FOUR CLIMATE SCENARIOS This presentation reviewed the results of a study of hydrological effects of climate change in the Great Lakes region conducted by the National Oceanic & Atmospheric Administration's Great Lakes Environmental Research Laboratory.

To establish a climate baseline, researchers collected daily precipitation and maximum- minimum air temperatures data for 1948-99 from 1,800 meteorological stations around the Great Lakes, and temperature, wind speed, humidity and cloud cover over the lakes from 40 stations.

Using these data to represent present climate conditions, three different general circulation models were used to simulate four future climate scenarios: "warmer and dry," "hot and dry," "warmer and wet," and "hot and wet" This enabled the scientists to determine the effects of the full range of projected maximum/minimum air temperatures and high/low precipitation amounts for hydrological analysis. Evaporation and precipitation are the two most important factors controlling Great Lakes water levels.

THE ONCE-GREAT LAKES?

Based on a presentation by Thomas E. Croley II, Research Hydrologist
Great Lakes Environmental Research Laboratory, NOAA

All four climate change scenarios projected a general increase in temperature across the region, with areas in southern latitudes tending to become much warmer than northern ones. The "hot and wet" scenario produced the largest temperature rise. The "warmer and wet" scenario produced the largest increase in precipitation.

Around Lake Michigan, for example, all four climate scenarios show seasonal temperatures over land will be warmer throughout the year than in the past. The "hot and dry" scenario produced the greatest increase in winter and spring temperatures, while the "warmer and wet" scenario resulted in the warmest summer and fall temperatures.

The seasonal temperature cycle remained similar to the historic climate in all scenarios. Possible changes in seasonal precipitation patterns were less clear, with the "dry" scenarios alternating between higher and lower than the present climate. Precipitation in both of the "wet" scenarios increased in all seasons except summer.

EFFECTS ON WATERSHED HYDROLOGY The four climate change scenarios then were run through a watershed hydrology model and applied to all of the 121 watersheds that contribute water to the Great Lakes. Although each scenario gave different estimates of the change in precipitation over each lake basin, the increase in temperatures in all four scenarios caused a significant reduction in snowpack, particularly in the northern latitudes. All four future climate scenarios indicated soil moisture would also be less than in the past.

Across the Michigan watershed, all of the scenarios predicted water from snow will be less than half of what it has been during winter and spring. Under the "wet" scenarios, the annual cycle of precipitation peaks about the same time as in the past, at least on a monthly time scale, while in the "dry" scenarios it seems to peak about a month earlier, which is true for soil moisture levels as well. In all scenarios, soil moisture in the basin increases more during the winter than in the past, reflecting less snowpack storage, and it is less during the remainder of the year than today.

Increased air temperature also significantly increases average annual evapotranspiration throughout the Great Lakes basin in all climate change scenarios. Interestingly, the "warmer and wet" scenario shows the most evapotranspiration, particularly in the southern part of the basin. While this result may seem odd, this scenario also delivers the largest increase in precipitation of all the climate change scenarios, so more water is available for evapotranspiration.

Increased evaportranspiration and decreased snowpack will result in less runoff. Runoff under the "warmer and wet" scenario appears to be most similar to the baseline. Runoff decreases the most in the "hot and dry" scenario, and decreases the least under "warmer and wet."

Evapotranspiration on the Michigan watershed increases under all scenarios except in June in the "dry" scenarios and July in the "hot" scenarios. The evapotranspiration peak occurs in May and June for the "hot and wet" scenario, probably because water availability is less limiting under that scenario. Runoff is greater in the winter in all scenarios because of the reduction in snowpack, and it is less during the rest of the year, which reflects the patterns in snow and soil moisture.

EFFECTS ON LAKE THERMODYNAMICS The four climate change scenarios were then run through lake thermodynamic models. Water and air temperature and wind speed are key determinants of Great Lakes evaporation rates.

The "wet" scenarios generally indicate less cloud cover, which transferred more heat into the lakes than the "dry" scenarios. The "dry" scenarios predict slightly higher wind speeds than today, while both "wet" scenarios produce about the same amount of wind. The seasonal cycle of cloud cover and wind is about the same as today—cloudier and windier in winter than in summer.

Similar to predicted over-land air temperatures, average air temperatures over the lakes are warmer than today in all four climate scenarios, with the warmest temperatures occurring under the "hot and wet" scenario. All four scenarios show average humidity will be higher throughout the seasonal cycle than in the past.

The "hot and dry" scenario produced the highest humidity, which may seem counterintuitive until the seasonal cycle is examined. Temperatures and humidity under the "hot and dry" scenario are higher in the winter and spring, but the peak occurs a month earlier than today. Consequently, humidity in the "hot and dry" scenario is highest during the time of year when humidity is generally low anyway, so it's not going to significantly affect evaporation.

For Lake Michigan, all four scenarios omit lake ice entirely, and the amount of heat stored in the lake is higher in all seasons than in the past. Both "hot" scenarios transferred more heat into the lake, despite the "hot and dry" scenario's larger amount of cloud cover.

All four scenarios showed an increase in heat absorption and water temperature in each of the Great Lakes, with the largest water temperature increases occurring in the northernmost lakes. The largest increase occurs under the "hot and dry" scenario, the least under the "warmer and dry" scenario. The deep lakes are predicted to have surface temperatures that frequently stay above 39 degrees Fahrenheit throughout the year. This will prevent buoyancy-driven turnovers of the water column, resulting in changes in bottom chemistry, oxygen depletion, and the release of nutrients and metals released from lake sediments. It will also practically eliminate ice cover from the lakes.

Under all of the climate change scenarios, the increase in heat storage alone is sufficient to cause increased evaporation from all of the Great Lakes. The most evaporation occurs under the "hot and wet" scenario; the least under the "warmer and dry" scenario. In the case of Lake Michigan, the rise in surface temperature and increased evaporation are spread throughout the seasonal cycle, with the largest increases in both temperature and evaporation occurring during the summer.

EFFECTS ON GREAT LAKES BASIN WATER SUPPLIES The combination of precipitation, runoff and lake evaporation gives us the net basin water supply to each lake. All of the changed-climate scenarios indicate net basin supplies will generally be less than the historic annual average for all of the Great Lakes.

The "warmer and wet" scenario most closely resembles the historic baseline of net basin supply, meaning it would cause the least amount of change as compared to today. The greatest losses in net basin water supplies occur under the "hot and dry" scenario. In between are the "warmer and dry" and "hot and wet" scenarios, which have about the same net effect.

On a seasonal basis, net basin supplies will be less from May through November in all of the future climate scenarios. Only the "warmer and wet" scenario shows a higher net basin supply during the winter and part of the spring than in the past.

Projected higher air temperatures lead to greater over-land evapotranspiration and lower runoff to the Great Lakes. Runoff peaks earlier, since the snowpack is reduced and the snow season is greatly shortened. This also causes in a reduction in available soil moisture throughout the basin.

Under all scenarios, water temperatures climb and peak earlier; resident heat in the deep lakes increases throughout the year. Mixing of the water column diminishes. Ice formation is greatly reduced on the deep Great Lakes. All of these cause evaporation to increase.

As a result, average net basin supplies drop most where precipitation increases are modest (the dry scenarios), but they decline under each of the climate-change scenarios in all northern and mid-latitude basins. Net basin supplies are essentially the same—maybe a little higher—for the two southern lakes only under the “warmer and wet” scenario.

In sum, these findings suggest a warming climate can be expected to bring a decline in the water levels of the Great Lakes, particularly the big three upper lakes. The extent of that decline largely depends on whether precipitation increases significantly and whether the rise in regional temperatures can be minimized through large, meaningful reductions in global greenhouse gas emissions.