IOWA STATE UNIVERSITY
Climate Science Program

Object-oriented evaluation of downscaled Midwest warm-season rainfall

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Motivation and Goals

Practitioner Problem: Bridge/Road Design, Flood Planning

Daily to multi-day rainfall is used for engineering standards and flood planning. What are *credible** projections of daily rainfall?

Science Problem:

Daily rainfall from climate projections is relatively novel. Are flood-relevant rainfall days reproduced?

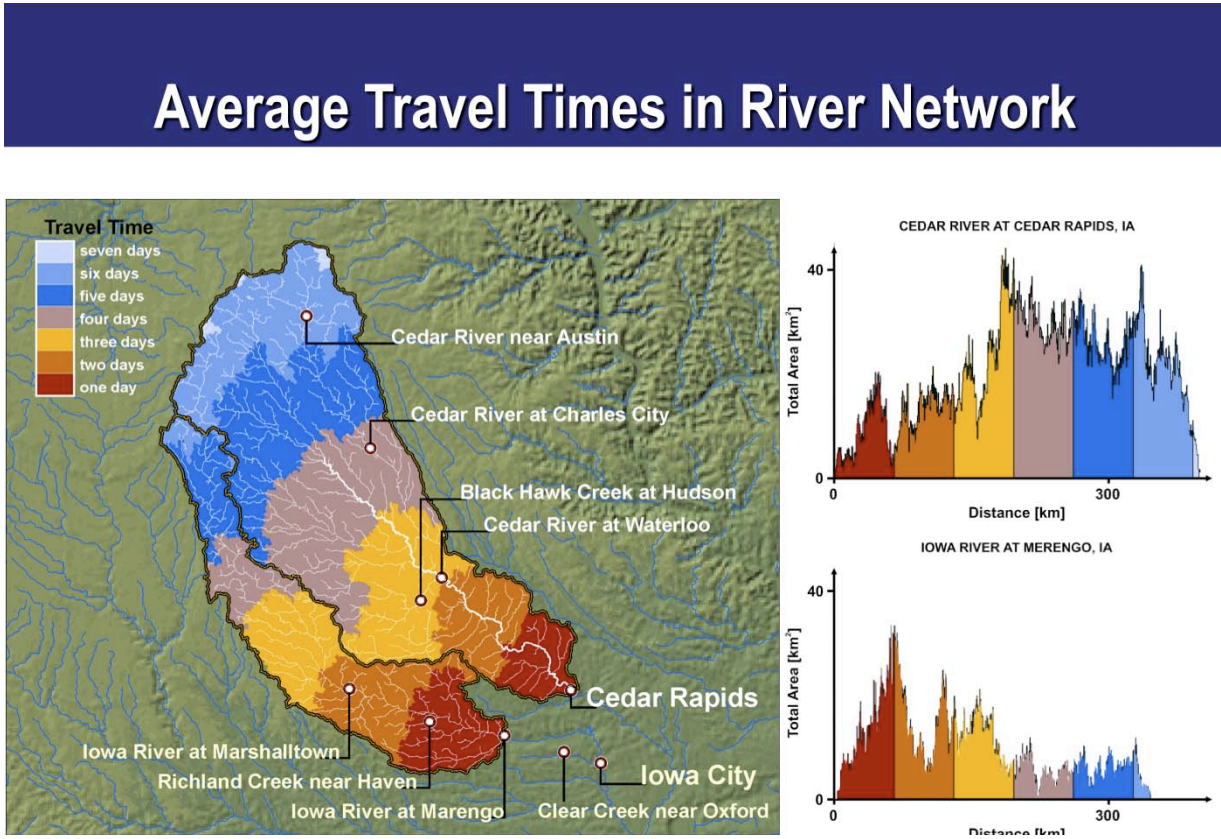
Goals:

Develop climate projection evaluation framework to identify daily rainfall events relevant to engineering design and flood planning.

***credible*:** Cash (2002), EOS (2013)

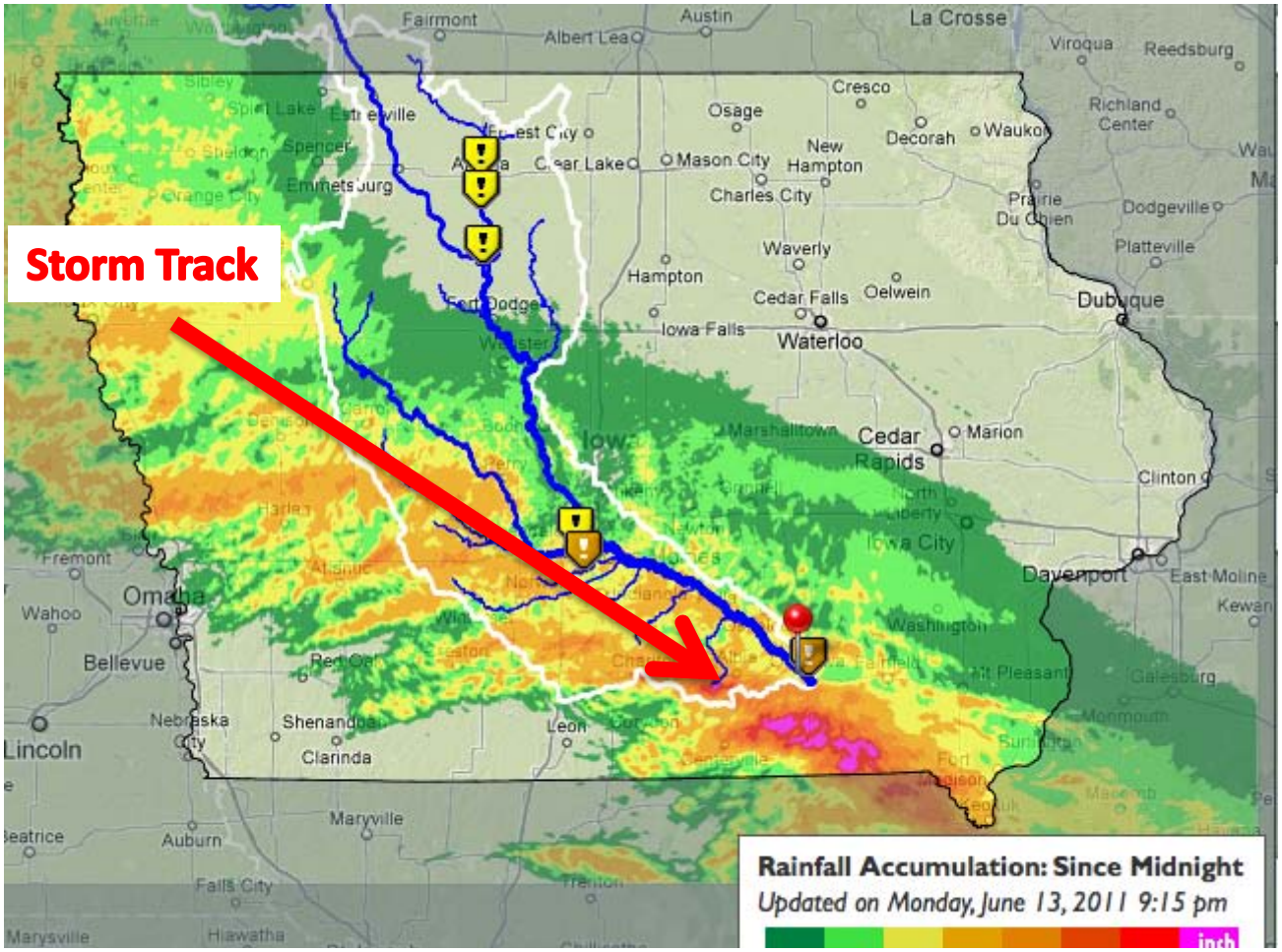
Waterway Traffic Jams: Rainfall timing and location create floods

- Rainfall at the north end of the Cedar River Basin requires ~ 7 days to reach its outlet.



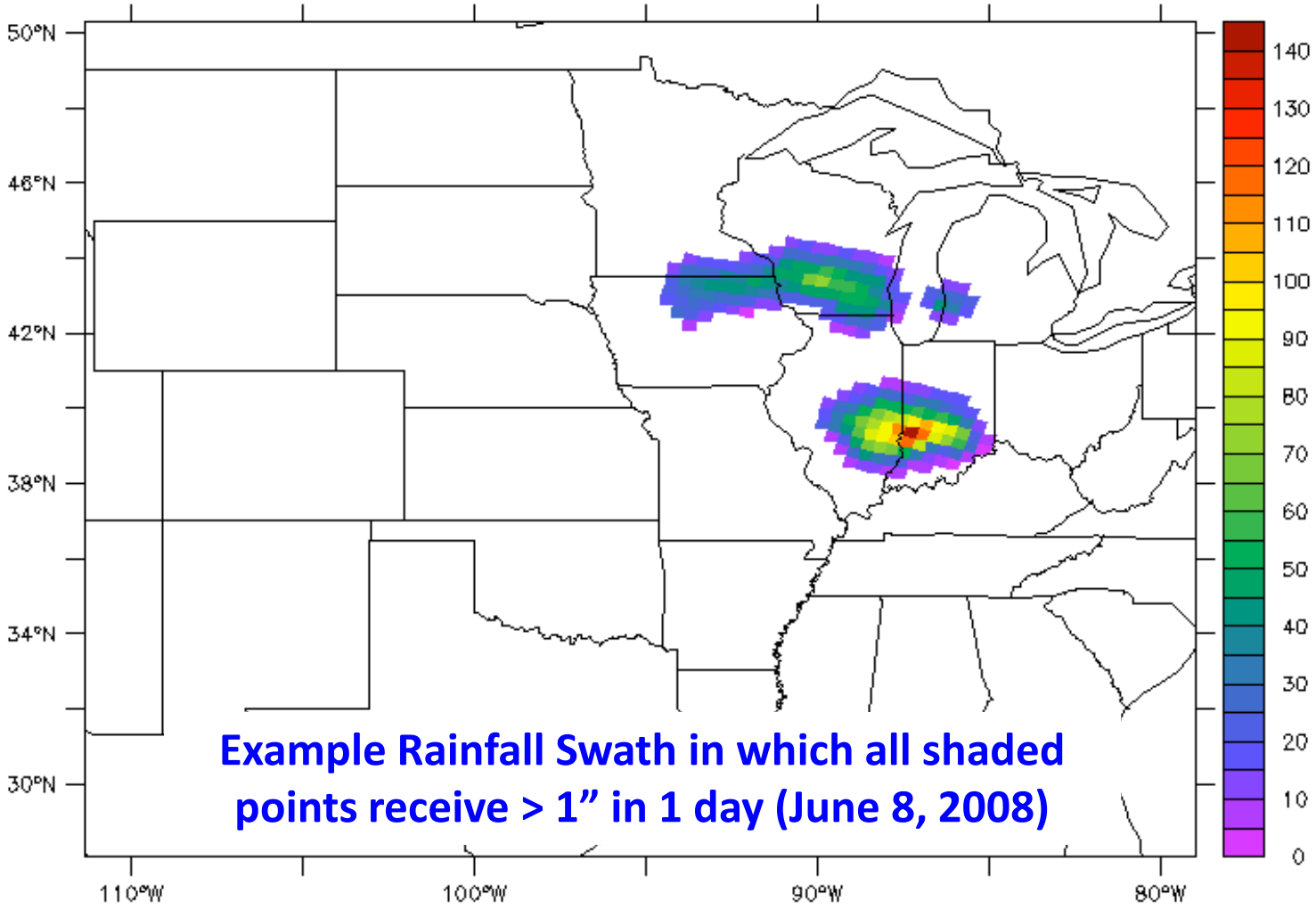
Courtesy Iowa Flood Center http://www.iowafloodcenter.org/

Storms oriented along a river basin creates multi-day traffic jam scenario



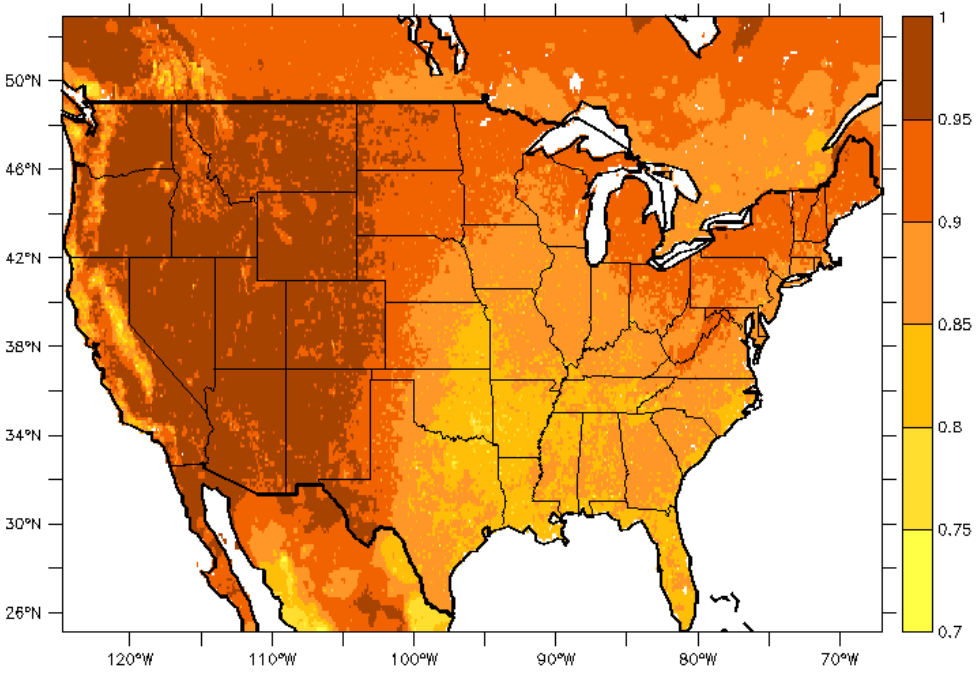
Courtesy Iowa Flood Center http://www.iowafloodcenter.org/

Example of rainfall object from Maurer 1/8th degree daily data

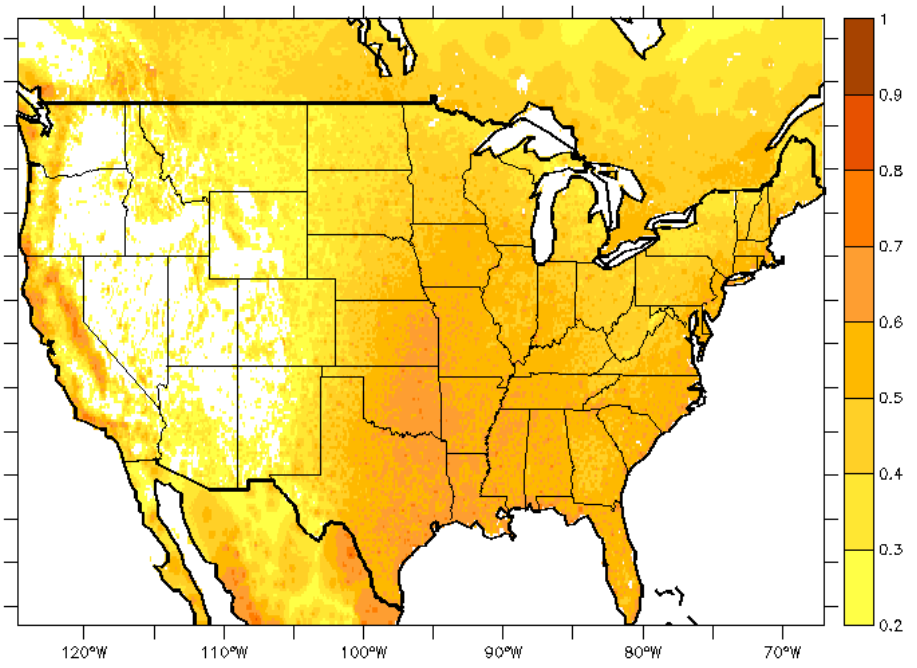


Example Rainfall Swath in which all shaded points receive > 1” in 1 day (June 8, 2008)

Percentile and seasonal fraction for 0.5”



Apr- Sep Percentile for 0.5” day^{-1} ranges 85-90% in Midwest.



Fraction of Apr-Sep rainfall from 0.5” day^{-1} ranges 50-60%.

Applying Object Analysis to Downscaled Data

(a) Datasets (What is being evaluated)

Maurer 1/8th-degree forcing data for VIC retrospective simulations

(b) Object Definition (How the evaluation is conducted)

MODE software from METv3.0

All: 0.5” at two or more contiguous grid points

Large: 0.5” at 675 contiguous grid points (97,200 km^2)

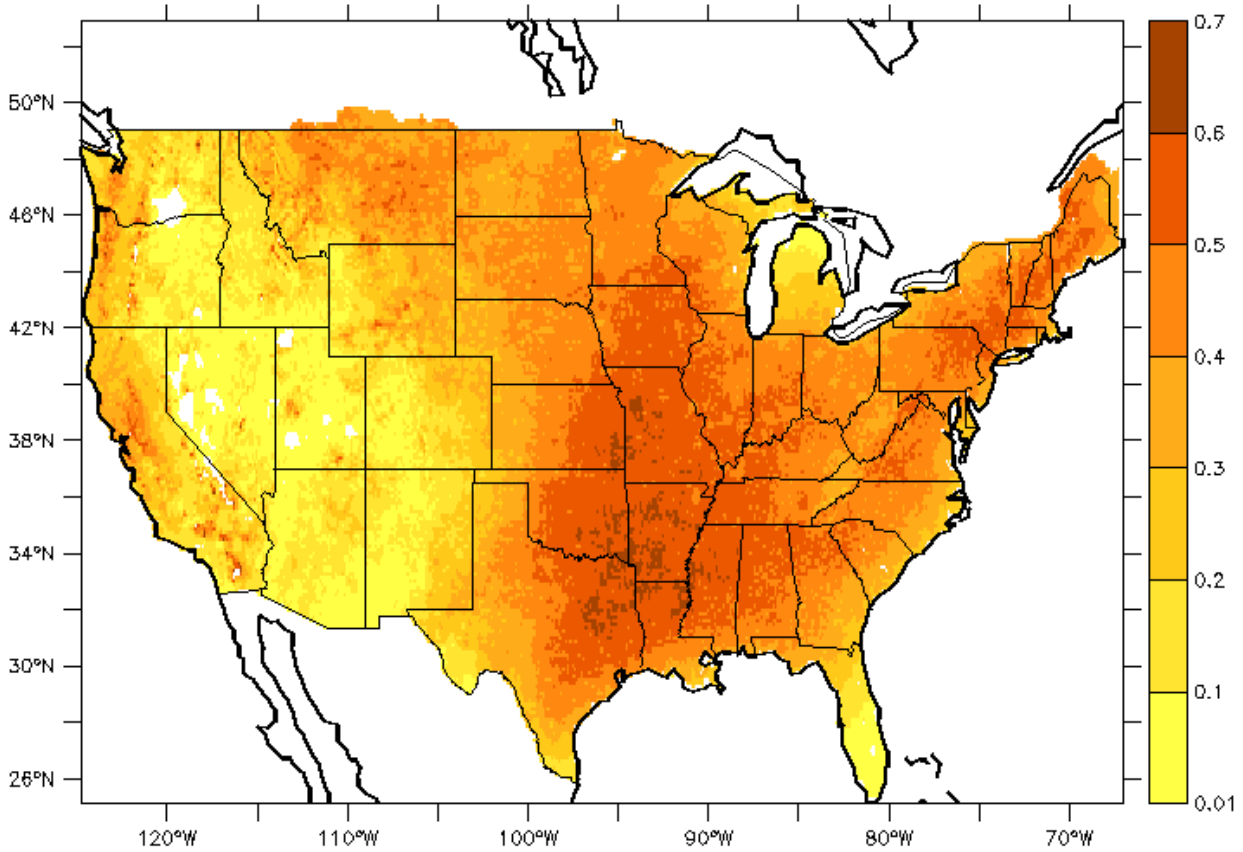
(c) Statistical Evaluation (What has happened)

Frequency, Seasonality, Correlation with Climate Indices, Trend, Contribution to Seasonal Rainfall, ***Correlation with Engineering Design Metrics, Spatial extent and orientation***

(d) Meteorological Evaluation (How it has happened)

North American Regional Reanalysis (1979 – 2010) data at 00 and 12 UTC water budget components: wvconv, prw, evap, analysis_increment

Large 0.5” objects contribute 25-35% of Apr-Sep Rainfall



Large 0.5” objects contribute 50-60% of rainfall >0.5” day^{-1}, equivalently 25-35% of Apr-Sep rainfall.

Large 0.5” objects and engineering standards: Annual Maximum Daily Precipitation

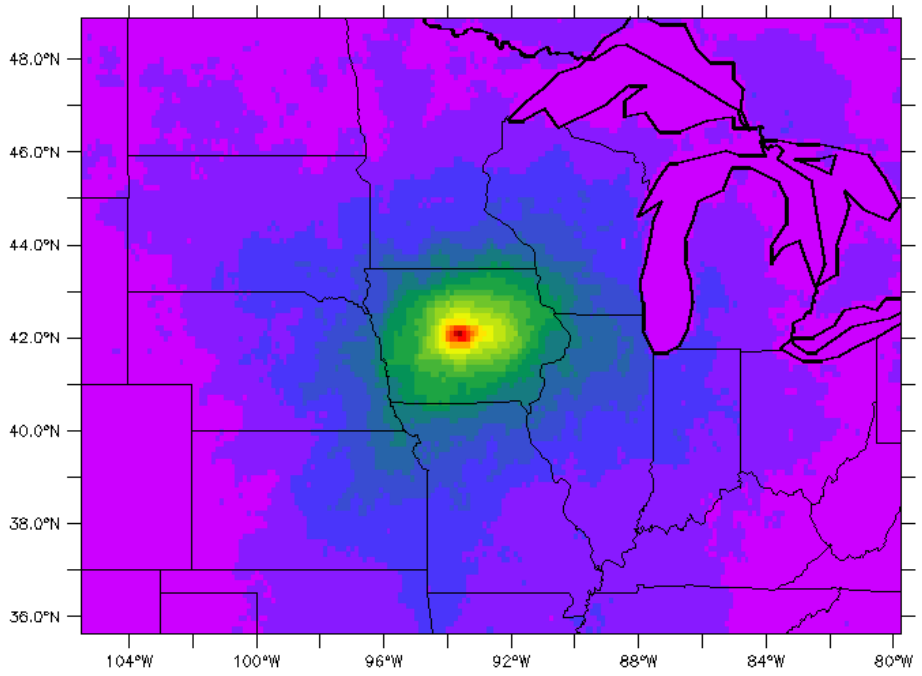
80-90% of ***annual maximum daily precipitation*** occurs within large object.

Large 0.5” objects and engineering standards: Annual Peak Streamflow

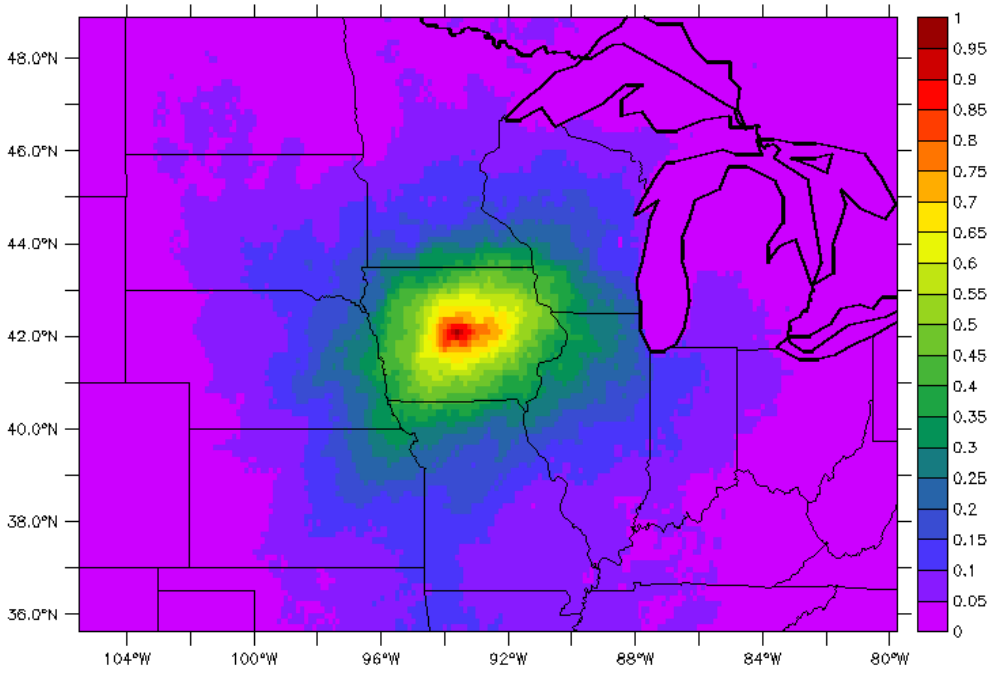
Drainage time, Two-day: South Skunk + Squaw Creek
Drainage time, Five-day: Raccoon River
Drainage time, Seven-day: Cedar River

	Correlation with Basin-Average Annual Maximum Daily Rainfall Cedar, Raccoon, South Skunk + Squaw	Correlation with Annual Peak Streamflow Cedar, Raccoon, South Skunk + Squaw
Watershed Daily Average Apr-Sep (Apr-Jun) Accumulation	0.476 (0.462), 0.465 (0.248), 0.269 (0.208)	0.593 (0.638), 0.590 (0.612), 0.586 (0.530)
Waterway Traffic Index Apr-Sep (Apr-Jun) Accumulation	0.490 (0.480), 0.464 (0.271), 0.371 (0.114)	0.576 (0.633), 0.612 (0.608), 0.710 (0.588)
Waterway Traffic Index Lag Maximum Correlation (Lag)	0.584 (3), 0.439 (5), 0.551 (7)	0.602 (2), 0.539 (5), 0.674 (6)
CDRA0.5 Frequency	0.603, 0.530, 0.510	0.552, 0.605, 0.628
CDRA 0.5 Frequency Lag with Maximum Correlation	0.603 (0), 0.530 (0), 0.510 (0)	0.552 (0), 0.629 (2), 0.628 (0)

Spatial Extent and Orientation: Point Frequency Maps (1960-1999)



All 0.5” objects



Large 0.5” objects

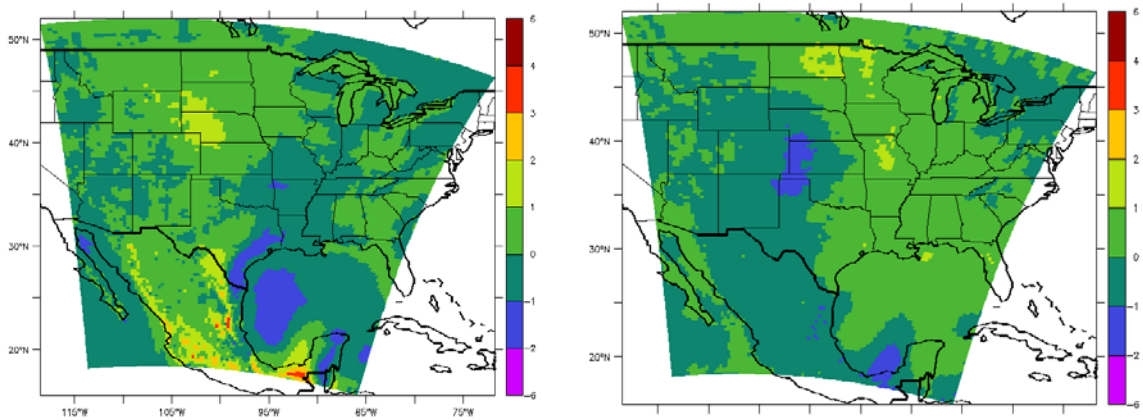
Large objects have a SW to NE orientation with 0.6 point frequency covering ~50% of Iowa and 0.4 point frequency covering the entire state.

Point Frequency Maps across the Region

Large objects can be

(1) more extensive outside of NE and IA

(2) less spatially coherent outside of NE and IA



00 UTC

12 UTC

Water Vapor Convergence

Water vapor convergence is

(1) persistent with nocturnal maximum for large objects in Iowa,

(2) transient, perhaps embedded within a fast-moving synoptic system, for large objects in North Dakota, and

(3) short-lived with afternoon maximum for large objects in Colorado.

Precipitable Water Change

Precipitable Water Change is

(1) persistent for large objects in Iowa,

(2) widespread and locally persistent for large objects in North Dakota, and

(3) short-lived with afternoon maximum for large objects in Colorado.

00 UTC

12 UTC

Applying Object Analysis to Downscaled Data

(a) Datasets (What is being evaluated)

NARCCAP: Dynamical Downscaling, nominal 50-km grid

Asynchronous Regional Regression (ARRM): Statistical Downscaling (percentile regression), 1/8th degree grid using Maurer as target

(b) Object Definition

MODE software from METv3.0

All: 0.5” at two or more contiguous grid points

Large: 0.5” at 675 contiguous grid points (97,200 km^2)

(c) Statistical Evaluation

Point Frequency Maps, Change in Frequency

ARRM: 1960 – 1999 (training period), 2020-2059, 2060-2099

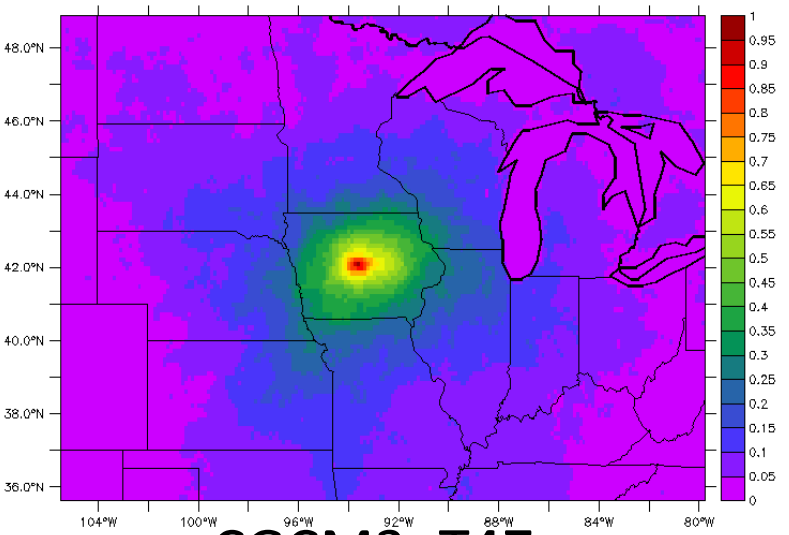
NARCCAP: NCEP-driven 1981-1999, GCM-driven 1971-1999, 2041-2070

(d) Meteorological Conditions

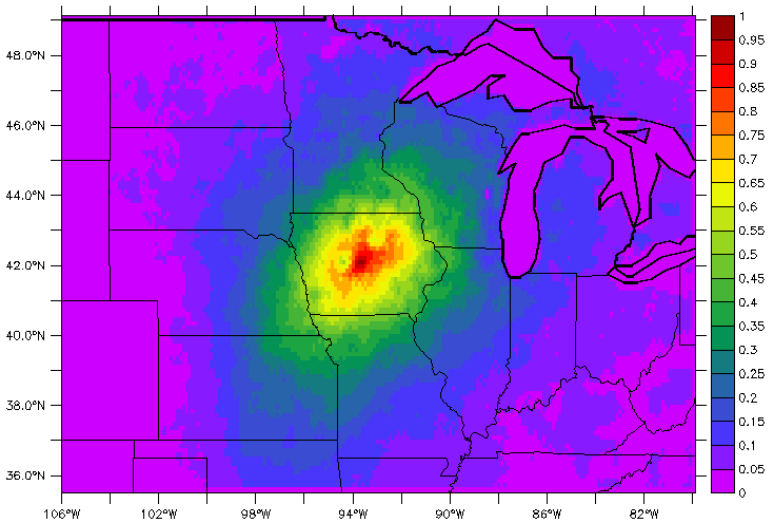
Not easy to do!

All Objects

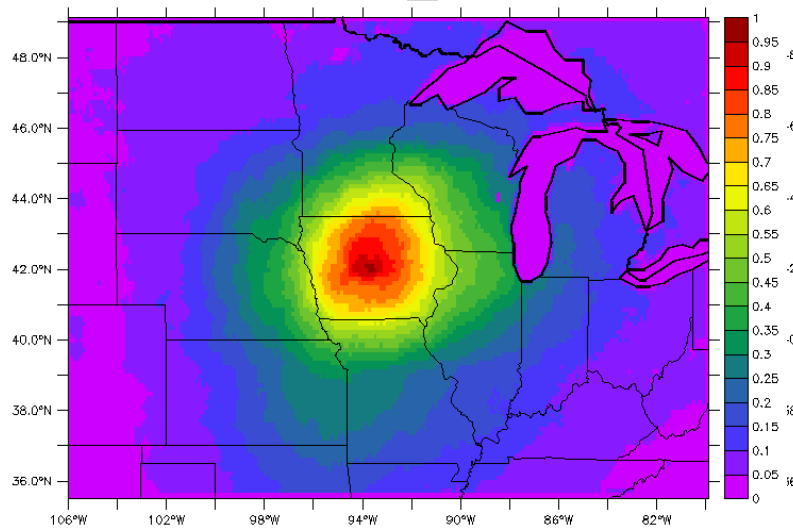
Maurer (1960 – 1999)



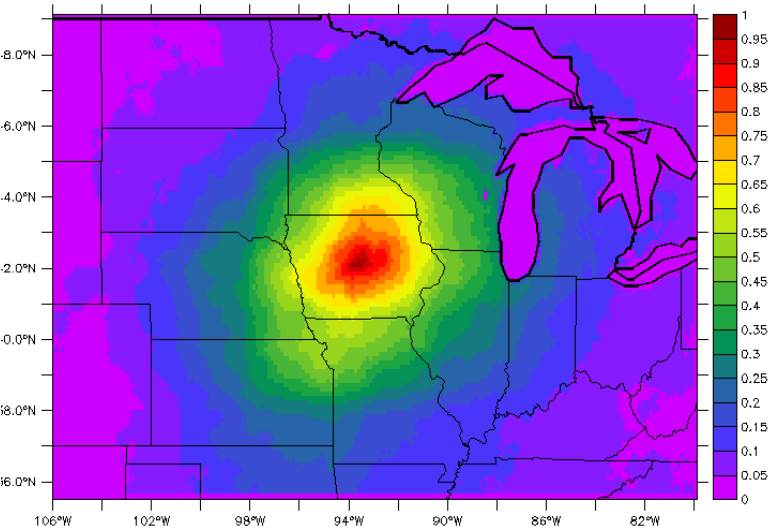
CCSM



CGCM3_T47

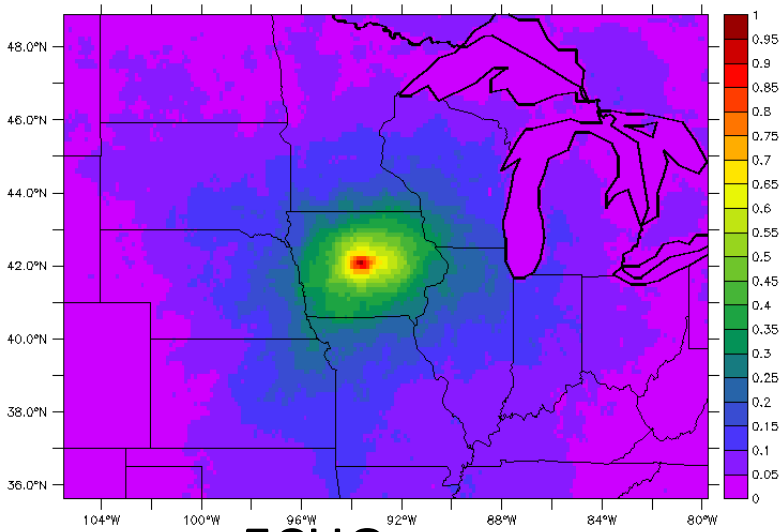


CGCM3_T63

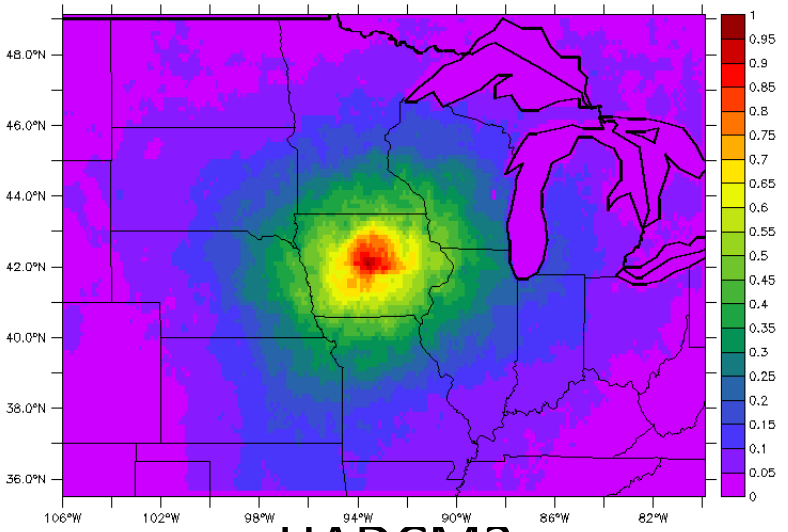


All Objects

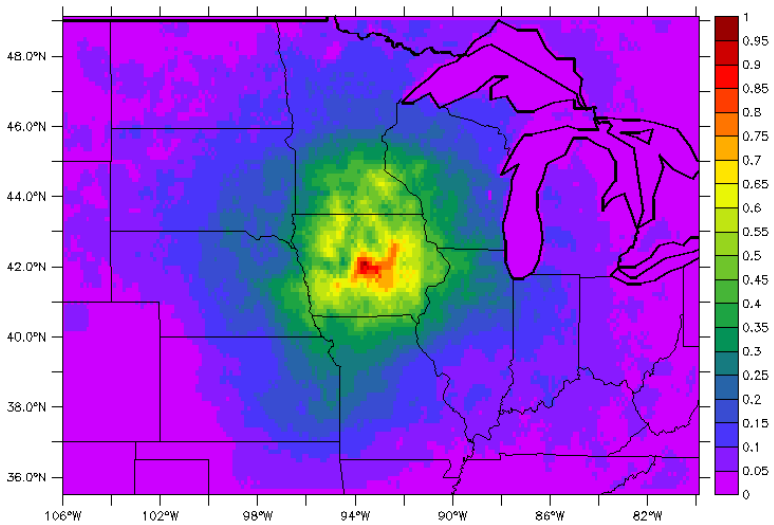
Maurer (1960 – 1999)



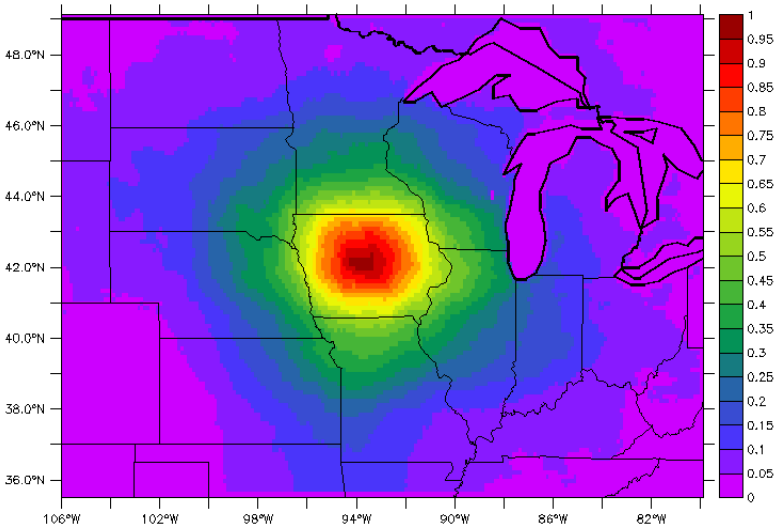
ECHAM5



ECHO

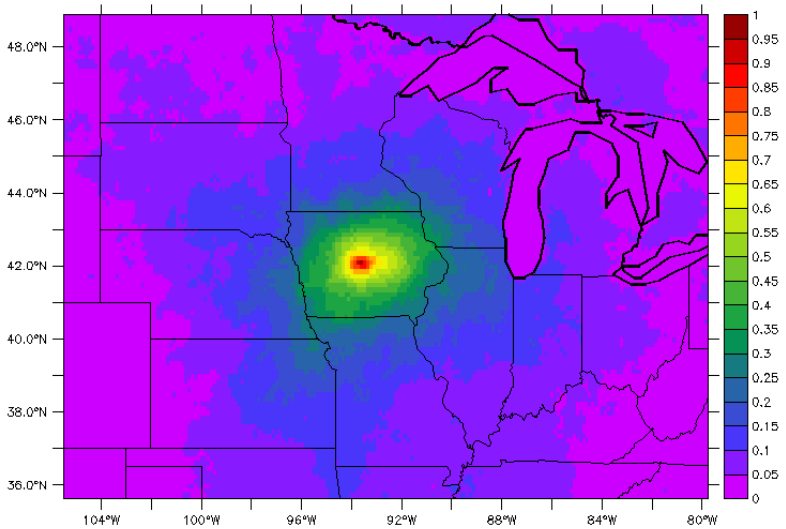


HADCM3

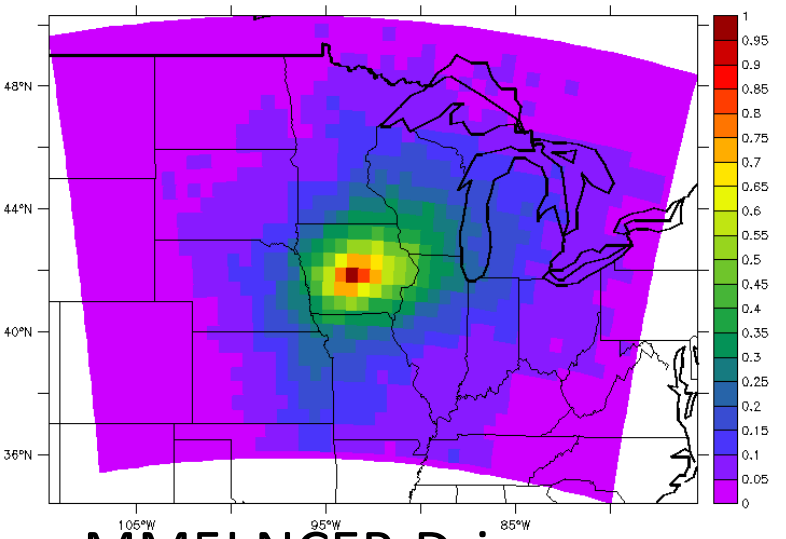


All Objects

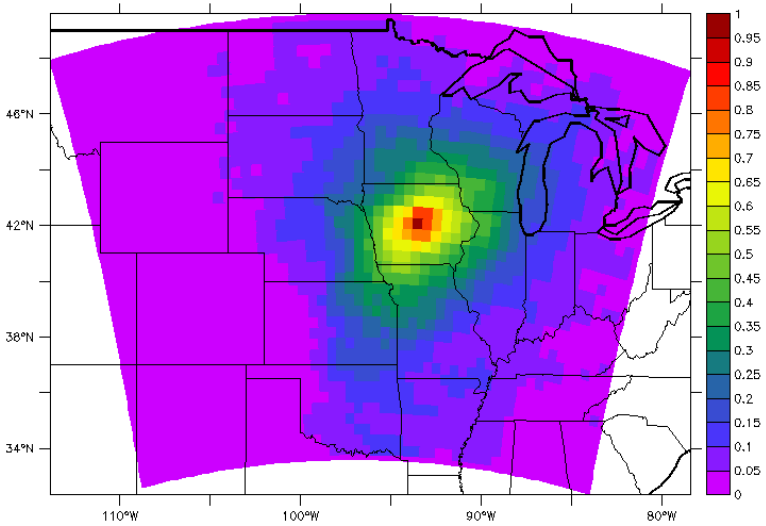
Maurer (1960 – 1999)



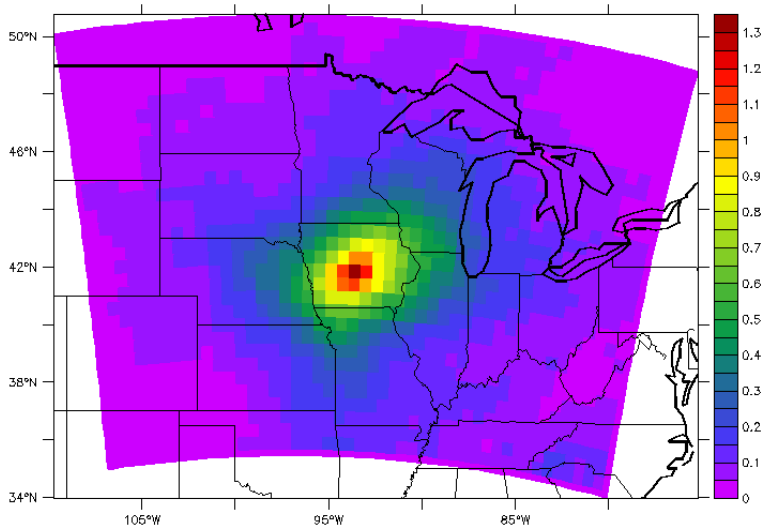
WRFG NCEP-Driven



CRCM NCEP-Driven



MM5I NCEP-Driven



Historical Period Object Analysis

(a) ARRM

Pass-through of GCM spatial structure.

Objects can be grouped into two categories: very little or a lot of spatial variability.

Size of all objects is more like observed large objects.

(c) NARCCAP

Different RCMs produce similar spatial structure.

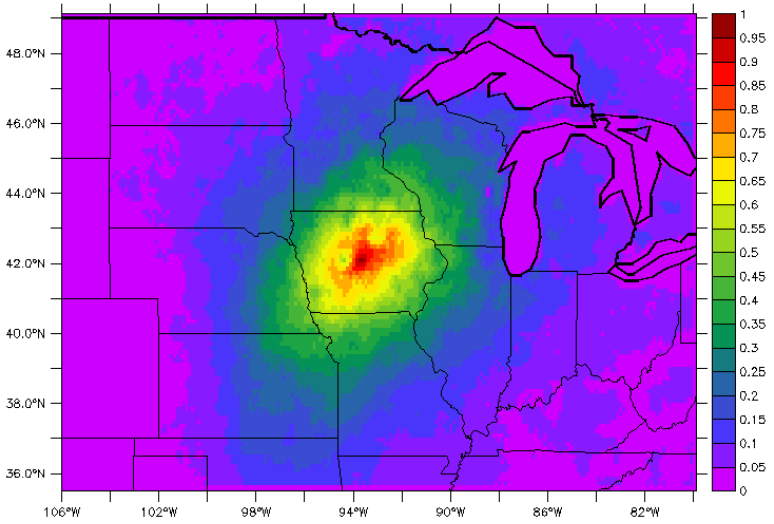
Size and orientation of all objects is more like observed large objects.

(d) Meteorological Conditions

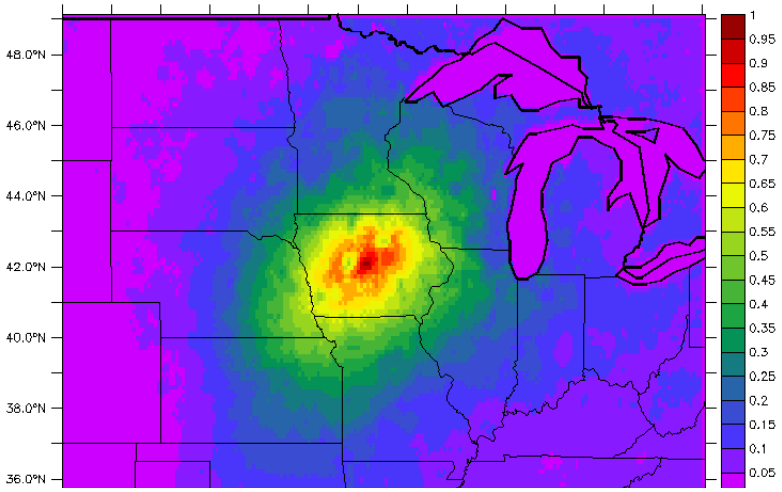
Not easy to do!

Future Period Object Analysis

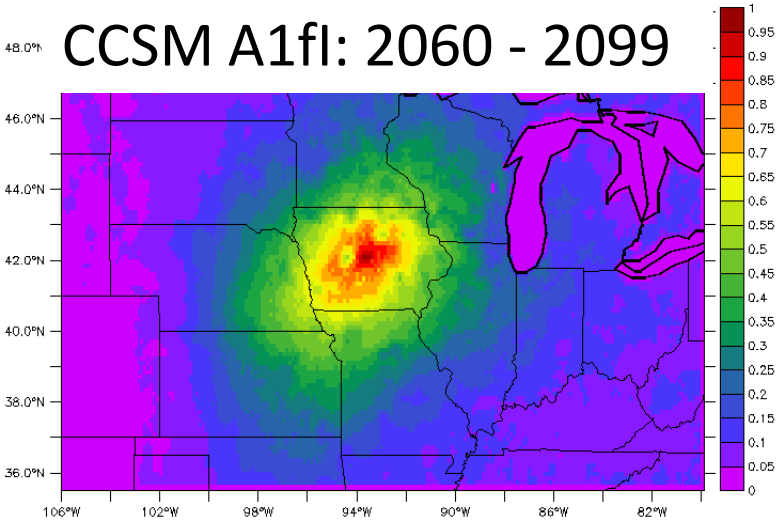
CCSM A1fI: 1960 - 1999



CCSM A1fI: 2020 - 2059

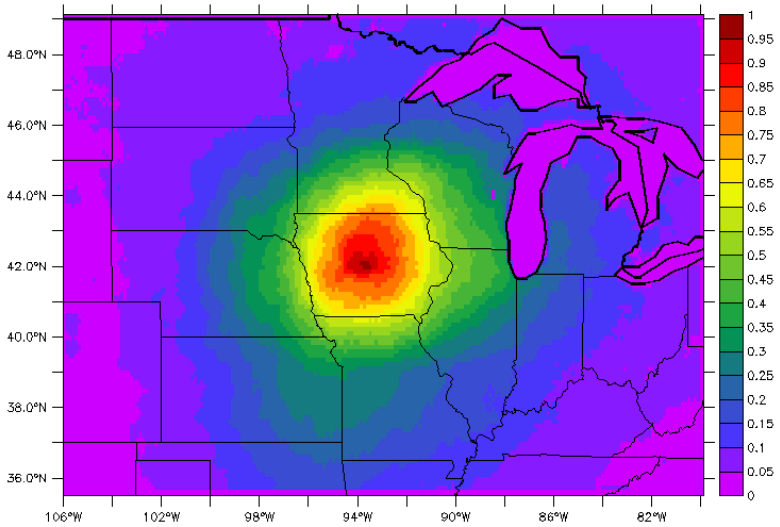


CCSM A1fI: 2060 - 2099

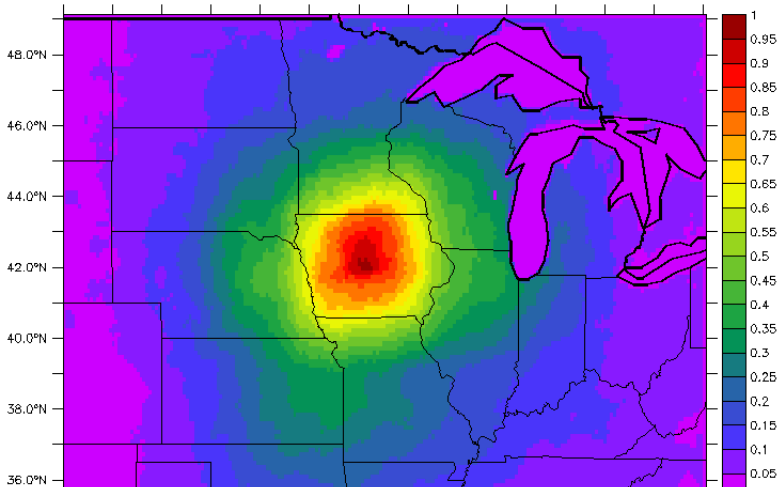


Future Period Object Analysis

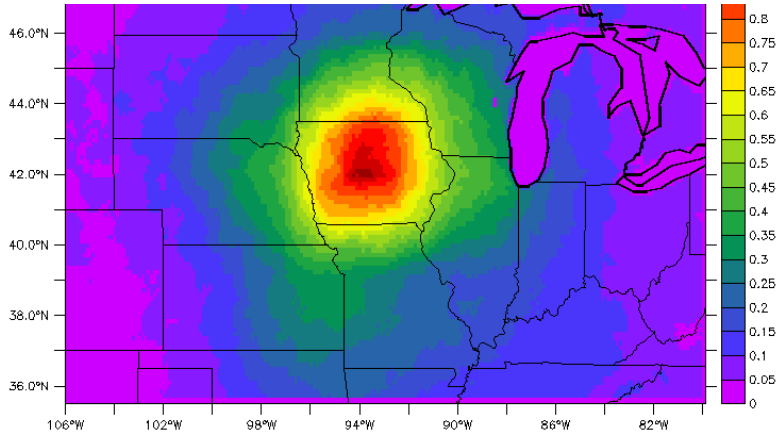
CGCM3_T47 A2: 1960 - 1999



CGCM3_T47 A2: 2020 - 2059

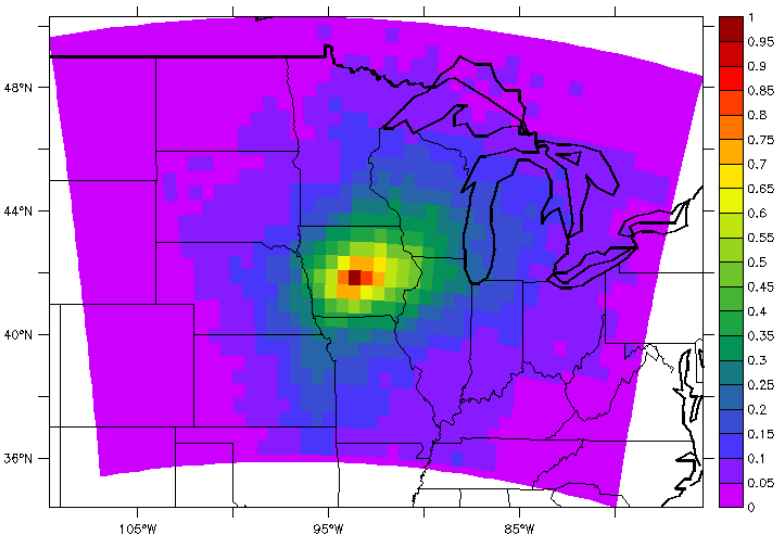


CGCM3_T47 A2: 2060 - 2099

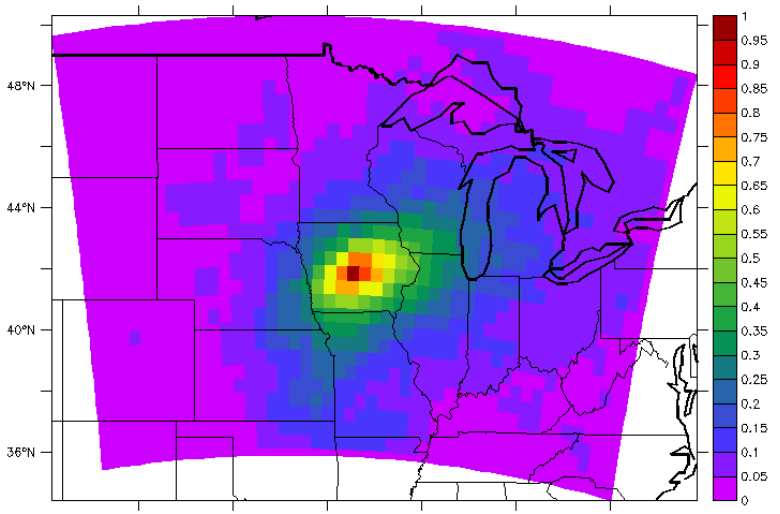


Future Period Object Analysis

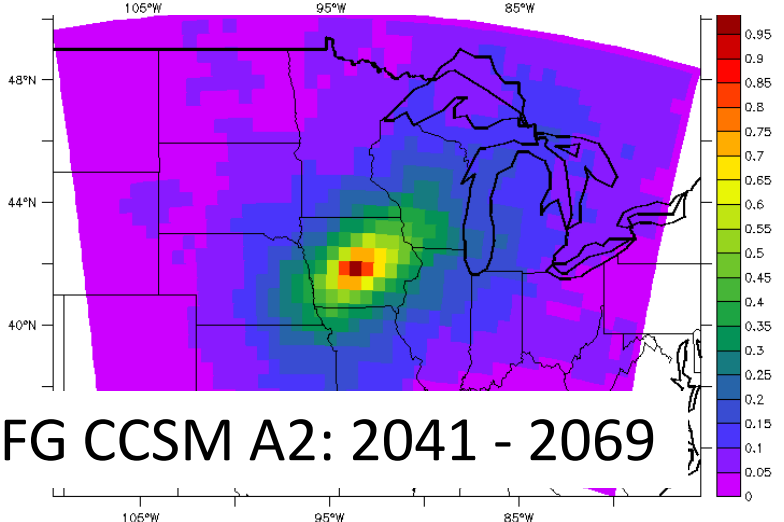
WRFG NCEP: 1981-2004



WRFG CCSM A2: 1971-1999

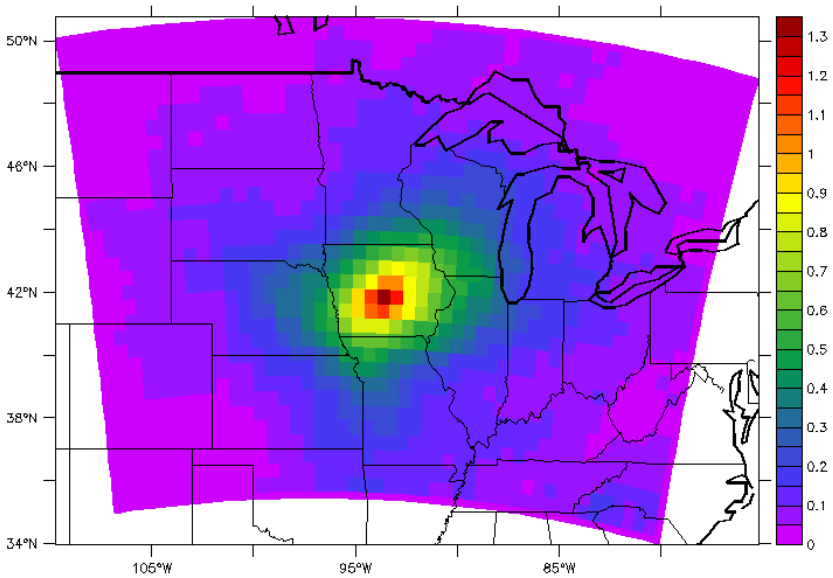


WRFG CCSM A2: 2041 - 2069

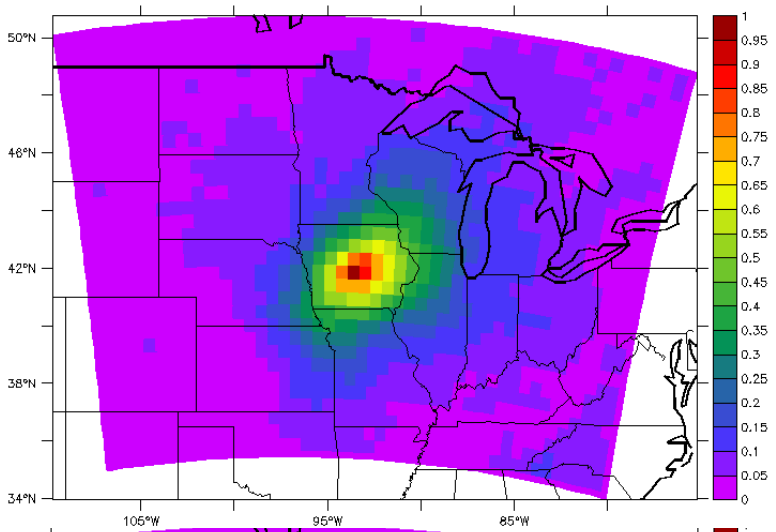


Future Period Object Analysis

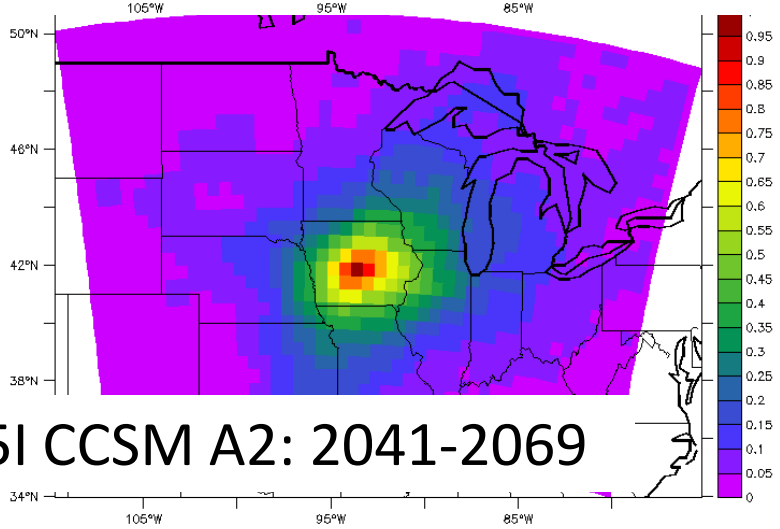
MM5I NCEP: 1981-2004



MM5I CCSM A2: 1971-1999

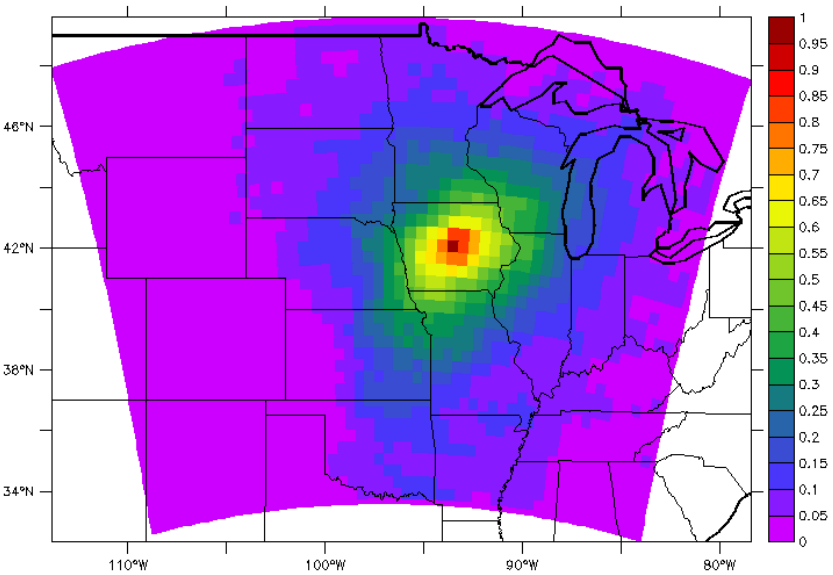


MM5I CCSM A2: 2041-2069

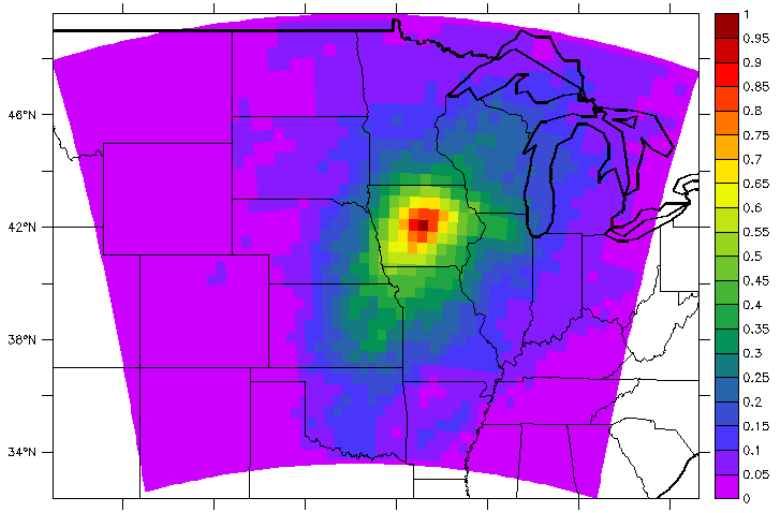


Future Period Object Analysis

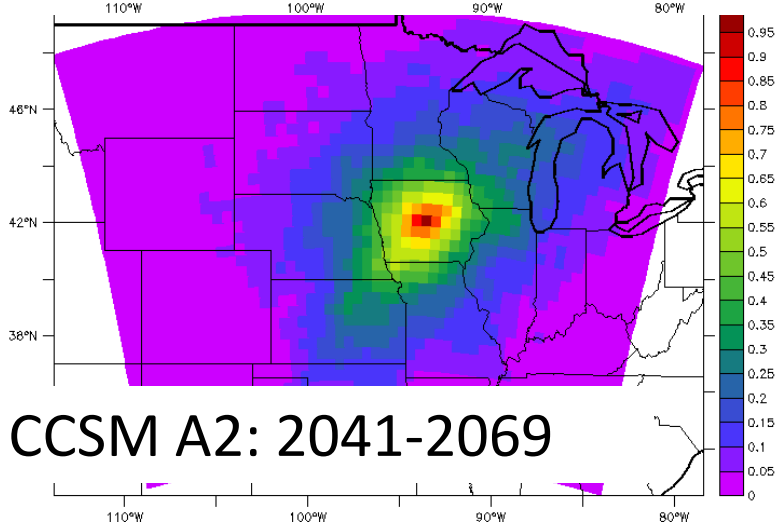
CRCM NCEP: 1981-2004



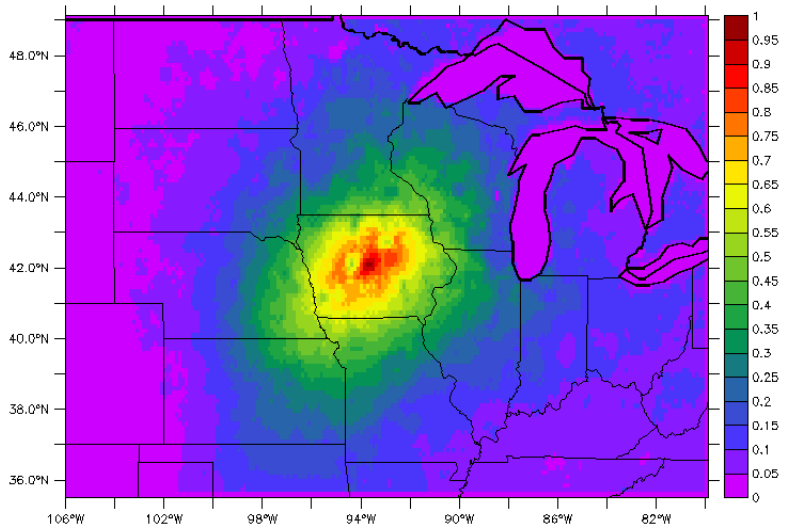
CRCM CCSM A2: 1971-1999



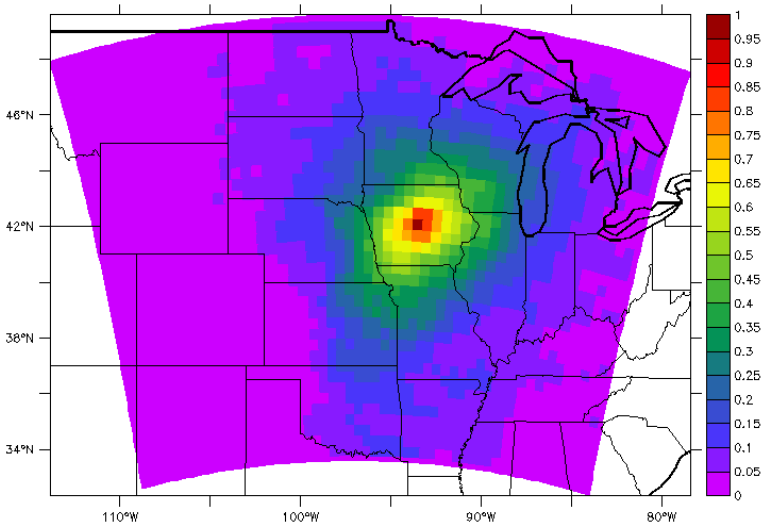
CRCM CCSM A2: 2041-2069



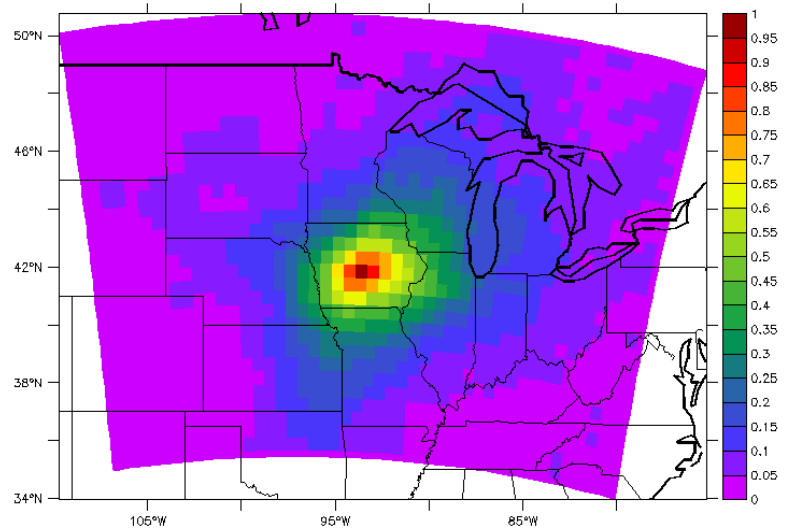
CCSM: 2020 – 2059



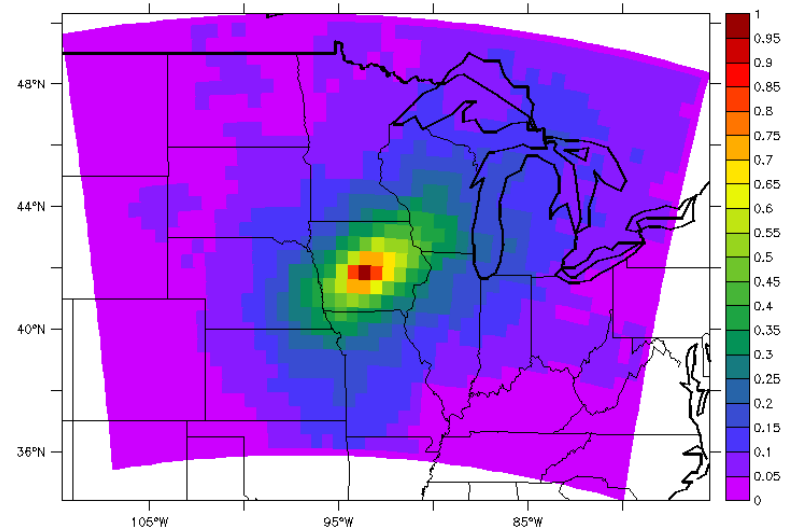
CRCM CCSM A2 2041 - 2070



MM5I CCSM A2 2041 - 2070

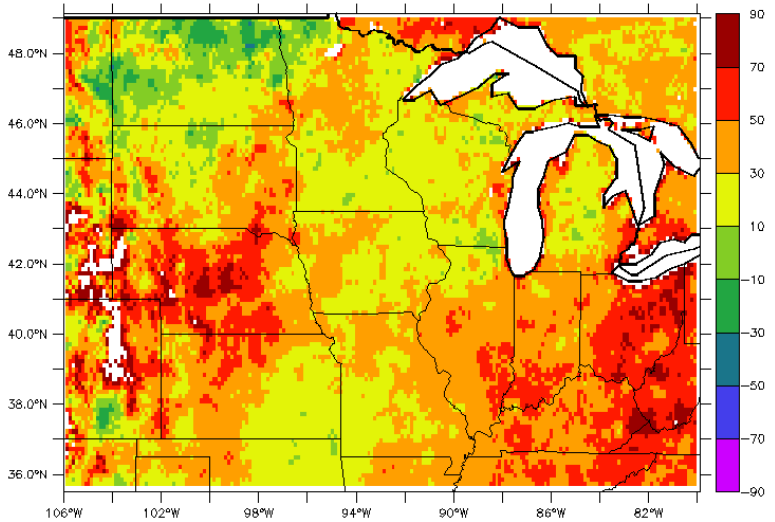


WRFG CCSM A2 2041 - 2070

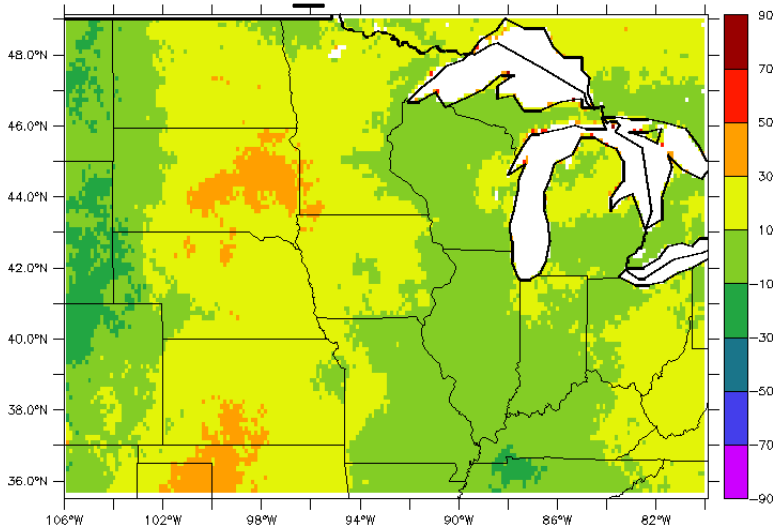


Percent Change of Large Object Frequency ARRM, 1960-1999 and 2020-2059

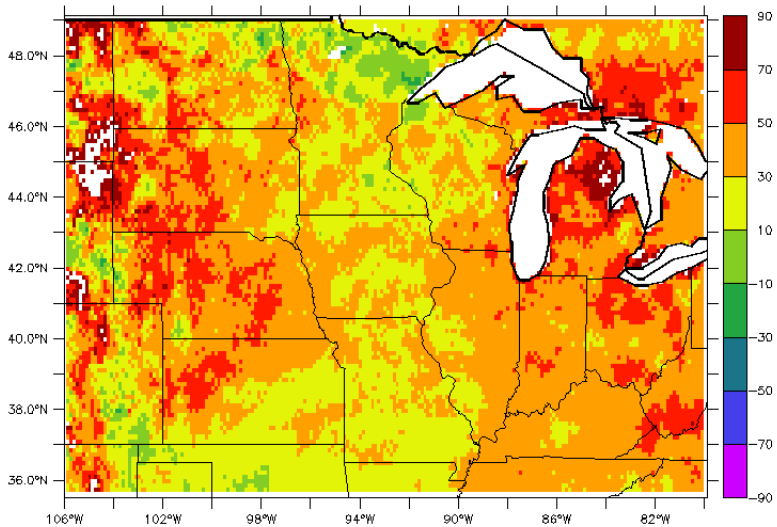
CCSM A1FI



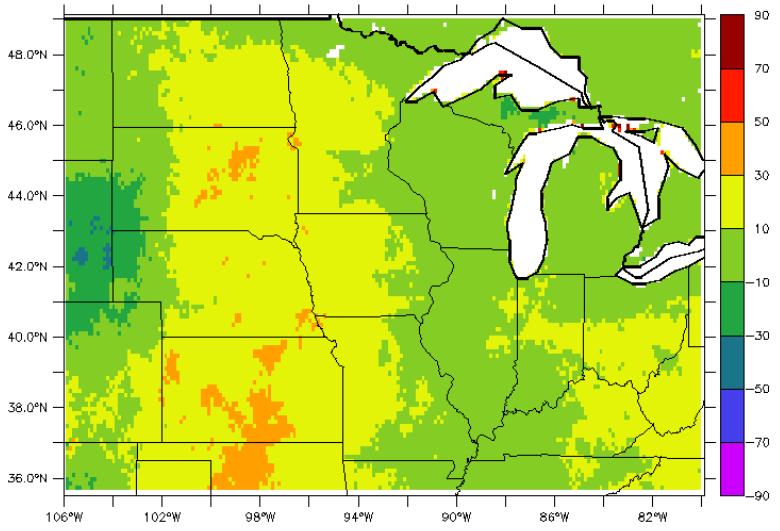
CGCM3_T47 A1B



CCSM A2

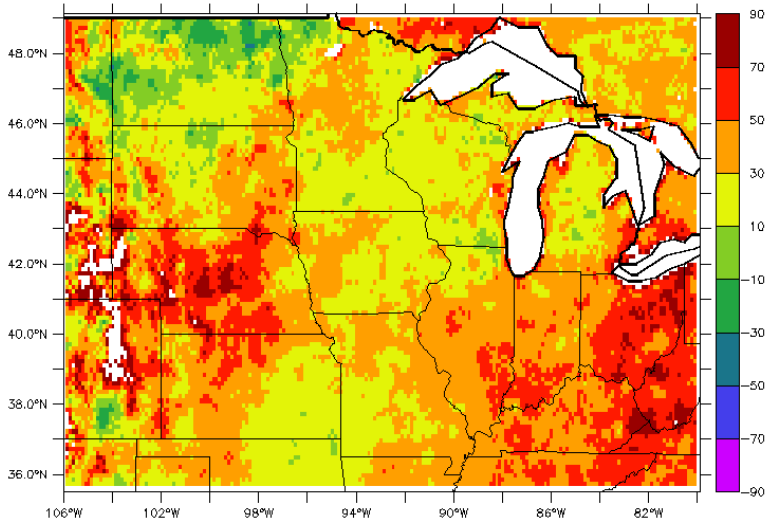


CGCM3_T47 A2

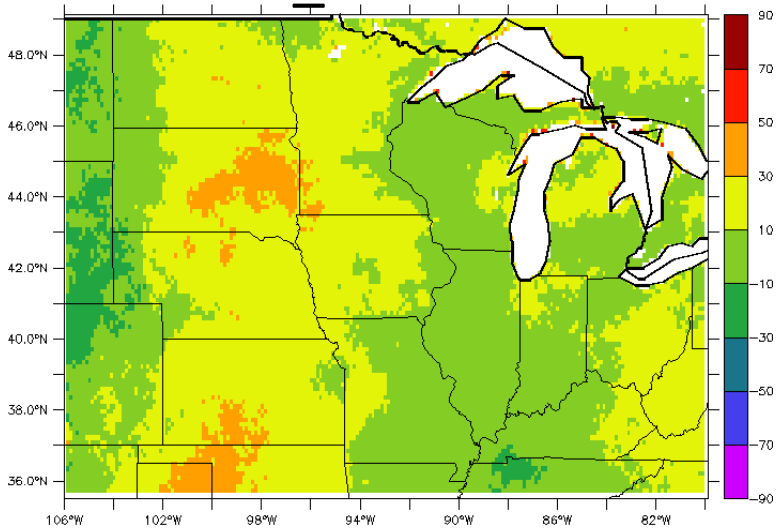


Percent Change of Large Object Frequency ARRM, 1960-1999 and 2020-2059

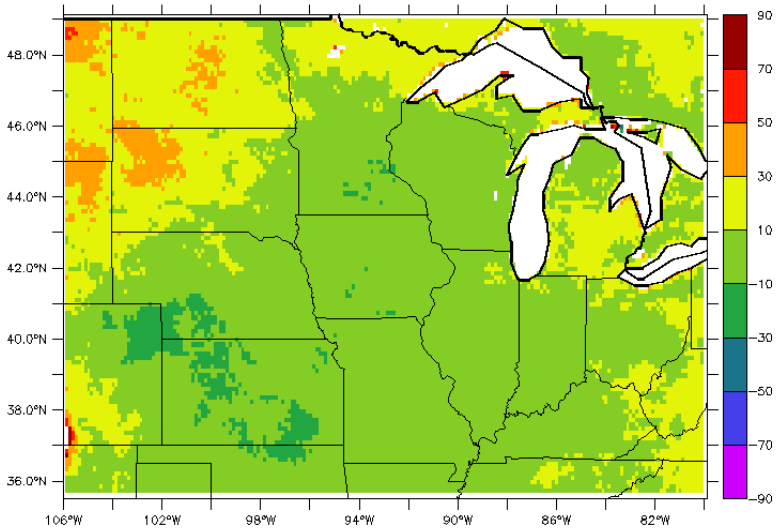
CCSM A1FI



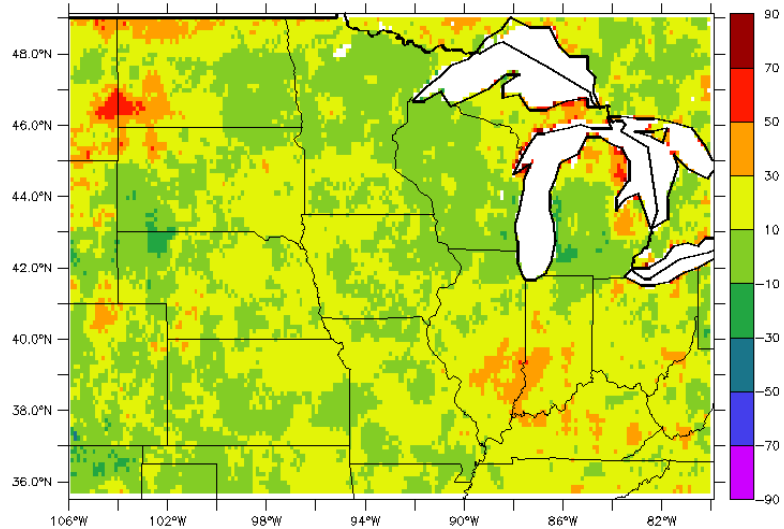
CGCM3_T47 A1B



HADCM3 A2

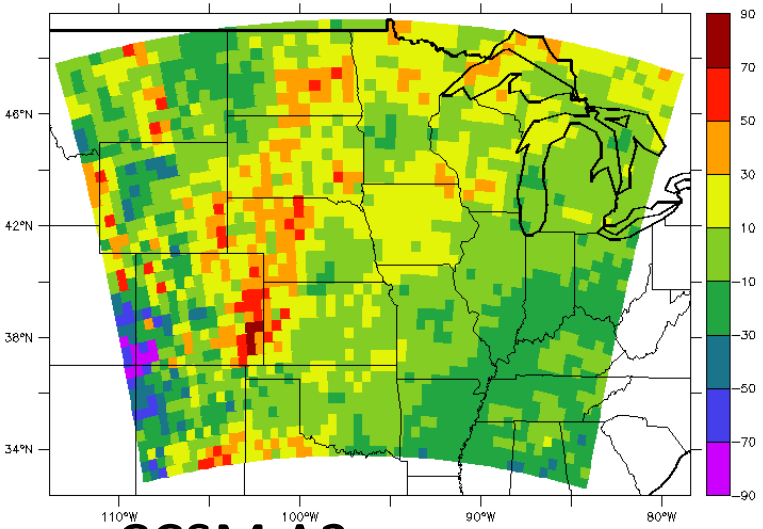


EHCAM5 A1B

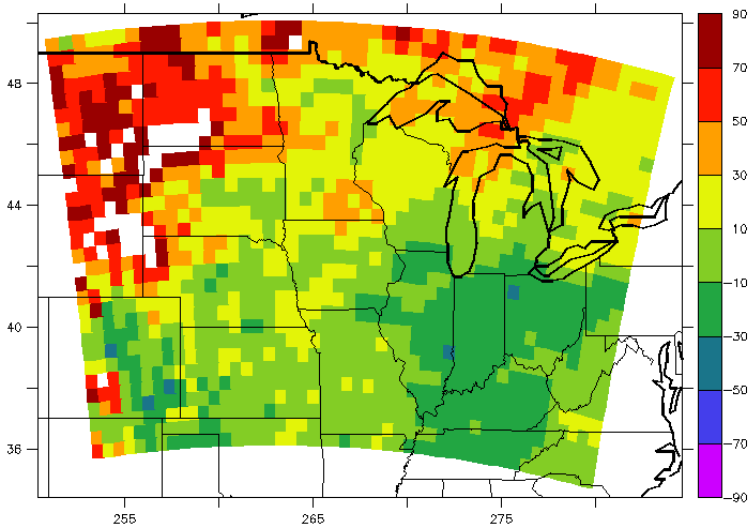


Percent Change of Large Object Frequency NARCCAP, 1971-1999 and 2041-2069

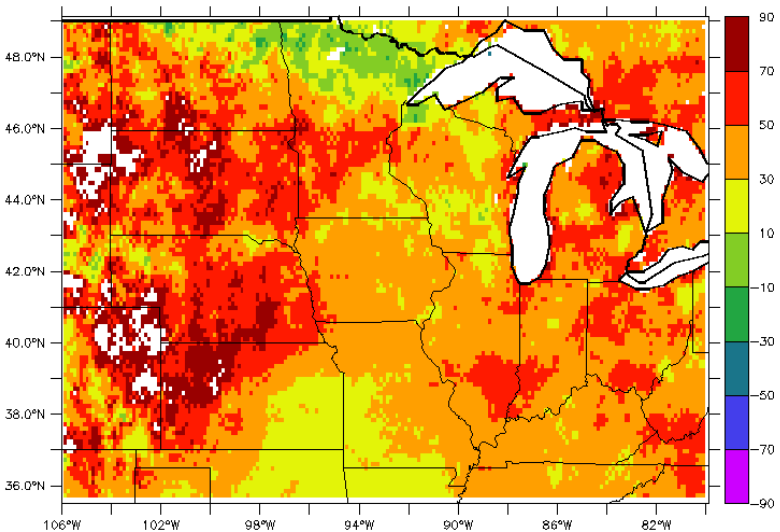
CRCM CCSM A2



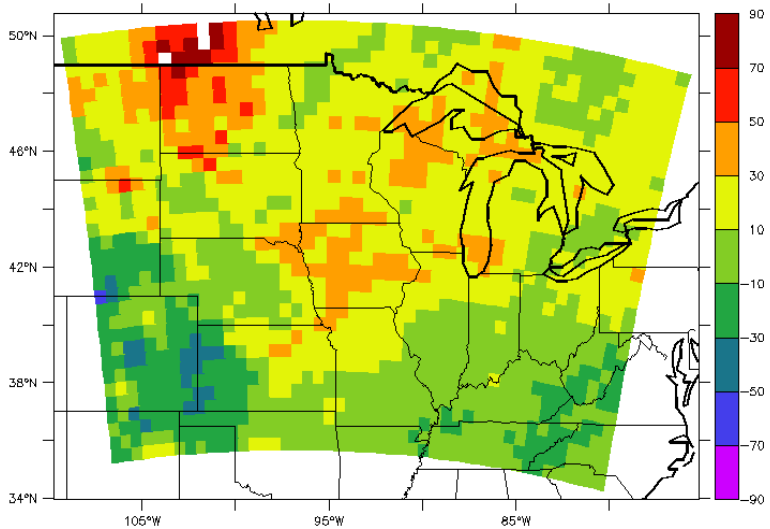
WRFG CCSM A2



CCSM A2



MM5I CCSM A2



Summary

- I have used object-oriented analysis (MODE) to evaluate rare, high-amount 1-day rainfall events in historical and downscaled data.

- The object-oriented analysis in the Midwest enables us to
  - ***relate directly rainfall and flood engineering design statistics***
  - identify relevant meteorological conditions and their spatial and temporal variation
  - evaluate spatial and temporal variability of flood-relevant rainfall within the training period of downscaled data sets
  - evaluate changes of flood-relevant rainfall in climate projections

- Preliminary findings are
  - ARRM and NARCCAP 0.5” objects have spatial size similar to observed large 0.5” objects
  - ARRM passes-through GCM spatial pattern of 0.5” objects while NARCCAP adjusts the spatial pattern
  - Neither downscaling method predicts a change in spatial pattern of 0.5” objects
  - Most downscaled projections predict an increase in frequency ~10%.