United States Environmental Protection Agency

Going the Extra Mile in Downscaling: Why Downscaling Is Not Just "Plug-and-Play"

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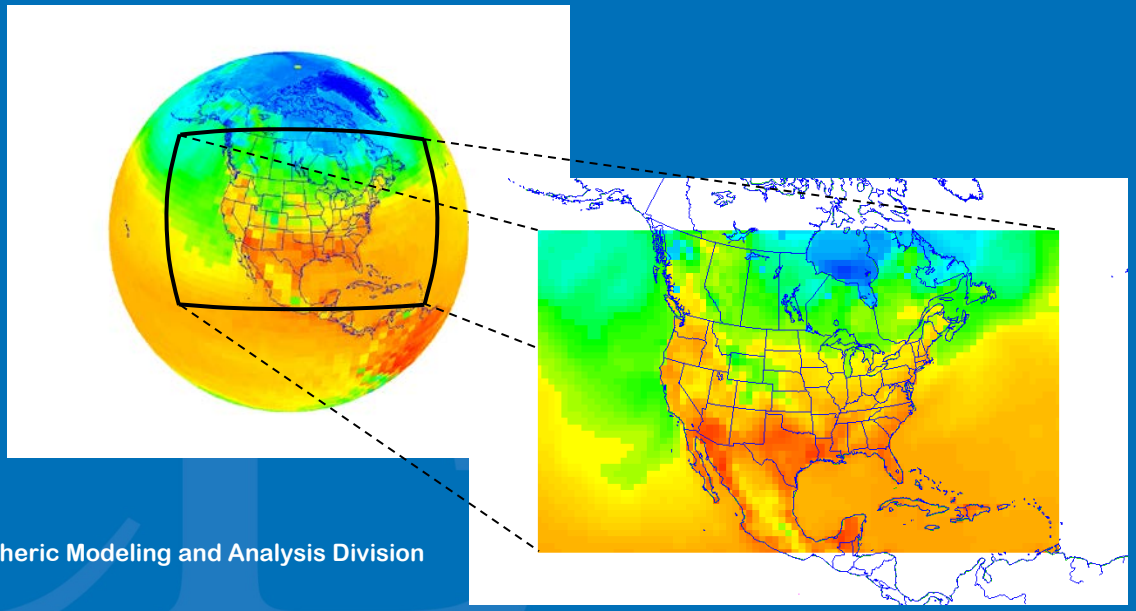


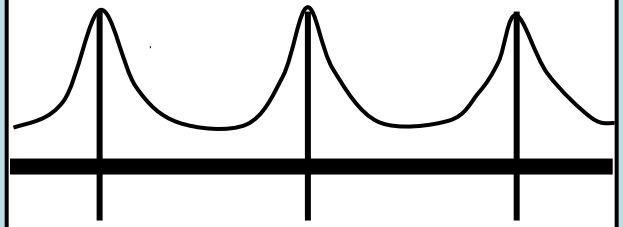
Office of Research and Development
National Exposure Research Laboratory, Atmospheric Modeling and Analysis Division

Motivation for Regional Climate Modeling Research

- *We will respond to the threat of climate change, knowing that failure to do so would betray our children and future generations.*
  – President Obama (21 Jan 2013)
- *If we embrace this [climate change] challenge, … we will save lives, protect and preserve our treasured natural resources, cites, and coastlines for future generations.* **– President Obama's Climate Action Plan (June 2013)**
- *We have a clear responsibility to act now on climate change. This Agency has the courage to act.* **– EPA Admin. McCarthy (22 Jul 2013)**

Global Climate

- Comprehensive science
- Emissions scenarios
- Multi-century data
- Coarse resolution



Regional Climate Modeling using Downscaling

Regional Impacts of Climate Change

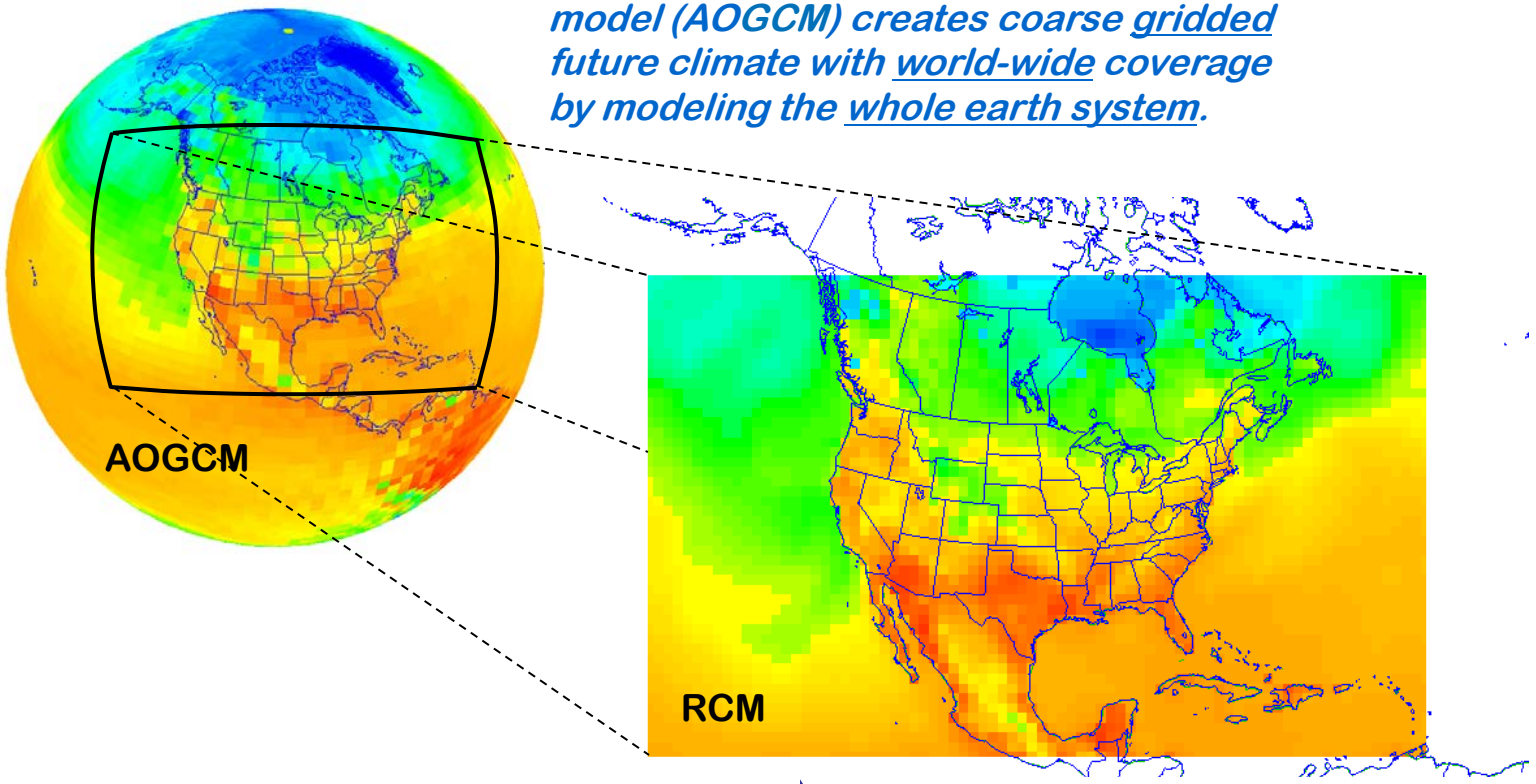
- Effects on air quality, ecosystems, and human health
- Frequency and intensity of extreme events

Large, well-established programs

EPA's interests

What is "dynamical downscaling"?

Atmospheric-oceanic global climate model (AOGCM) creates coarse gridded future climate with world-wide coverage by modeling the whole earth system.



Regional climate model (RCM) generates gridded higher-resolution climate over focal area using a dynamical, physics-based atmospheric model.

More detail in local effects from:
- *scale-appropriate physics*
- *topography & land/water interfaces*
- *urban areas (population centers)*

Developing Downscaling Methodology for Environmental Applications

- Use historical data sets to develop downscaling methodology
  - 20-year runs driven by historical data at comparable size to AOGCM
  - Evaluate RCM results against observation-based data sets
  - See Bowden et al. (*J. Climate*, 2012), Otte et al. (*J. Climate*, 2012), Bowden et al. (*Clim. Dyn.*, 2013), Bullock et al. (*JAMC*, in press)
- Apply downscaling methodology to AOGCM simulations
  - AR5 Ensemble: time slices, RCPs, AOGCMs
    - NASA GISS ModelE2, NCAR CESM 1.0, NOAA GFDL CM3, …
- Examine air quality-climate change interactions, as well as impacts on human exposure, energy demands, ecosystems, etc.

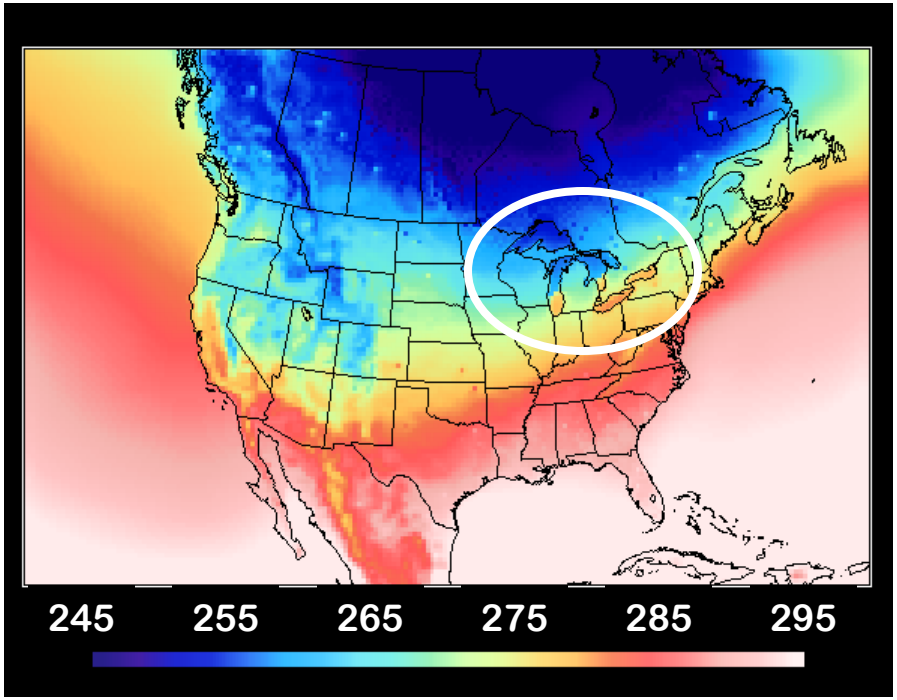
Downscaling CESM Using WRF

- Community Earth System Model (CESM)
  - Participating in IPCC AR5
  - Data are ~1.0 deg, 6-h

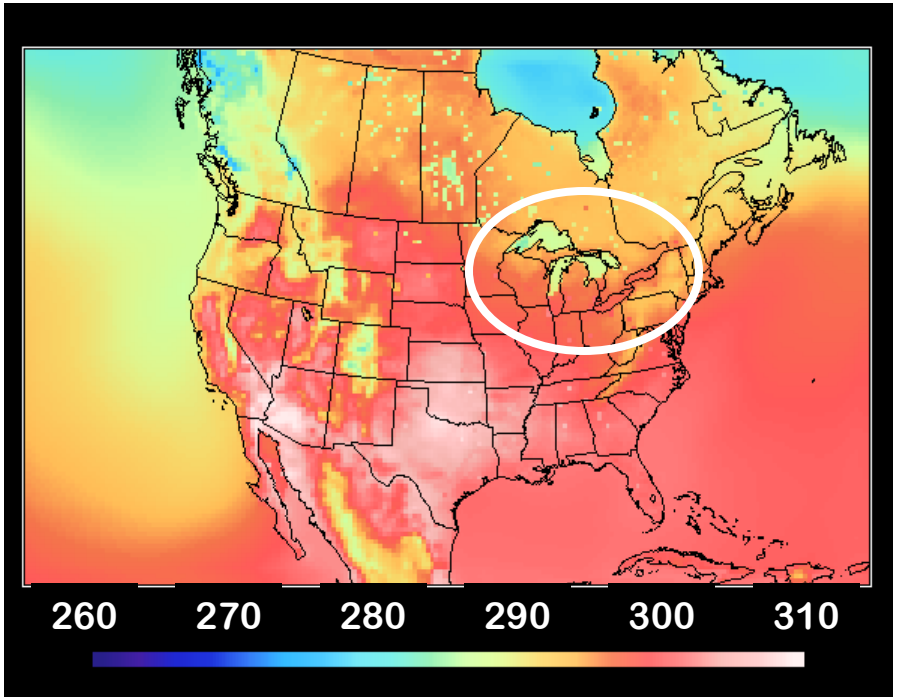
- Weather Research and Forecasting (WRF) Model v3.4.1
  - 36-km North America domain with 34 layers up to 50 hPa
  - Continuous 11-year simulation plus 3-month spin-up
    - RRTMG longwave and shortwave radiation
    - WSM6 microphysics
    - G3 and Kain-Fritsch plus subgrid feedback on radiation (Alapaty et al., *GRL*, 2012; Herwehe et al., in preparation)
    - YSU PBL scheme
    - NOAH land-surface model
    - Spectral nudging on wavelengths >1500 km (only above PBL)

A First Look at the Downscaled Output…

Monthly Average 2-m Temperature (K)



January “1995”

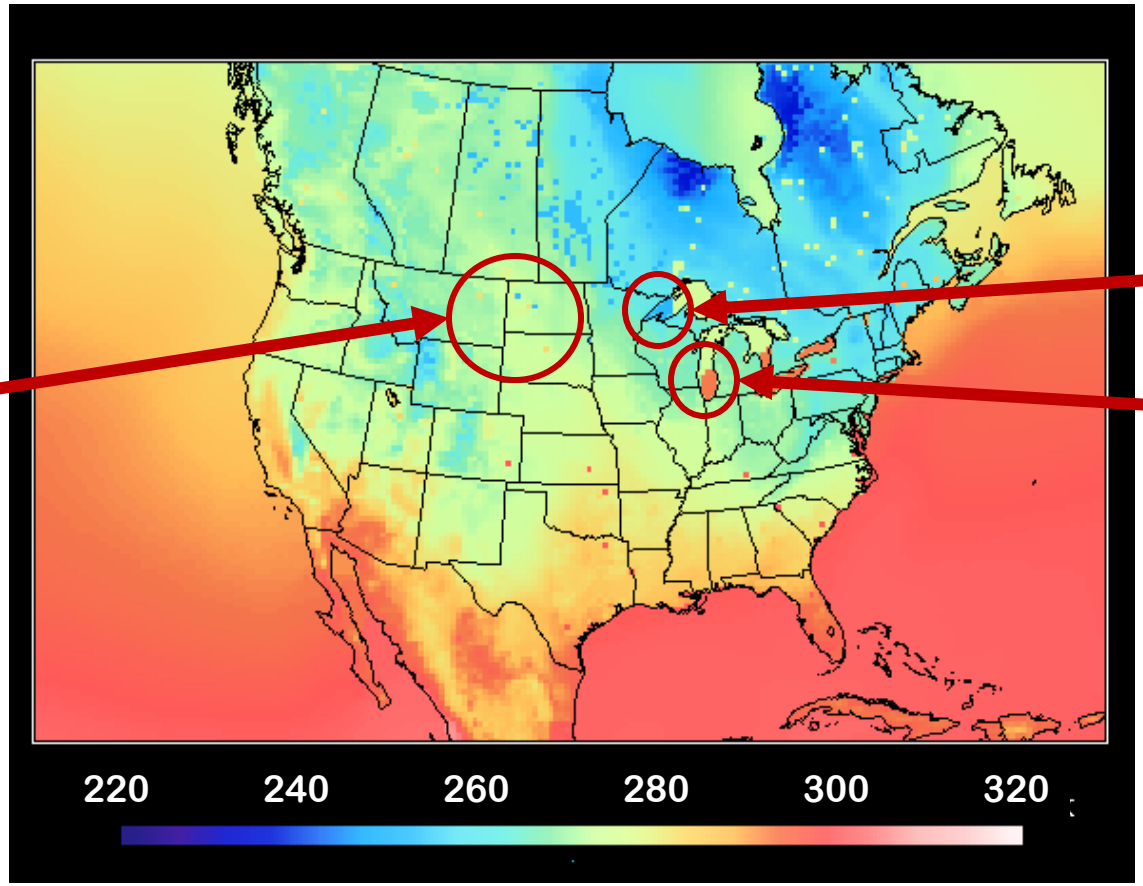


July “1995”

OK at first glance, but large temperature gradients over Great Lakes. Why?

Time to Double-Check the Input Data…

Skin Temperature (K) – 00 UTC 01 Dec "1995"



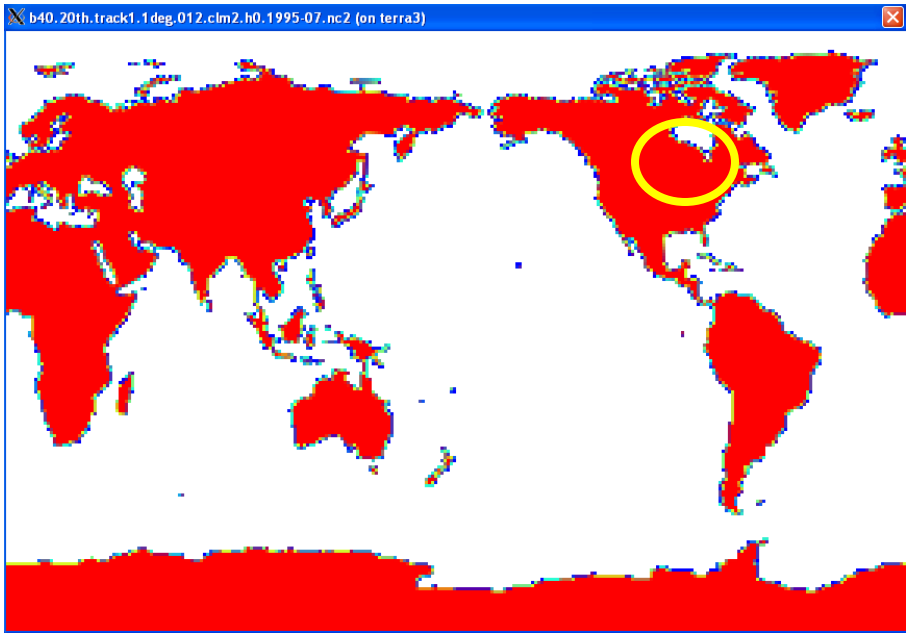
Inland lakes easy to identify throughout domain.

251.7 K

293.3 K

Unrealistic lake temperatures are part of input. How did this happen?

CESM Fields (part of standard downscaling suite)

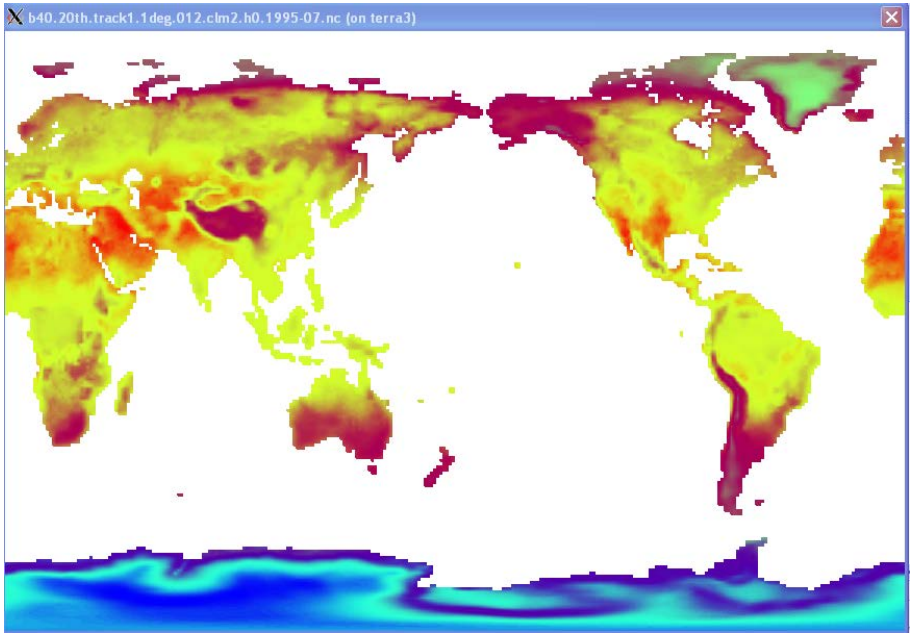


landmask: 0 for ocean, 1 for land

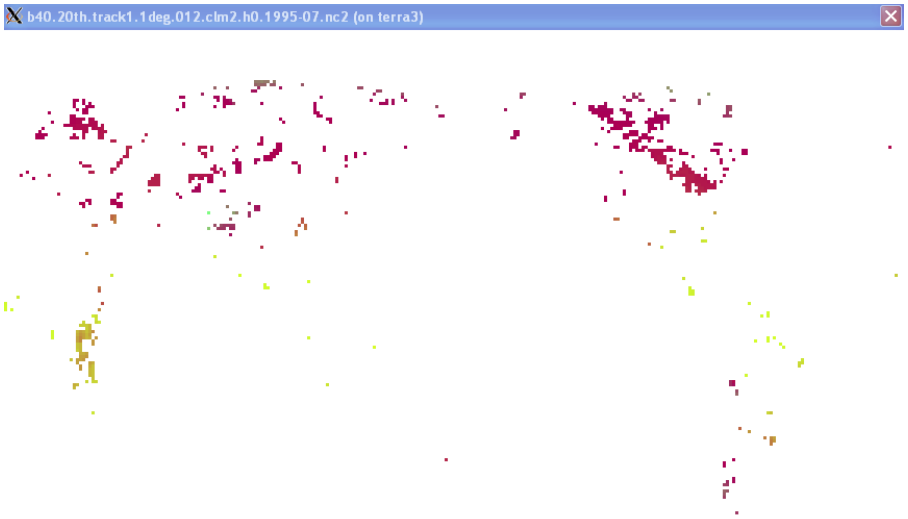
landfrac: missing over ocean, fractional along coastlines

Note that Great Lakes are not apparent in either CESM field. WRF uses nearest water point to set inland lake temperatures!

Getting Resourceful…



CESM Ground Temperature (TG)



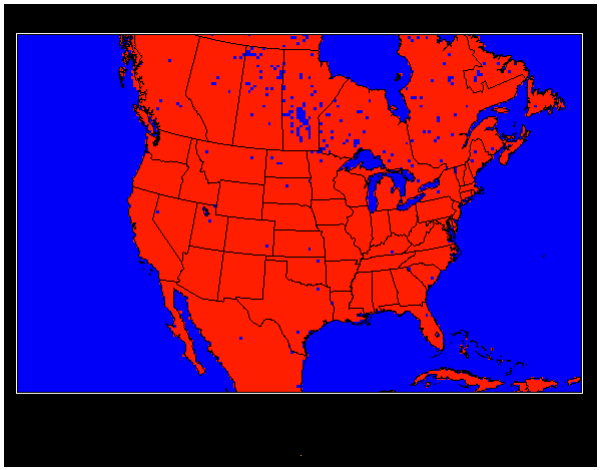
CLM Lake Temperature (TLAKE)
(not part of CMIP5 downscaling suite)

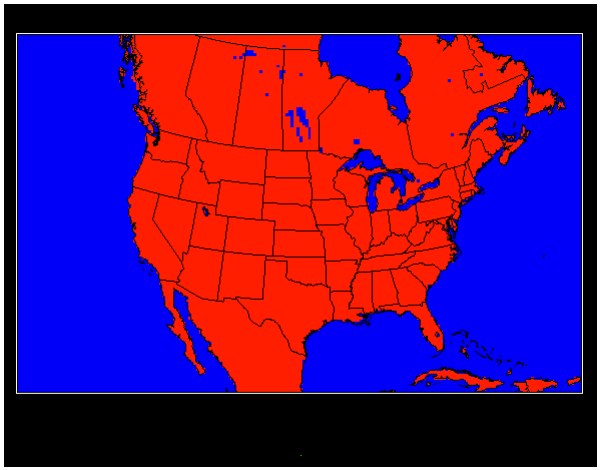
Note: TG is not equal to TLAKE, even where TLAKE is valid.

Can we find a way to blend TLAKE with TG in WRF???

- This is NOT straightforward…otherwise everyone would do it.
- Modifications needed in:
  - Acquiring monthly CLM fields with 6-h and monthly CESM fields
    - Not necessarily available on Earth System Grid
  - WRF "geogrid" … need to add lake classification in land use
    - Option is fairly new in WRF to add supplemental category
  - WRF pseudo- "ungrib" … collect TLAKE
  - WRF "metgrid" … process TLAKE field onto WRF domain
  - After WRF "metgrid" … blend TLAKE with TG

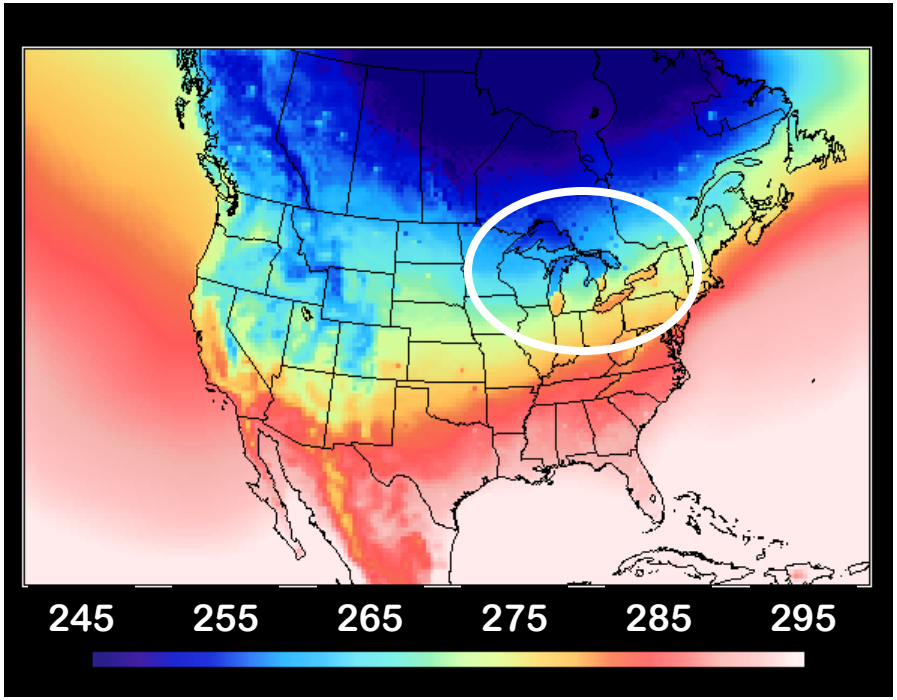
Land Mask: USGS 2-min



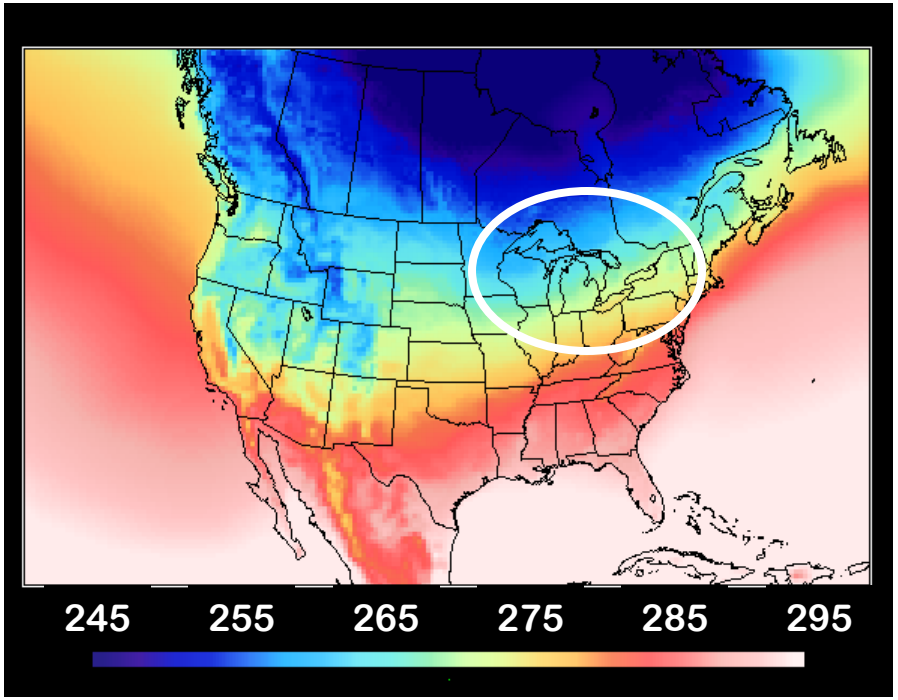


Land Mask: USGS 2-min + Lakes

January “1995” 2-m Temperature (K)

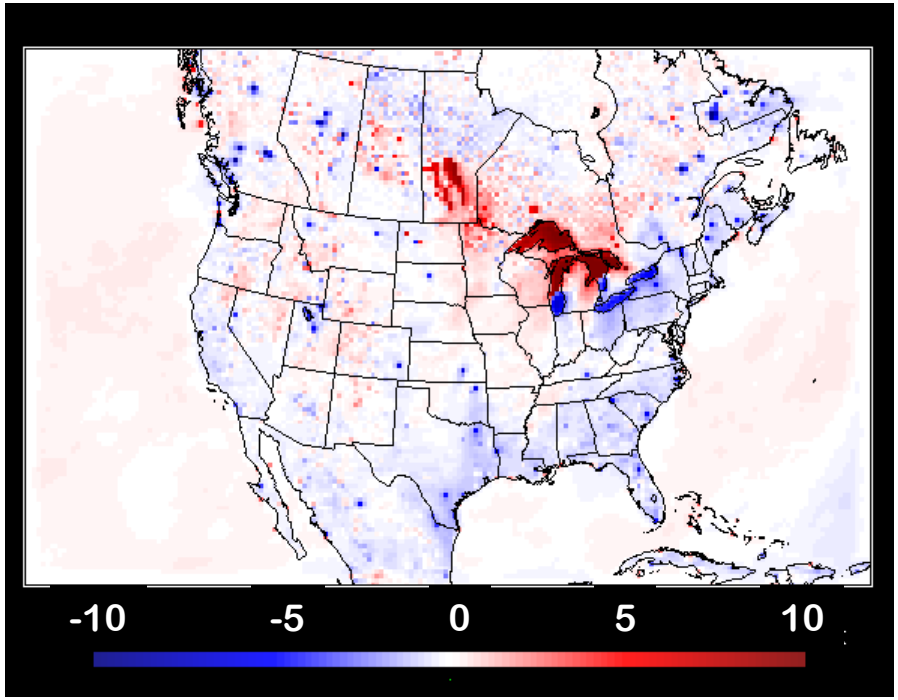


default method

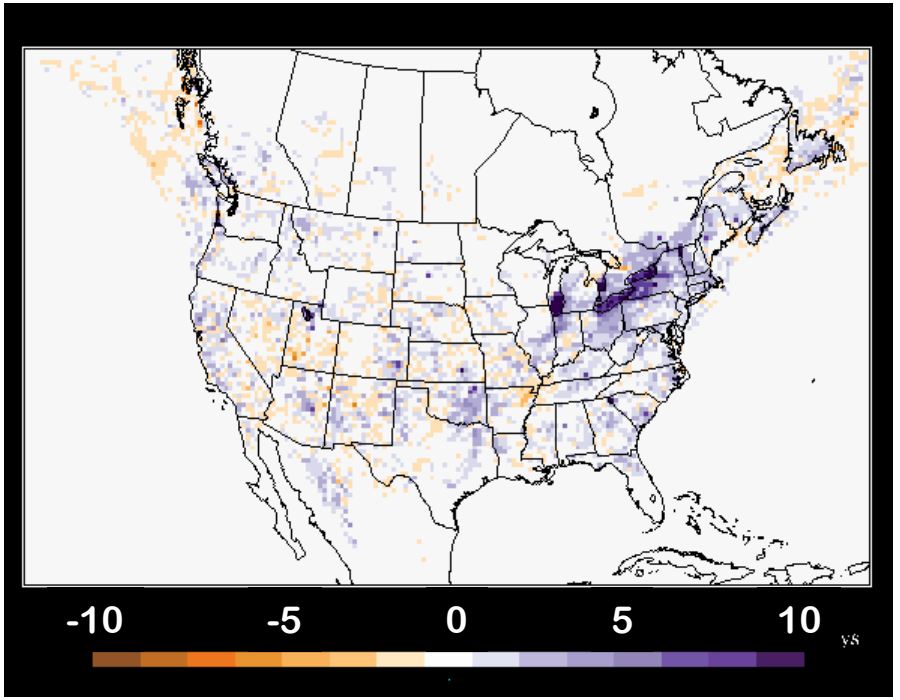


updated method

January “1995” 2-m Temperature

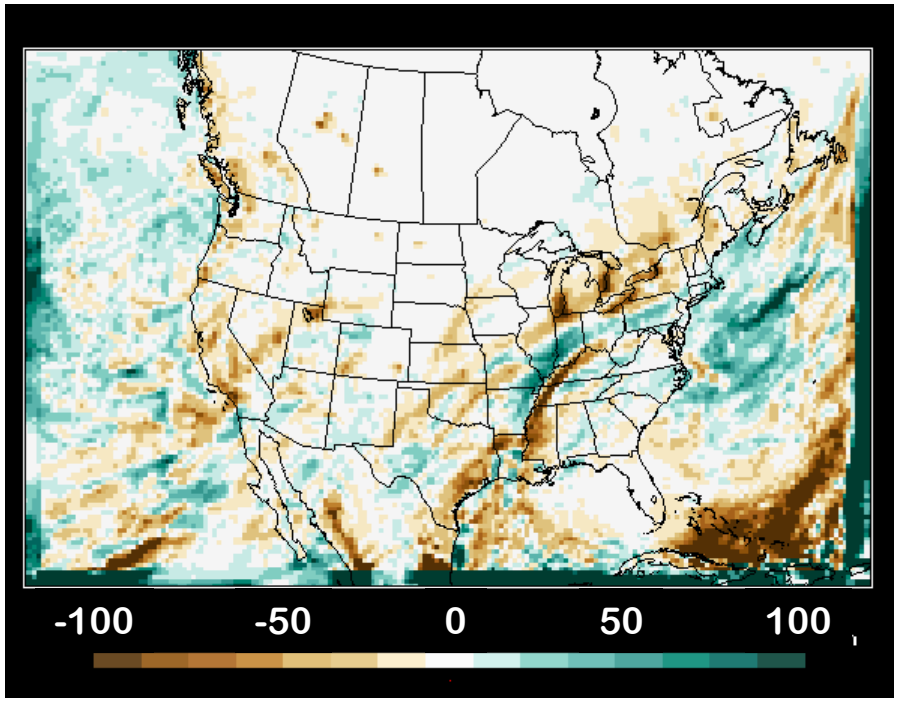


change in
average daily min temperature (K)

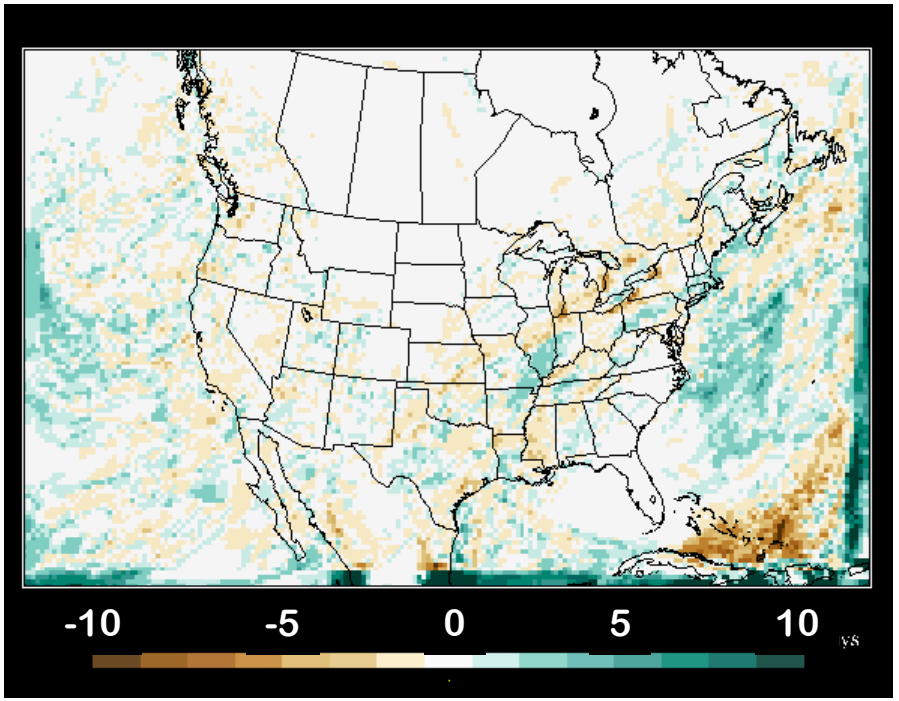


change in
number of days of T < 32°F

January “1995” Precipitation

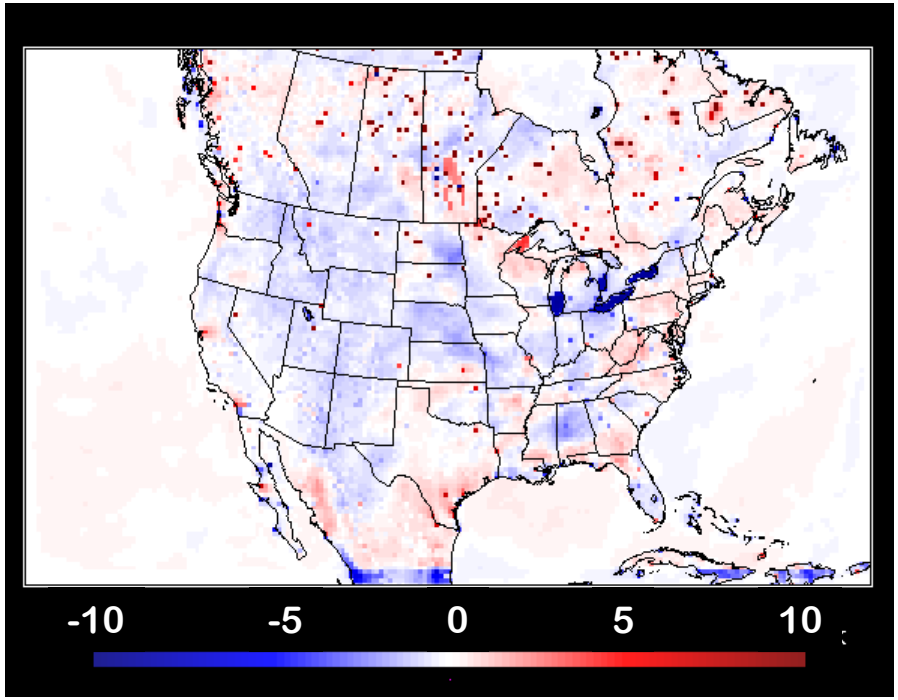


change in
average total precipitation (mm)

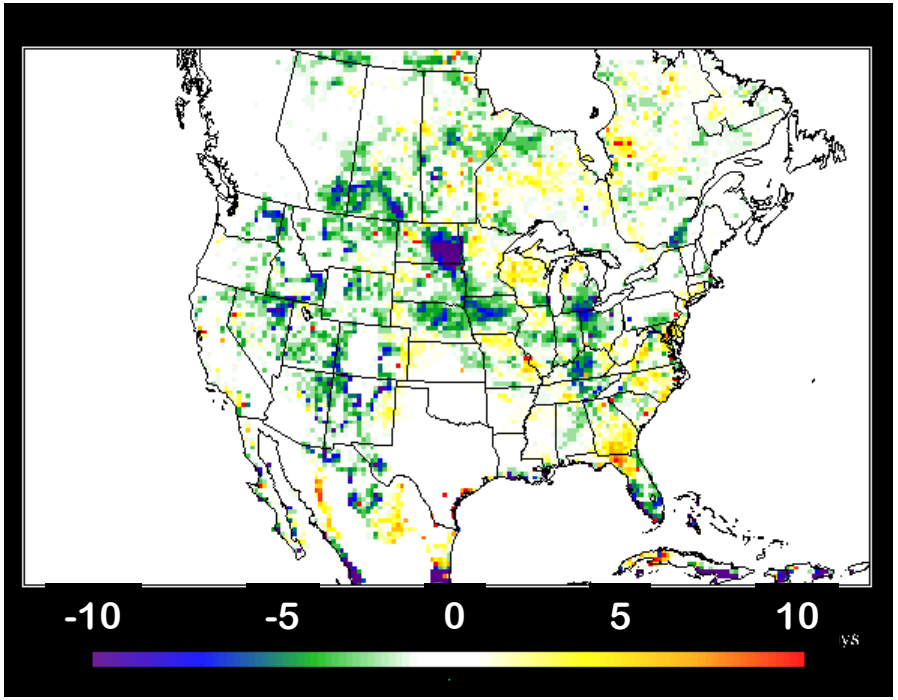


change in
number of days of P > 0.5 in

July “1995” 2-m Temperature



change in
average daily max temperature (K)



change in
number of days of T > 90°F

Closing Thoughts

- Downscaling is not just a “plug-and-play”, one-size fits all procedure
- Going the extra mile can make a BIG difference
  - Quality of the downscaled fields
  - Conclusions drawn from downscaled fields
  - Effects on extremes
- Need to inform archivers of AOGCM data of more specific data needs for downscaling
- Blending TLAKE and TG (as shown here) may not be a substitute for a more advanced lake model in WRF (e.g., Mallard et al. poster)
- Major caveat: Change to convective scheme needs to be removed to isolate effects if changing lake temperature. Qualitative differences in winter are likely to hold.