North American Drought

Michael F. Wehner
Lawrence Berkeley National Laboratory
mfwehner@lbl.gov

CCSM workshop
Breckenridge, CO
June, 2008

Collaborators: Dave Easterling, Jay Lawrimore, Richard.Heim, Russell Vose, Ben Santer

From http://www.drought.noaa.gov/palmer.html

- The Palmer Index is most effective in determining long term drought—a matter of several months—and is not as good with short-term forecasts (a matter of weeks). It uses a 0 as normal, and drought is shown in terms of minus numbers; for example, minus 2 is moderate drought, minus 3 is severe drought, and minus 4 is extreme drought.
- The Palmer Index can also reflect excess rain using a corresponding level reflected by plus figures; i.e., 0 is normal, plus 2 is moderate rainfall, etc.

PDSI deficiencies

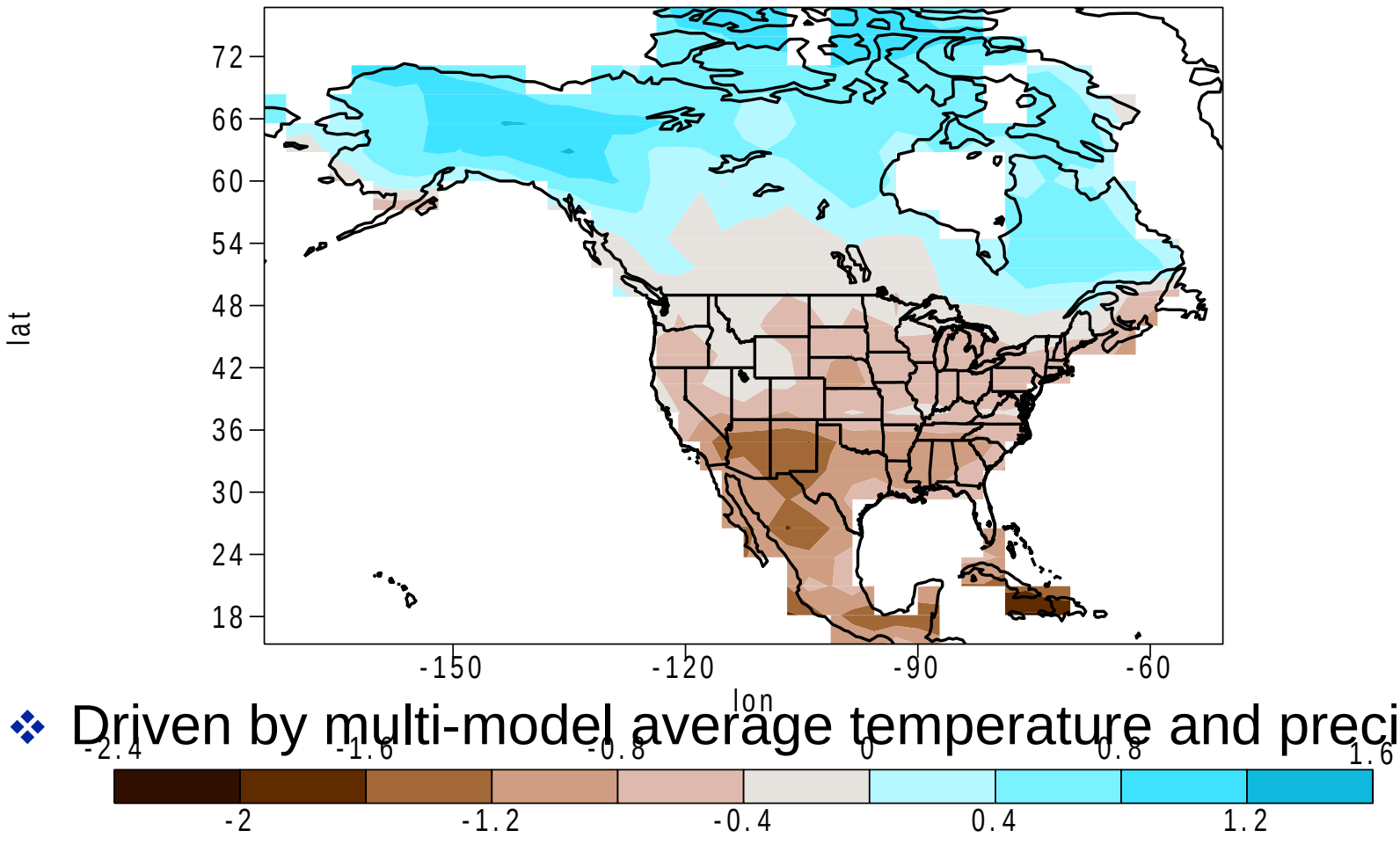
- PDSI is often criticized.
  - A valid criticism is that the surface moisture model is unsophisticated. Evaporation may be overly sensitive to temperature.
  - However, for a cross model comparison study, this weakness becomes a strength.
  - GCMs vary greatly in their surface hydrology models.
  - Applying the simpler Palmer model to all the GCMs allows a uniform comparison of different climate models.

Palmer Drought Severity Index

- Code is a slightly modified version of that used by NOAA to calculate the official PDSI map.
  - Highly accurate surface characteristics.
- Driven by monthly mean surface air temperature and precipitation from the IPCC AR4 models
  - Used 19 models. Regridded to T42 prior to the PDSI calculation.
    - Calculate each realization separately.
    - Reference period is each models 1950-1999 ensemble mean
- 20C3M and SRES A1B scenarios.
- Compare to PDSI results driven by NCDC US observations and GPCP/HADCRUTv

Palmer Drought Severity Index

- End of 21st Century (A1B) relative to 1950-1999 average



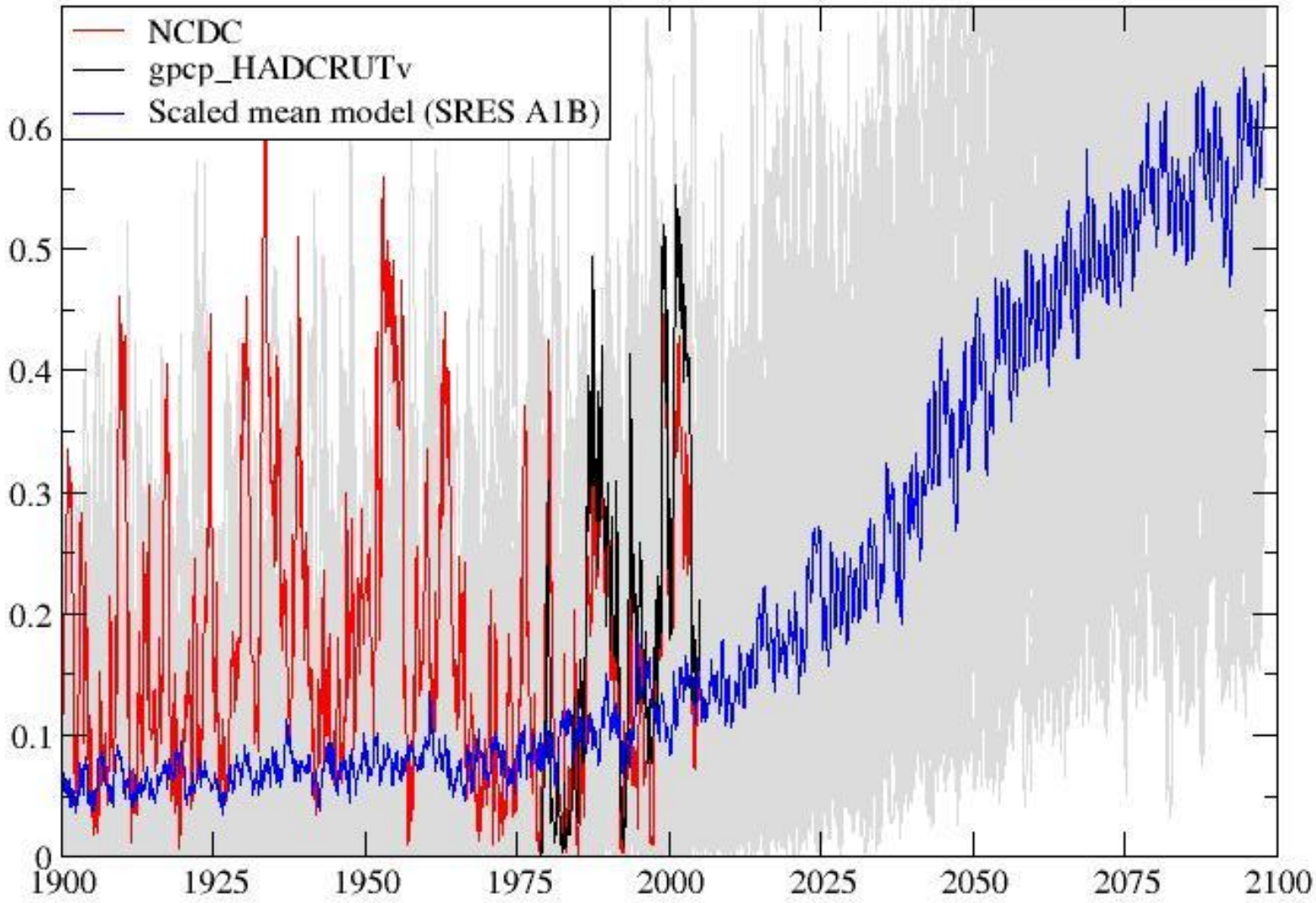
- Driven by multi-model average temperature and precipitation

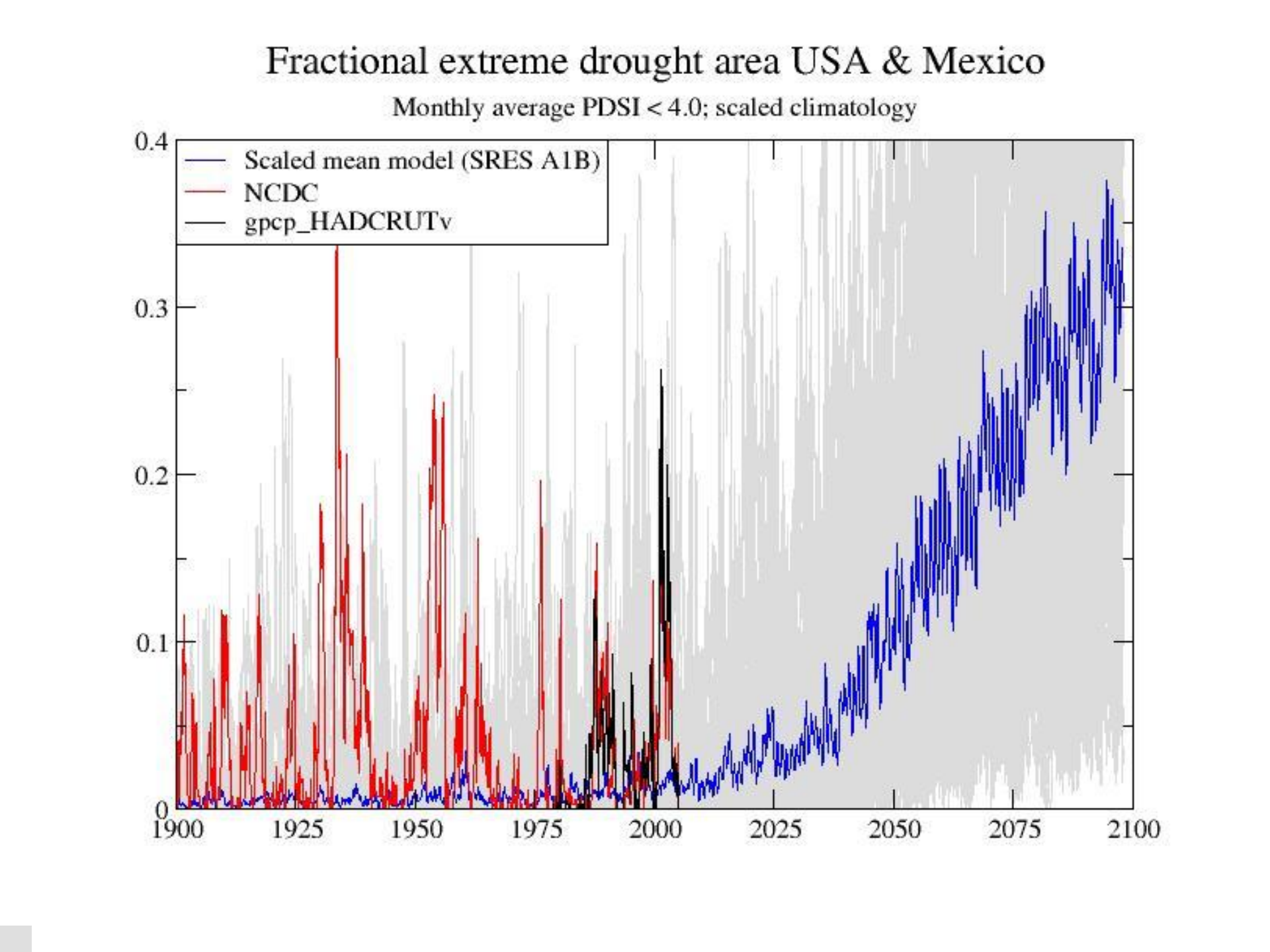
Model performance

- Drought indices measure the departure of soil moisture from the climatological mean
  - Nonetheless model bias is important
  - A moist bias over the USA & Mexico results in a severe underprediction of the drought area
- We can correct the bias by a normalizing to the 1950-1999 observed NCDC climatology.
  - Variability is scaled by a multiplicative factor.
- This correction dries out the Palmer land model resulting in an improvement in the PDSI index *for some models.*

Fractional drought area USA & Mexico

Monthly average PDSI < 2.0; Scaled climatology




Fractional extreme drought area USA & Mexico
Monthly average PDSI < 4.0; scaled climatology
Scaled mean model (SRES A1B)
NCDC
gpcp_HADCRUTv
0.4
0.3
0.2
0.1
0
1900
1925
1950
1975
2000
2025
2050
2075
2100

Model performance (2)

- All bias corrected models still underpredict the drought area.
- Some models do much better than others.

- Discard the obvious poor performers.
  - Equally weight the rest.
  - Poor performers predict more future drought than the better performers.

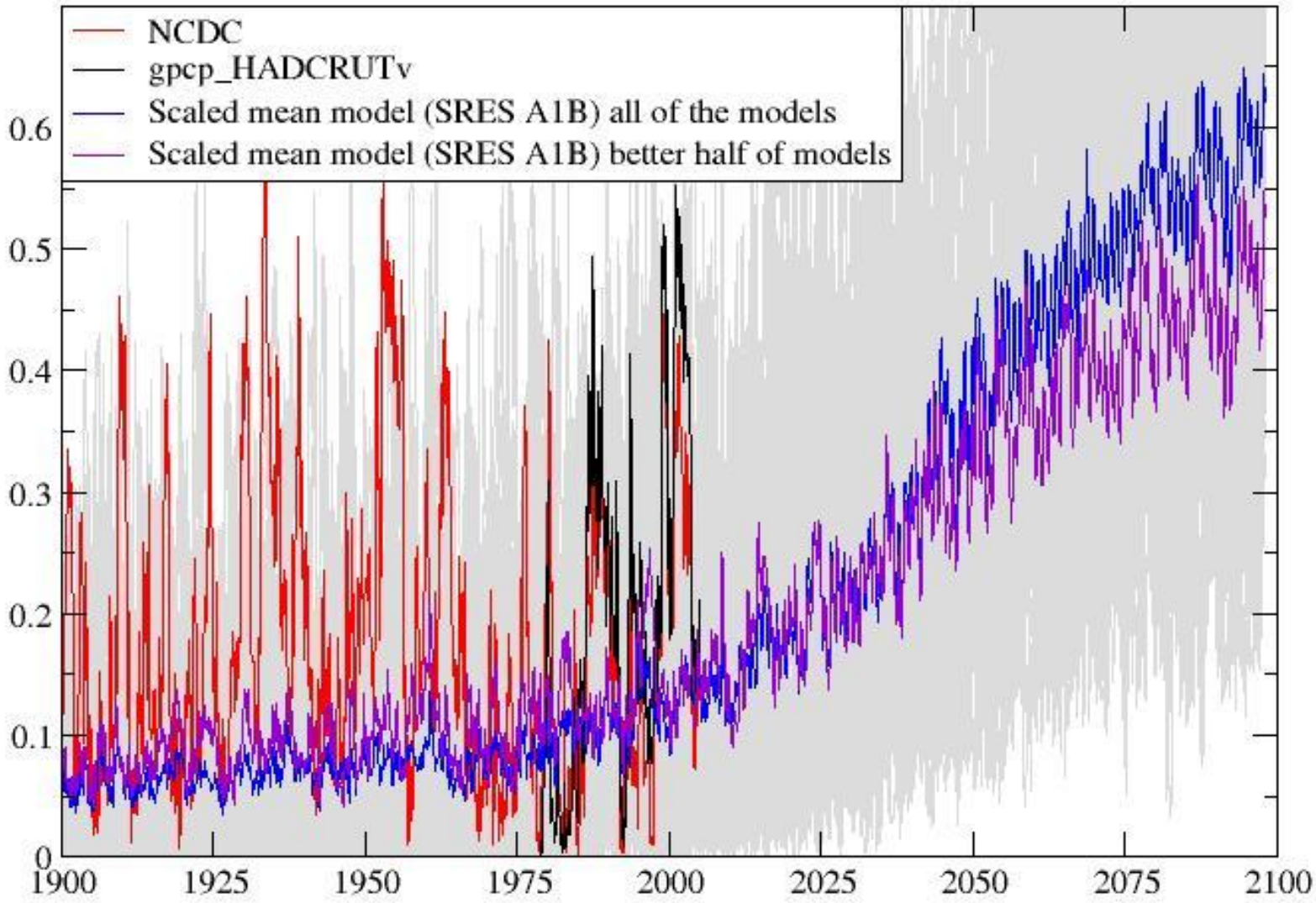
1950-1999 average Mexico & CONUS drought fractional area

Bias corrected results

Model	Drought	Extreme Drought
ncdc observations	**0.168806578**	**0.034437019**
csiro	0.14808779	0.022924561
pcm	0.137485981	0.018892112
gfdl2.0	0.121160864	0.009945515
gfdl2.1	0.116677165	0.019054879
ccsm3.0	**0.115016688**	**0.014367067**
echam5	0.10787045	0.015052567
cgcm3.1_t63	0.107596155	0.016911189
mri_cgcm2_3_2a	0.106140988	0.008441853
iap_fgoals1_0_g	0.102484481	0.009147541
cccma_cgcm3	0.098624454	0.01422216
bccr_bcm2_0	0.090926724	0.006808807
Mean model	**0.09076191**	**0.009711458**
cnrm_cm3	0.081159334	0.006879526
hadcm3	0.078109092	0.005080268
miub_echo	0.073056347	0.004657245
hadgem1	0.07188468	0.005782828
inmcm3	0.058873725	0.002484735
ipsl	0.050600449	0.002390866
miroc_T42	0.034387906	0.000753741
miroc_hires	0.024333023	0.000720241

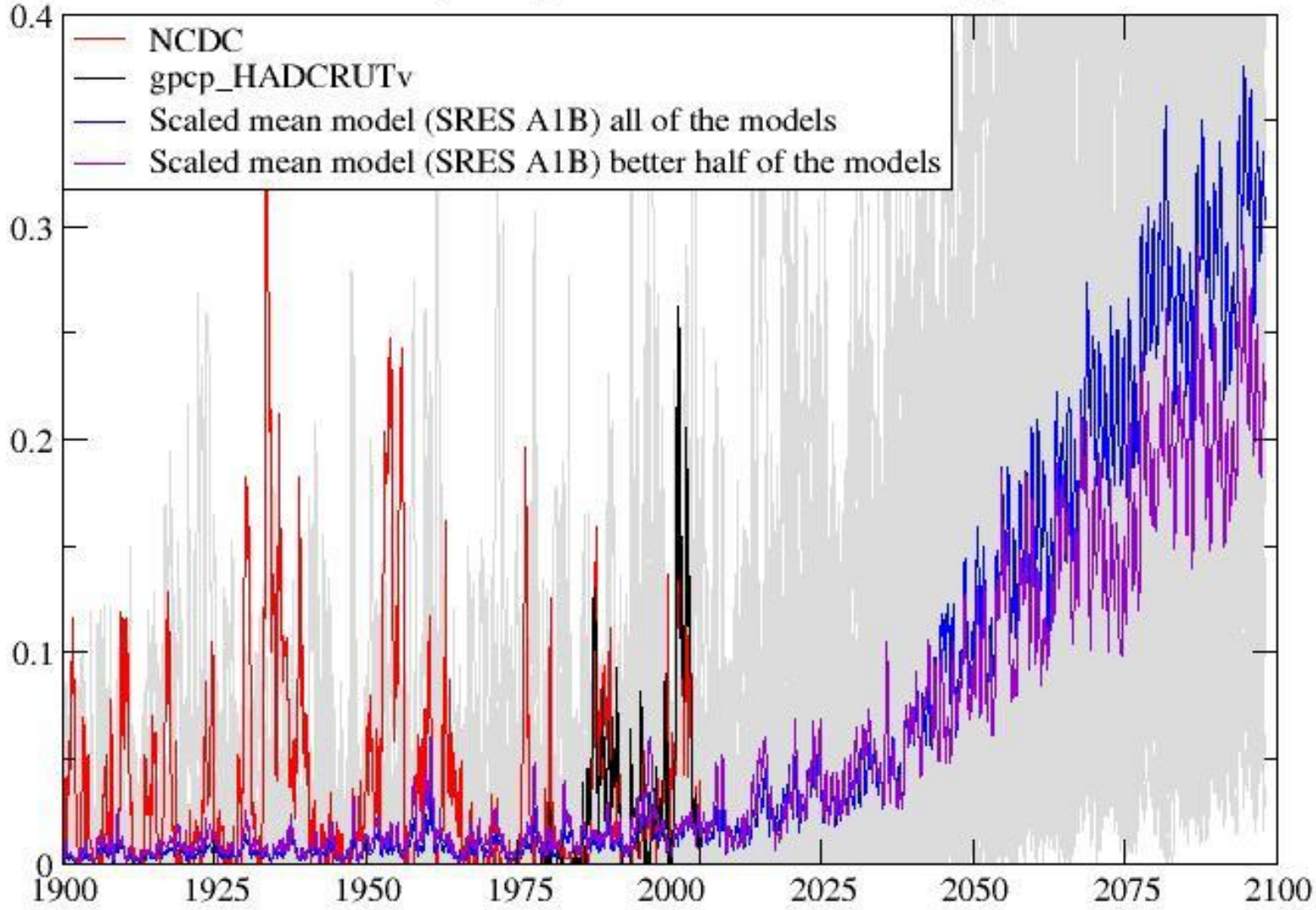
Fractional drought area USA & Mexico

Monthly average PDSI < 2.0; Scaled climatology



Fractional extreme drought area USA & Mexico

Monthly average PDSI < 4.0; scaled climatology



Conclusions

- Models do not produce intense enough dry events relative to their ***own*** climatologies.
  - which are too wet to begin with!
  - Bias correction helps some models
  - Models that better simulate the 20th century mean drought area predict less future drought than the poor performing models
    - **Future large scale droughts in the Southwest and Mexico are likely due to increased evaporation**

- The anthropogenic signal does not appear to rise in the raw model data above the noise at present
  - Human induced drought conditions may be attributable around 2050 (PDSI<2)
  - Human induced extreme drought conditions may be attributable around 2070 (PDSI<4)