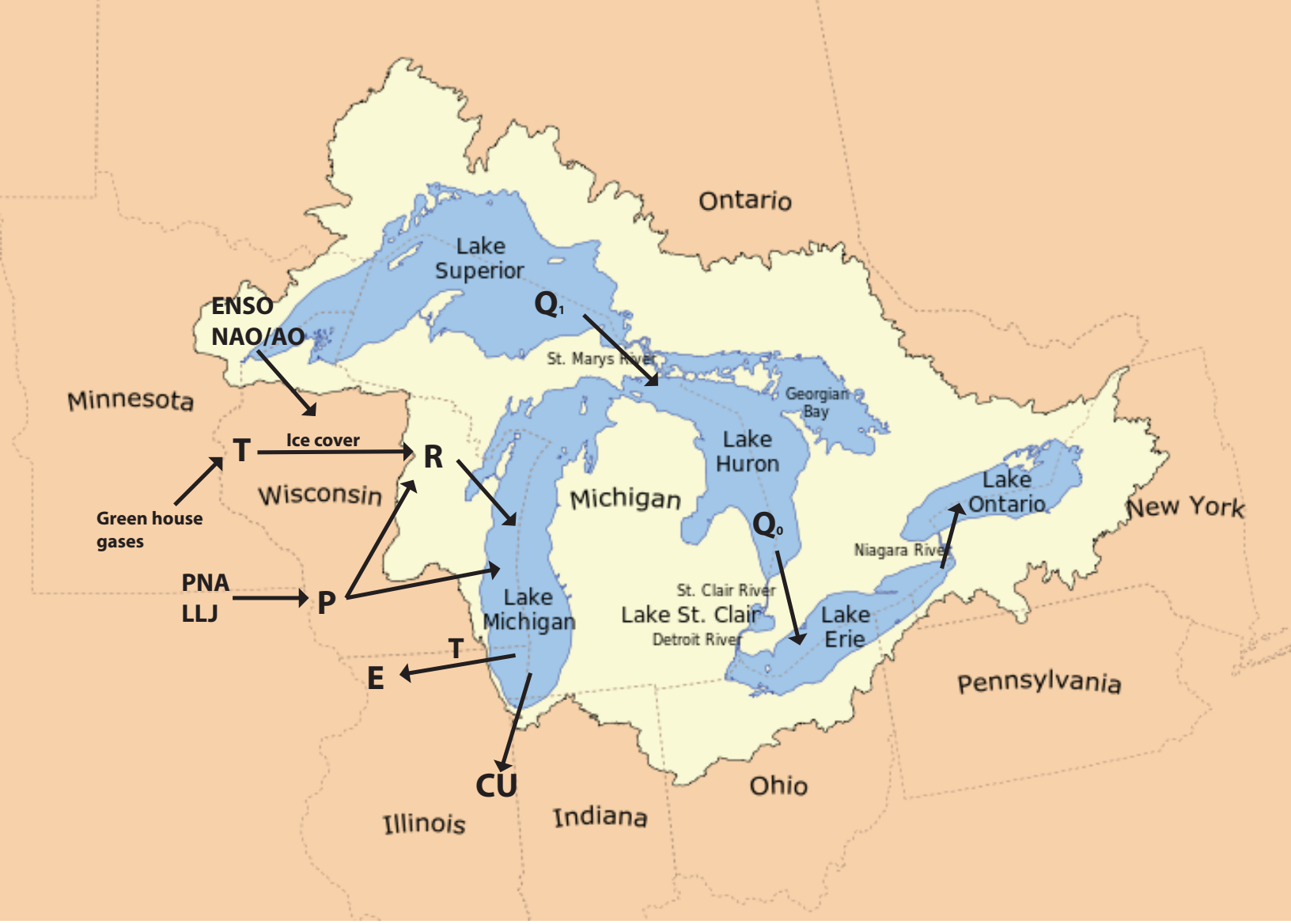


L = I + P + R - O - E - CU +/- D
L is the change in lake level
Q_1 is annual inflow from an upper lake
P is annual over-lake precipitation
R is annual runoff into the lake
Q_0 is annual outflow from the lake
E is annual over-lake evaporation
CU is annual consumptive use of water from the lake
D is annual total diversion

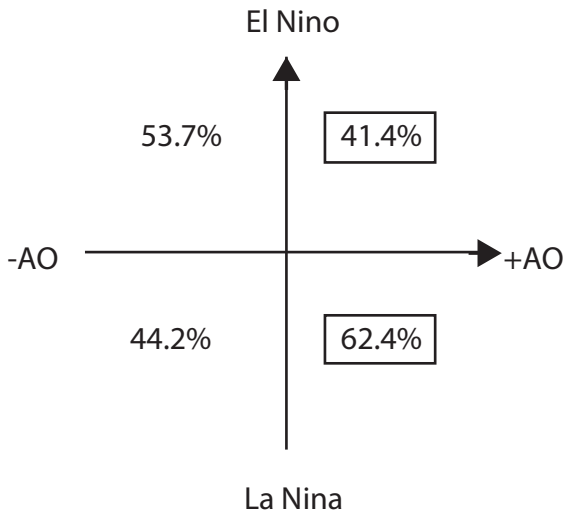
PNA: Pacific North American teleconnection
positive phase –> small amount of P –> L(d)
negative phase -> large amount of P –> L(u)
LLJ: Low level jet
Origin of the cold air is from the Arctic and located north of the Jet Stream (font)
Origin of the warm air is from the Pacific Ocean and the Gulf of Mexico and Gulf Stream

Extrinsic factors
Glacial isostatic rebound (-/+)
Outflow regulation

1. "off-line" models as Great Lakes Advanced Hydrologic Prediction System
2. GCMs as input –> very large drop of lake level
3. Lofgren: improve the surface energy budget of GCMs –> smaller decrease of lake level

Referrence:

1. *Coasts, water levels, and climate change: A Great Lakes perspective;*
2. *Hydroclimate Factors Of The Recent Record Drop In Laurentian Great Lakes Water Leve;*
3. *Association between Winter Precipitation and Water Level Fluctuations in the Great Lakes and Atmospheric Circulation Pattern*



Ice cover

Long-term mean (1963-2011): 53.9%
El Nino winters mean: 47.8%
-AO winters mean: 60.2%

Lake Superior: ice-albedo feedback process plays a bigger role in this deepest and largest lake

Using the combined Niño3.4 and NAO indices, mild ice winters (state 4) and severe ice winters (state 1) can be reliably projected.

NAO/AO: North Atlantic Oscillation or Arctic Oscillation

simultaneous -NAO/AO and La Nina events (negative PNA) –> severe ice cover
simultaneous +NAO/AO and El Nino events (positive PNA) –> mild ice cover

PDO (The Pacific Decadal Oscillation) –> modulate the effect of ENSO on the WSI:

The correlation between ENSO and WSI is weak (-0.13) during the cold phase of PDO and strong (0.70) during the warm PDO phase. During the warm phase of PDO without a strong ENSO, winters are colder.

WSI: Great Lakes Winter Severity Index, defined as the temperature for Duluth, MN, Sault Set. Marie, MI, Detroit, MI, and Buffalo, NY, averaged over November through February.

700hPa: circulation pattern is northwest-to-southeast orientation over North America

–> severe ice winters: positive anomaly over the west coast reinforces the ridge, and the negative anomaly over the Great Lakes also reinforces the trough –> stronger ridge-trough system –> anomalous northwesterly wind –> advect the Arctic cold, dry air to the Great Lakes region

–> mild ice winter: negative anomaly over the Aleutian region and the west coast reduces the intensity of the ridge, and the positive anomaly over the Hudson Bay-Great Lakes region and also reduces the intensity of the trough –> flatten the ridge-trough system –> westerly or southwesterly winds –>advection of the dry and warm air –> warm winter

Read more from paper *Atmospheric teleconnection patterns associated with severe and mild ice cover on the Great Lakes, 1963-2011*