Great Lakes Climate Change Hydrologic Impact Assessment
IJC Lake Ontario—St. Lawrence River Regulation Study

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Fox-Wolf Watershed Alliance
Stormwater Conference 2007
and
University of Wisconsin Sea Grant Institute
Wisconsin Coastal Management Program
National Oceanic and Atmospheric Administration

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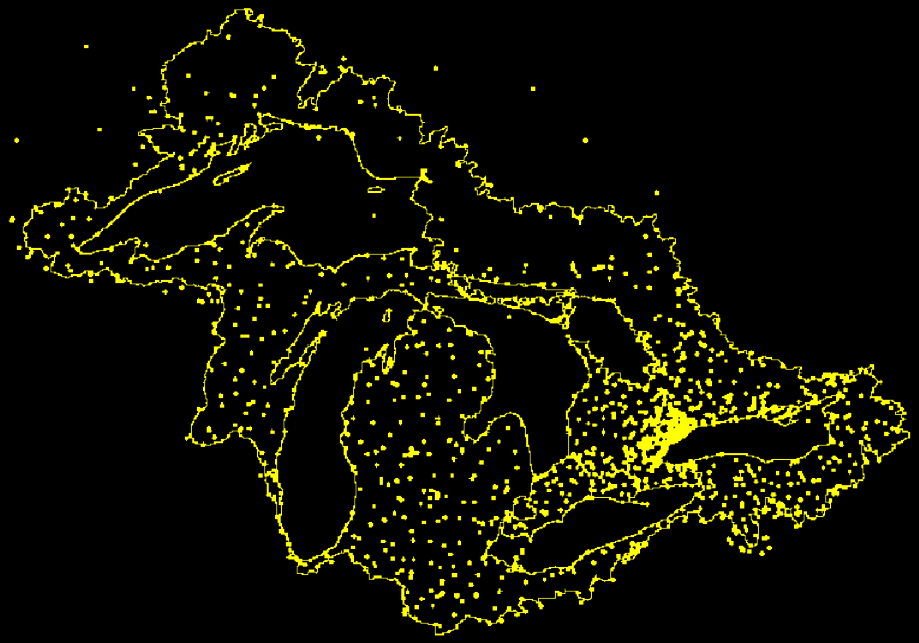
Green Bay, Wisconsin

Climate Data



Climate Changes

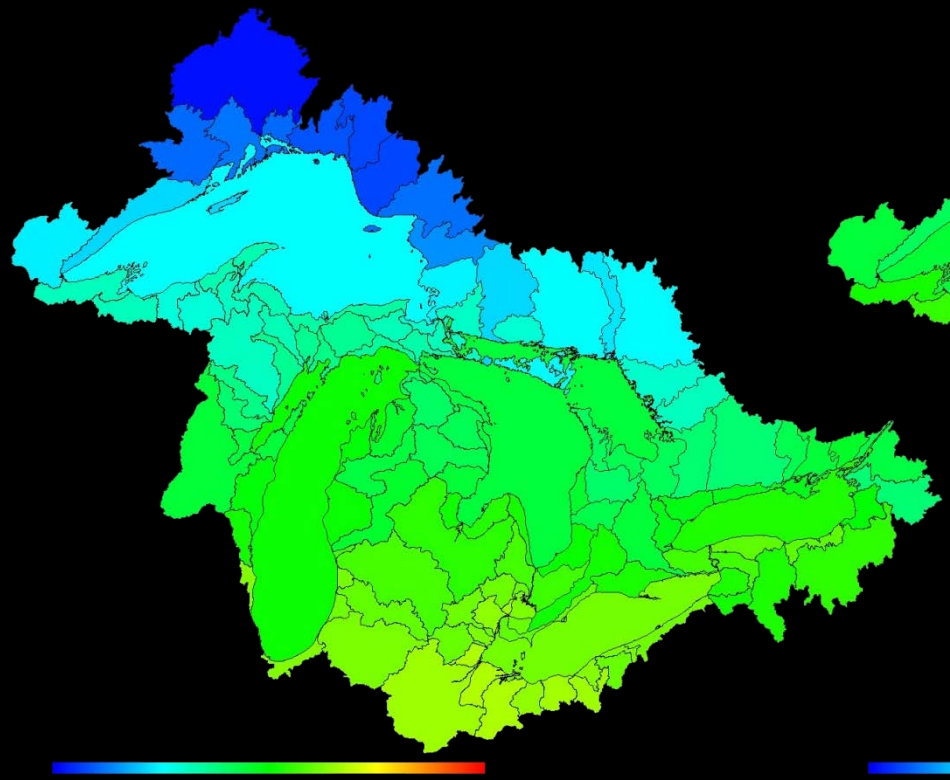
- "Base Case" Scenario (Historical)
- Extract Differences for Each Month of Year
- Extract Ratios for Each Month of Year
- Apply Ratios & Differences to Base Case

Modeling Procedure

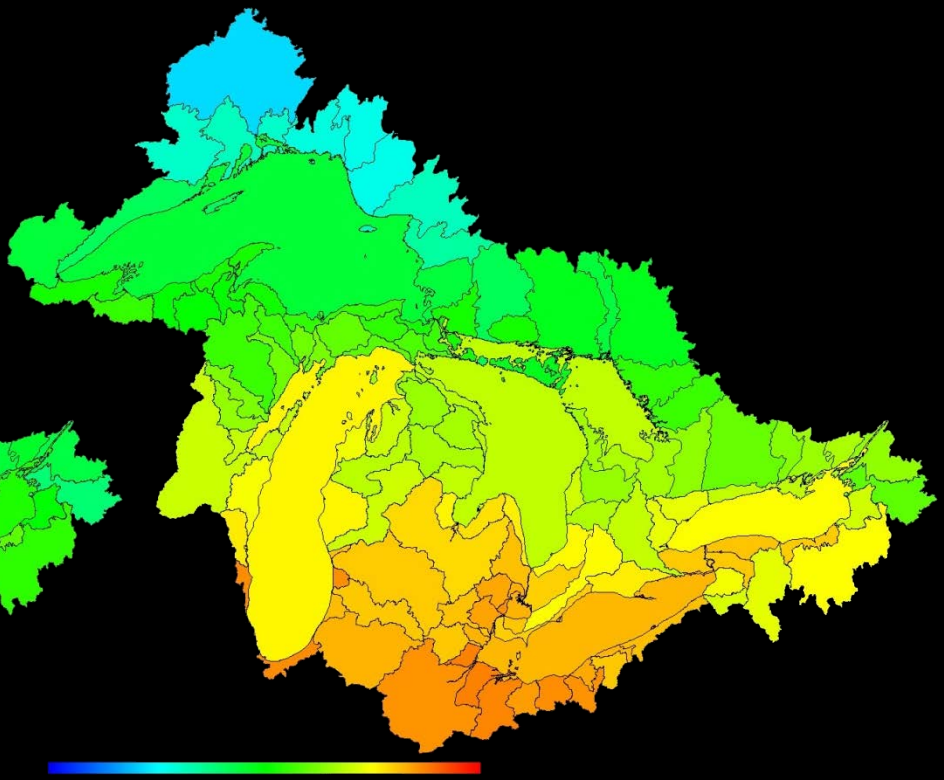
- Arbitrary Initial Conditions
- Estimate "Steady-State" Conditions
  - repeat 52-yr simulation
- Simulate for All Scenarios (Including Base Case)
  - 121 watersheds and 7 lakes
- Interpret Differences As Hydrology Impacts

Climate Scenarios (Average Air Temperature, 0—15°C)

Base Case

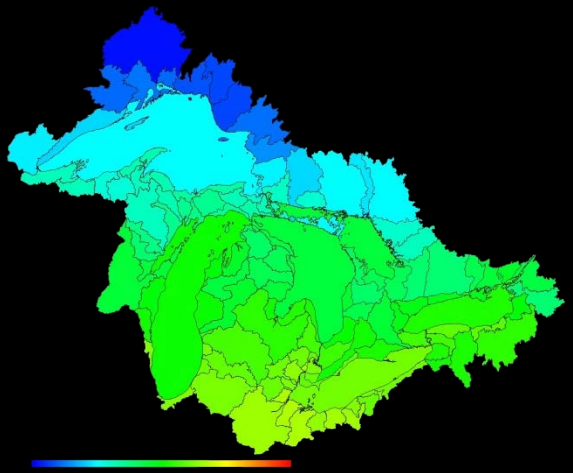


Canadian GCM 2, warm & dry

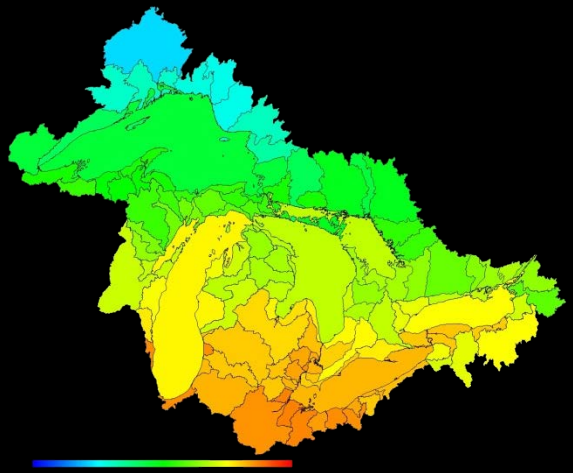


Climate Scenarios (Average Air Temperature, 0—15°C)

Base Case



Warm & Dry



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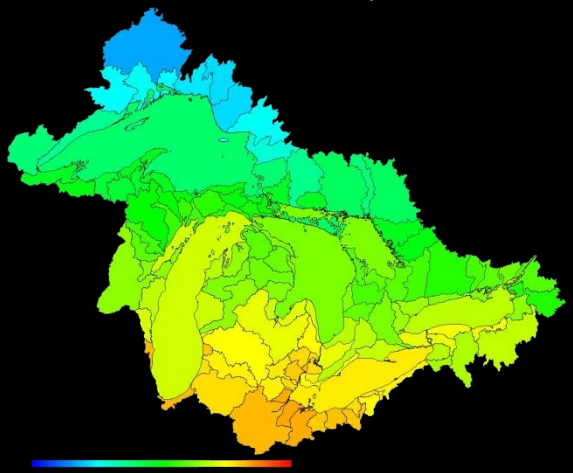

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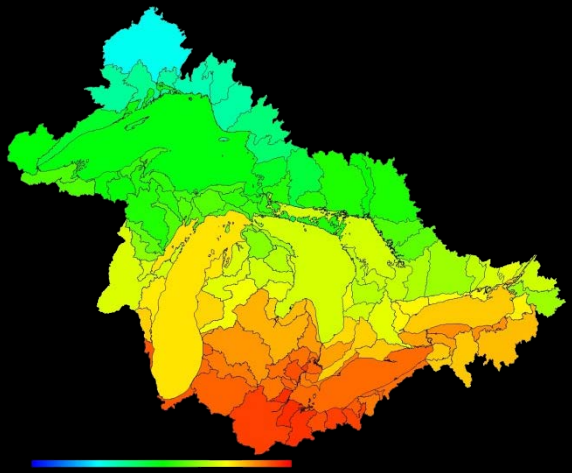
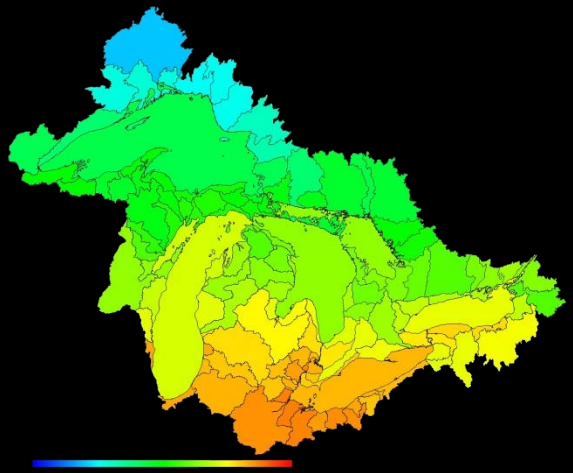
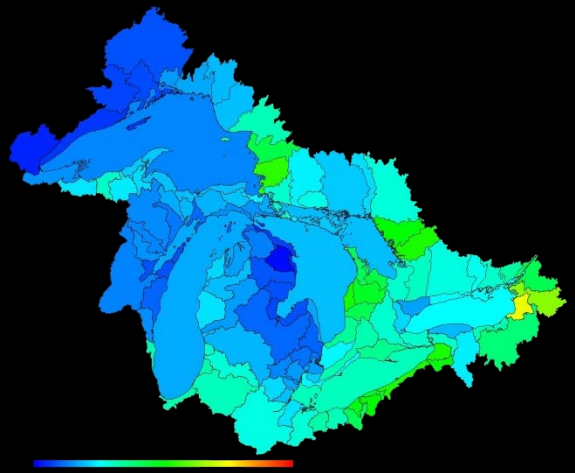


Cool & Wet



Climate Scenarios (Average Annual Precipitation, 0.7—1.4 m)

Base Case



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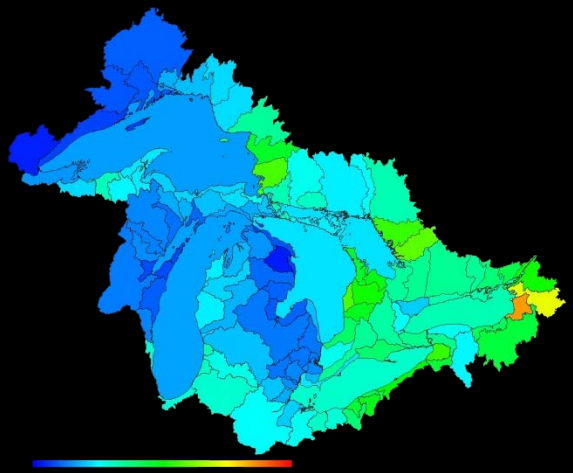

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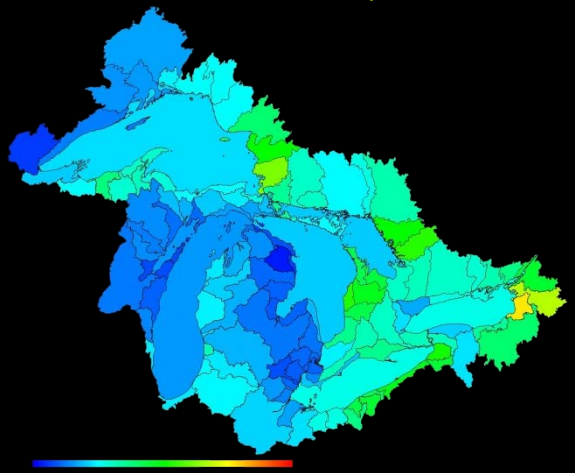
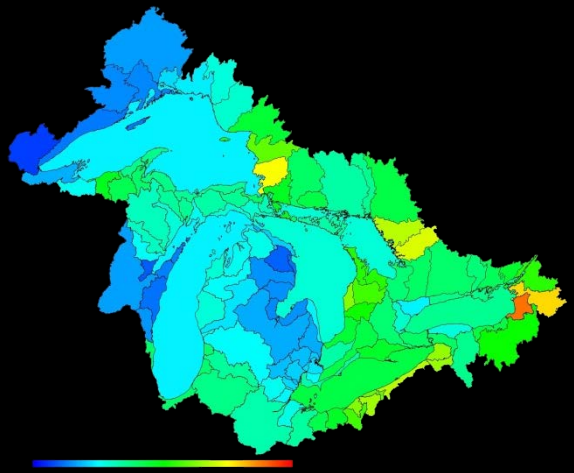


Warm & Wet



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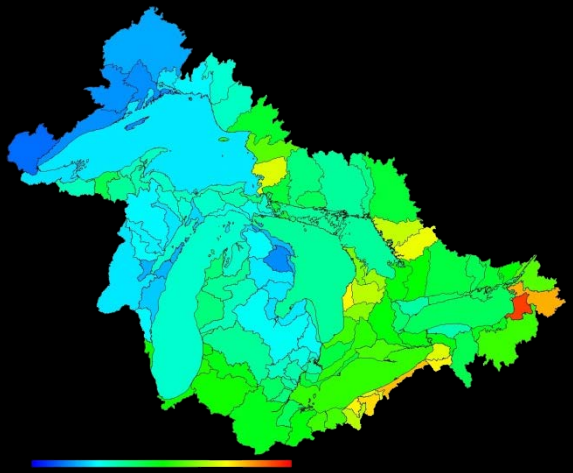
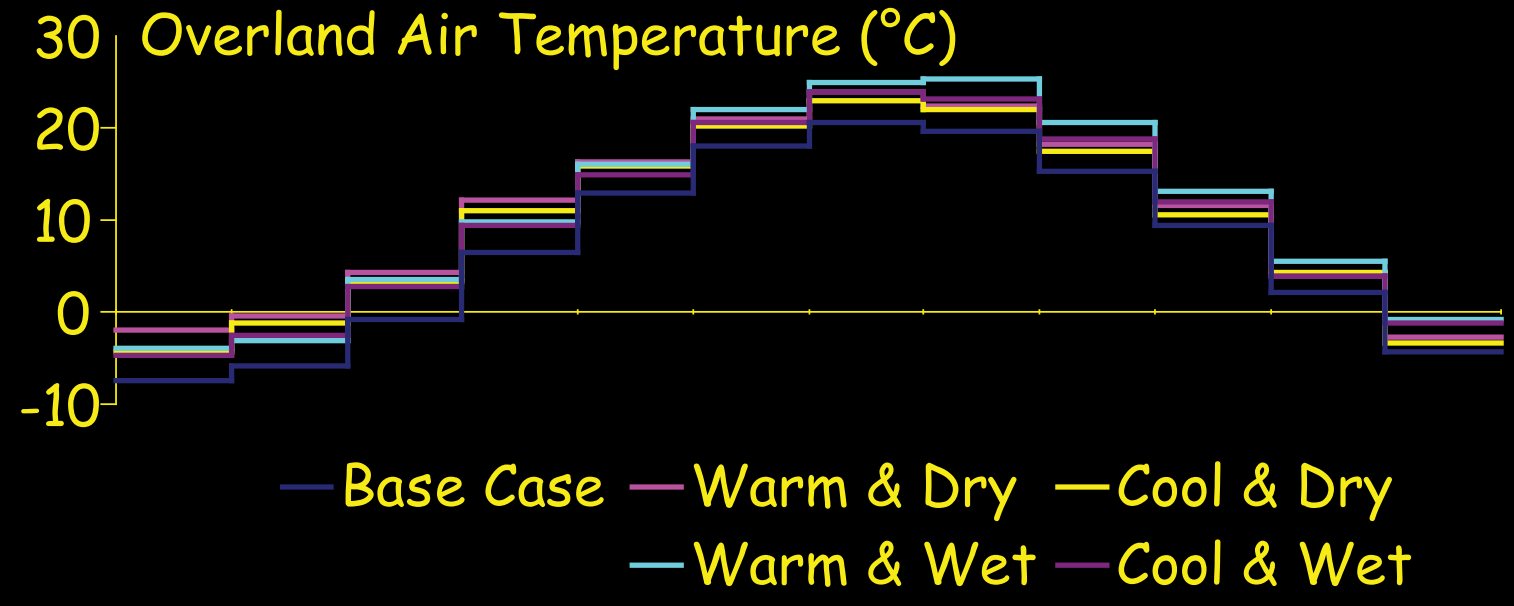
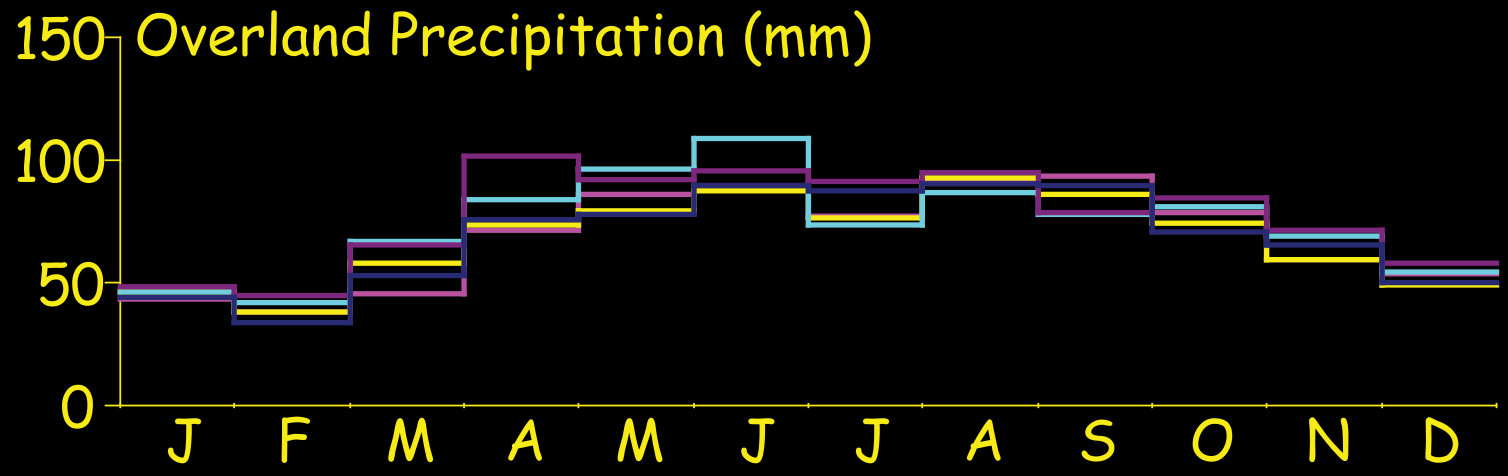
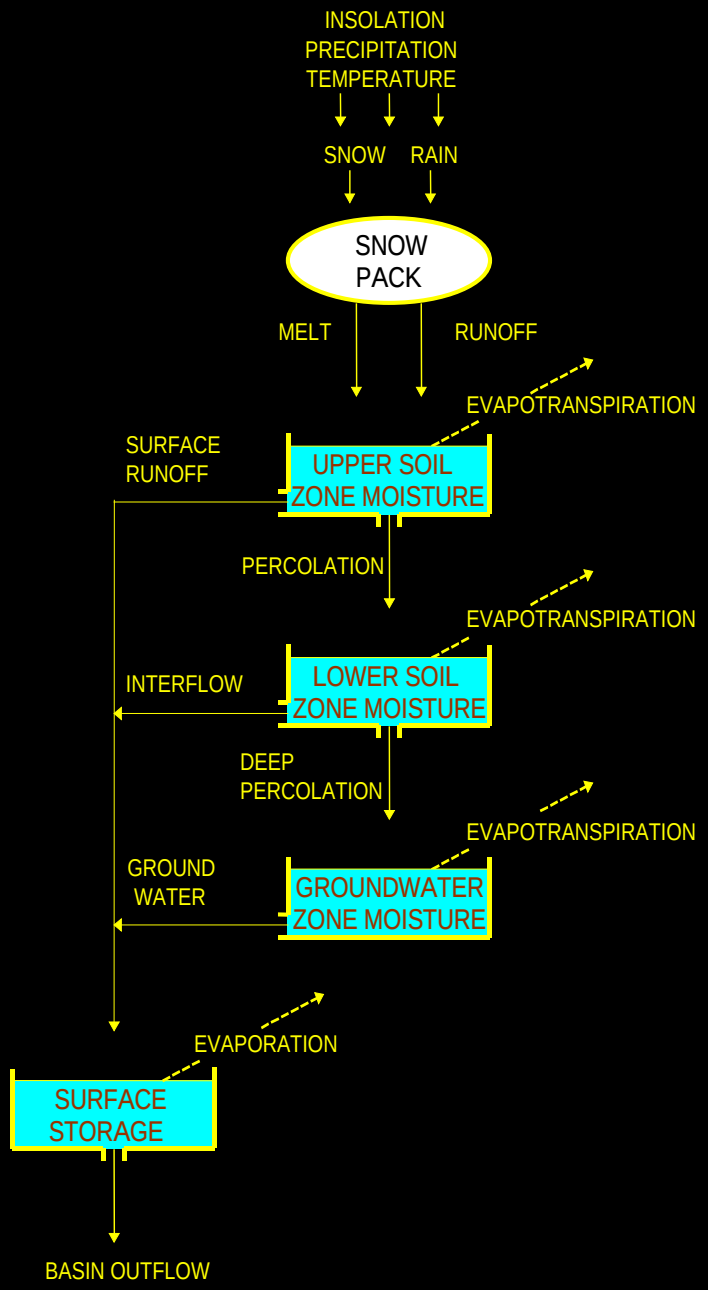
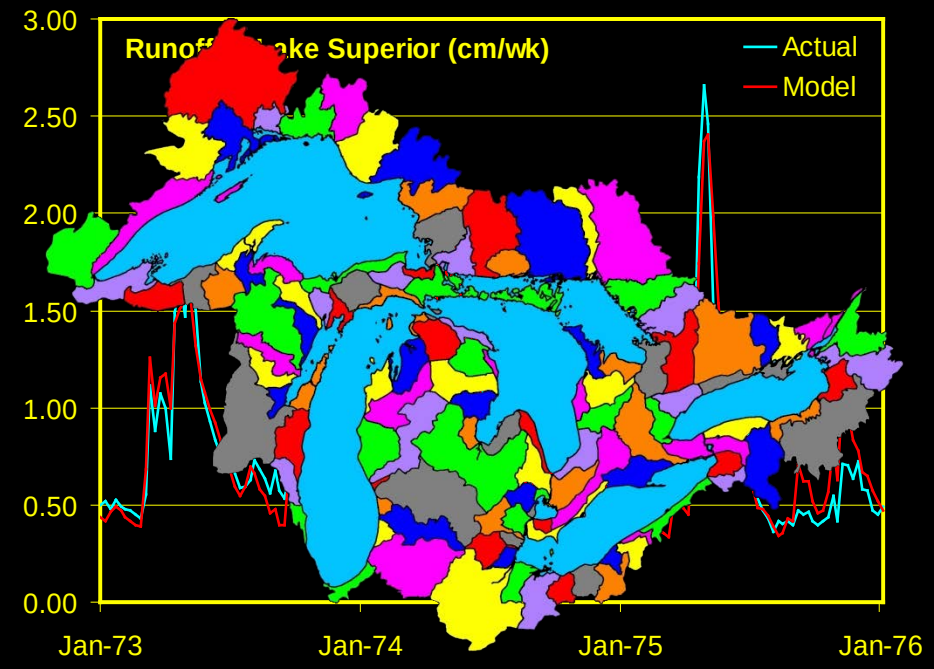


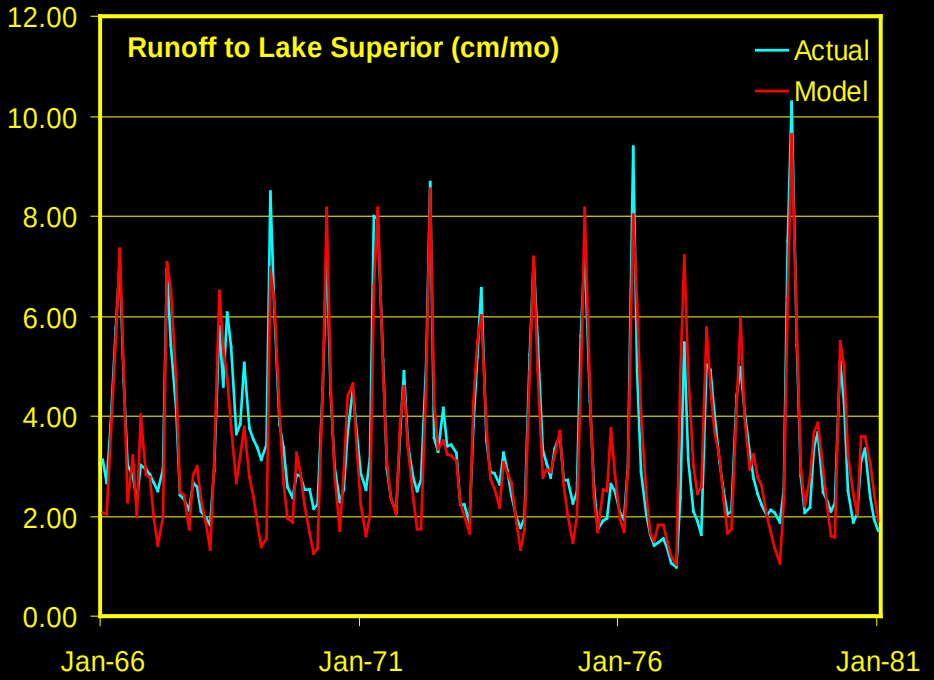
Climate Scenarios (Michigan Seasonal Meteorology)





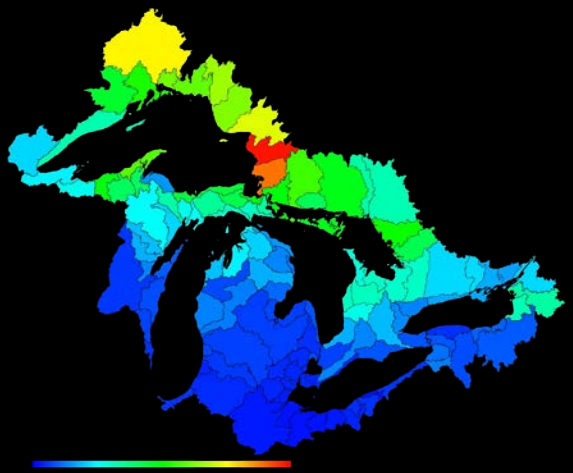

INSOLATION
PRECIPITATION
TEMPERATURE
SNOW
RAIN
SNOW PACK
MELT
RUNOFF
EVAPOTRANSPIRATION
SURFACE RUNOFF
UPPER SOIL ZONE MOISTURE
PERCOLATION
EVAPOTRANSPIRATION
INTERFLOW
LOWER SOIL ZONE MOISTURE
DEEP PERCOLATION
EVAPOTRANSPIRATION
GROUND WATER
GROUNDWATER ZONE MOISTURE
EVAPORATION
SURFACE STORAGE
BASIN OUTFLOW


Actual
Model
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Jan-73
Jan-74
Jan-75
Jan-76

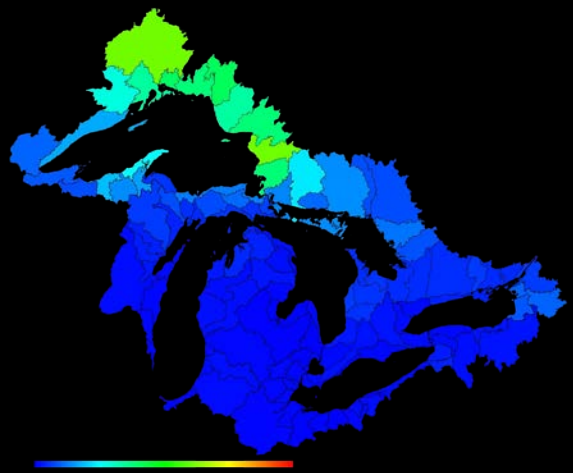

Runoff to Lake Superior (cm/mo)
Actual
Model
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Jan-66
Jan-71
Jan-76
Jan-81

Basin Response (Average Snow Water Moisture, 0—9 cm)

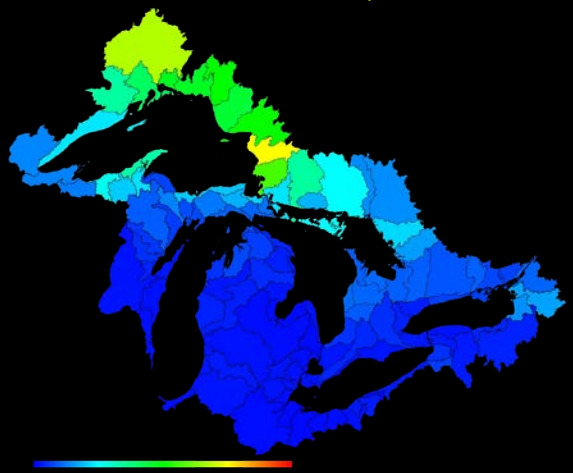
Base Case



Warm & Dry



Cool & Dry



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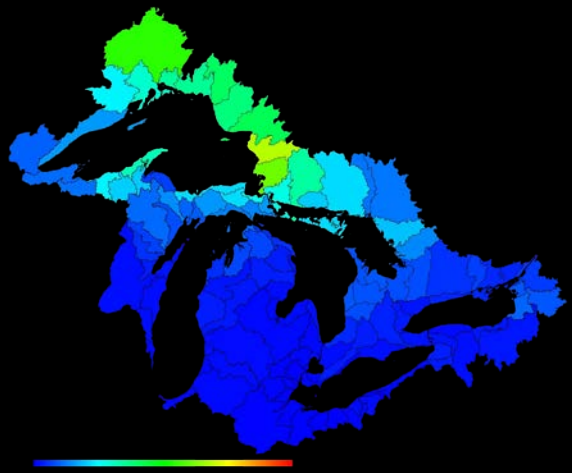
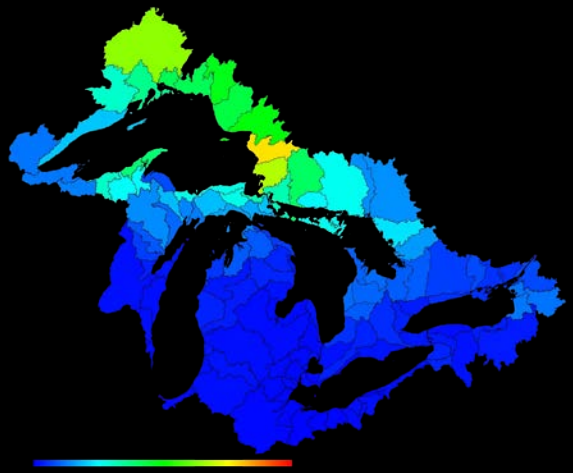
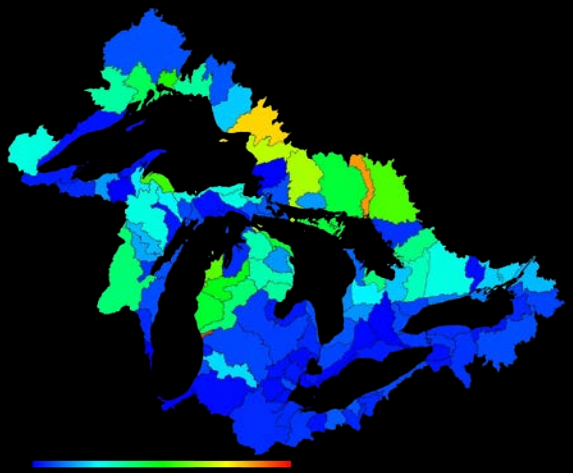


Cool & Wet

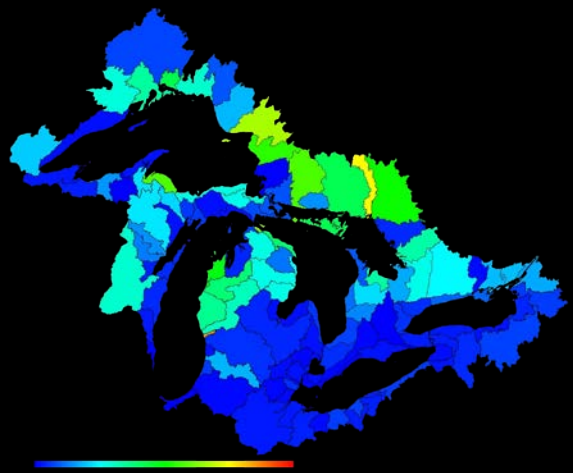


Basin Response (Average Soil Moisture, 0—1.7 m)

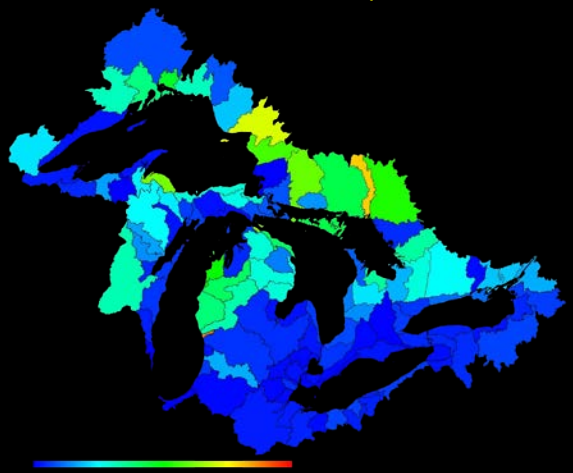
Base Case



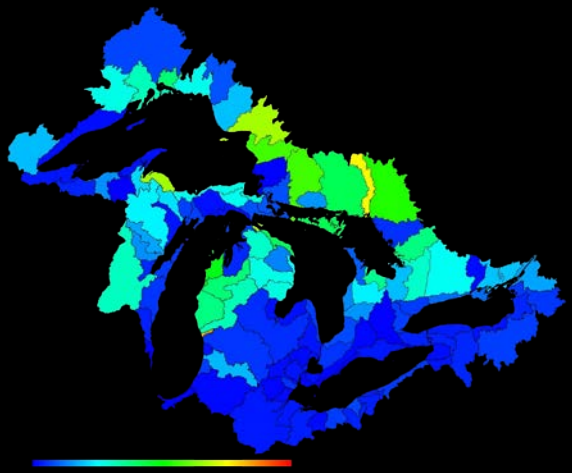
Warm & Dry



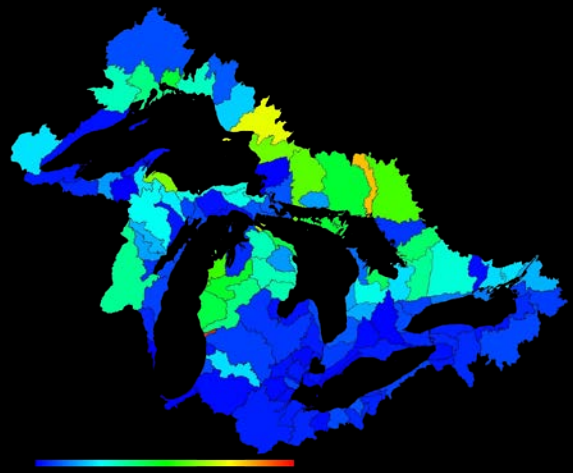
Cool & Dry



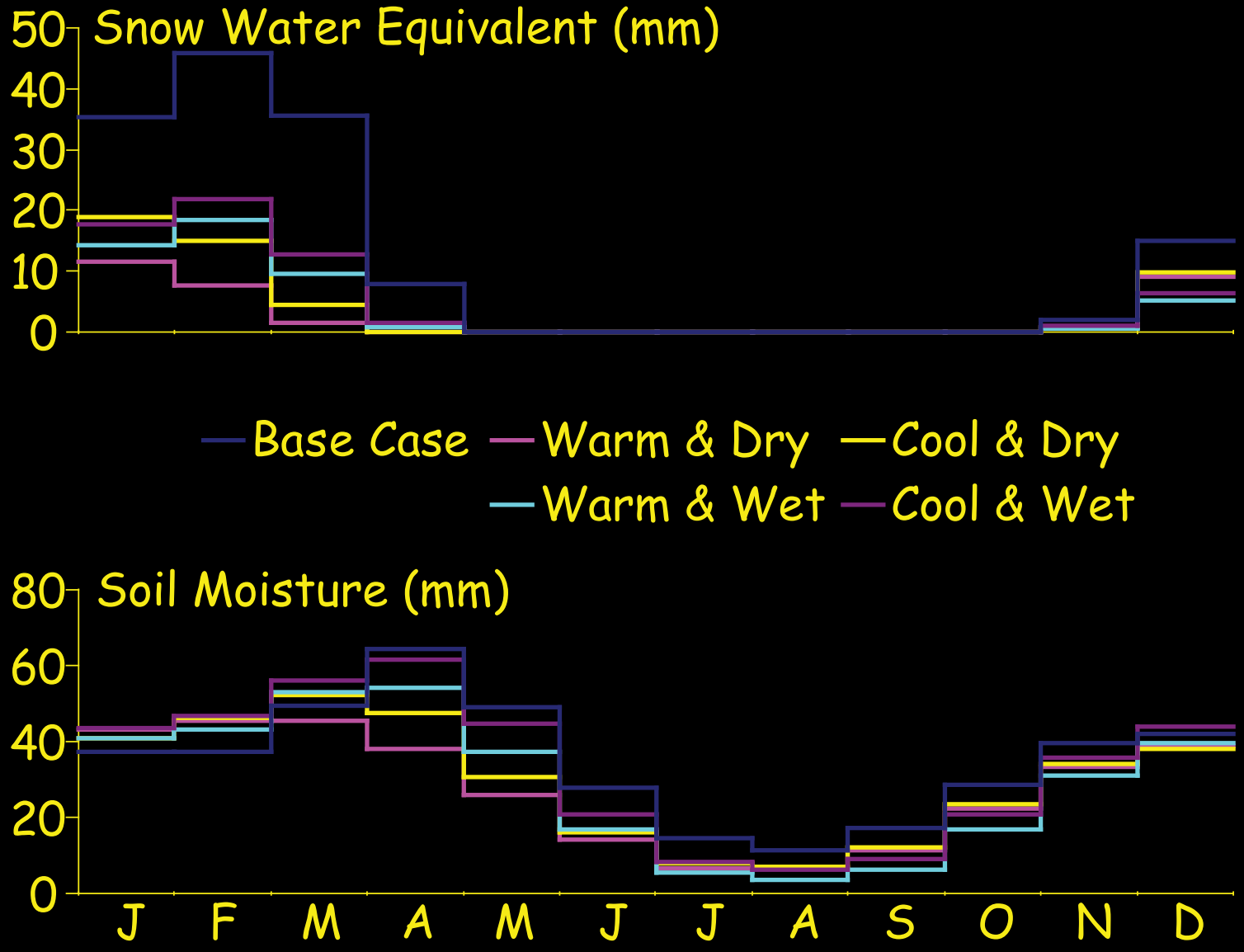
Warm & Wet



Cool & Wet

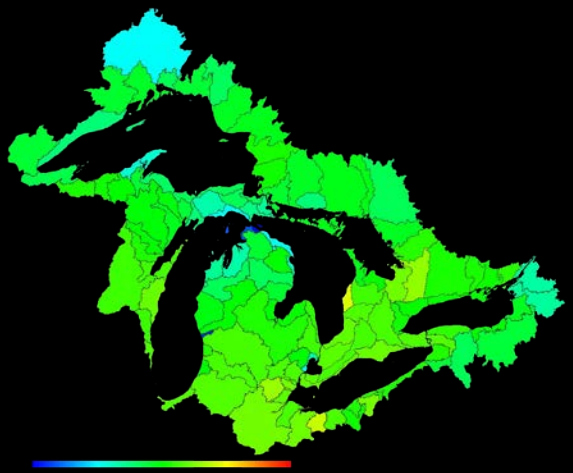


Basin Response (Michigan Seasonal Storages)

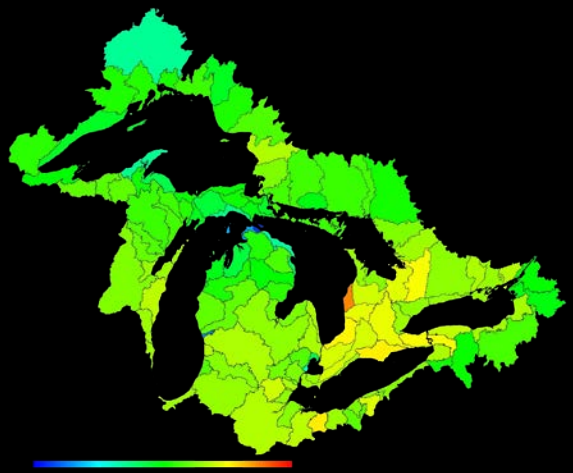


Basin Response (Average Ann. Evapotranspiration, 0.1—0.9 m)

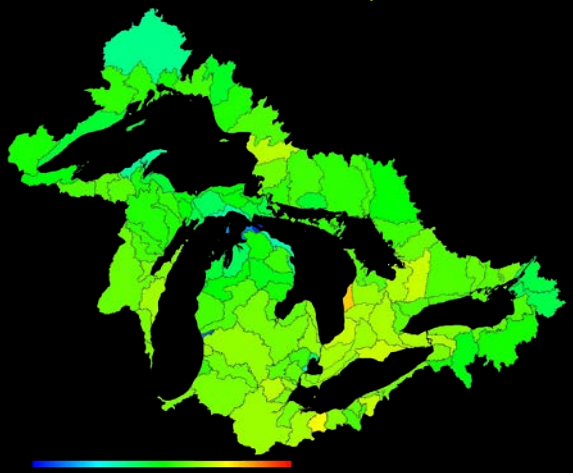
Base Case



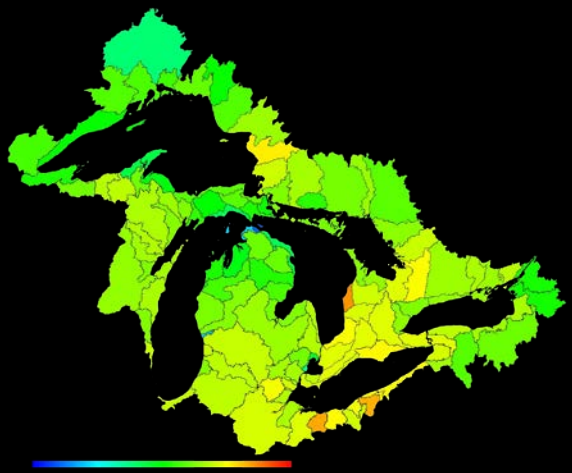
Warm & Dry



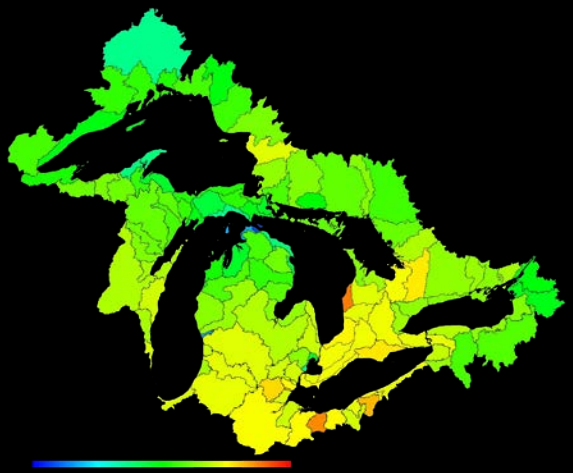
Cool & Dry



Warm & Wet

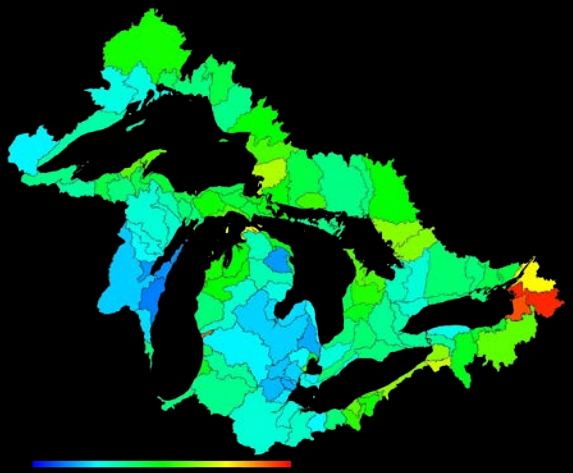


Cool & Wet



Basin Response (Average Annual Runoff, 0.1—0.8 m)

Base Case



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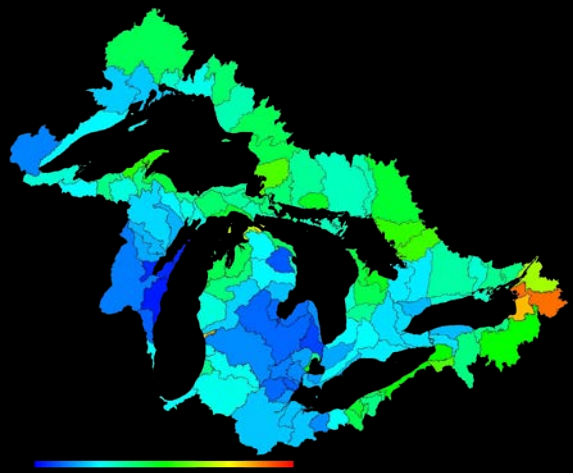
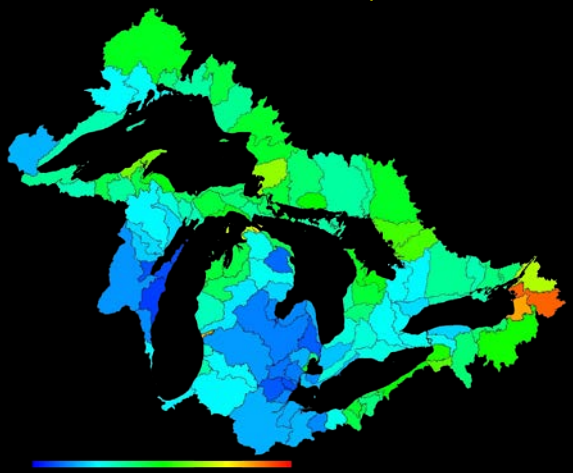


Cool & Dry



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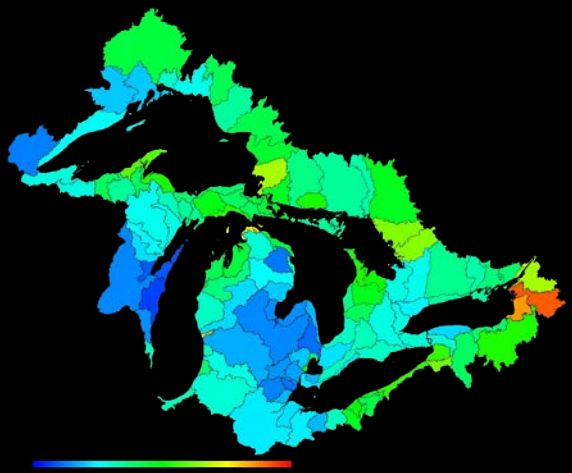
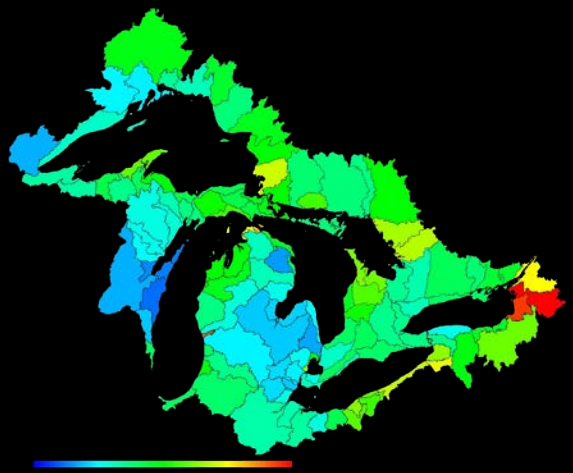
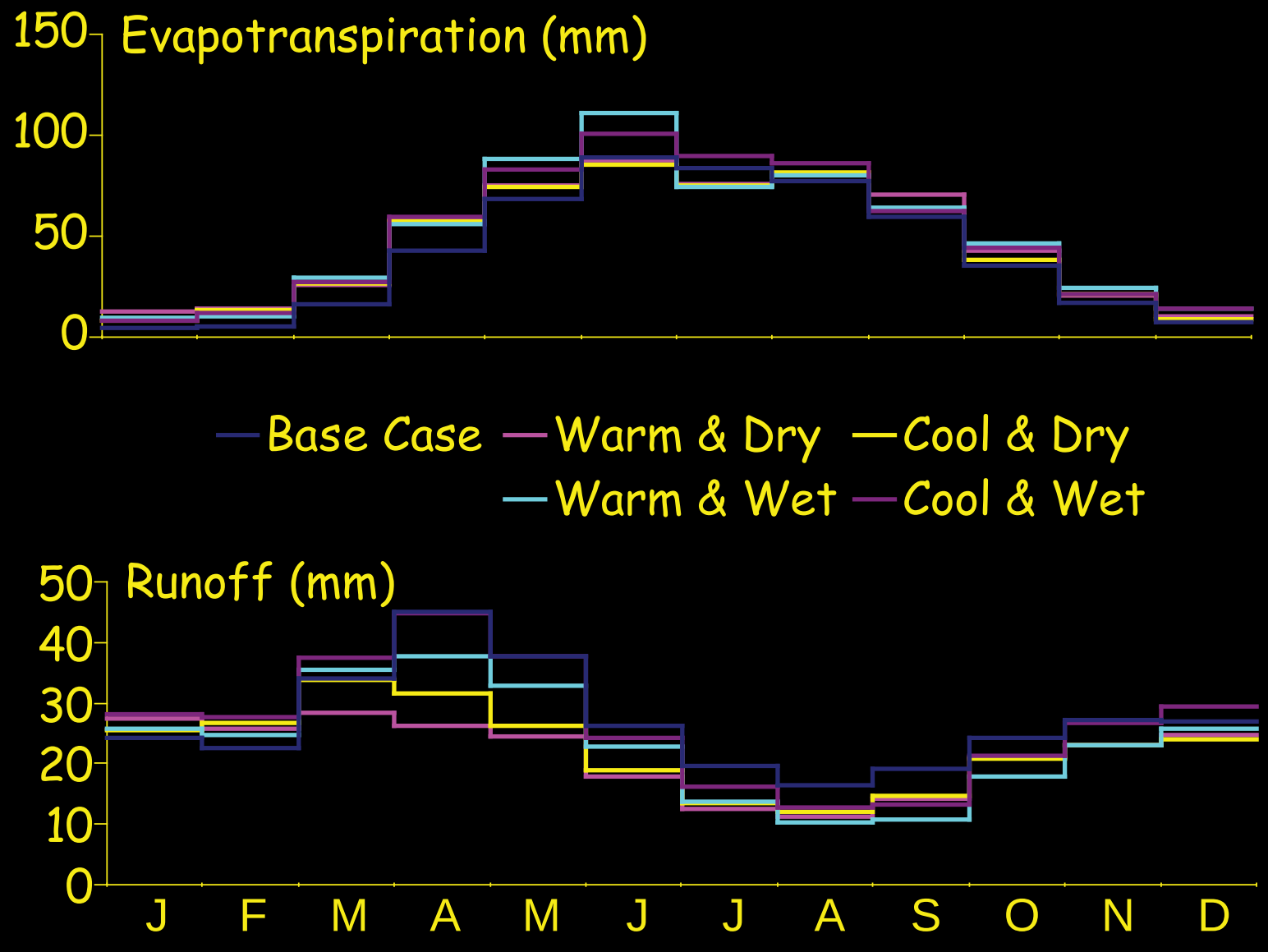


Cool & Wet

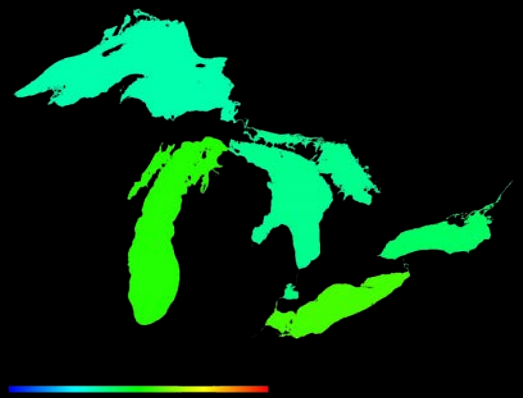


Basin Response (Michigan Seasonal Flows)



Climate Scenarios (Average Cloud Cover, 50—70%)

Base Case



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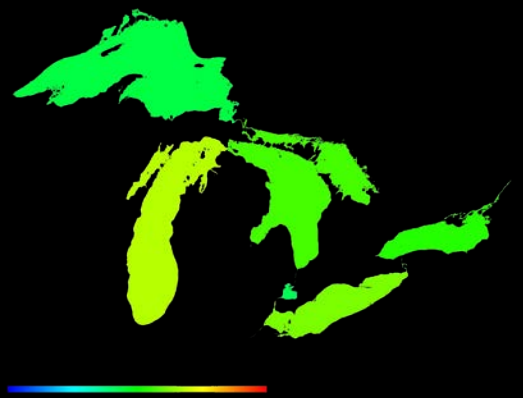
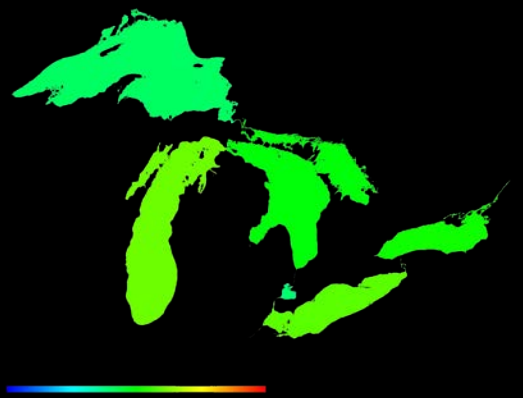


Cool & Dry



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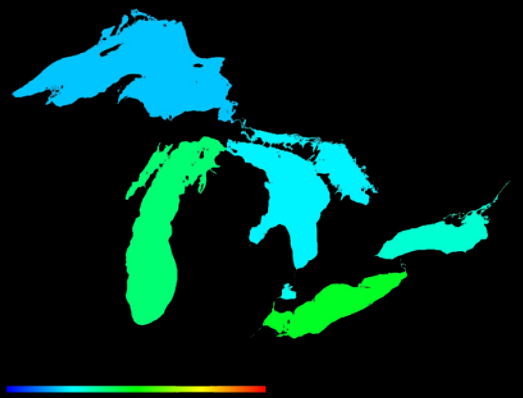
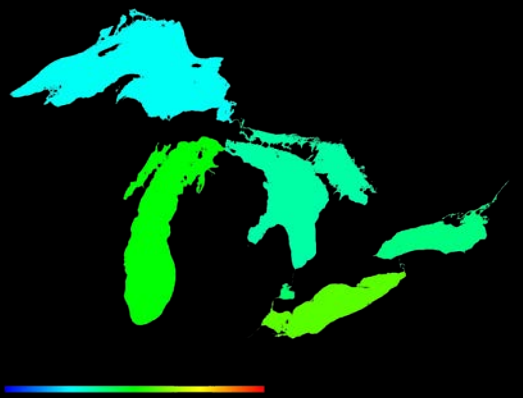
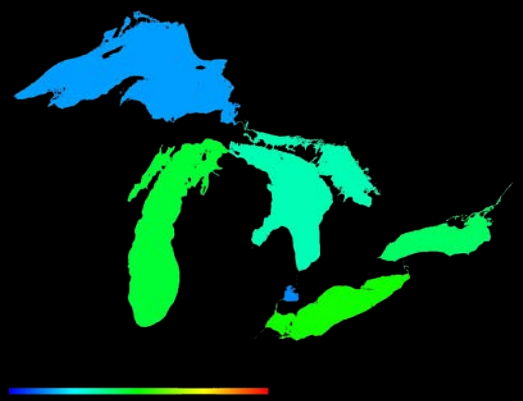


Cool & Wet

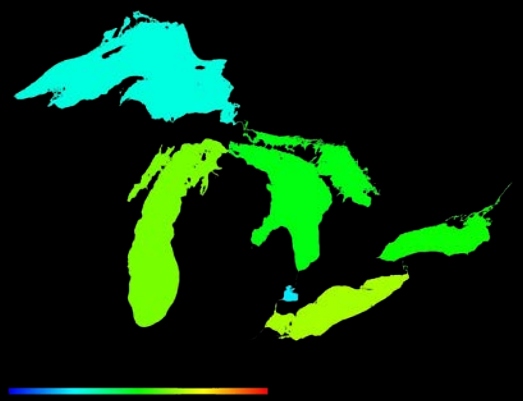


Climate Scenarios (Average Wind Speed, 5—7 m/s)

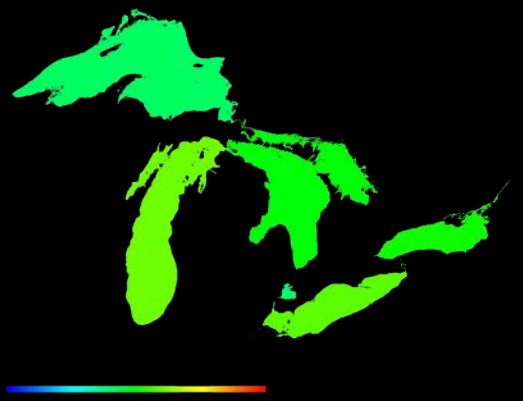
Base Case



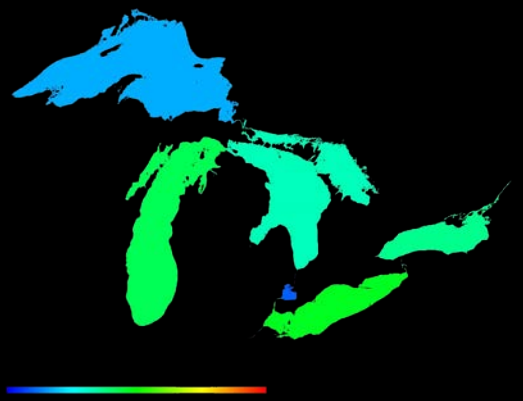
Warm & Dry



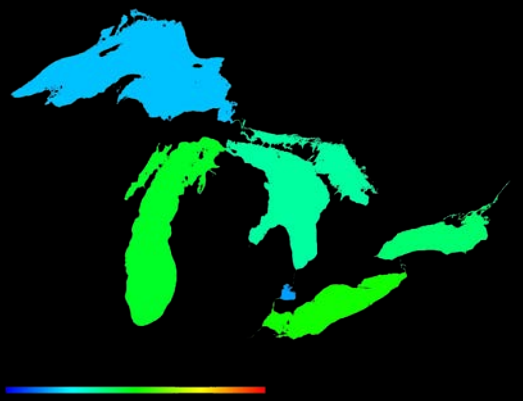
Cool & Dry



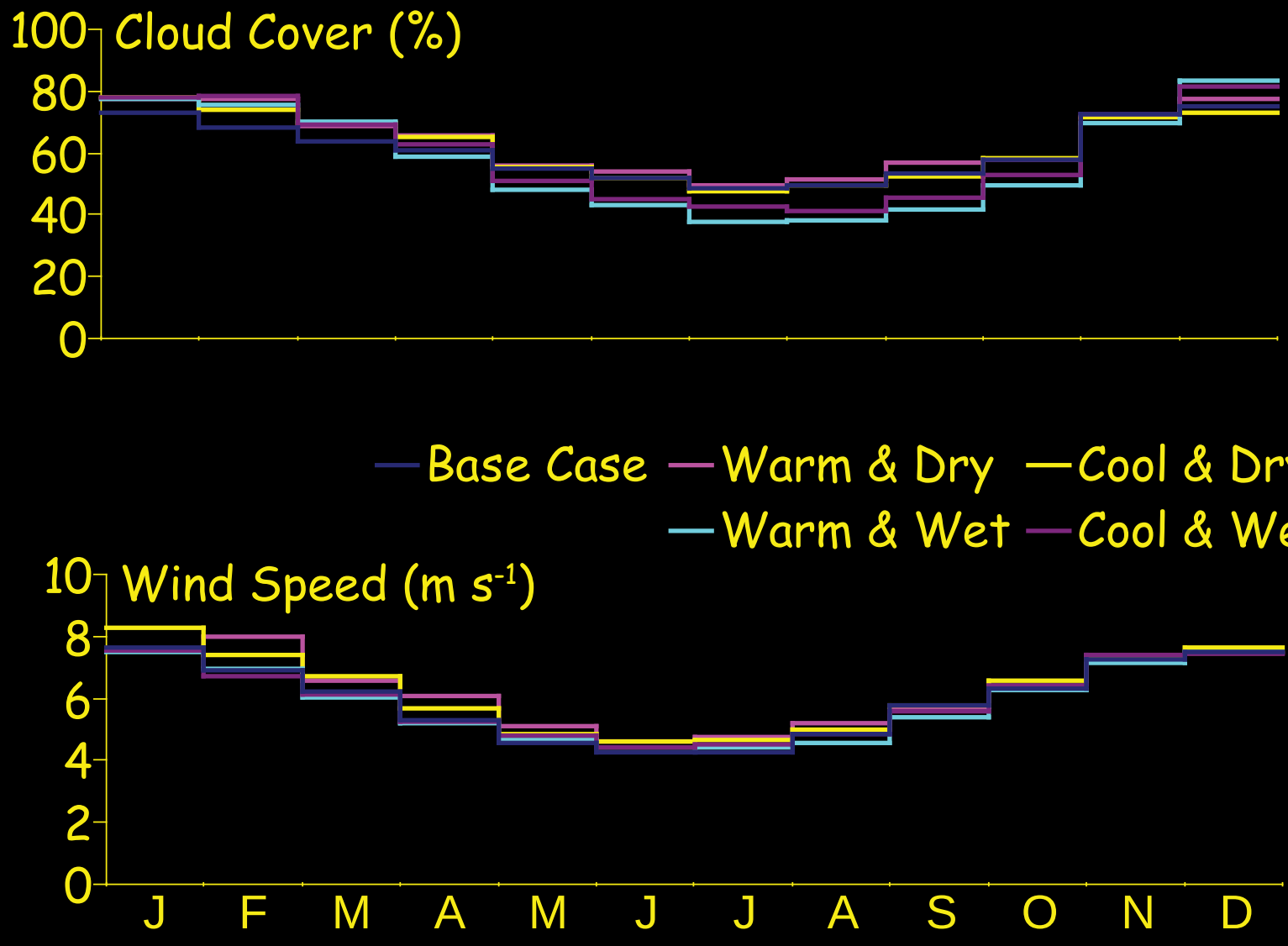
Warm & Wet



Cool & Wet

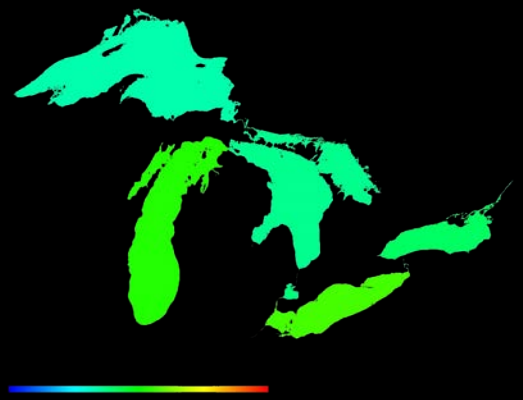


Lake Response (Michigan Seasonal Meteorology)

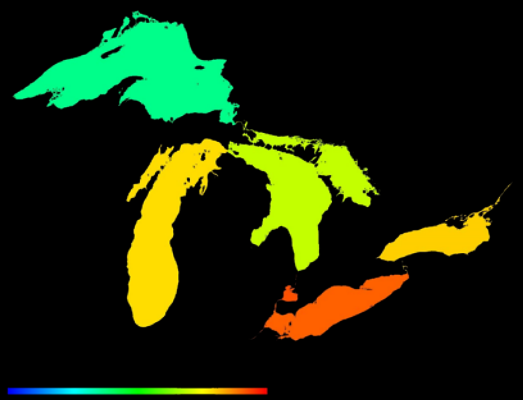


Climate Scenarios (Average Air Temperature, 3—14°C)

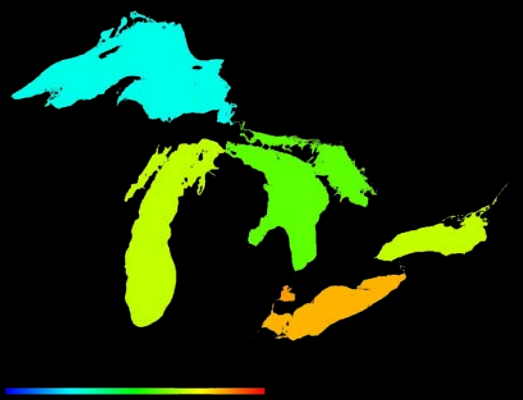
Base Case



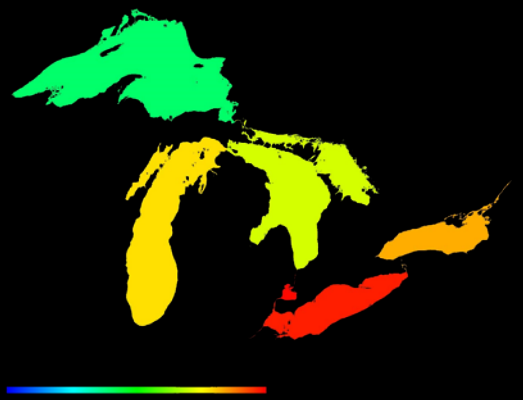
Warm & Dry



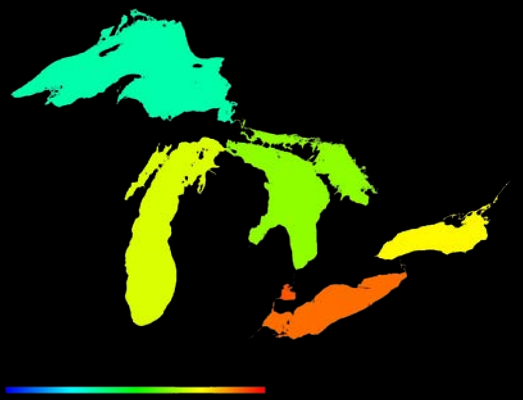
Cool & Dry



Warm & Wet

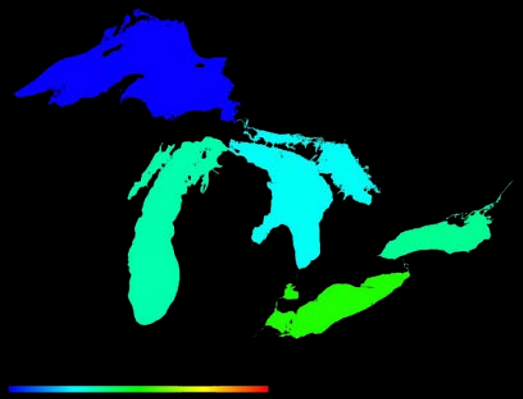


Cool & Wet

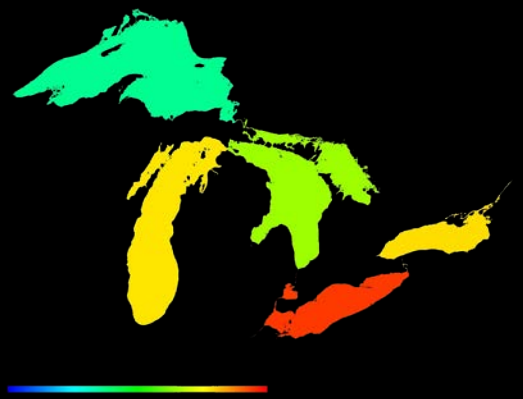


Climate Scenarios (Average Absolute Humidity, 7—14 mb)

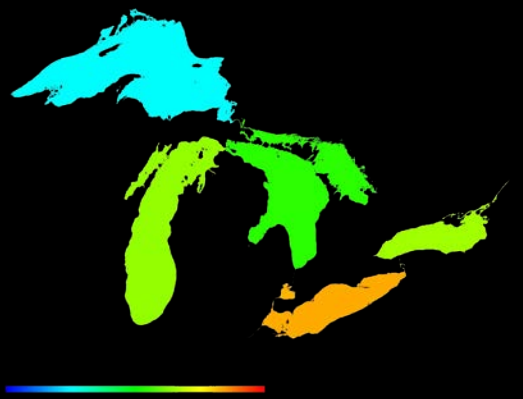
Base Case



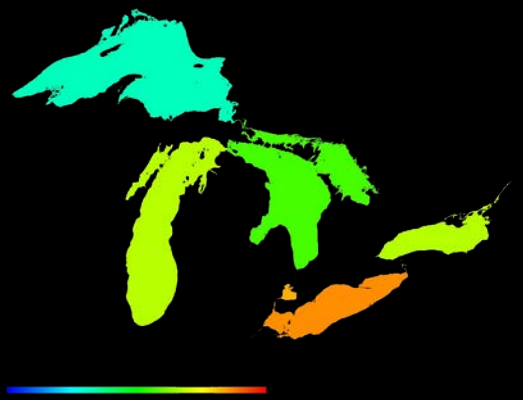
Warm & Dry



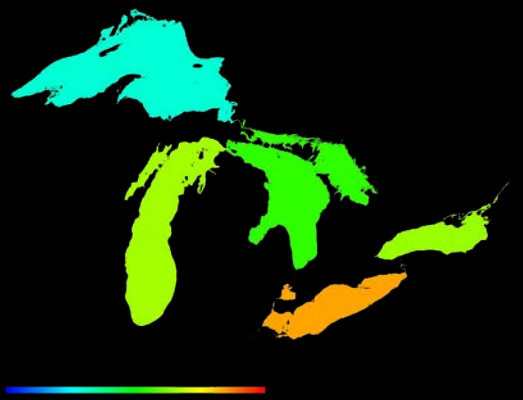
Cool & Dry



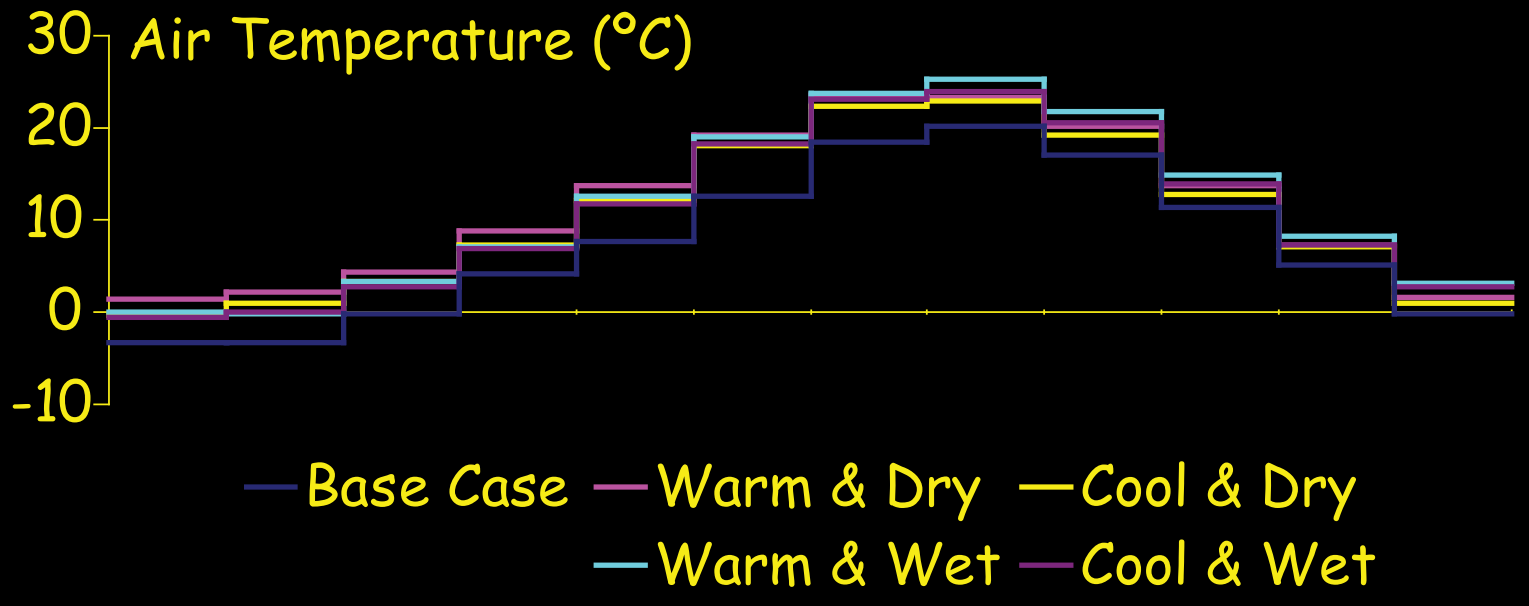
Warm & Wet

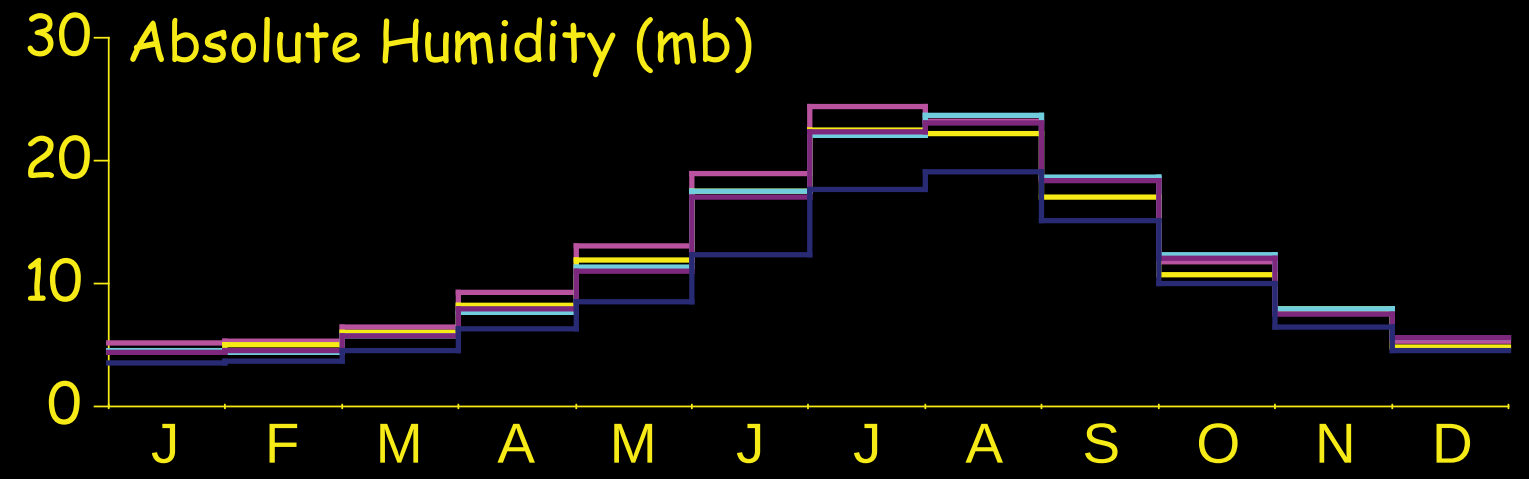


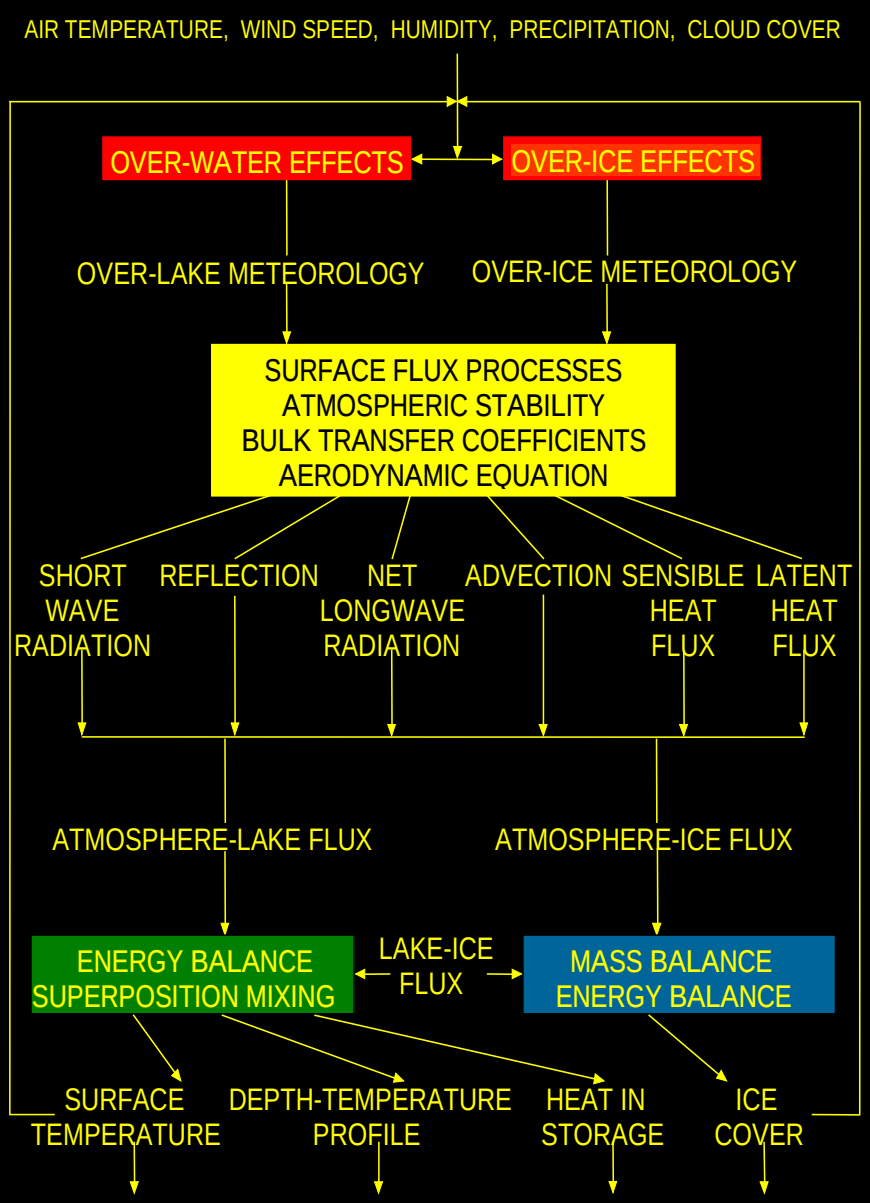
Cool & Wet

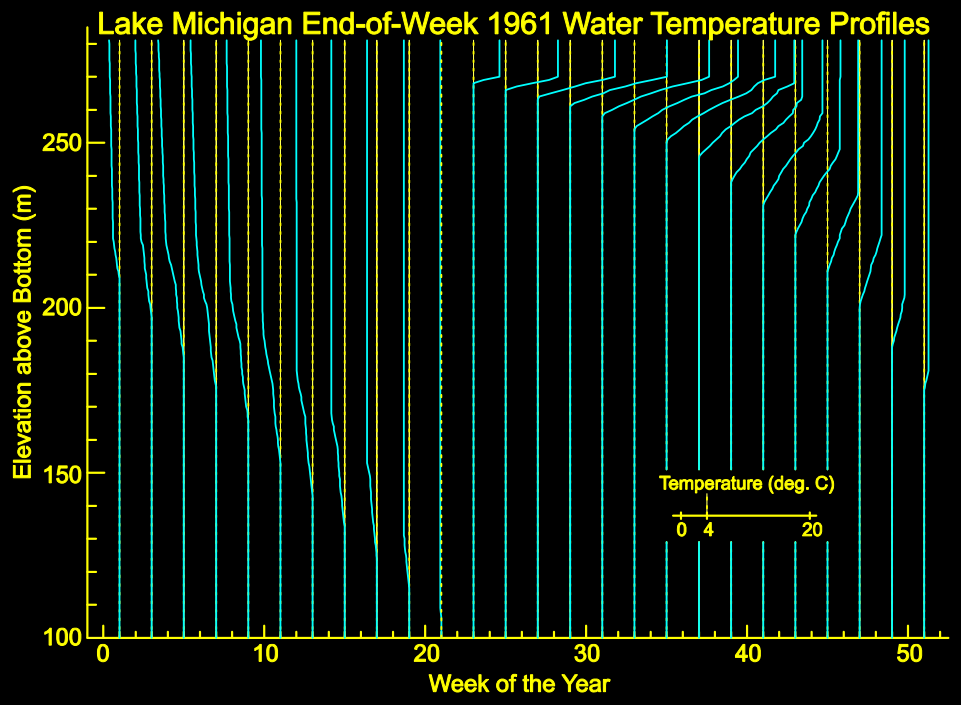


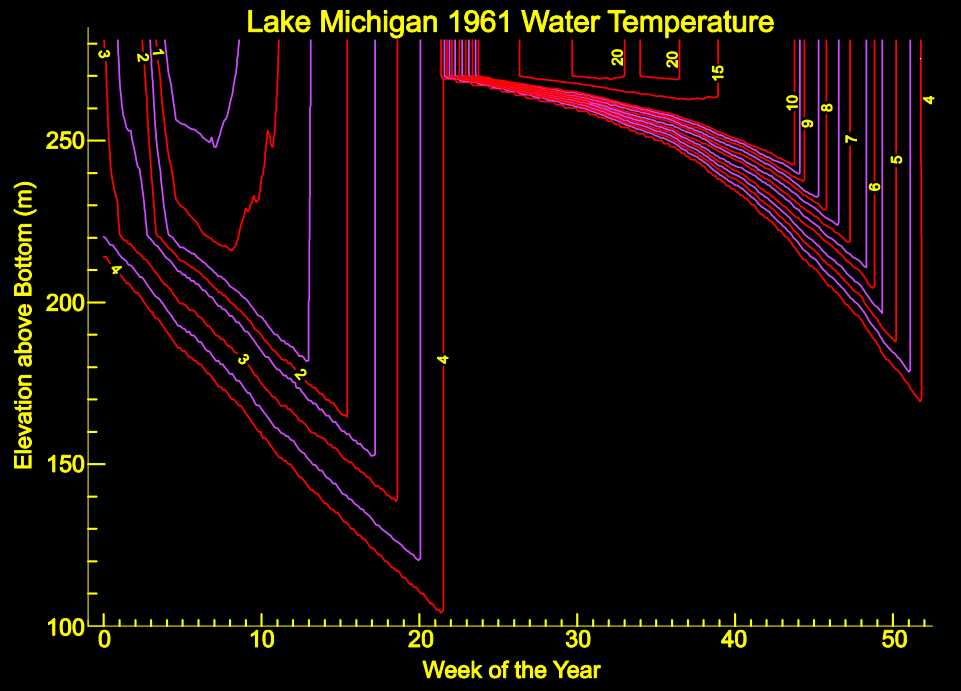
Climate Scenarios (Michigan Seasonal Meteorology)



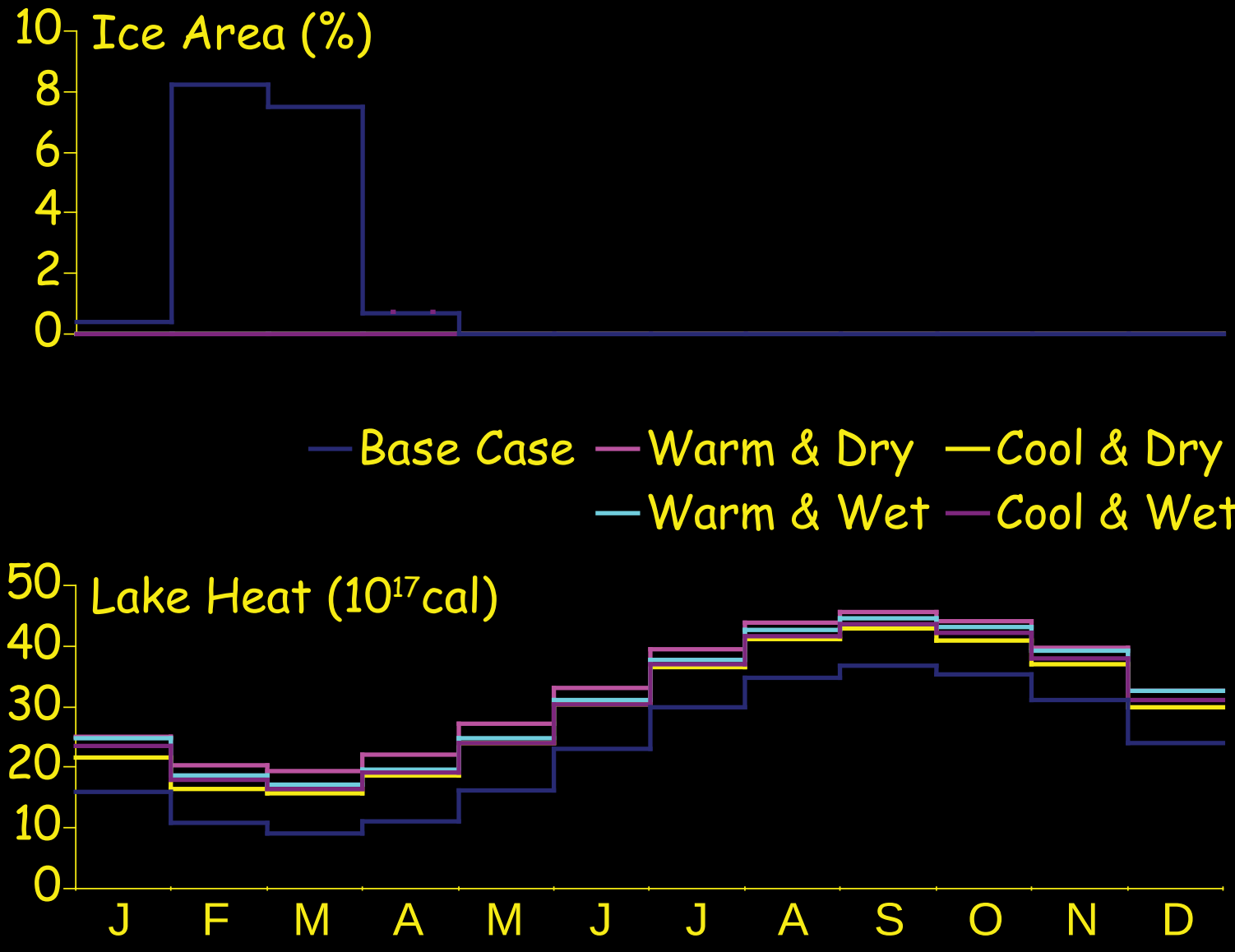



AIR TEMPERATURE, WIND SPEED, HUMIDITY, PRECIPITATION, CLOUD COVER
OVER-WATER EFFECTS
OVER-ICE EFFECTS
OVER-LAKE METEOROLOGY
OVER-ICE METEOROLOGY
SURFACE FLUX PROCESSES
ATMOSPHERIC STABILITY
BULK TRANSFER COEFFICIENTS
AERODYNAMIC EQUATION
SHORT WAVE RADIATION
REFLECTION
NET LONGWAVE RADIATION
ADVECTION
SENSIBLE HEAT FLUX
LATENT HEAT FLUX
ATMOSPHERE-LAKE FLUX
ATMOSPHERE-ICE FLUX
ENERGY BALANCE SUPERPOSITION MIXING
LAKE-ICE FLUX
MASS BALANCE ENERGY BALANCE
SURFACE TEMPERATURE
DEPTH-TEMPERATURE PROFILE
HEAT IN STORAGE
ICE COVER


Lake Michigan End-of-Week 1961 Water Temperature Profiles
Elevation above Bottom (m)
100
150
200
250
0
10
20
30
40
50
Week of the Year
Temperature (deg. C)
0
4
20

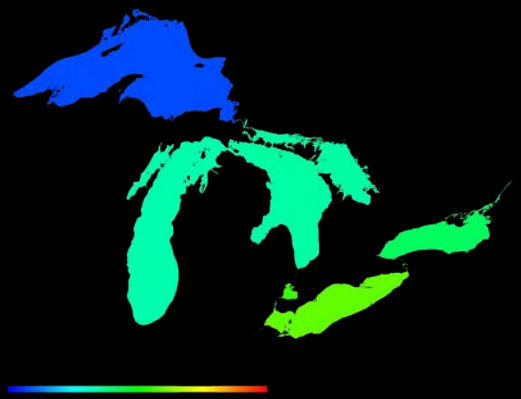

Lake Michigan 1961 Water Temperature
Elevation above Bottom (m)
100
150
200
250
0
10
20
30
40
50
Week of the Year

Lake Response (Michigan Seasonal Heat Storages)

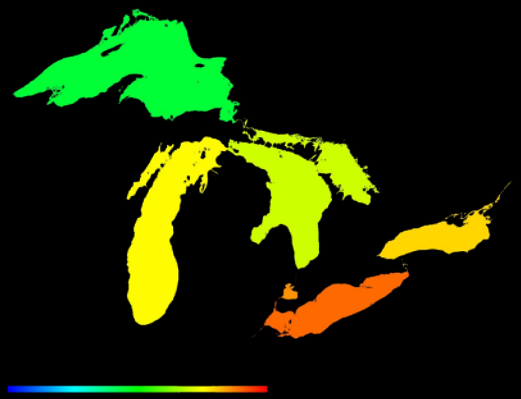


Lake Response (Average Surface Temperature, 5—15°C)

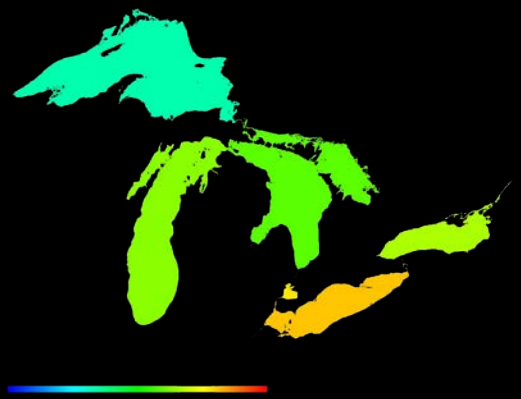
Base Case



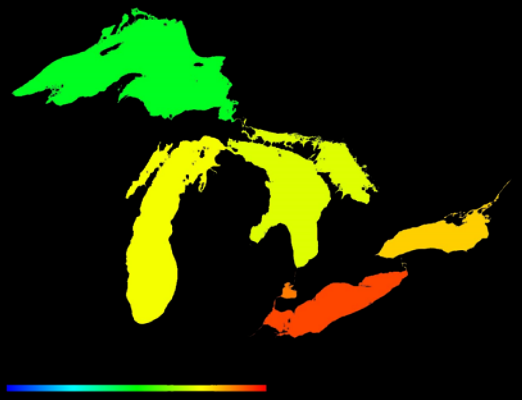
Warm & Dry



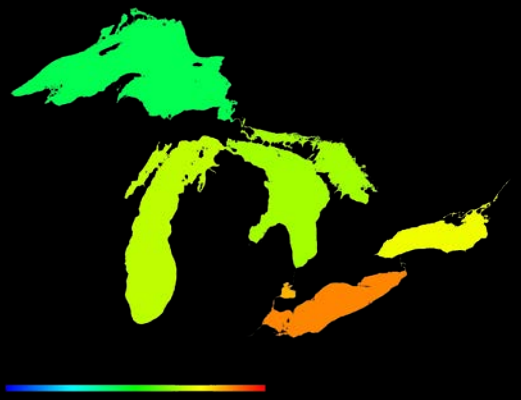
Cool & Dry



Warm & Wet

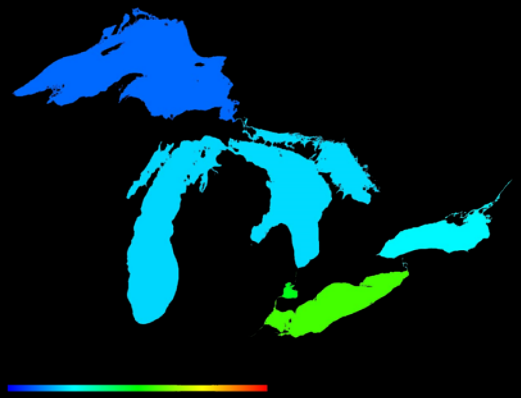


Cool & Wet

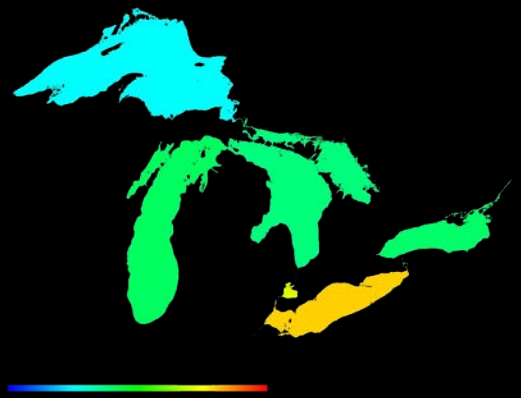


Lake Response (Average Annual Evaporation, 0.5—1.2 m)

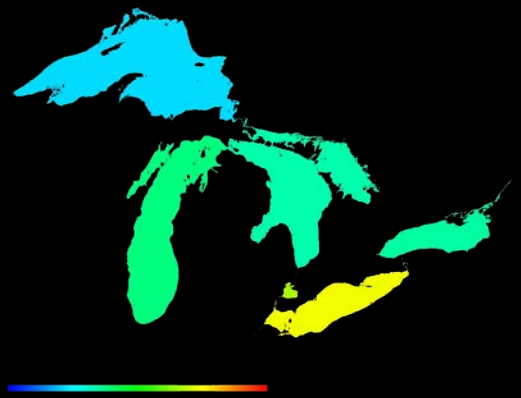
Base Case



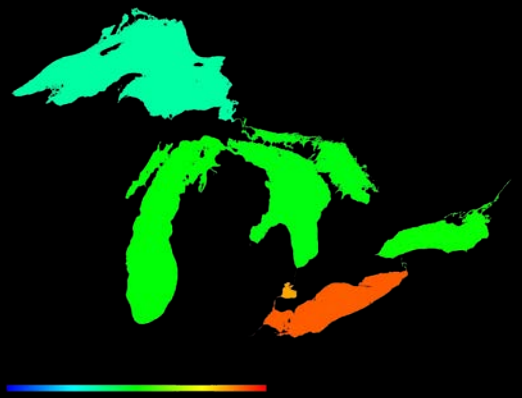
Warm & Dry



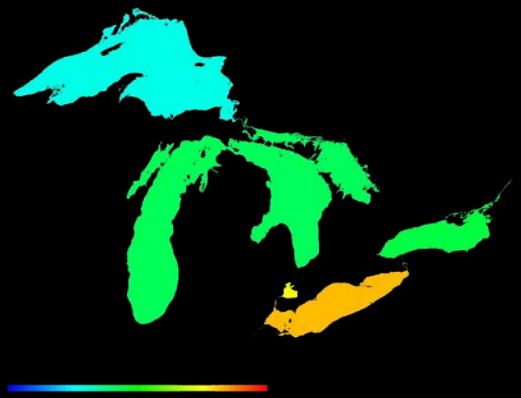
Cool & Dry



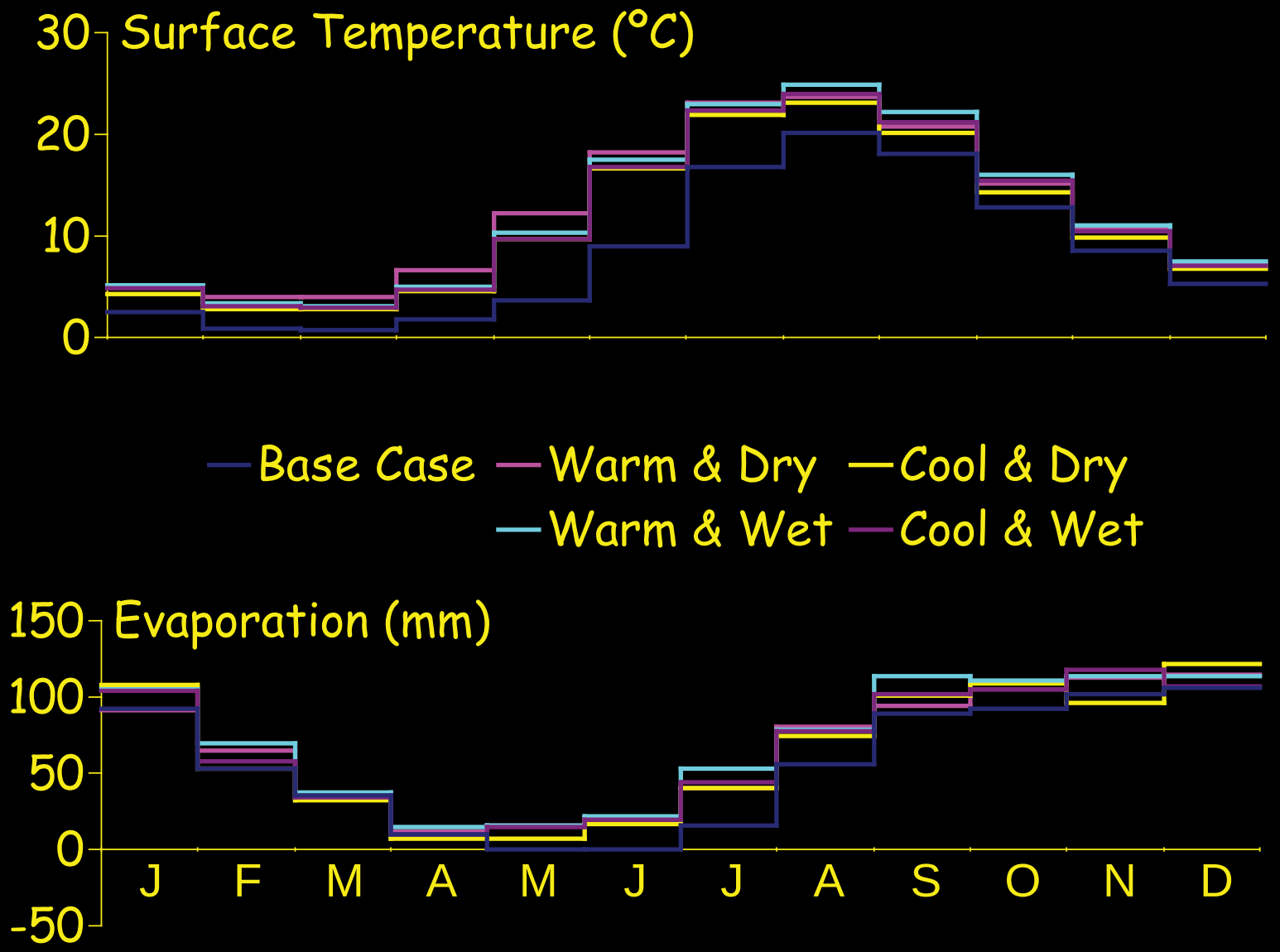
Warm & Wet



Cool & Wet

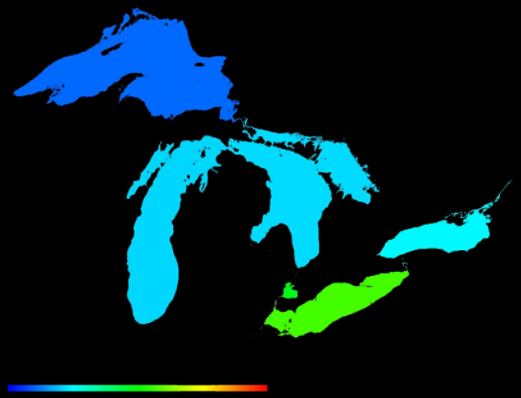


Lake Response (Michigan Seasonal Thermodynamics)

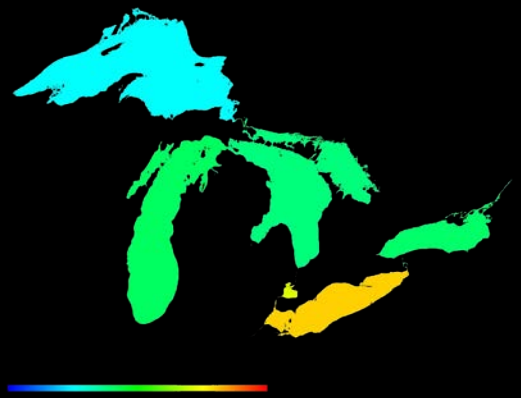


Lake Response (Average Annual Evaporation, 0.5—1.2 m)

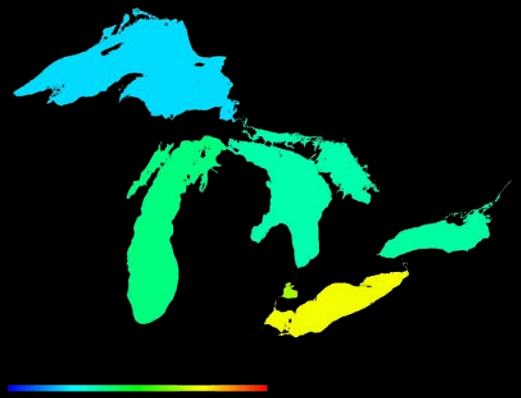
Base Case



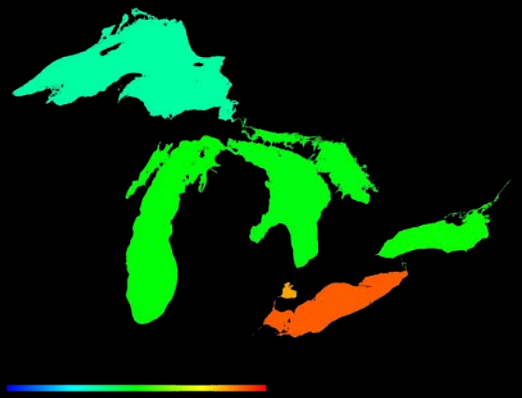
Warm & Dry



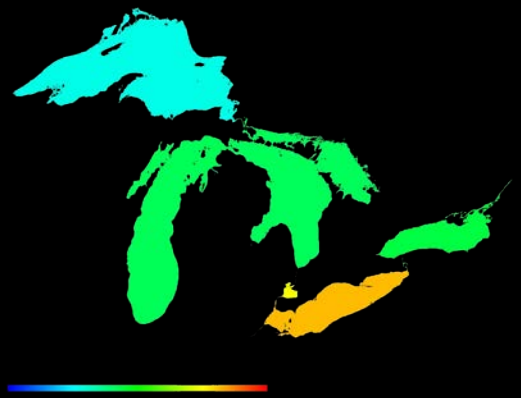
Cool & Dry



Warm & Wet

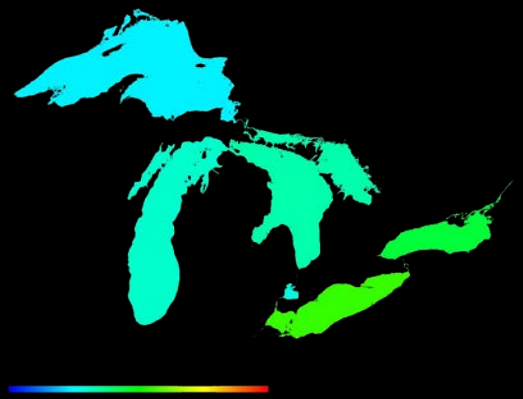


Cool & Wet

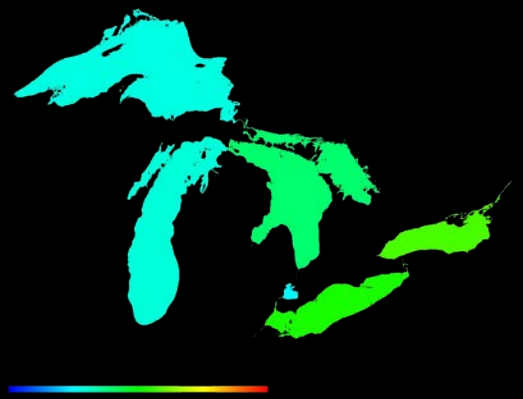


Lake Response (Average Annual Precipitation, 0.7—1.1 m)

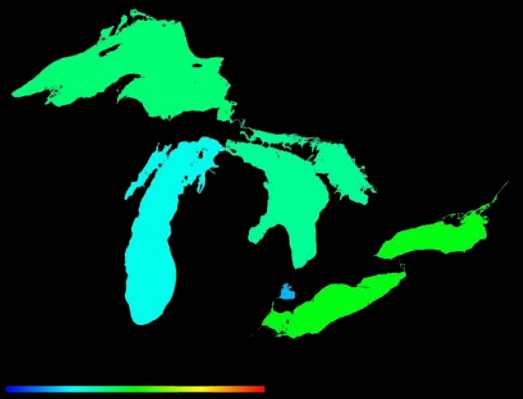
Base Case



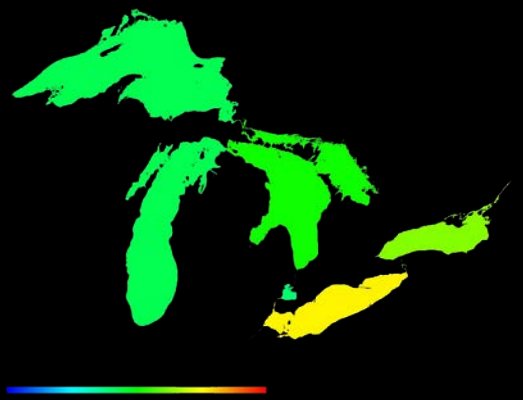
Warm & Dry



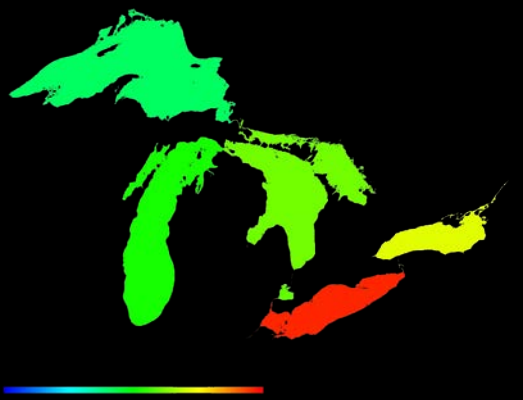
Cool & Dry



Warm & Wet

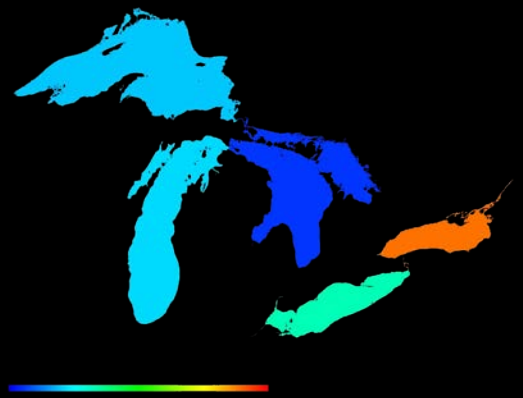


Cool & Wet

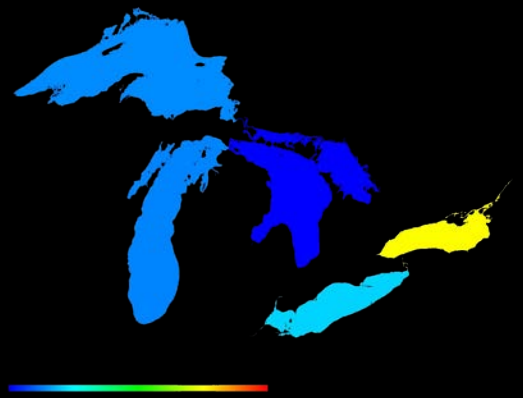


Climate Scenarios (Average Annual Runoff, 0.3—1.9 m)

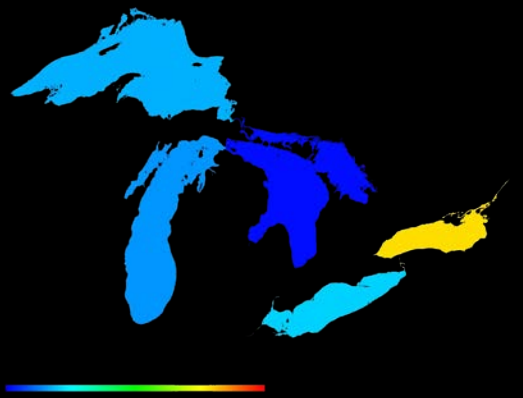
Base Case



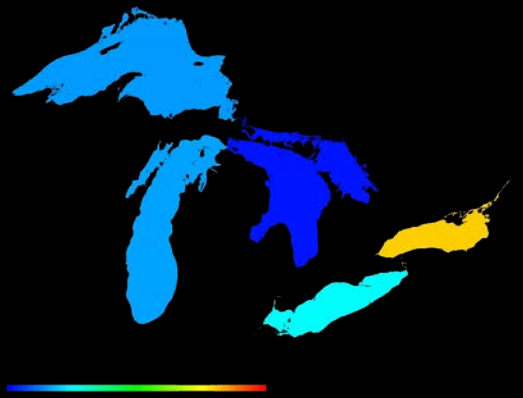
Warm & Dry



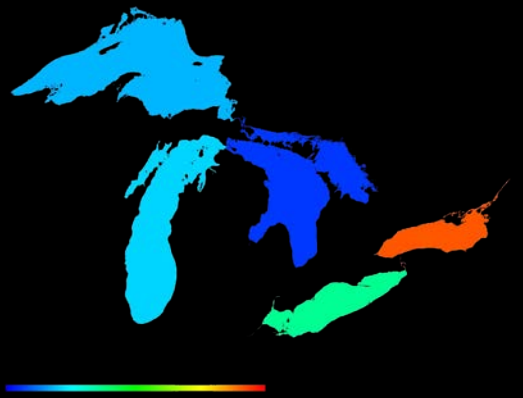
Cool & Dry



Warm & Wet

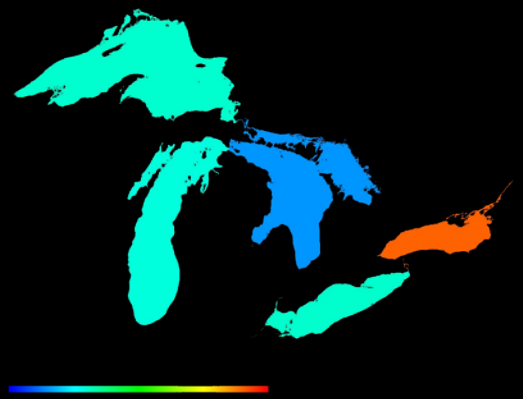


Cool & Wet

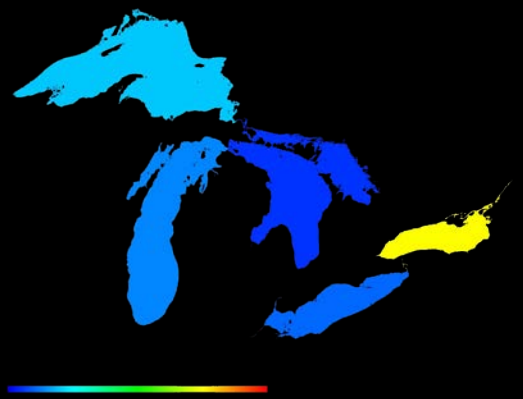


Climate Scenarios (Average Annual NBS, 0.3—2.1 m)

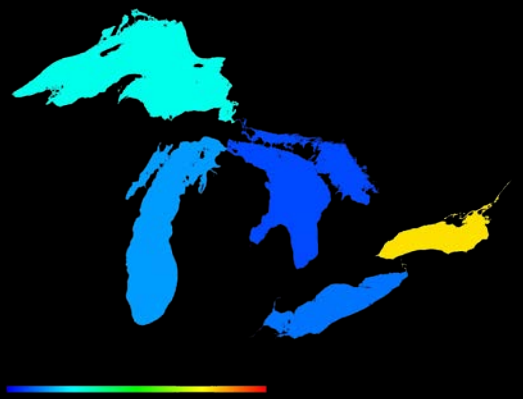
Base Case



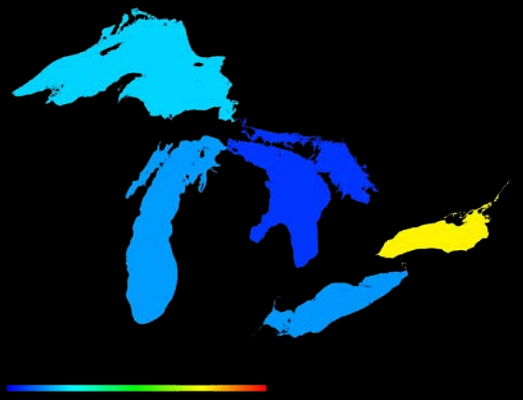
Warm & Dry



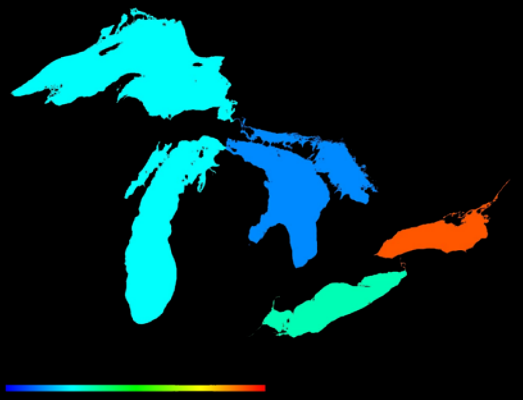
Cool & Dry



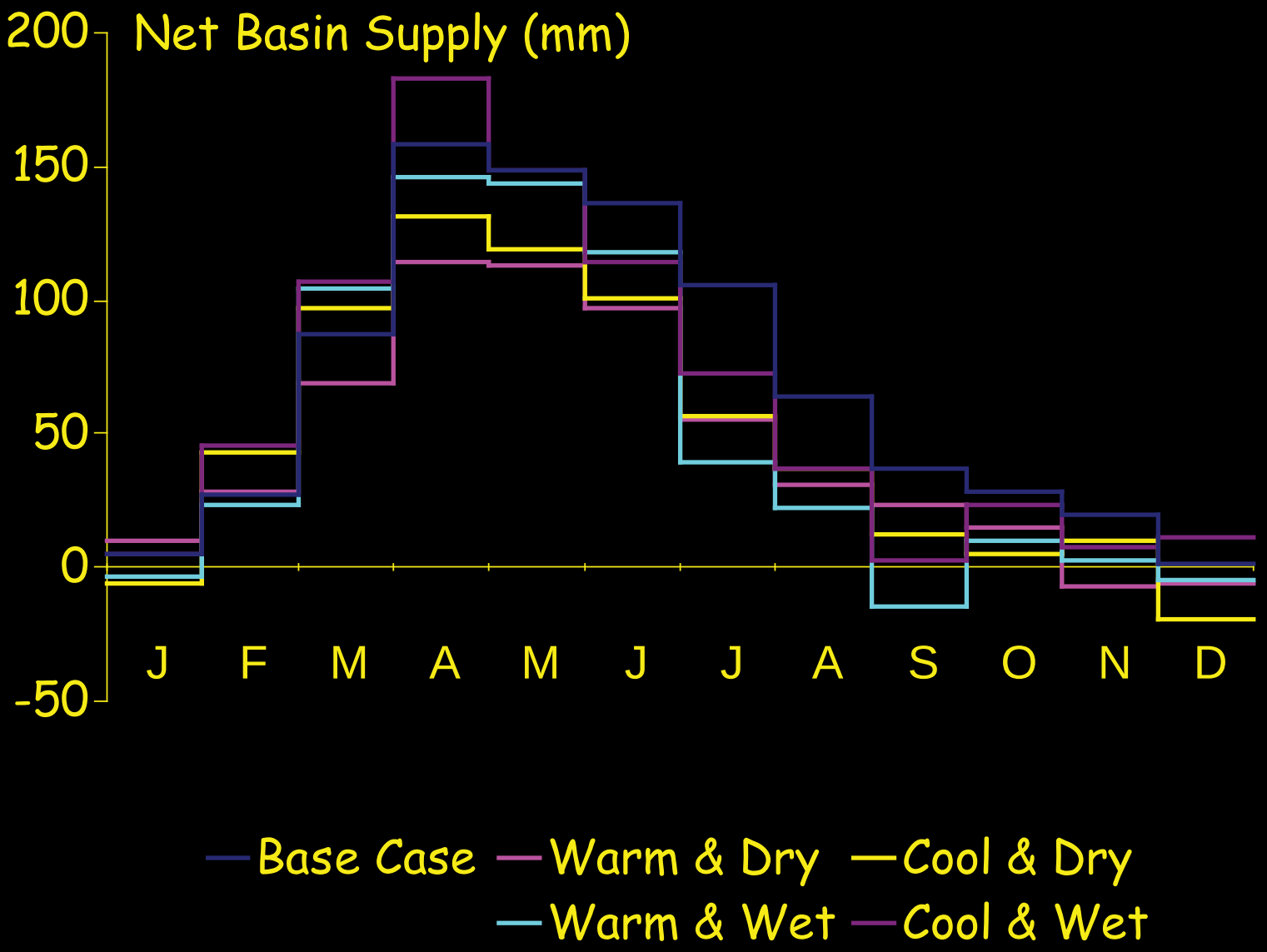
Warm & Wet



Cool & Wet



Lake Response (Michigan Seasonal Net Basin Supplies)



Summary

- Higher Air Temperatures
  - Higher Evapotranspiration and Lower Runoff
  - Earlier Runoff Peaks
  - Reduced Soil Moisture

- Higher Water Temperatures
  - More Heat In Deep Lakes
  - Diminished Mixing
  - Reduced Ice Formation
  - Increased Lake Evaporation

- Net Supplies Drop
  - For Northern and Mid-Latitude Lakes, All Climates
  - For Southern Lakes, Except Cool & Wet Scenario