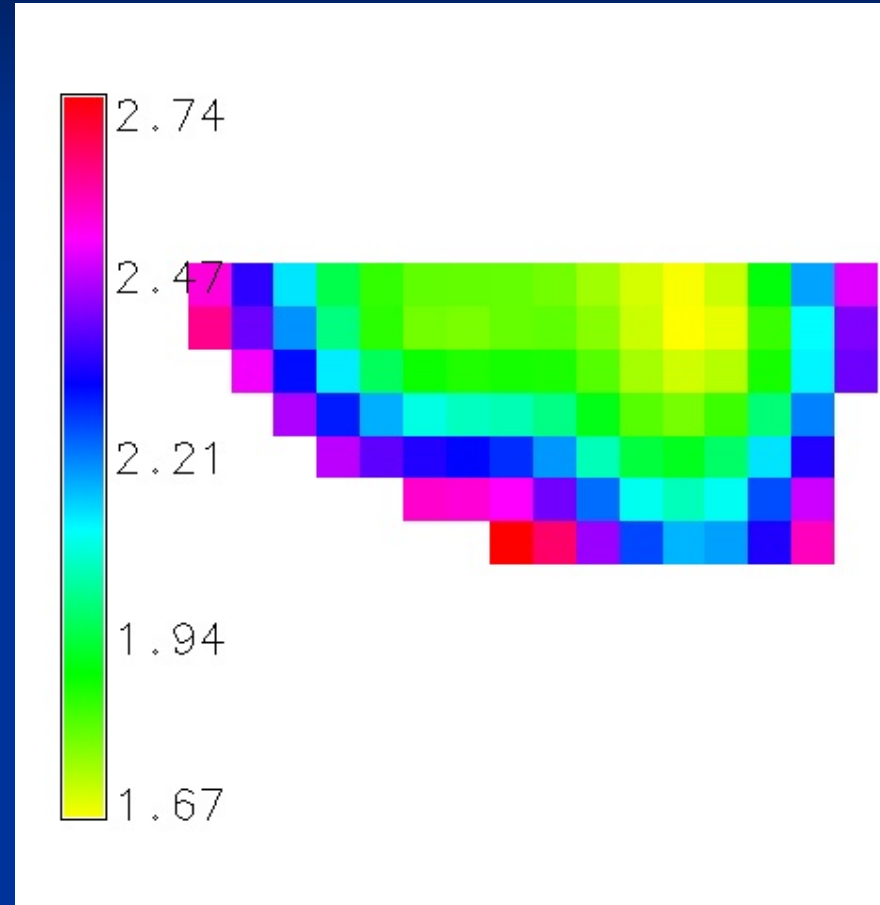
Temperature degrees Kelvin



Precipitable water change SW

- Same simulations taking SRES a1b 30 year average for precipitable water minus pre_industrial average for precipitable water.

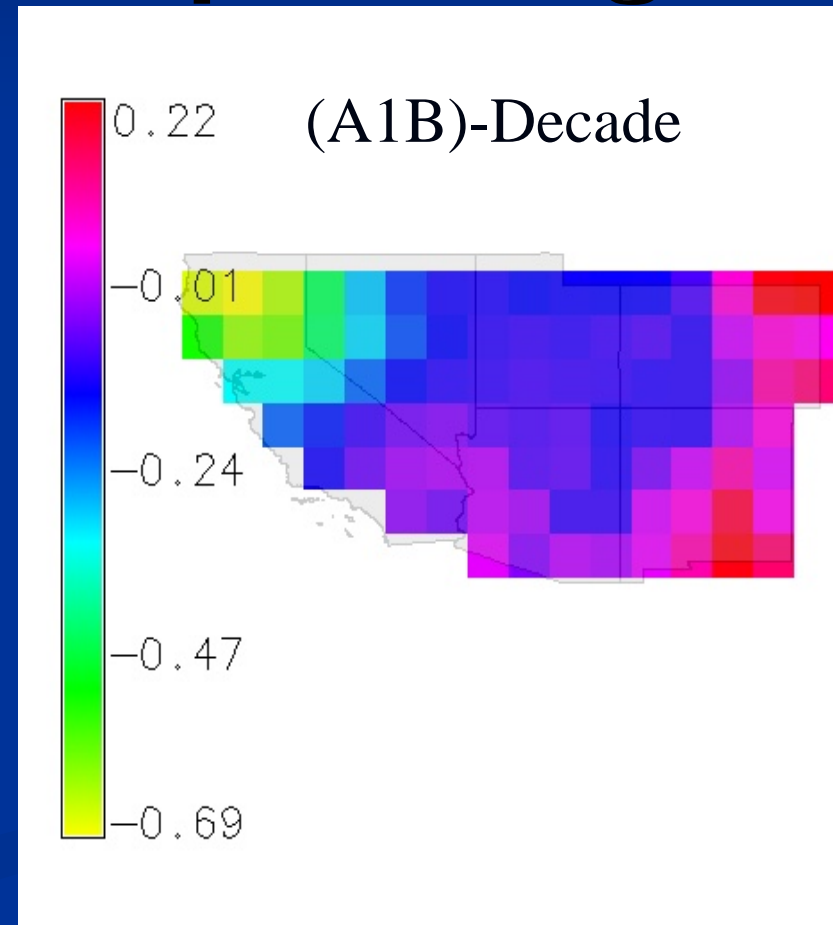
precipitable water	mean difference
min	1.67232 kg/m squared
max	2.74124 kg/m squared
range	1.06891 kg/m squared
mean	2.09135 kg/m squared



Units are in kg/meters squared

Decadal Averages from 1870-1999 20C3M simulation minus A1B 2069-2099 precip averages

decade	Fractional change	Mean Change
1880	-6.70%	-.082 mm/day
1890	-6.85%	-.069 mm/day
1900	-7.94%	-.0870 mm/day
1910	-14.70%	-.2076 mm/day
1920	-6.60%	-.0795 mm/day
1930	-9.80%	-.1158 mm/day
1940	-1.40%	-.00048 mm/day
1950	-4.60%	-.0524 mm/day
1960	-8.60%	-.1063 mm/day
1970	-9.30%	-.1122 mm/day
1980	-7.20%	-.1158 mm/day
1990	-9.90%	-.1181 mm/day
1999	-1.80%	-.00319 mm/day



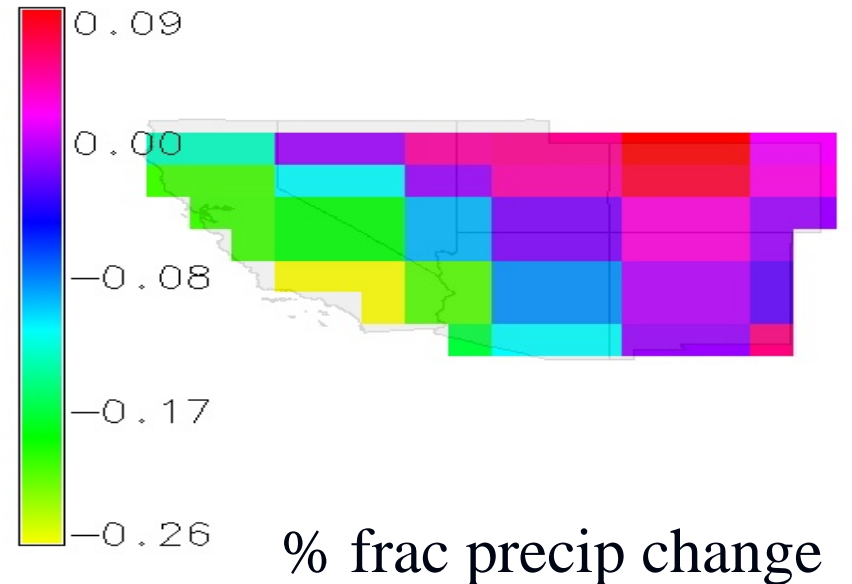
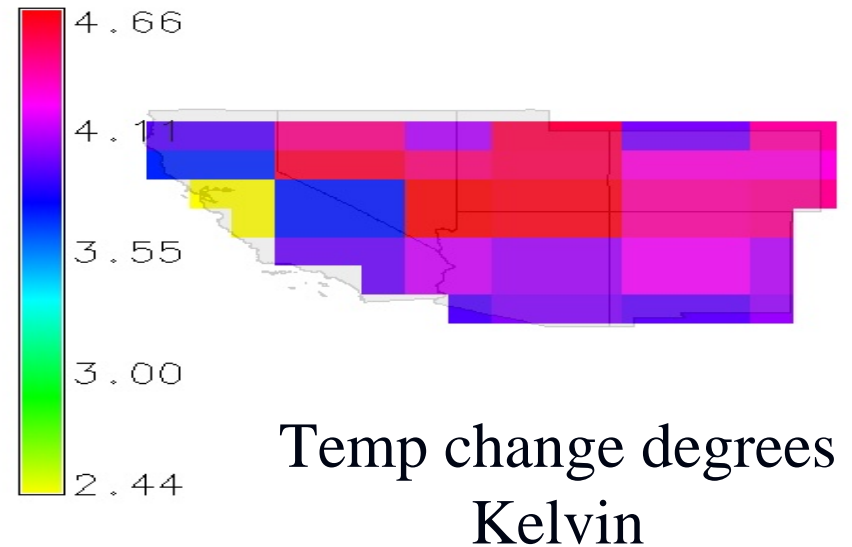
Units mm/day Mean change Precip

Ukmo Model Comparison

ukmo simulation	(a1b)-(pre_industrial temp)
min	2.4406 degrees Kelvin
max	4.66422 degrees Kelvin
range	2.22415 degrees Kelvin
mean	4.15805 degrees Kelvin

ukmo simulation	(a1b)-(pre_indust precip)
min	-25%
max	9%
range	35%
mean	-5.927%

Ukmo model for mean temp and precip diff (A1B-Pre-industrial)



Conclusions

- GRASS GIS is able to manipulate over 6000 raster climate files, quick and effectively.
- Using the Ncar and Ukmo models and the A1B, 20c3m, and Pictrnl simulations. The temperature in the Southwest United States is predicted to increase, precipitation is predicted to decrease, and precipitable water is predicted to increase.
- At LANL putting climate data inside of GRASS GIS has connected T-3 with the energy infrastructure modeling group. This group is going to use climate data to put together a model of the worlds energy use and its connection to climate change.

Future Questions

- What will different simulations of the IPCC A1,B1, and A1C show for the future climate of the Southwest United States?
- How accurate are the smaller scale climate simulations?
- When compared to observed climate data how accurate are these simulations?

Special Thanks

- To Department of Energy
- GCEP program and administration
- Los Alamos National Laboratory
- Todd Ringler T-3 Fluid Dynamics
- COSIM group (climate ocean and ice modeling group)

References

- NCO Unidata:
<http://www.unidata.ucar.edu/software/netcdf/software.shtml#NCO.2007>
- Seamless <http://seamless.usgs.gov/2007>
- NCAR Science and Research Data for IPCC AR4 http://eos-website.sr.unh.edu/data_guides/ci_science_dg.jsp.