

# Influence of Climate Change on Water Quantity in the Great Lakes Region



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# Outline



## What we know globally

- What the atmosphere does (highlighting greenhouse gases)

- Global phenomenology of climate change

## What we need to know locally

- Water budgets, highlighting the Great Lakes

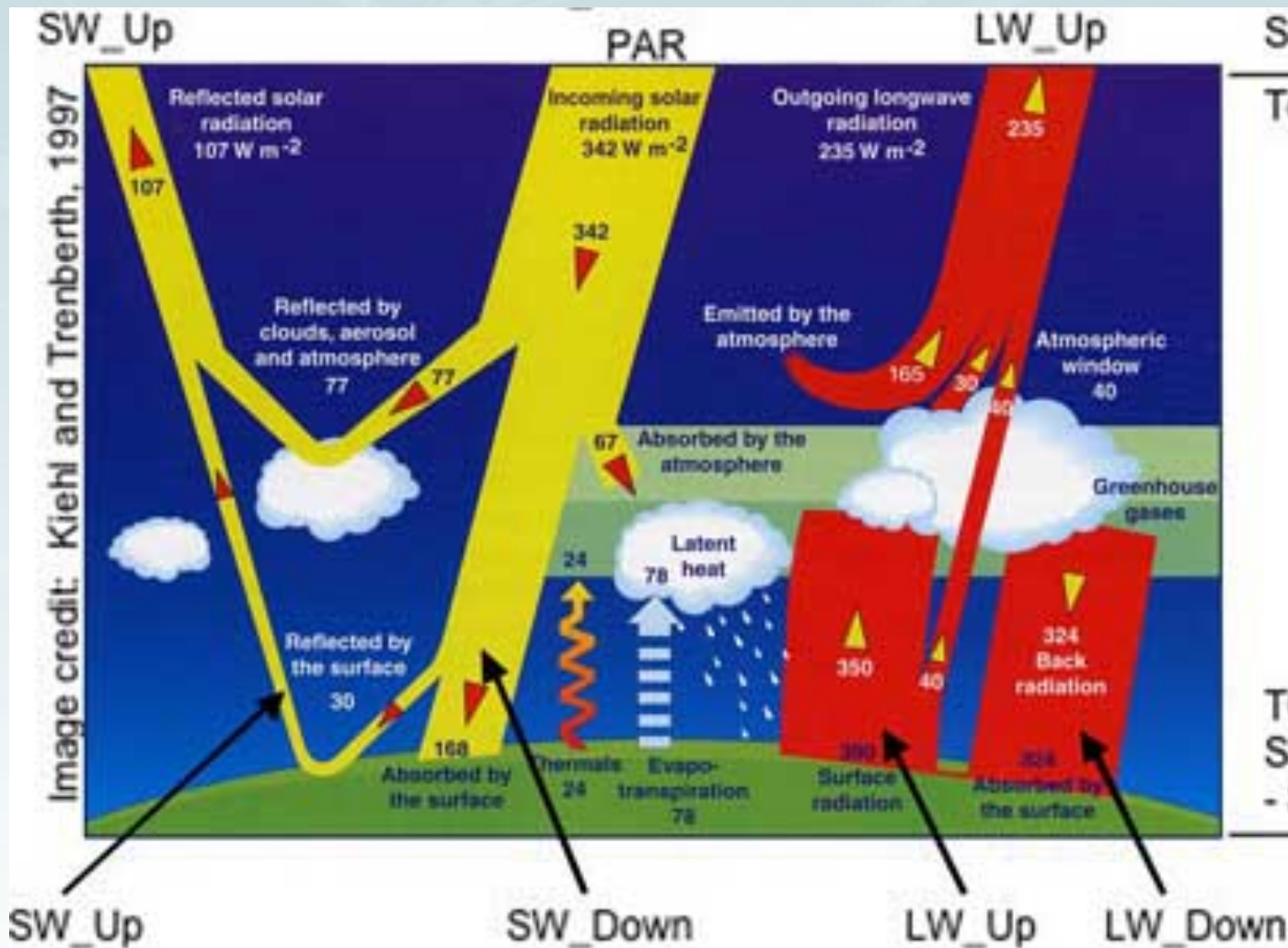
- A sampling of potential health effects



# What the Atmosphere and Surface Do



# Overall energy budget



# What is longwave radiation? (aka thermal radiation or far infrared)



Wikimedia  
Commons/Cody.pope

# Thermal radiation



It's emitted and absorbed by many things, emission depending on its temperature

Solid and liquid objects especially, but also greenhouse gases at certain wavelengths

You can also think of objects that get hot enough to show visible light (red hot)

Greenhouse gases include  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{CH}_4$ , and others

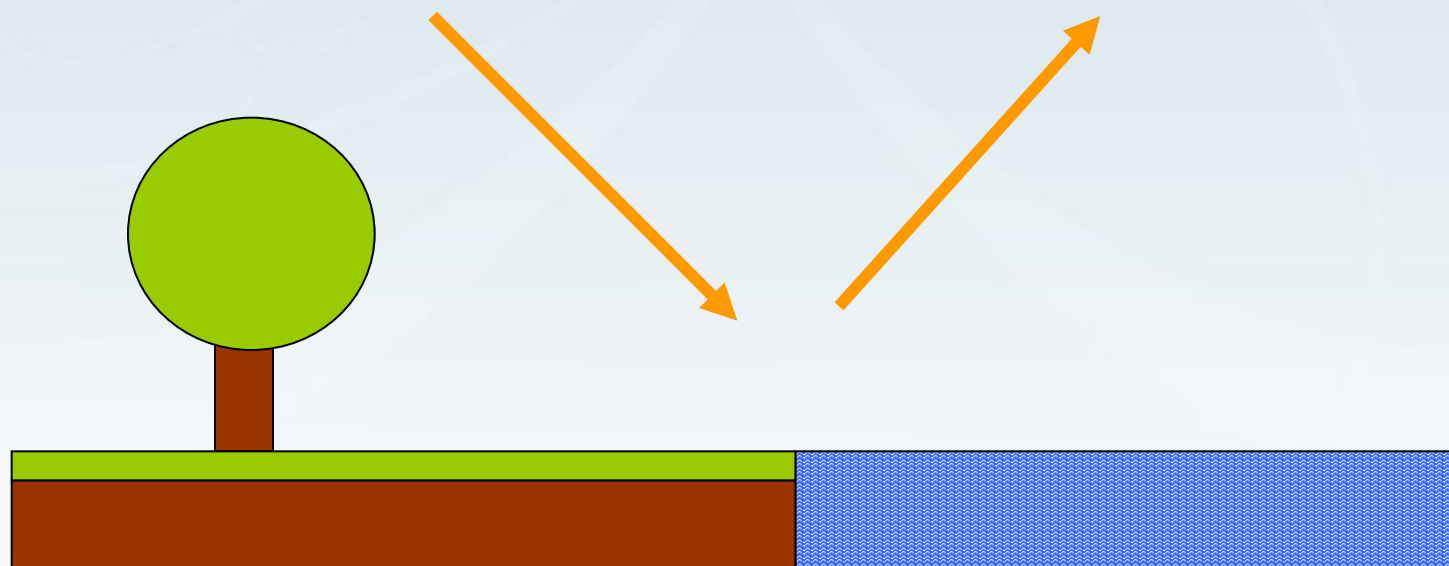
The more greenhouse gases the atmosphere, especially higher up, the harder for heat to escape

# Water vapor feedback



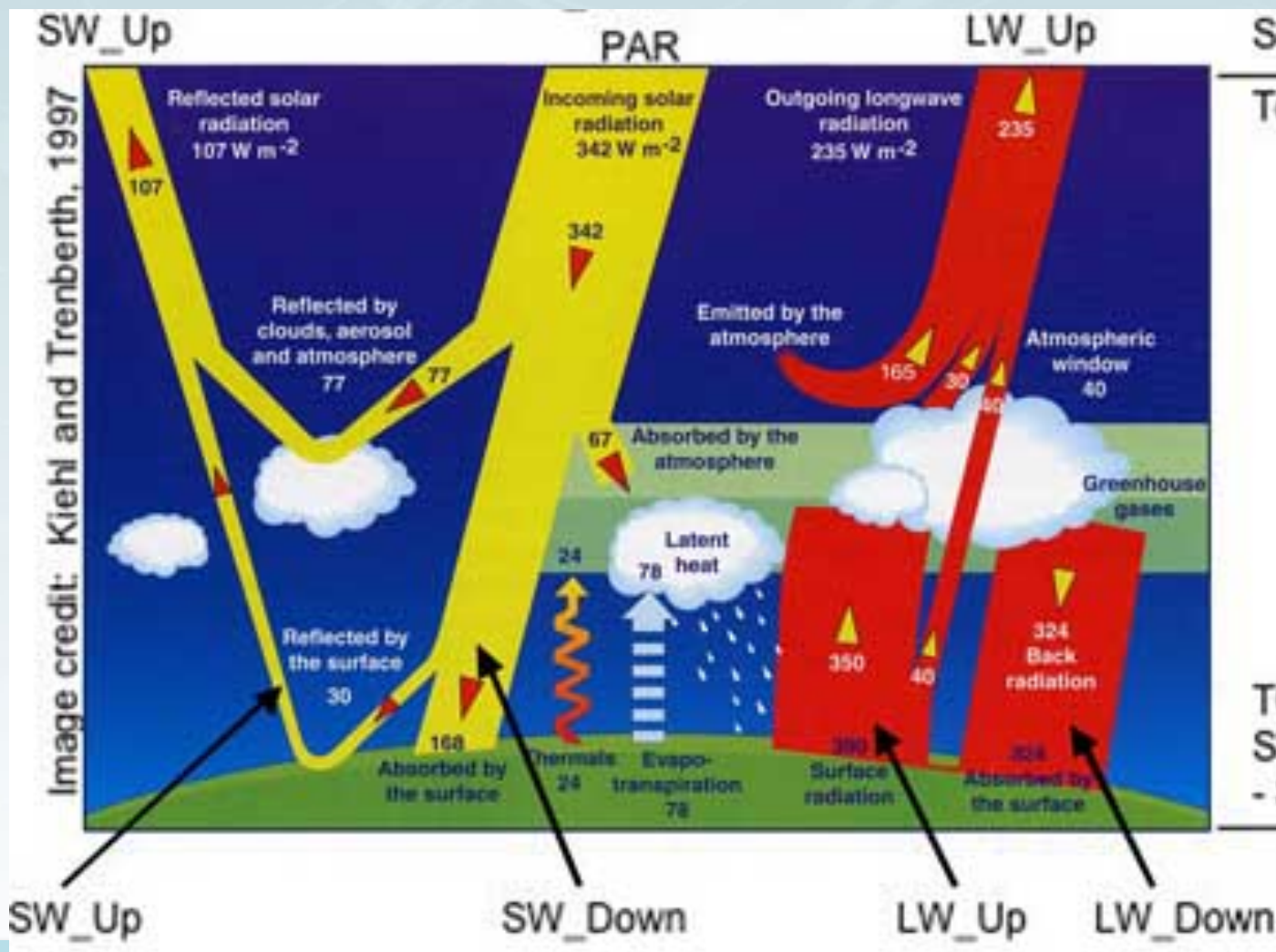
More anthropogenic  
GHGs

More water vapor  
How much? How  
high? Clouds?





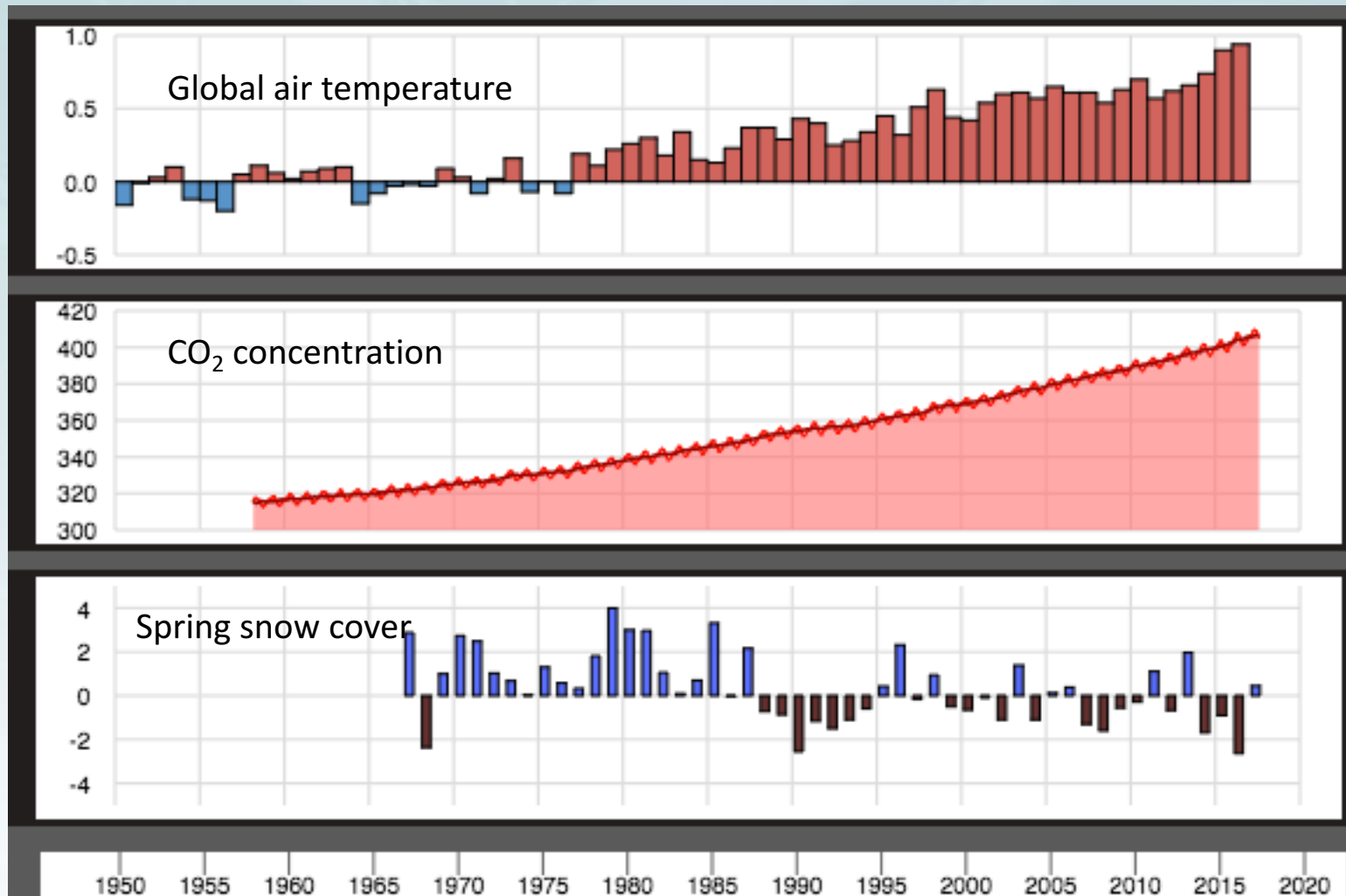
# Overall energy budget







# **Global Phenomenology of Climate Change**



# What do climate models do?



Climate models are surrogate Earths created on a computer.

They can be manipulated to create “what if” scenarios.

Using alternative formulations, they can also create multiple realizations of surrogate Earth.

Limitation—never as complex as the real Earth, cannot simulate it perfectly, computing constraints

# Northern Hemisphere Temperature Change

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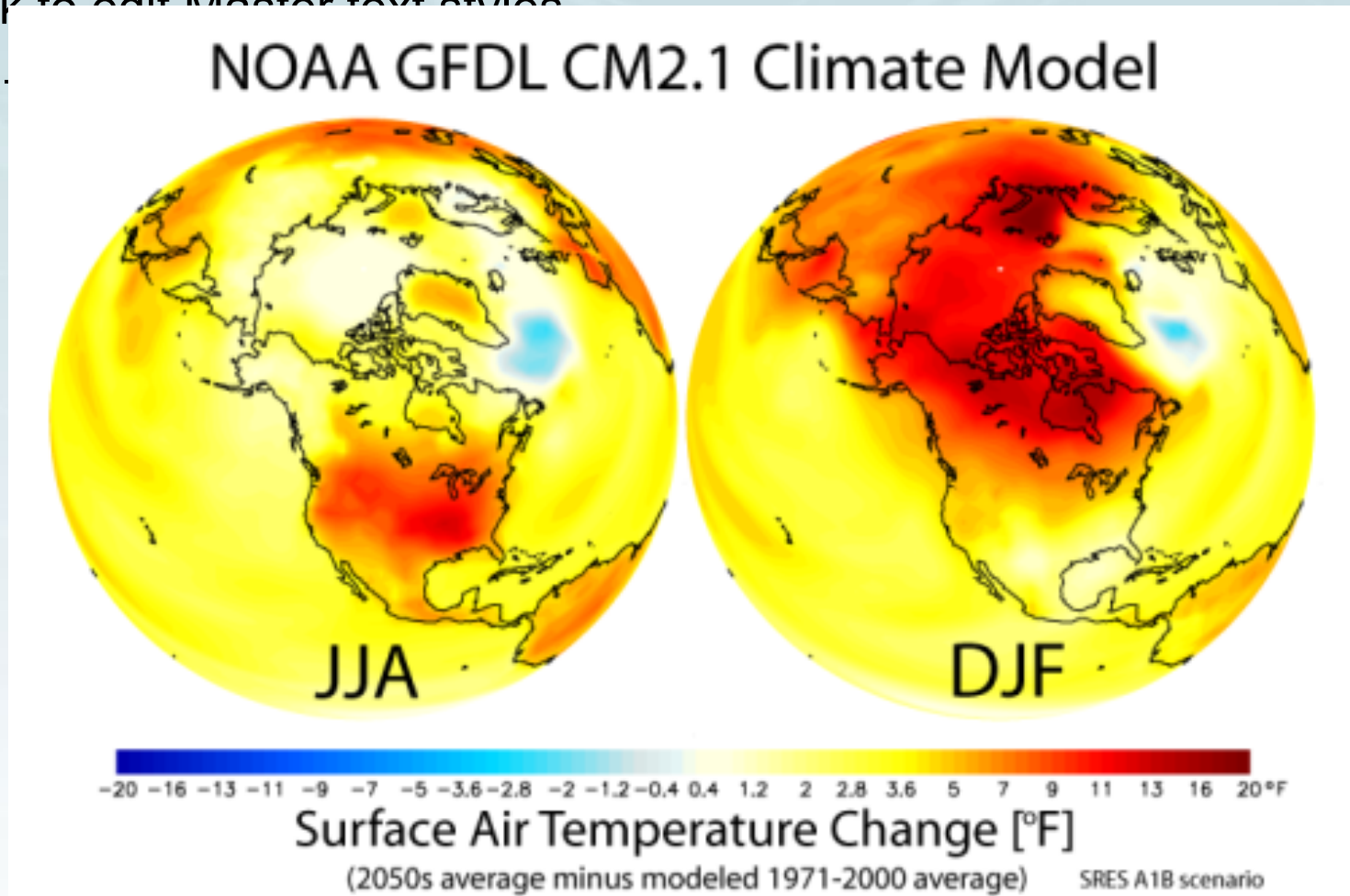
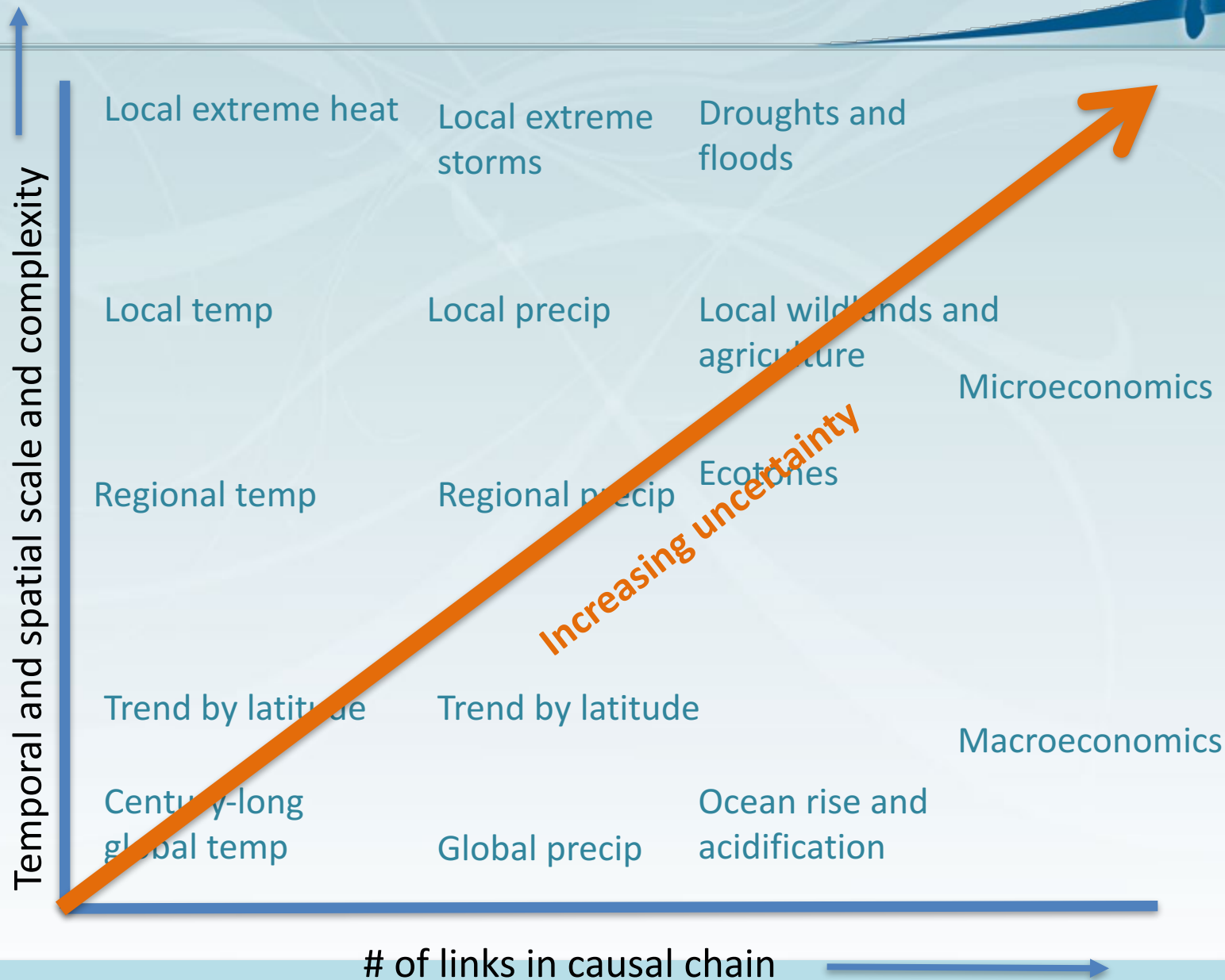


Figure courtesy GFDL





# Great Lakes Regional Impacts



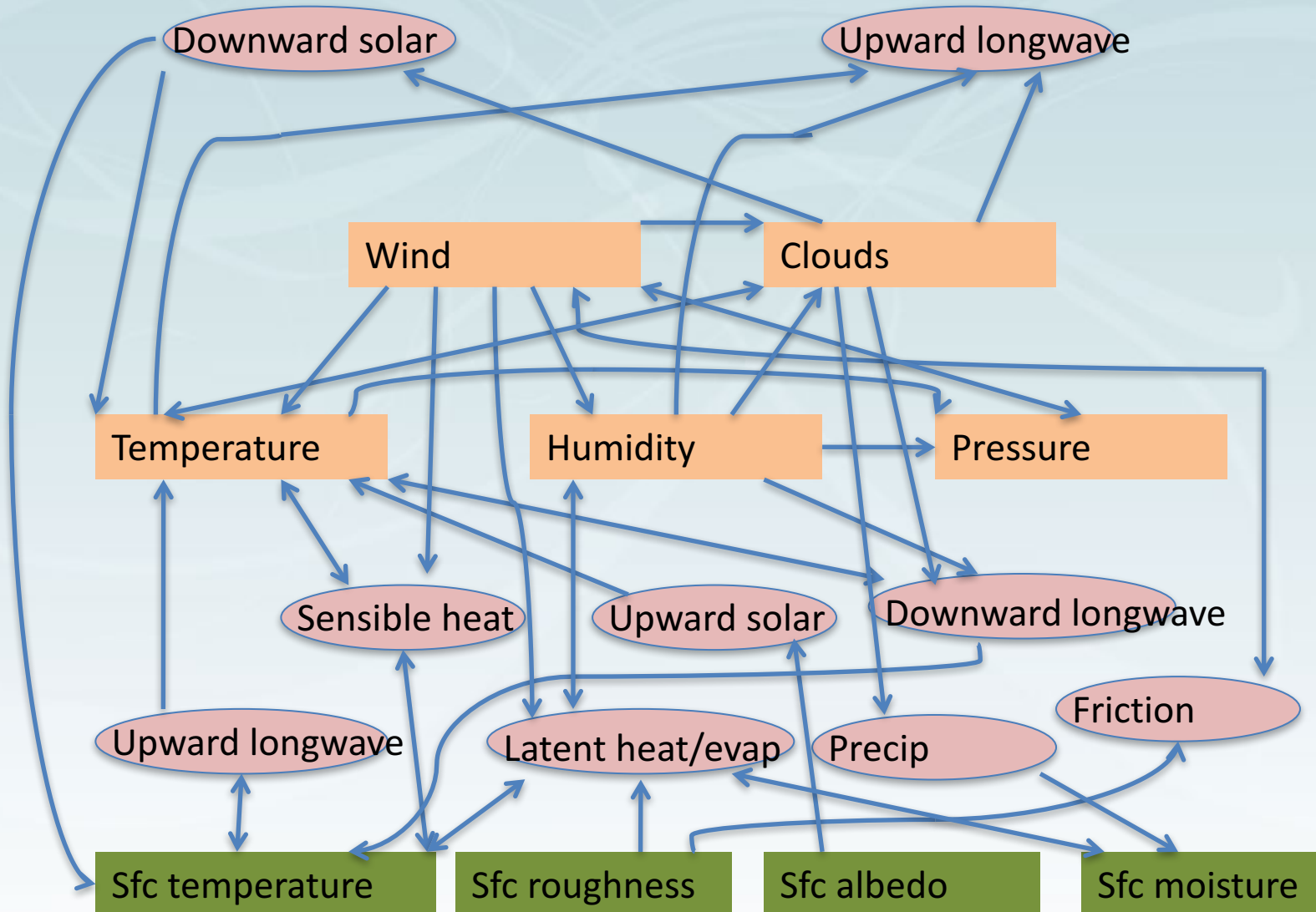


# Competing Hypotheses Behind Evapotranspiration

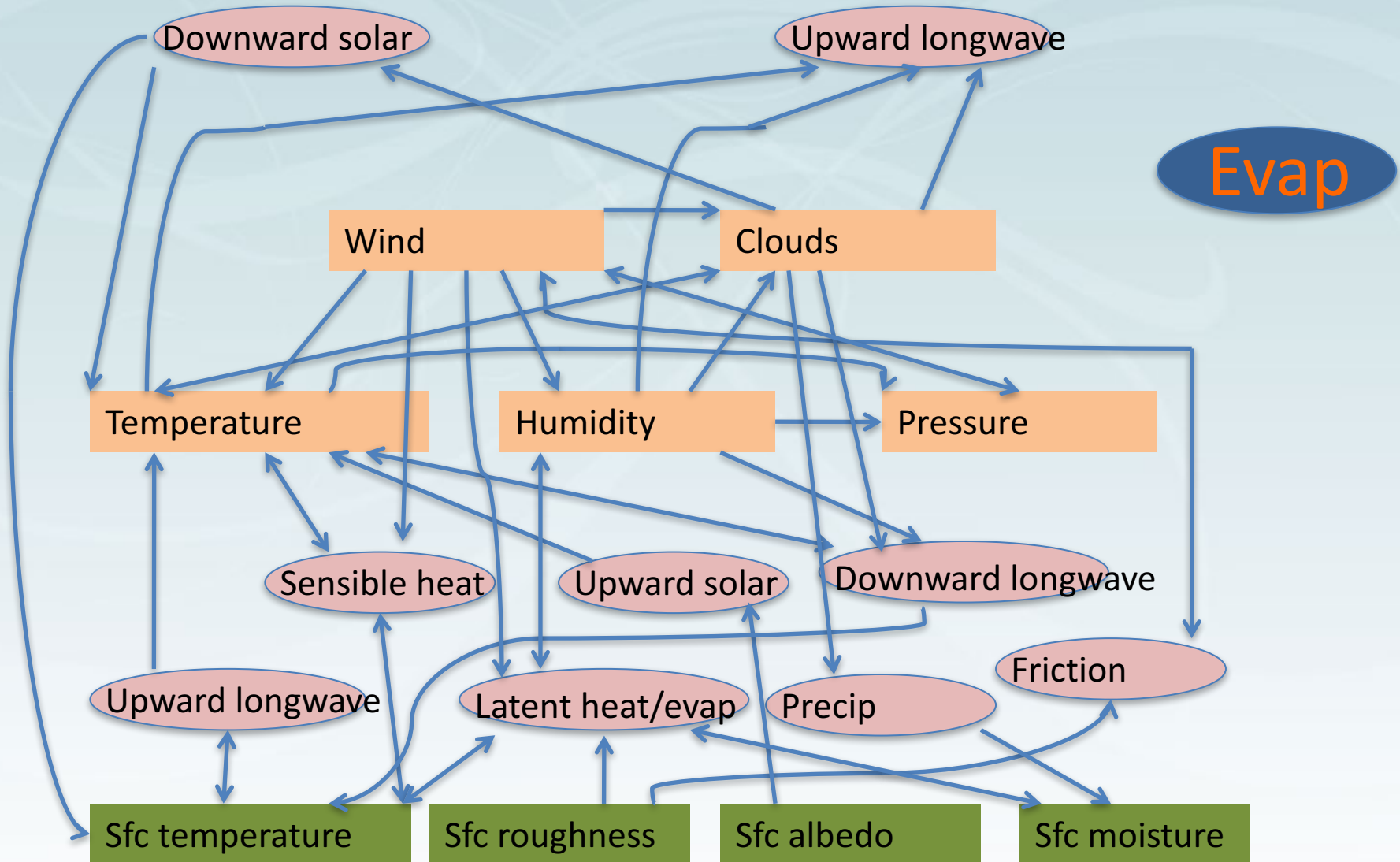


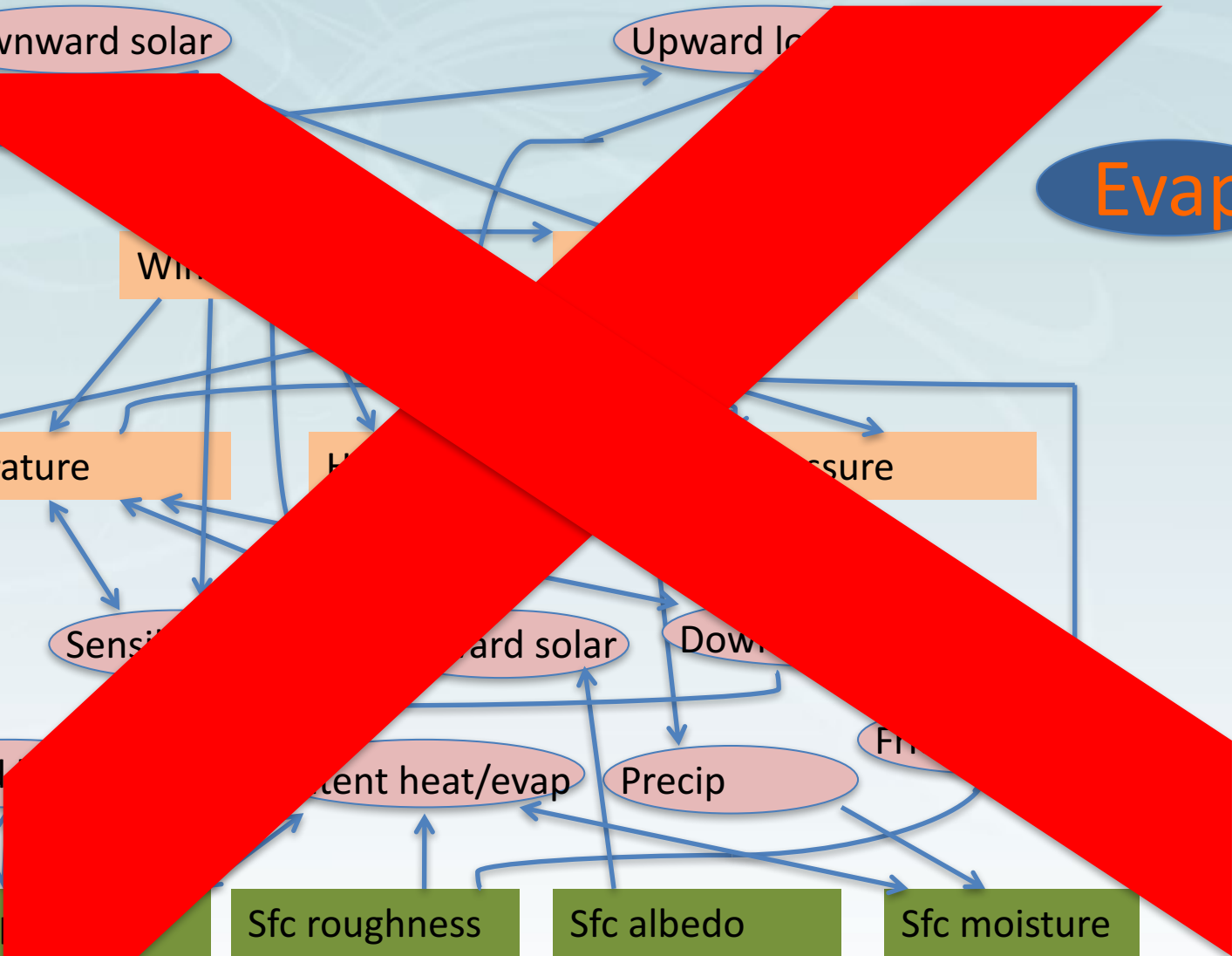
- A. Evapotranspiration from land is *caused* by air temperature
- B. Evapotranspiration results from a more complex set of air-surface interactions constrained by the amount of energy available

# The Real World (simplified)

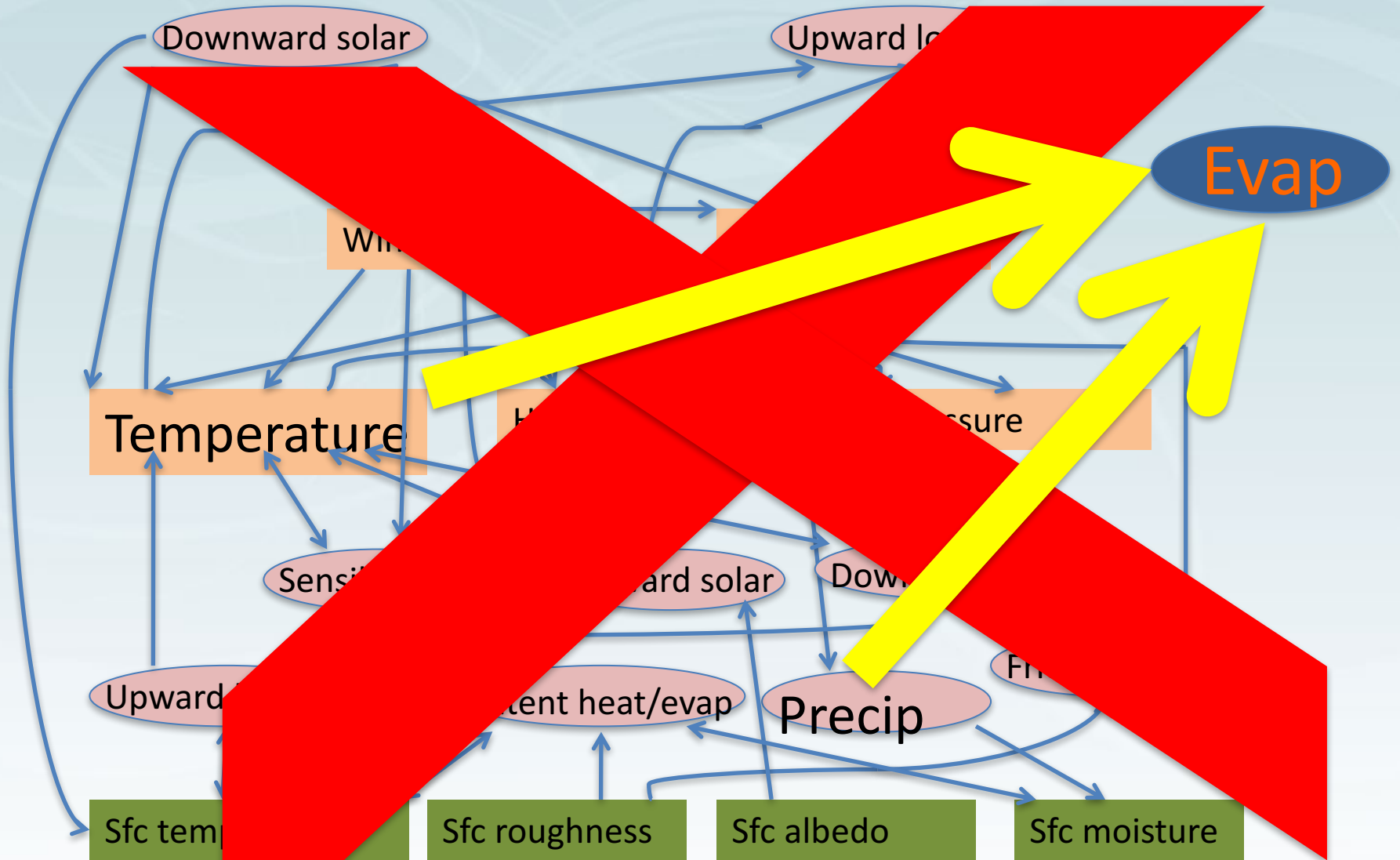


# Calculate evapotranspiration

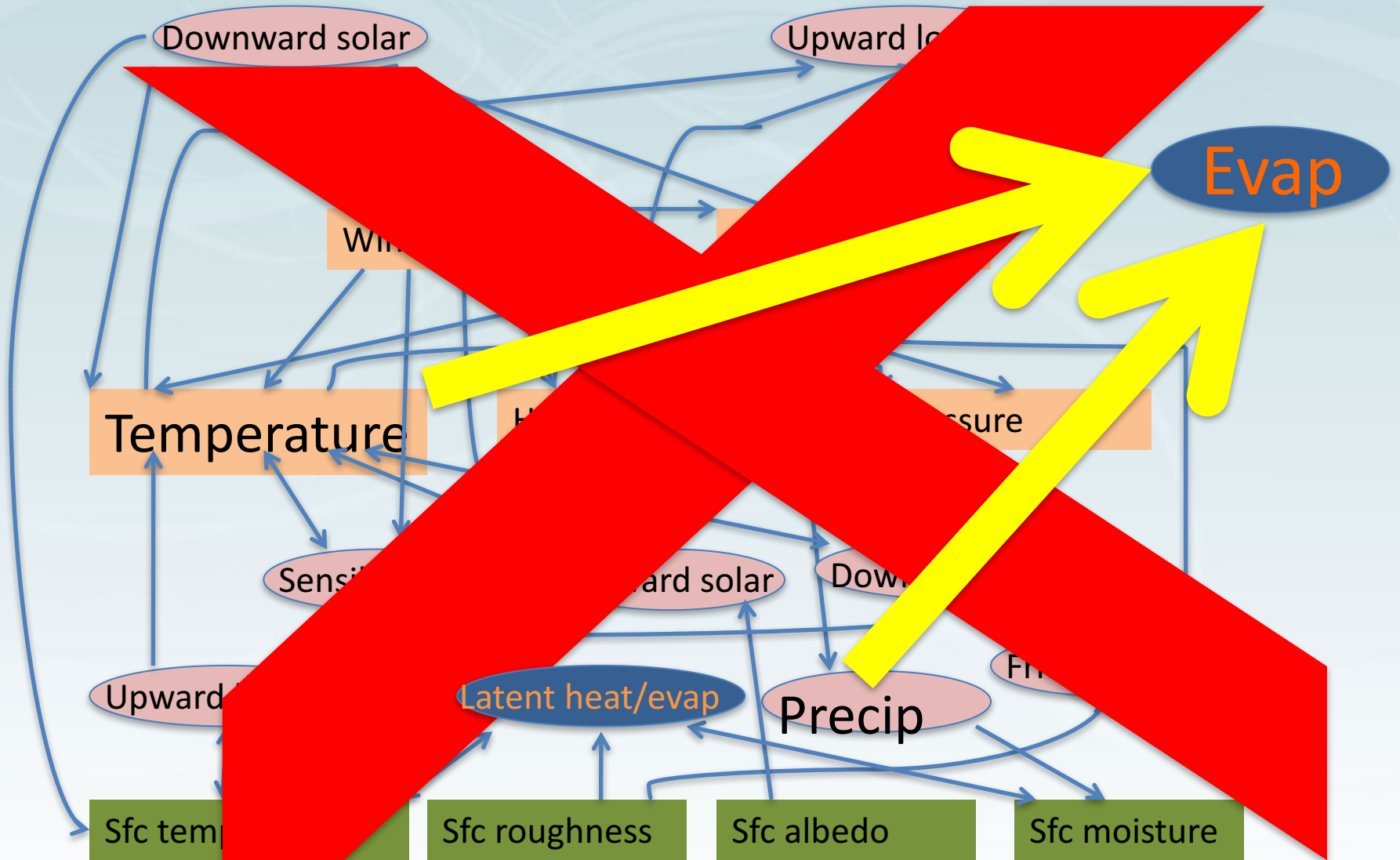




# Drastic simplification



# Redundant variable





# Which hypothesis is right?

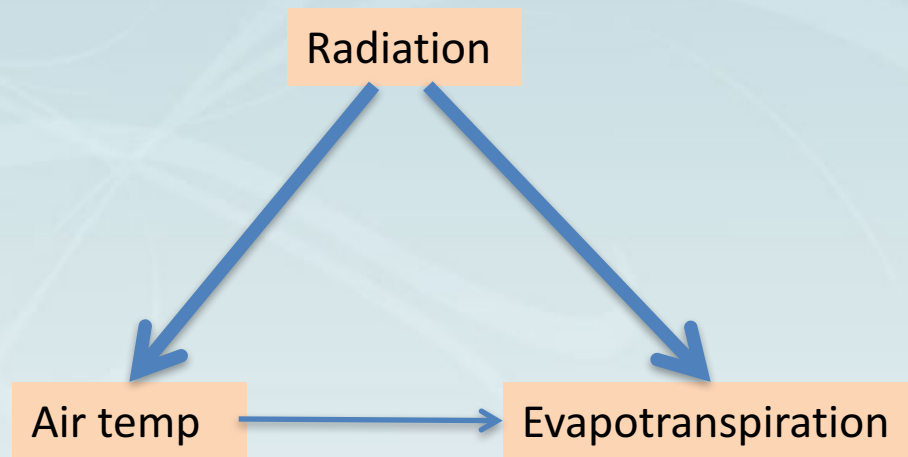


Hypothesis A prevailed for a long time among Great Lakes scientists—based on a non-quantitative rule of thumb

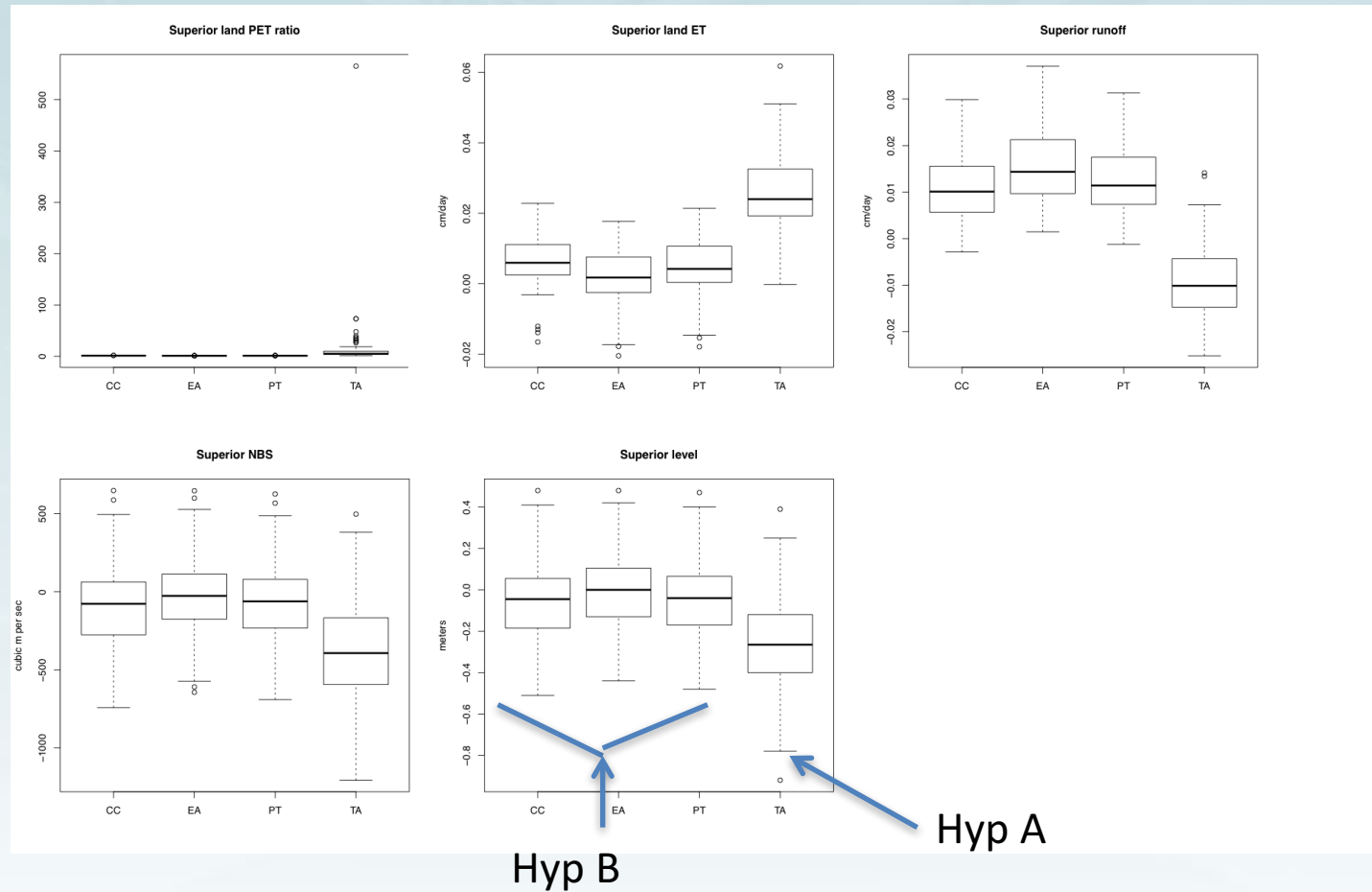
I am a major proponent of hypothesis B—based on the firm paradigm of energy conservation

Few had taken a critical look at A; most are now persuaded by B

# An Analogy—A State Fair



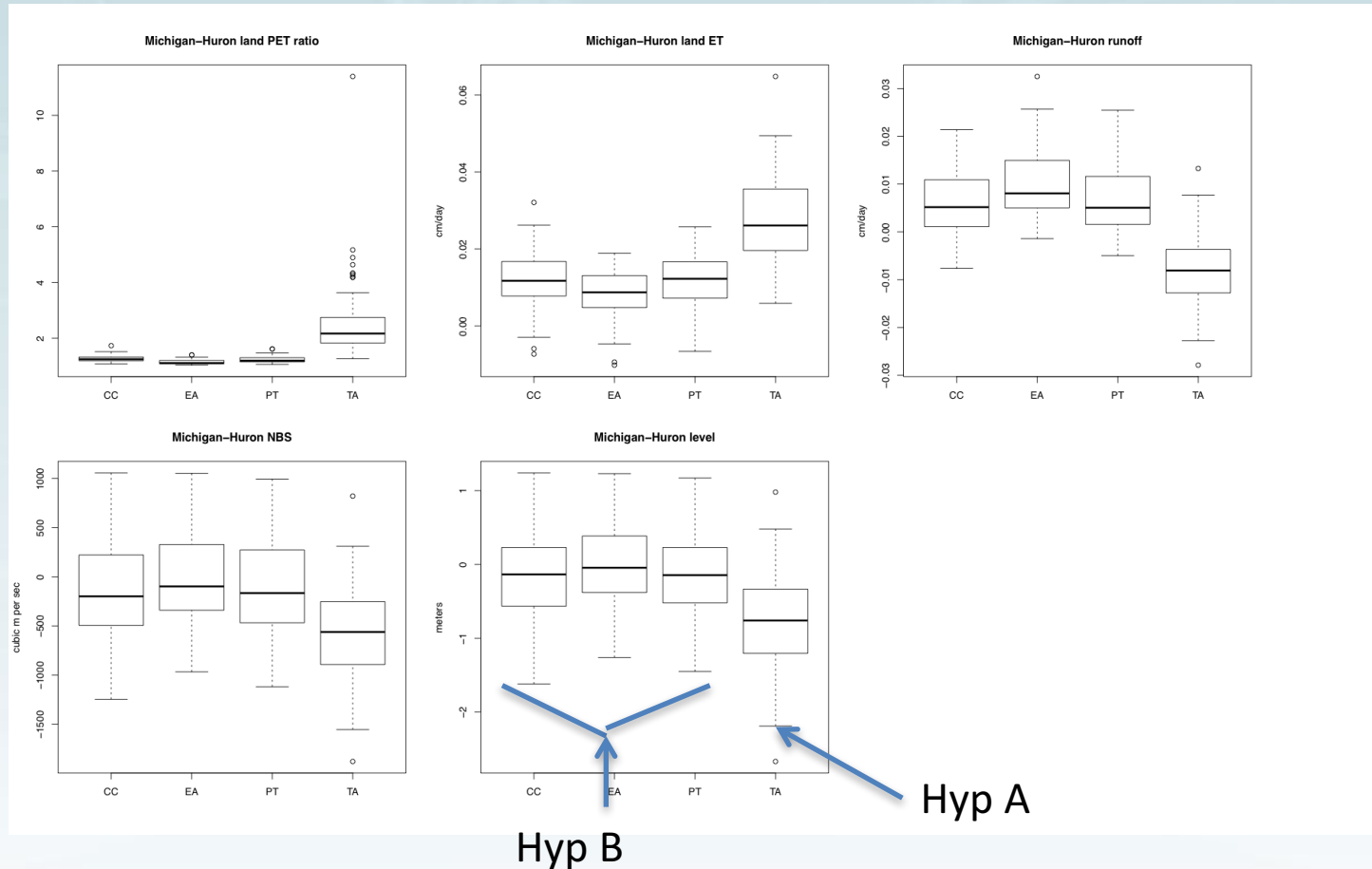
# Lake Superior water budget changes



Hyp A

Hyp B

# Lake Michigan-Huron water budget changes





Make things as simple as possible, but not simpler.

--attributed to Albert Einstein

...the proponents of competing paradigms practice their trades in different worlds.

--Thomas Kuhn, The Structure of Scientific Revolutions

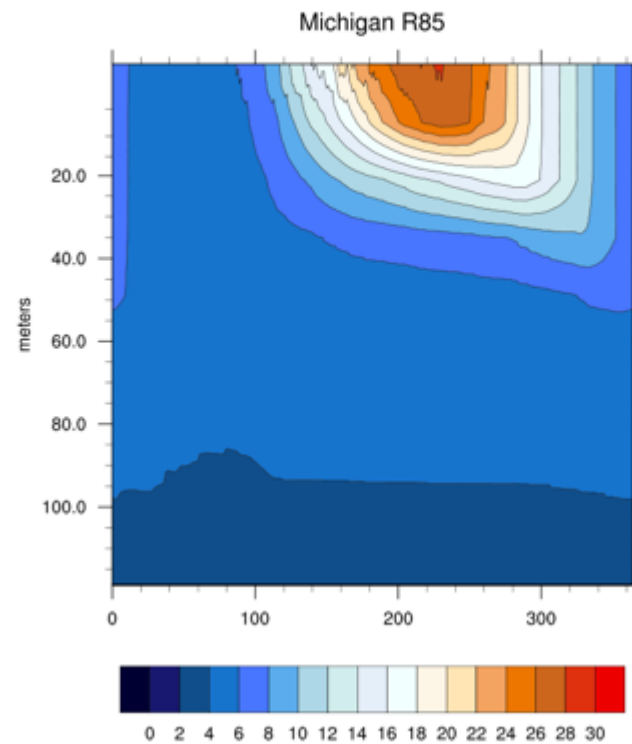
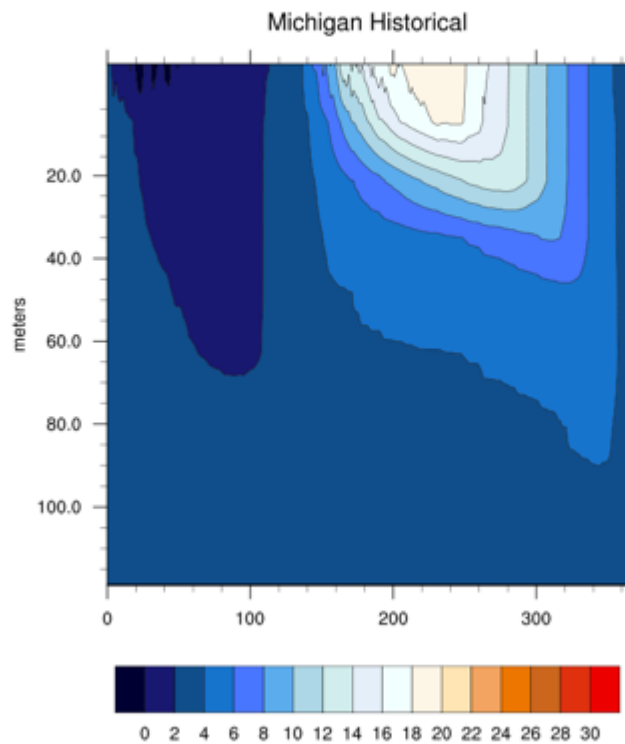
# Bottom line



Drops in Great Lakes levels that were expected when using hypothesis A are reduced or reversed by using hypothesis B



# Lake Michigan Annual Temperature Profiles



# Regional Special Issues



Potential for larger flash floods brings threats of:

- Sudden large loads of agricultural P, resulting in harmful algal blooms (esp. western L. Erie)
- Combined sewer overflows and E. coli
- These can combine with complex water flows in lakes and streams.



# Conclusions



# Solid Conclusions



Increased temperature—air and water

Shift in timing of some local events—ice formation and melt, maximum runoff, lake turnover, spring algal bloom

More water vapor in the atmosphere—implications for storms

The rules are changing, but less greenhouse gas means both less threat and less uncertainty!

# Less Secure Conclusions



Possible drop in levels of the Great Lakes

Changes in precipitation variability

Changes in nutrient loading and harmful and other algal blooms

Anoxic zone in Lake Erie

Potential for a myriad range of impacts

Effect in combination with other threats

Different reactions to uncertainty

# Websites



climate.gov—NOAA

realclimate.org

skepticalscience.com

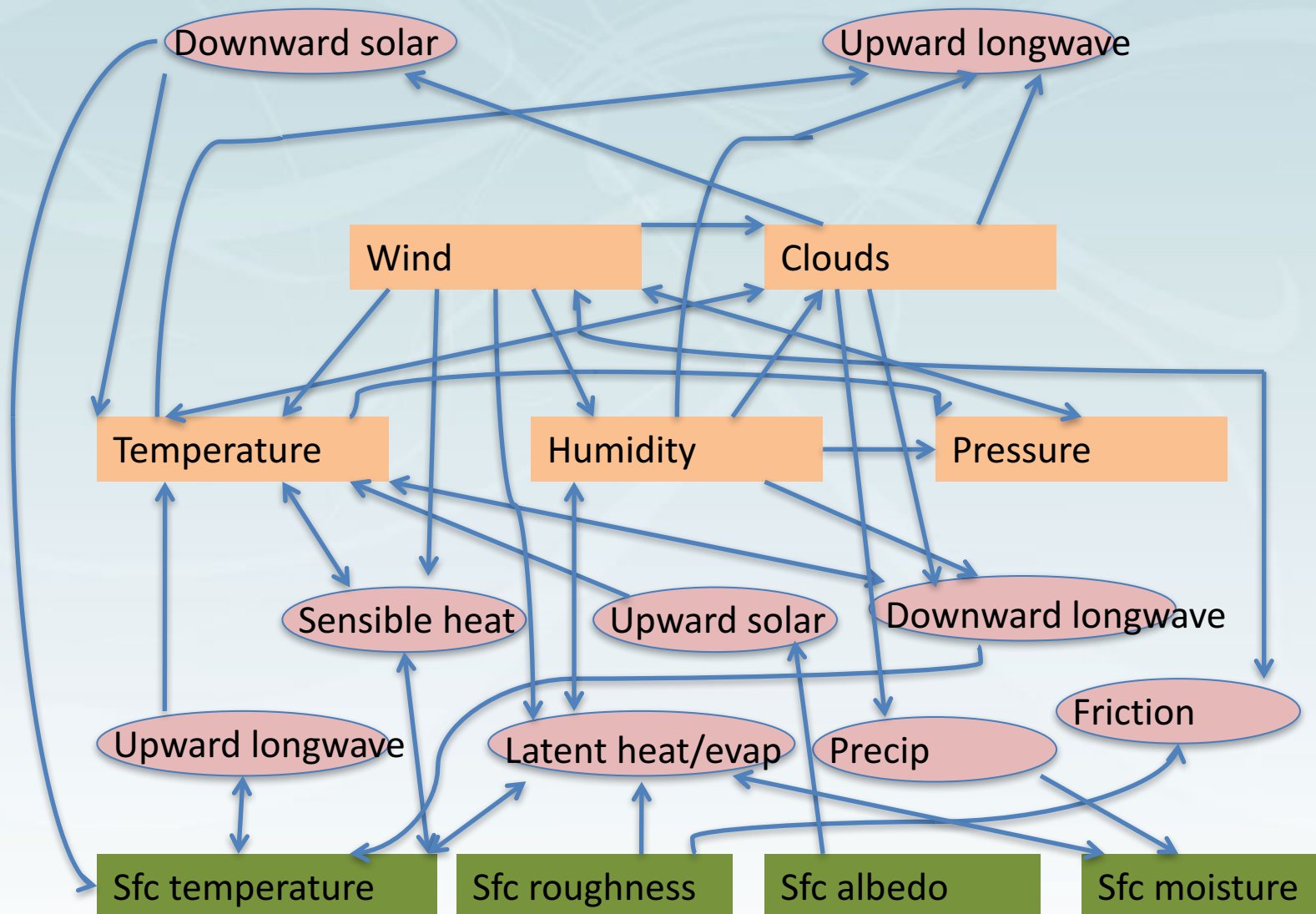
www.nwf.org/Global-Warming.aspx

[www.ipcc.ch](http://www.ipcc.ch)

climatepathblog.wordpress.com



# Remember that climate is both air and surface



# Questions

