Agronomy 406
World Climates

March 8, 2018

Team 1 Climate News.

Climate and agriculture.

Reading: UN Food and Agriculture Organization summaries for maize, wheat, soybean and sugarcane.

A look ahead

By Thursday after Spring Break (March 22):

View the video by Prof. Richard Alley entitled "4.6 Billion Years of Earth's Climate History: The Role of CO_2" and complete the related assignment.

The video and assignment are linked from the course schedule.

The video is only about 24 minutes but is packed with information. If you simply view it once through, you will find it overwhelming.

Print the assignment and turn it in at the **start of class on March 22.** Late assignments will not be accepted.

Growing Degree Days (GDD)
sometimes called "heat units" or other names

Concept of "thermal time":

Rates of chemical reactions and other biophysical processes often depend on temperature.

Many organisms have a minimum temperature for development, and develop more rapidly as temperature increases.

Applies to many kinds of organisms that **do not regulate their own temperature:**

plants, insects, etc.

Relates to development but not necessarily yield.

Growing degree day base temperatures

Maize (corn), sorghum, rice	10^{o}C (50^{o}F)
Wheat, barley, oats	0-5^{o}C (41^{o}F)
Soybean	10^{o}C (50^{o}F)
Sugarcane	12^{o}C (53.6^{o}F)
Sugar beet	1.1^{o}C (34^{o}F)

Notes:

Sometimes slightly different values are used.

Soybean development is also influenced by day length **(photoperiod)**.

Growing degree day requirements for some agricultural pests

Pest	Base	GDD
Black cutworm	50ºF	330 (e)
Corn rootworm	52ºF	700 (h)
European corn borer	50ºF	1500 (c)
Bean leaf beetle	46ºF	700 (d)
Japanese beetle	50ºF	1030 (d)

(c) Full life cycle, to egg laying.
(d) Complete development.
(e) Emergence and cutting after flight detected.
(h) To hatching and feeding.

Suppose your farm has a mouse infestation. Can the GDD approach be used to predict generations of rats or mice?

Wheat

Worldwide, second in value (behind rice) and fourth in tons produced (behind sugarcane, maize and rice).

Photosynthesis is C3, rather than C4 as in maize.

image from University of Nebraska Crop Watch

Wheat temperature and water requirements

High yielding crop uses 450 to 650 mm of water, less for cool climates. (How many inches?)

Rule of thumb: 5 inches of water to produce a crop, with each extra inch producing a yield increase of 7 bushels per acre (per Montana State University Extension).

Better suited to low temperatures than maize:

Low temperature limit for development is around 2 to 4^{o}C (35-40^{o}F) but GDD calculations fit better with T_{base} = 0^{o}C (32^{o}F). Implies relation is not linear.

Compare to T_{base} of 50^{o}F for maize.

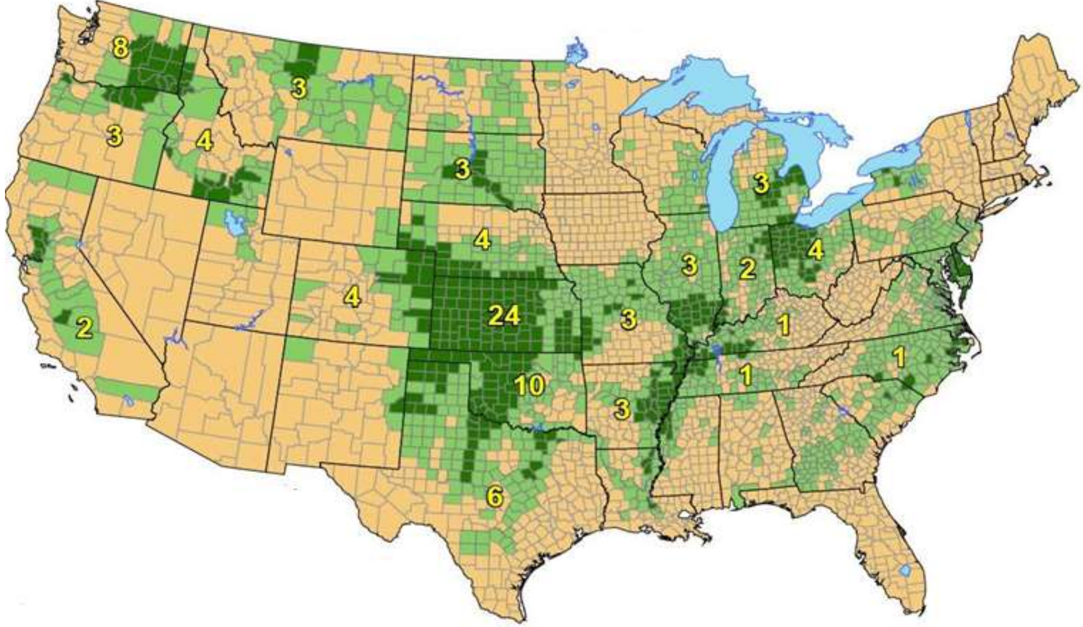
Wheat types

Two main types of wheat, depending on when it is planted:

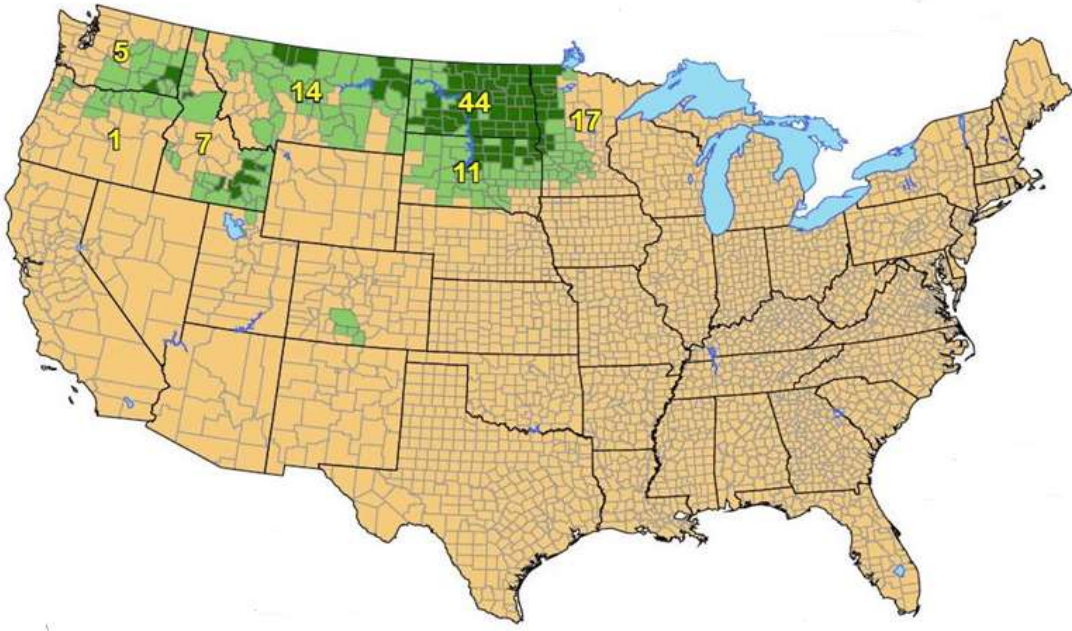
Spring wheat is planted in spring and harvested in late summer. It grows like most other grains.

Winter wheat is planted in fall and harvested in early to mid summer. In its early development stages it can withstand cold temperatures.

Winter wheat



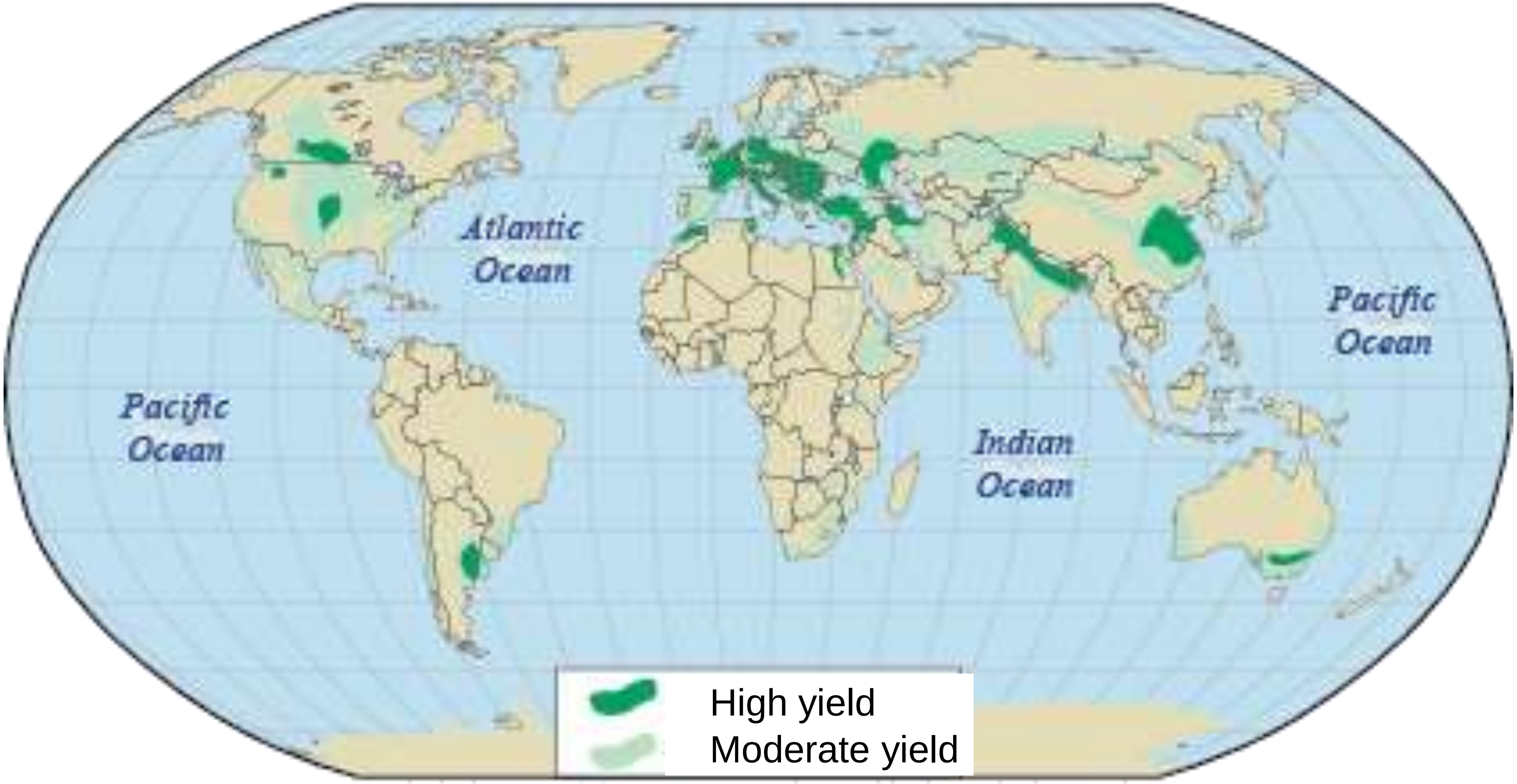
Spring wheat



Yellow numbers give each state's production as a the percentage of the national total.

USDA World Agricultural Outlook Board
Joint Agricultural Weather Facility

World wheat growing regions



Are there patterns to regions where wheat is **not** grown?

Winter wheat

Winter wheat must undergo cold acclimation and **vernalization** before it can bear grain:

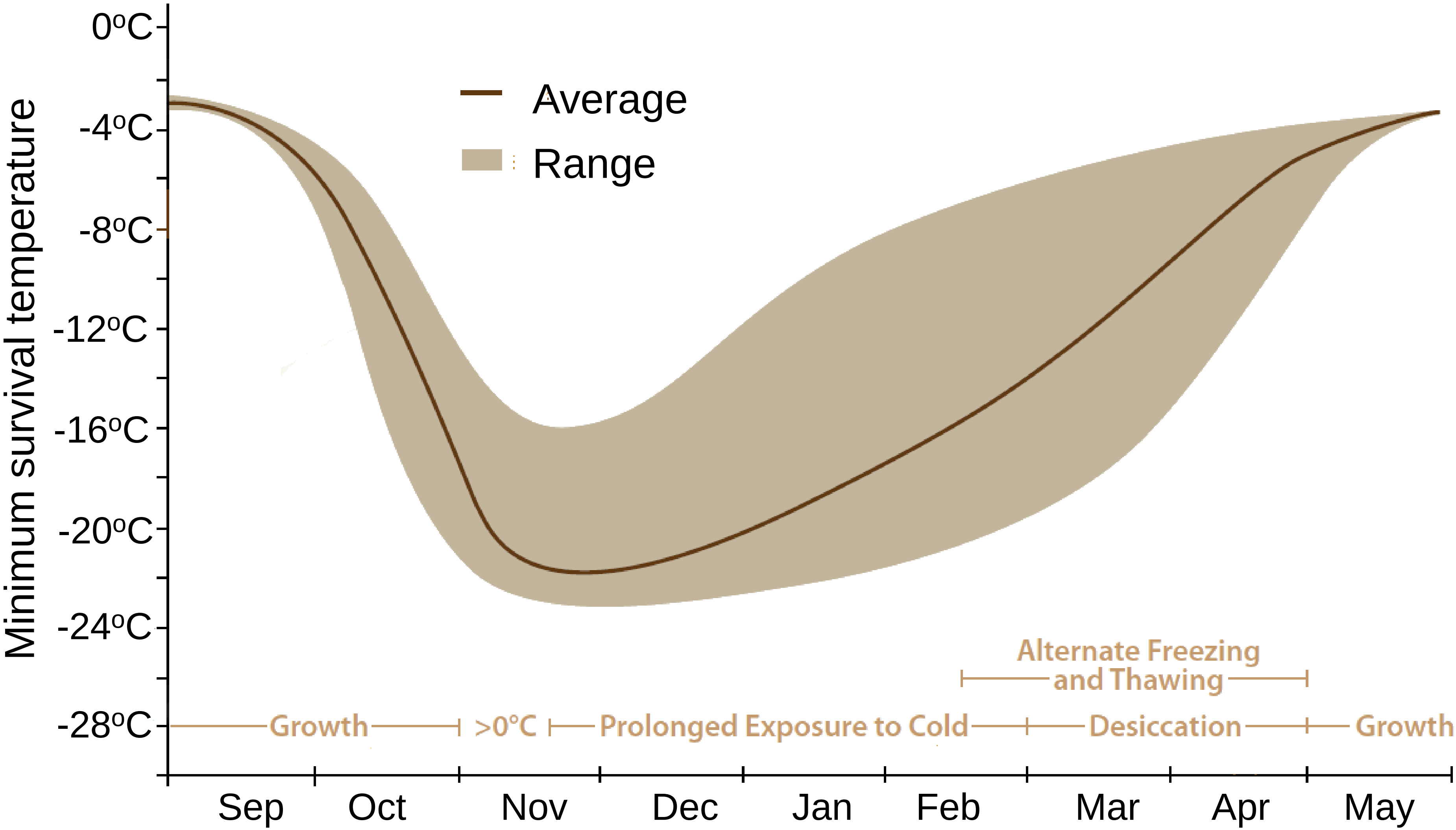
> low temperatures (30-60^{o}F, ideally around 40^{o}F) that induce dormancy, followed by warmer temperatures.

Winter wheat can benefit from snow cover that insulates seedlings from very cold temperatures.

Acclimation can allow winter wheat seedlings to survive cold temperatures. (Think of how people become accustomed to hot or cold temperatures.)

Typical acclimation of winter wheat

(varies with cultivar, etc.)



adapted from Winter Wheat Production Manual, Alberta Wheat Commission

Soybeans

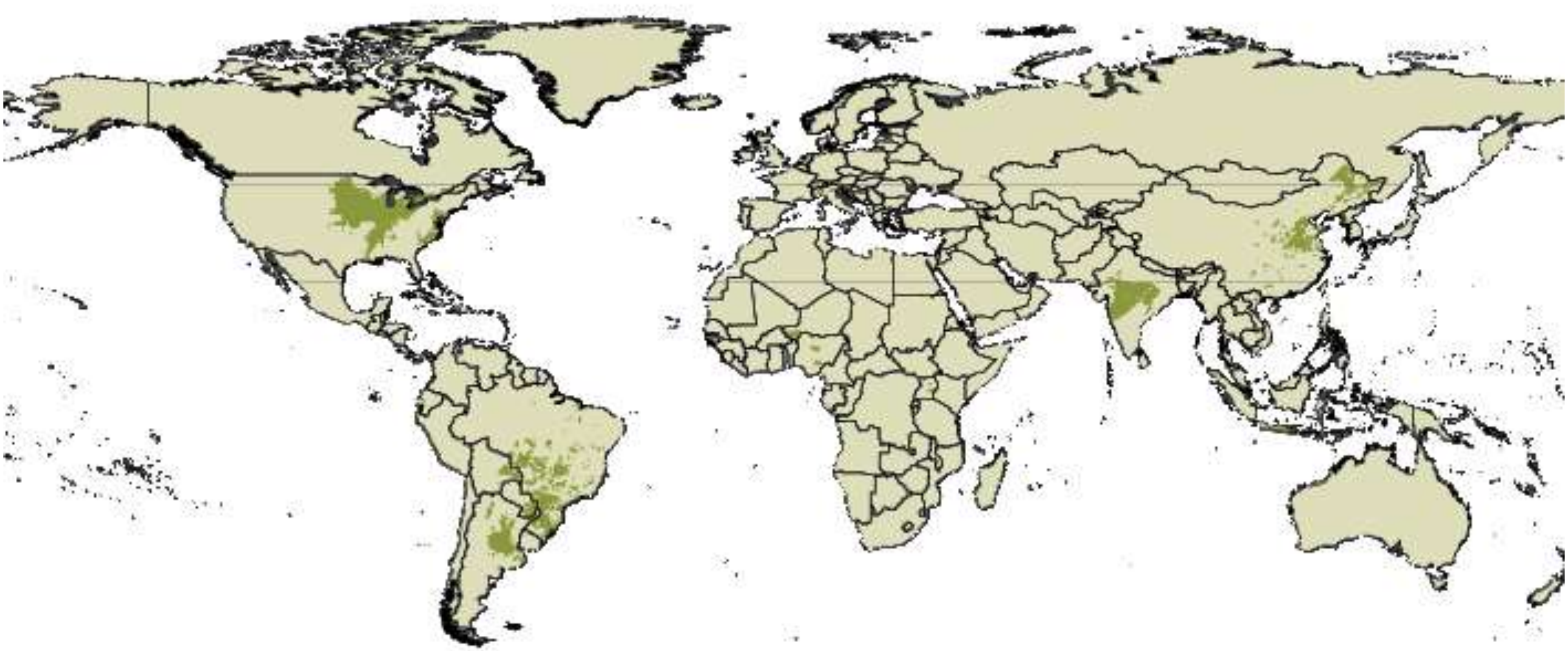
Third most valuable worldwide (behind rice and wheat), sixth in tonnage produced.

U.S. and Brazil are the largest producers.

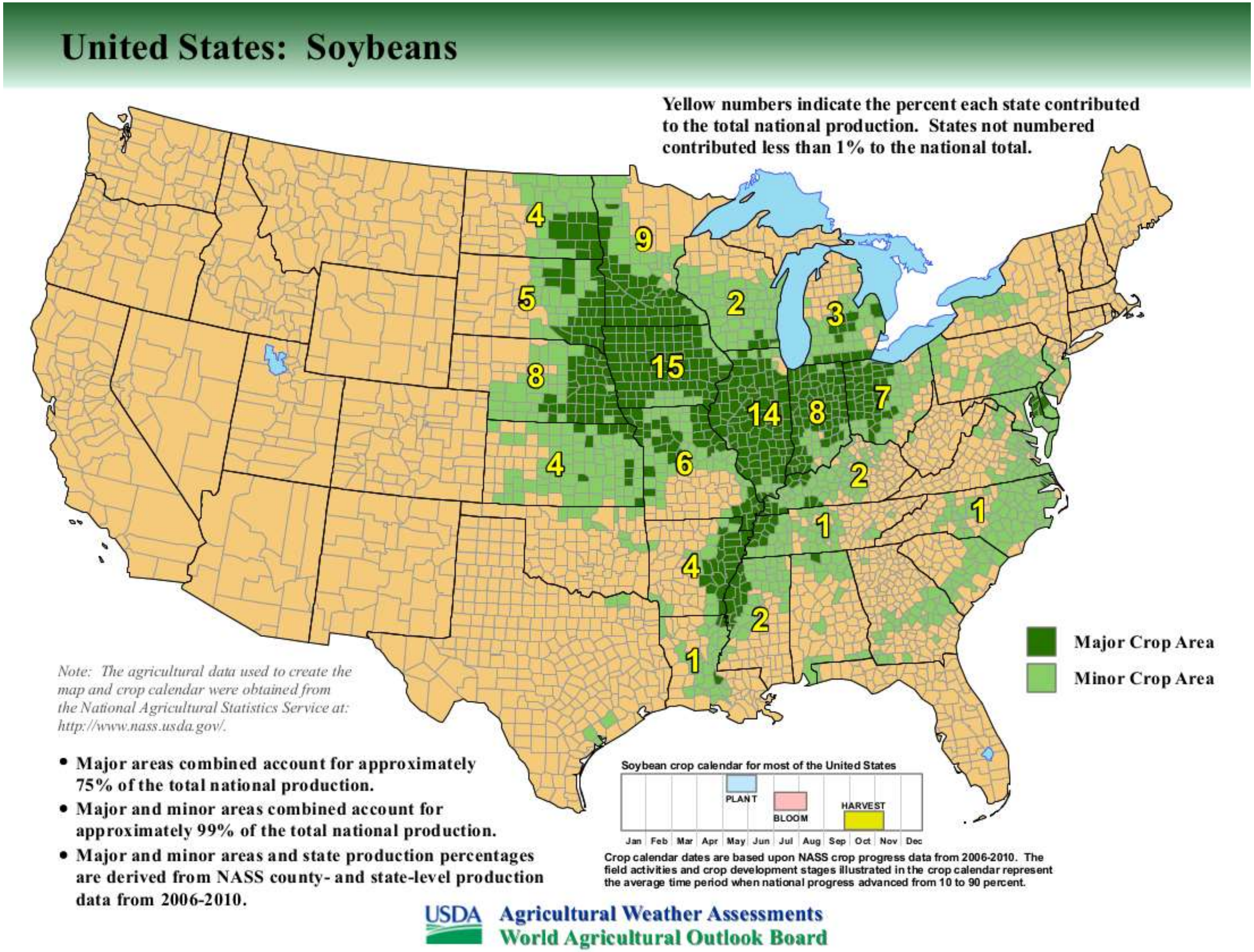
Similar climates as maize:

- T_{base} ~50^{o}F, GDD to maturity ranges ~2400-3000.
- Similar seasonal water requirements as maize, 450-700 mm (How many inches?)
- Water requirements vary depending on temperature, variety, etc.

Global soybean producing regions



U.S. soybean production



Soybeans and photoperiod

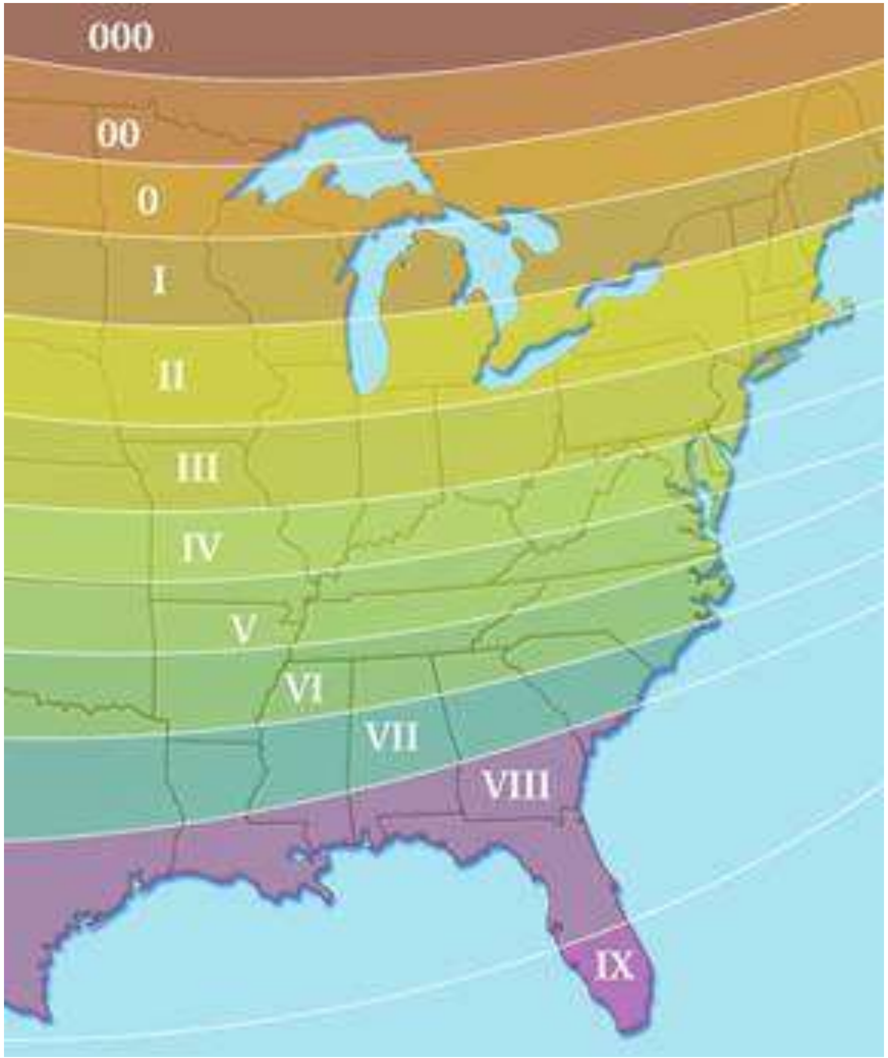
Soybean is sensitive to **photoperiod**:

- Flowers only when **nights are sufficiently long.**
- Requirements for darkness depend on variety.

Maturity groups are developed for specific latitudes.

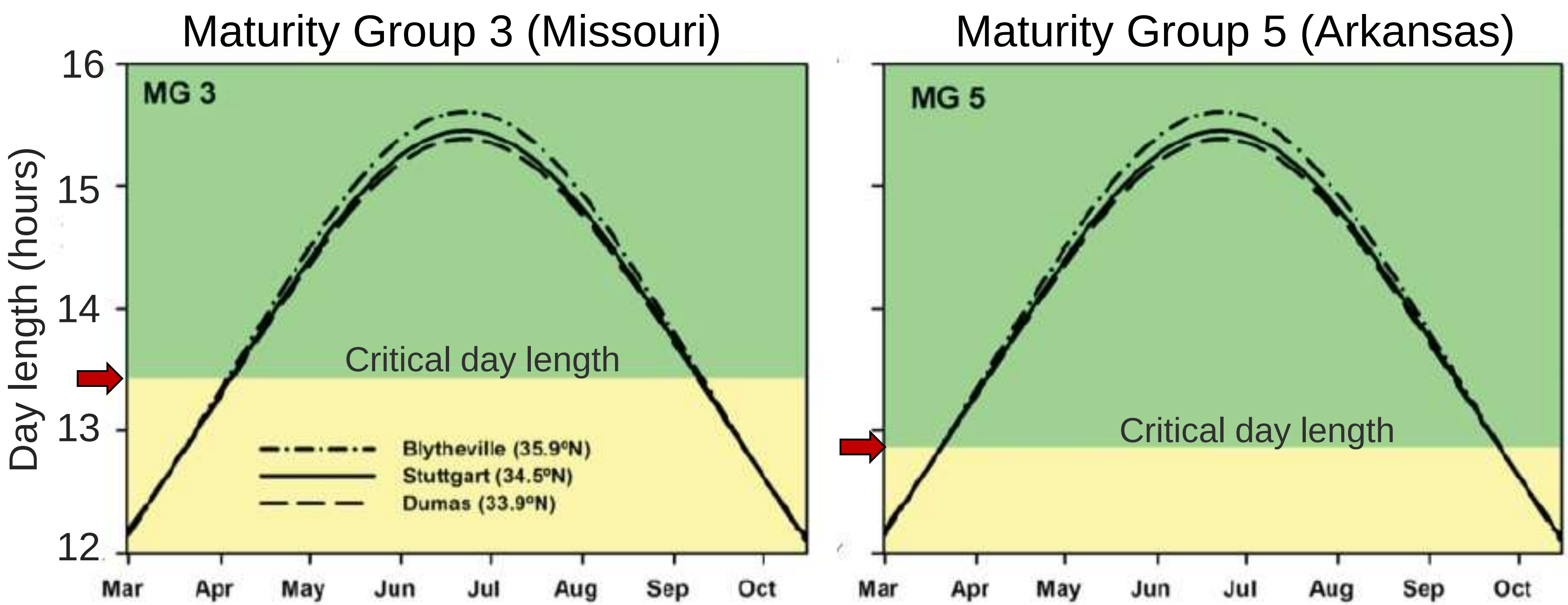
Soybean maturity groups

Maturity groups range from 000 (in southern Canada) to X (for Mexico and the Caribbean).



from Soybean Gene Zoo, University of Missouri Division of Plant Sciences

Soybean dependence on day length



Favorable to reproductive development

Unfavorable to reproductive development

Adapted from Purcell et al. (2014), Soybean Growth and Development.

Soybeans and photoperiod

Varieties in different maturity groups should be planted at the appropriate latitude:

If a variety is planted **too far south,** growth will be reduced by early flowering.

If a variety is planted **too far north,** flowering will be delayed. This can increase danger of frost.

Why does growing a variety too far north of its usual range delay flowering?

Day length and latitude

In your teams, draw a curves of day length (i.e., number of daylight hours per day) versus month for the following latitudes:

0^oN (Equator)

66.5^oN (Arctic Circle)

A latitude around the middle of this range.

Put all the curves on the same graph.

Use your graph to help explain why **growing a variety too far north of its usual range will delay flowering.** Assume 11 hours of darkness are required for flowering (this is approximately Maturity Group IV).

Sugarcane

- World's number-one crop by tons produced.
- The only perennial of the top-five global crops.
  - Does not need to be re-planted every year.
- Top producers are Brazil, India and China.
  - U.S. is a minor producer with only 1-2% of the global total.
- Sugarcane has **very high photosynthetic efficiency:**
  - Biomass generated per unit of light, given appropriate moisture, nutrients etc.

Sugarcane and climate

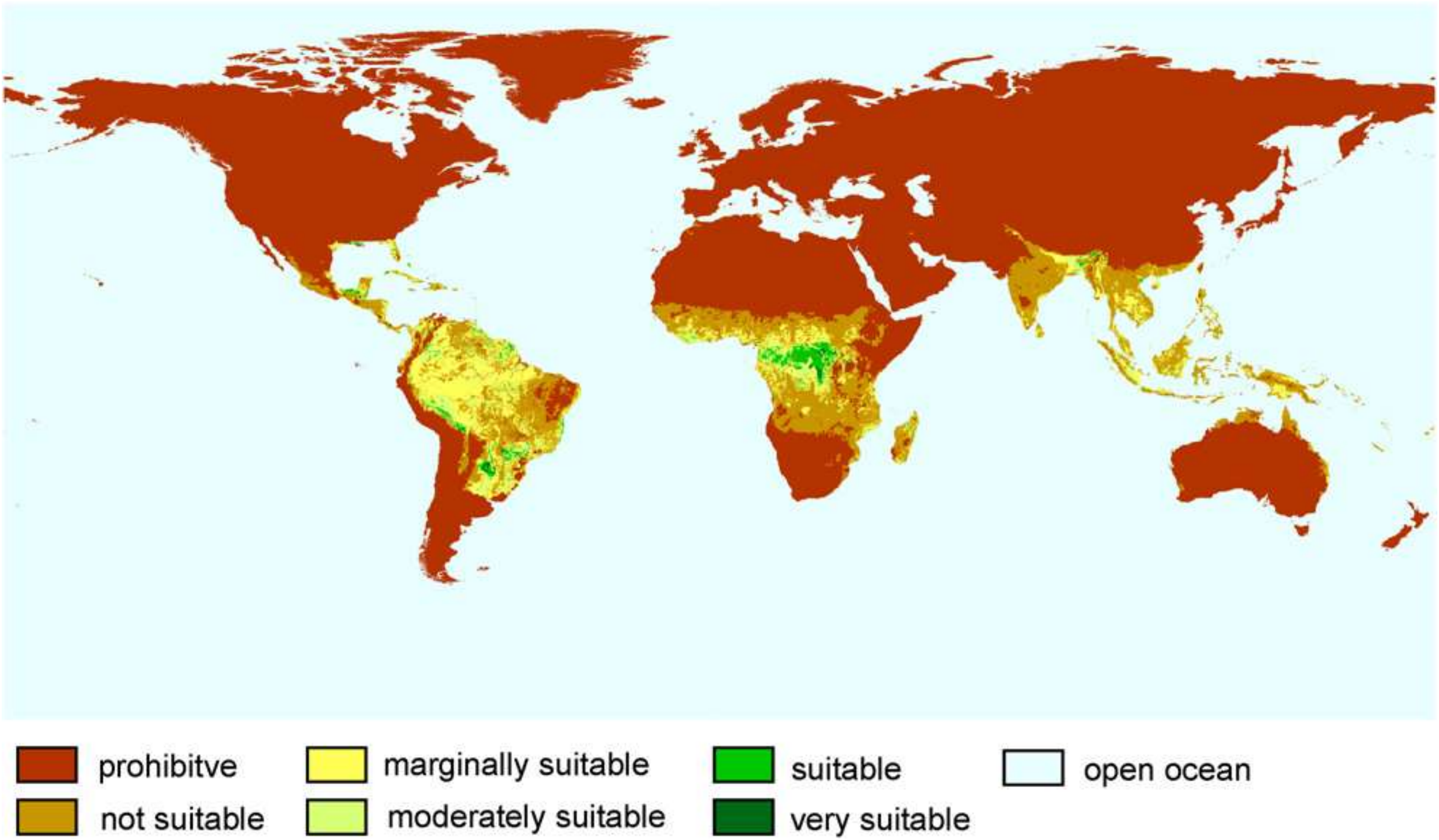
Grows best in hot and very sunny conditions for vegetative growth, followed by cooler conditions for producing sucrose.

Minimum temperature for active growth is about 20^{o}C (68^{o}F).

Requires abundant and steadily available water:

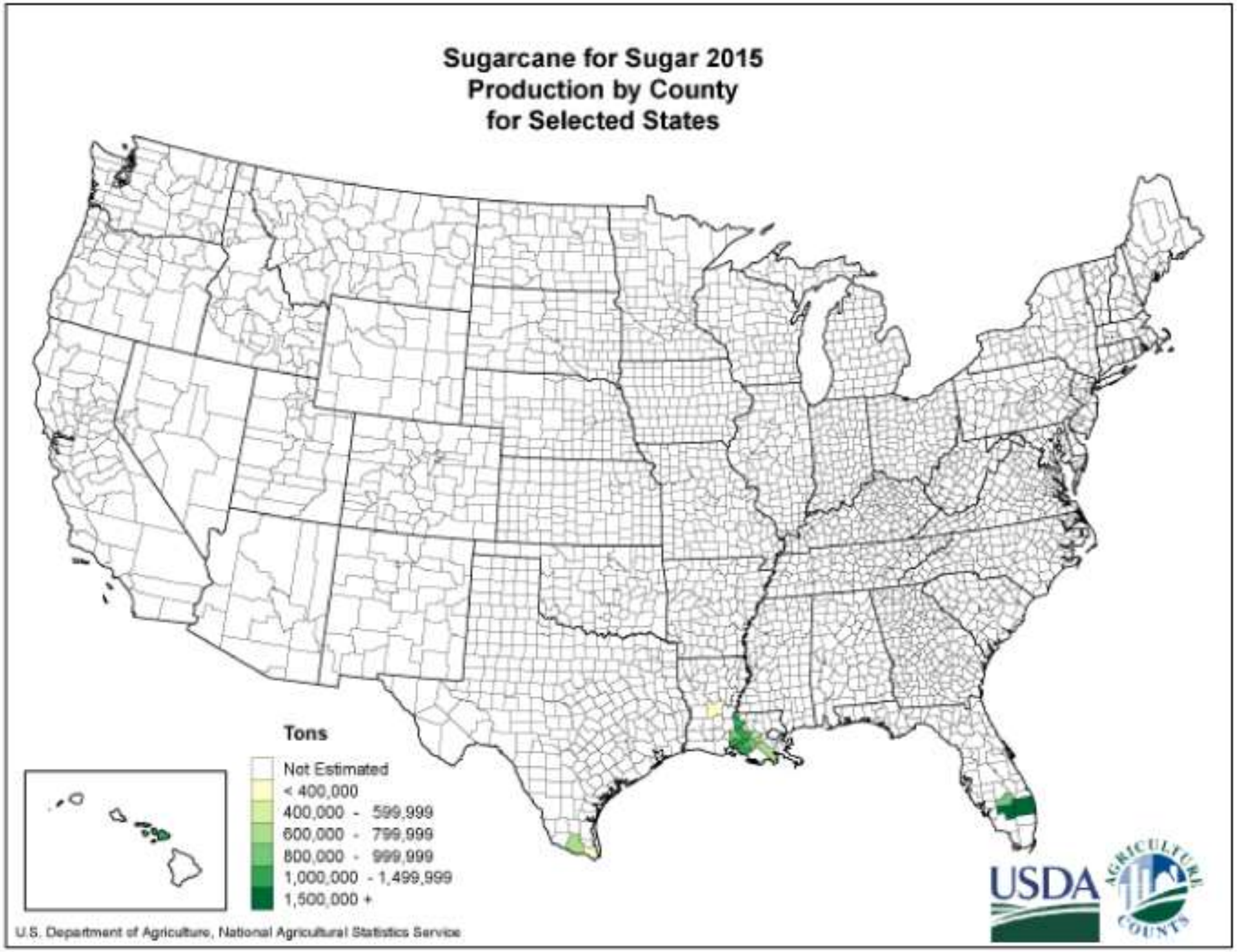
- 1500 to 2500 mm, preferably distributed evenly over the growing season. (How many inches?)

Climate and soils suitable for production of rain-fed sugarcane



from Mathews (2007, *Energy Policy*)

Sugarcane production in the U.S.



C3 and C4 photosynthesis

High photosynthetic efficiency of sugarcane is related in part to its **C4 photosynthesis** mechanism.

C3 and C4 mechanisms are named for the number of carbon atoms in the first stable product of photosynthesis.

What are the important differences in how these mechanisms work?

A (very) little biology

Both C3 and C4 mechanisms use the enzyme **RuBisCO** (often written just "rubisco") to fix CO_2 into carbohydrates.

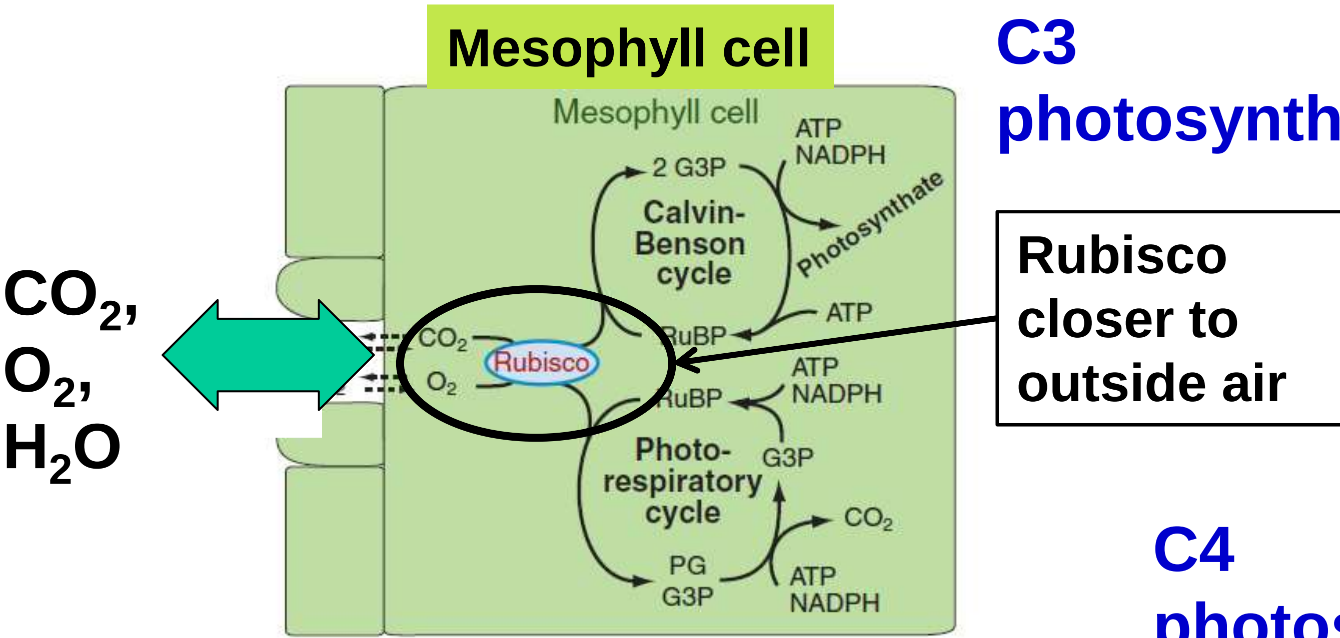
Rubisco can also take up O_2 instead of CO_2, resulting in **photorespiration.** This wastes some of the potential photosynthetic activity.

Tendency for rubisco to take up O_2 instead of CO_2 is greater when **CO_2 is low inside the leaf:**

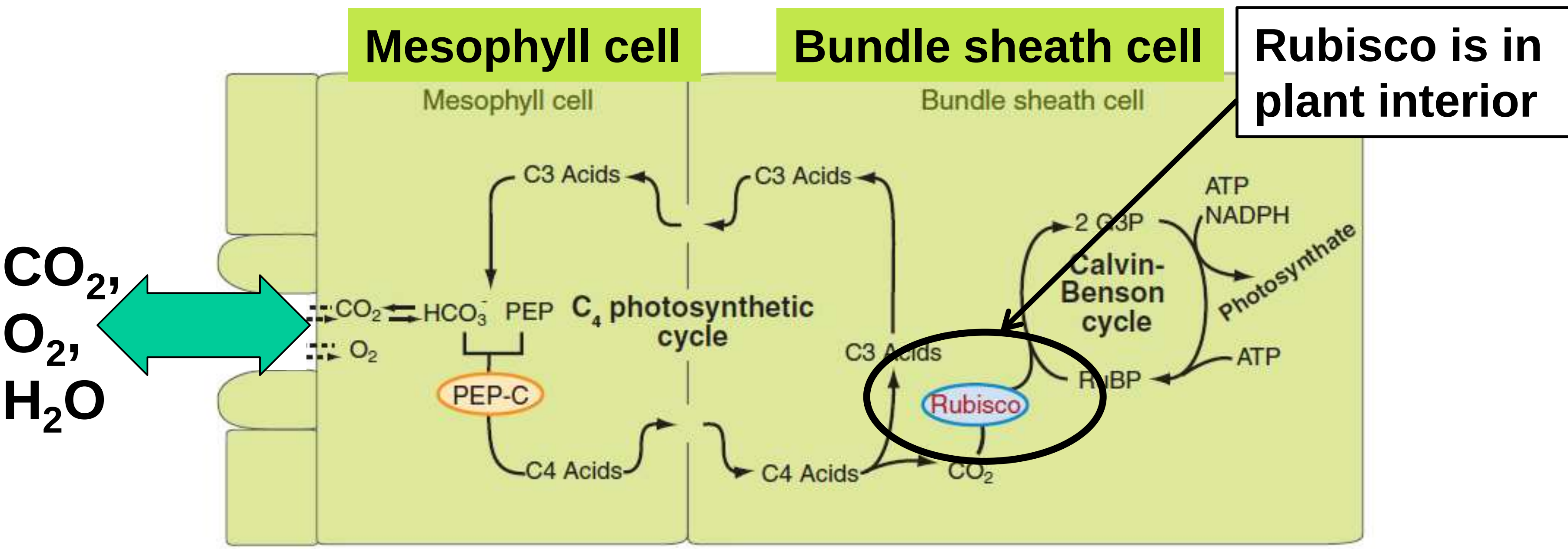
> This happens when **ambient CO_2 is low** or when the stomata close due to **water stress,** so that CO_2 in the leaf becomes depleted.

C4 plants add a step in the photosynthesis process that "protects" rubisco from O_2, increasing the efficiency of photosynthesis.

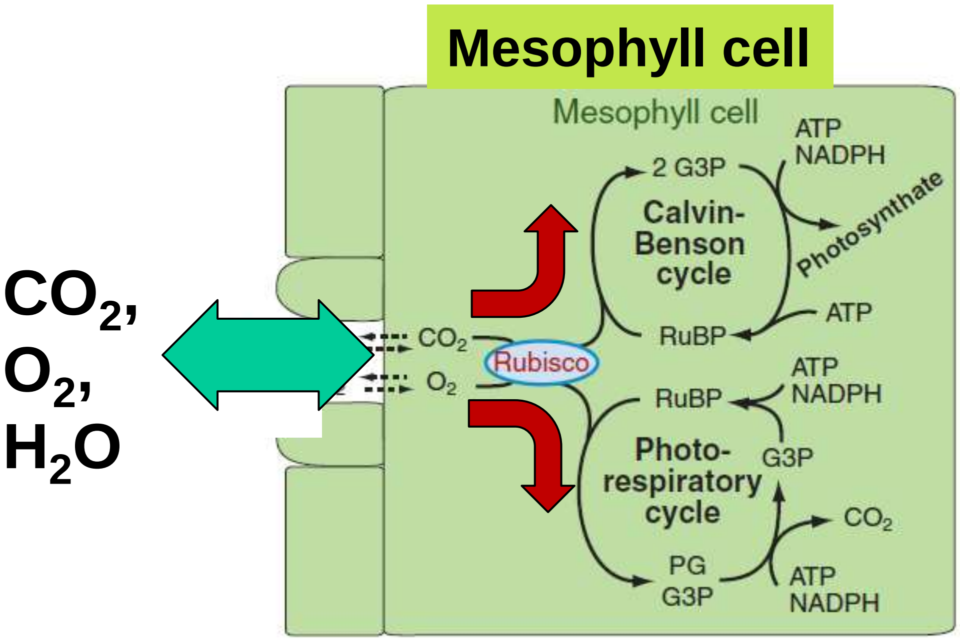
C3 photosynthesis



C4 photosynthesis

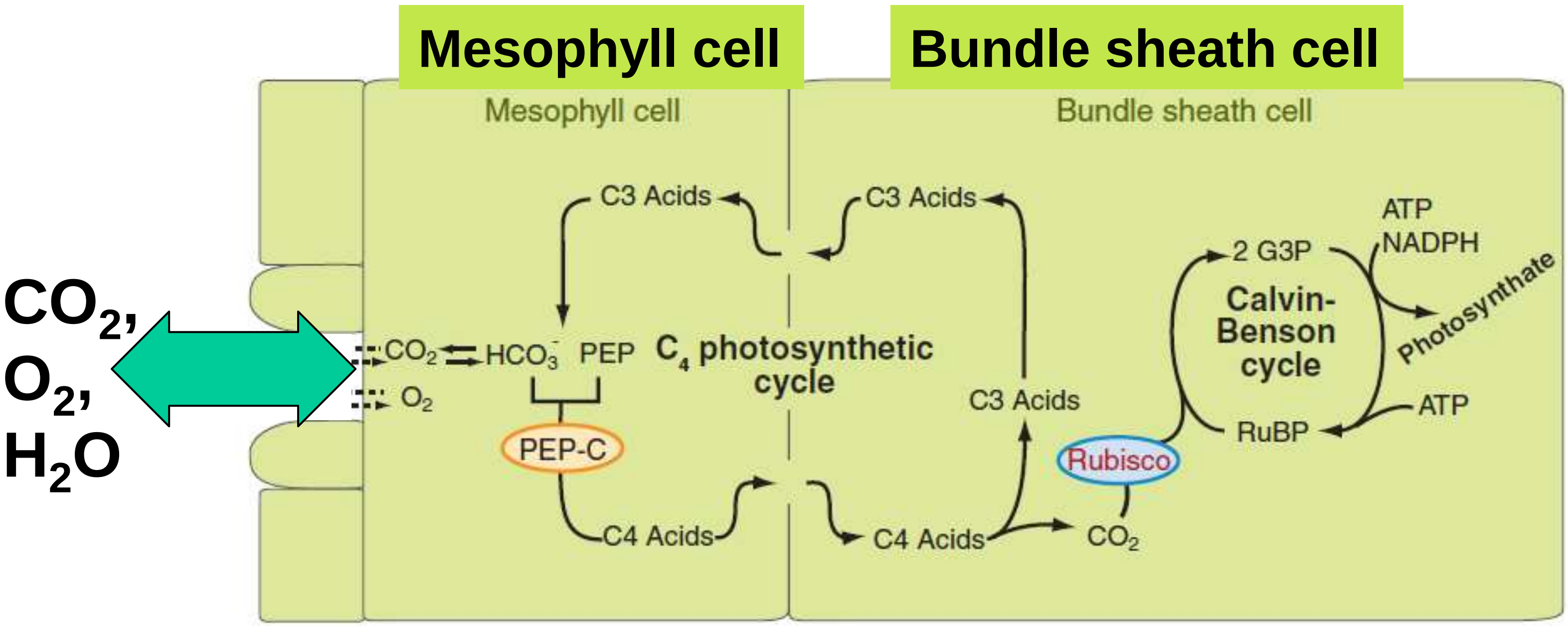


C3 photosynthesis



two paths are possible in C3: photosynthesis (uses CO_2) or photorespiration (uses O_2)

C4 photosynthesis



So what does this have to do with climate?

C3 plants are more affected by CO_2 content of the atmosphere compared to C4 plants, since their photosynthetic mechanism is more directly exposed to ambient CO_2.

C4 plants are less affected by atmospheric CO_2. They are affected by low CO_2 concentration but only up to a point below present day atmospheric CO_2.