Agronomy 406
World Climates

February 15, 2018

Hydrologic cycle.

Team 4 Climate News.

Review:

METED module, Understanding the Hydrologic Cycle

Active review session for the midterm

Goals:

- Practice with exam format and typical questions so you can do your best.
- Give motivation to begin looking over the semester's material.

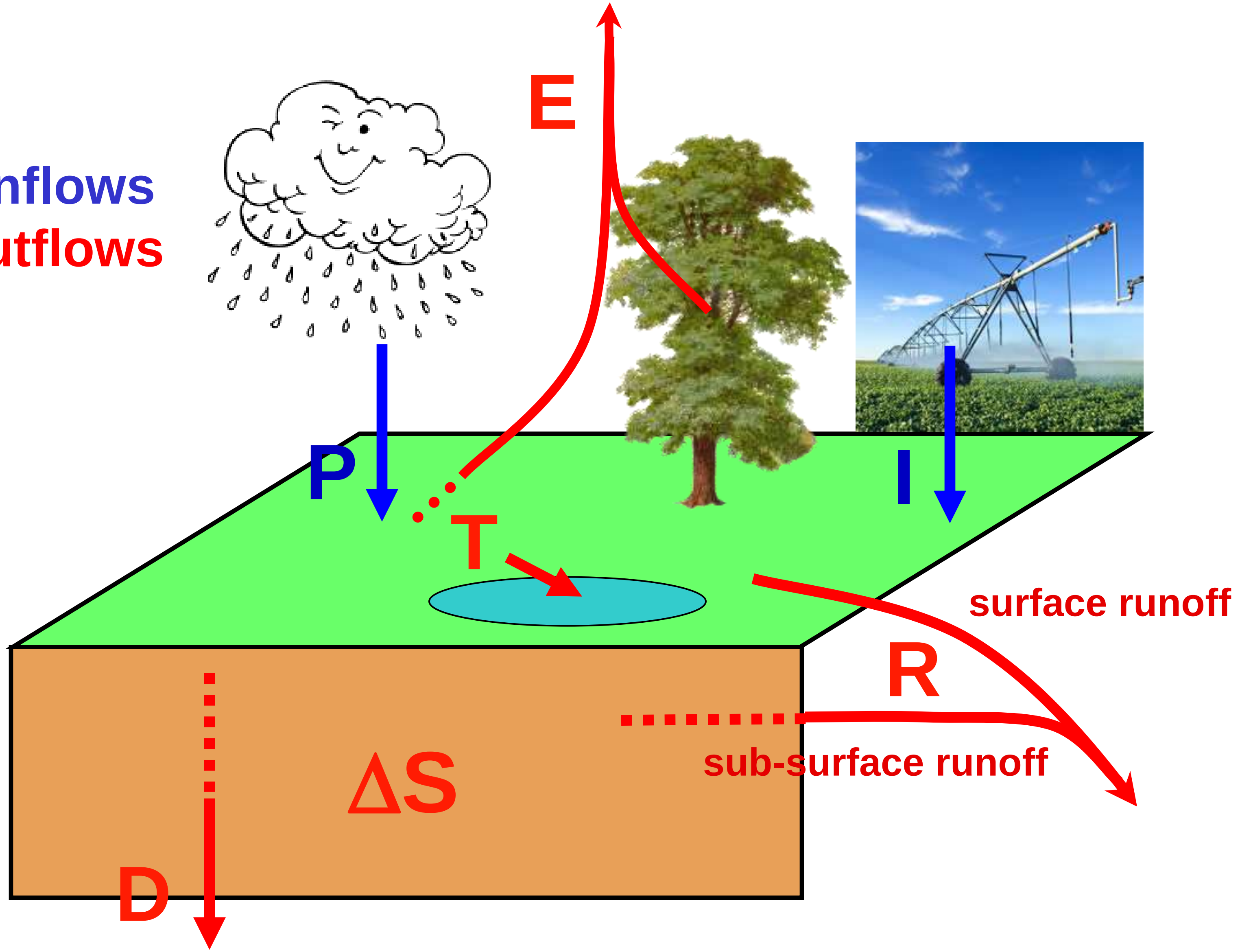
Similar format as the midterm:

- Limited time, about 15 minutes per question.
- Closed book, no calculators.
- Answers will be graded as an in-class assignment.
- Midterm from a previous year is linked from the class schedule.

Subsurface water

Components of the soil water budget

blue = inflows
red = outflows



Moving water from the ground to the atmosphere: Evapotranspiration

What is it?

evaporation (from soil or water)

\+ transpiration (by plants)

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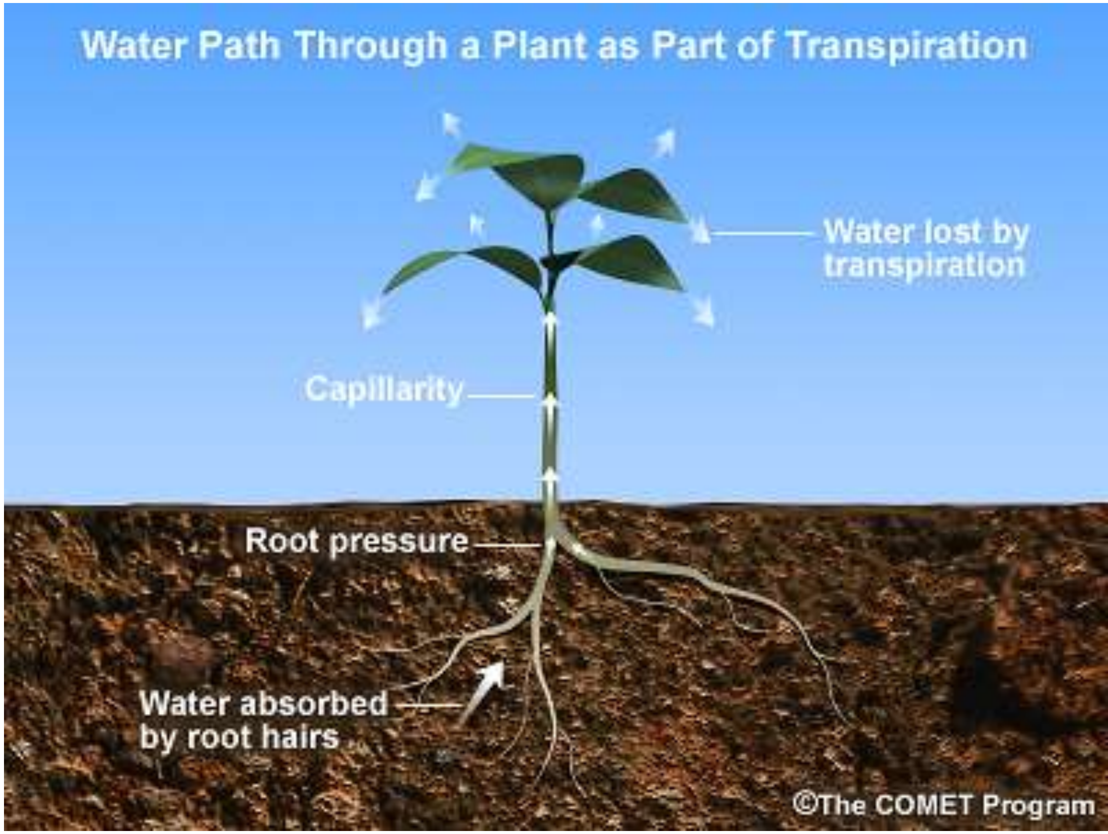
evapotranspiration

Evapotranspiration is a loss (outflow) from the soil but a gain (inflow) to the atmosphere.

Transpiration

Plant takes up water through fine hairs on their roots.

Water is drawn upward through the plant xylem by capillary action, evaporates in cavities within leaves, and is released through small openings called stomata.



In vegetated areas more water usually is lost by transpiration than by direct evaporation from soil.

Potential and actual evapotranspiration

Potential evapotranspiration (PET or PE):

PET is a reference maximum rate.

PET is the evapotranspiration that would be observed from **a freely-watered, vigorously growing short crop** under present atmospheric conditions.

Important! Since PET **assumes** a moist, vegetated surface exists, the actual surface and its properties are ignored. PET is affected **only** by the environment (mainly winds, temperature, sunlight).

Potential and actual evapotranspiration

Actual evapotranspiration (ET, sometimes AET):

- It is what it sounds like: evapotranspiration that **actually occurs.**
- ET may differ from PET.
- ET differs from PET if the **definition of PET is not satisfied.** Examples:

  The surface is not freely watered (e.g., dry soil).

  The surface is not an actively-growing short crop (e.g., soil is bare or the crop is senescent).

Team discussion

Over farmland in central Iowa, what **relationship between actual evapotranspiration (AET) and potential evapotranspiration (PET)** would you expect on each of the following dates, and why?

- January 1
- May 1
- July 1
- October 1

Crop water use for transpiration

Almost all crop water use is for transpiration.

- Only a tiny fraction is used to create plant tissue.

Depends on the type of crop and stage of development.

- Water use usually is greatest in the middle part of the crop life cycle.

Direct measurement of ET is difficult and expensive.

We can **estimate** crop water use if we know PET:

- Start with PET and apply a scaling factor (crop coefficient) that depends on crop type and stage of development.

The problem is then to estimate or measure PET.

Estimating evapotranspiration

Many formulas exist for estimating PET from weather measurements.

- The **Penman equation** (or variations) is probably most common. Considers net radiation, wind speed, and atmospheric humidity.

PET estimates can also be derived from measurements of **pan evaporation.**

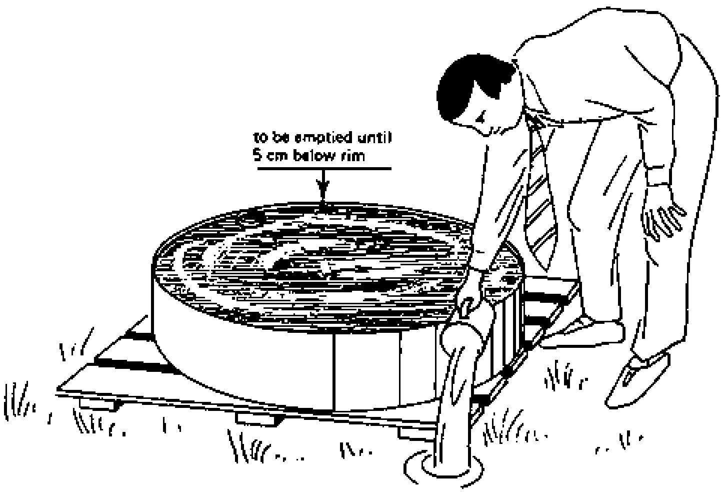
- Multiply pan evaporation by a pan coefficient that depends on measurement conditions.

For pan coefficients see: http://www.fao.org/docrep/S2022E/s2022e0a.htm

Estimating PET from measurements

The most direct method to estimate PET uses an **evaporation pan.** Most common is the Class A Evaporation Pan (shown here).

water level is measured inside a stilling well



What could possibly go wrong…?


QUALIMET

Returning water to Earth: Clouds and precipitation

Precipitation returns water from the atmosphere to the surface. Can be rain or snow.

- Clouds usually form when air **cools** below its dew point temperature.
- Precipitation occurs when cloud droplets or crystals grow large enough to fall out (precipitate).

The most common way that air is cooled is by **lifting.**

- Height where air cools to its dew point temperature is the **lifting (or lifted) condensation level.**

Atmospheric water budget

As before,

change of storage = inflow – outflow

For the atmosphere, this is

$$\Delta S = E - P + C$$

E = evapotranspiration (inflow)

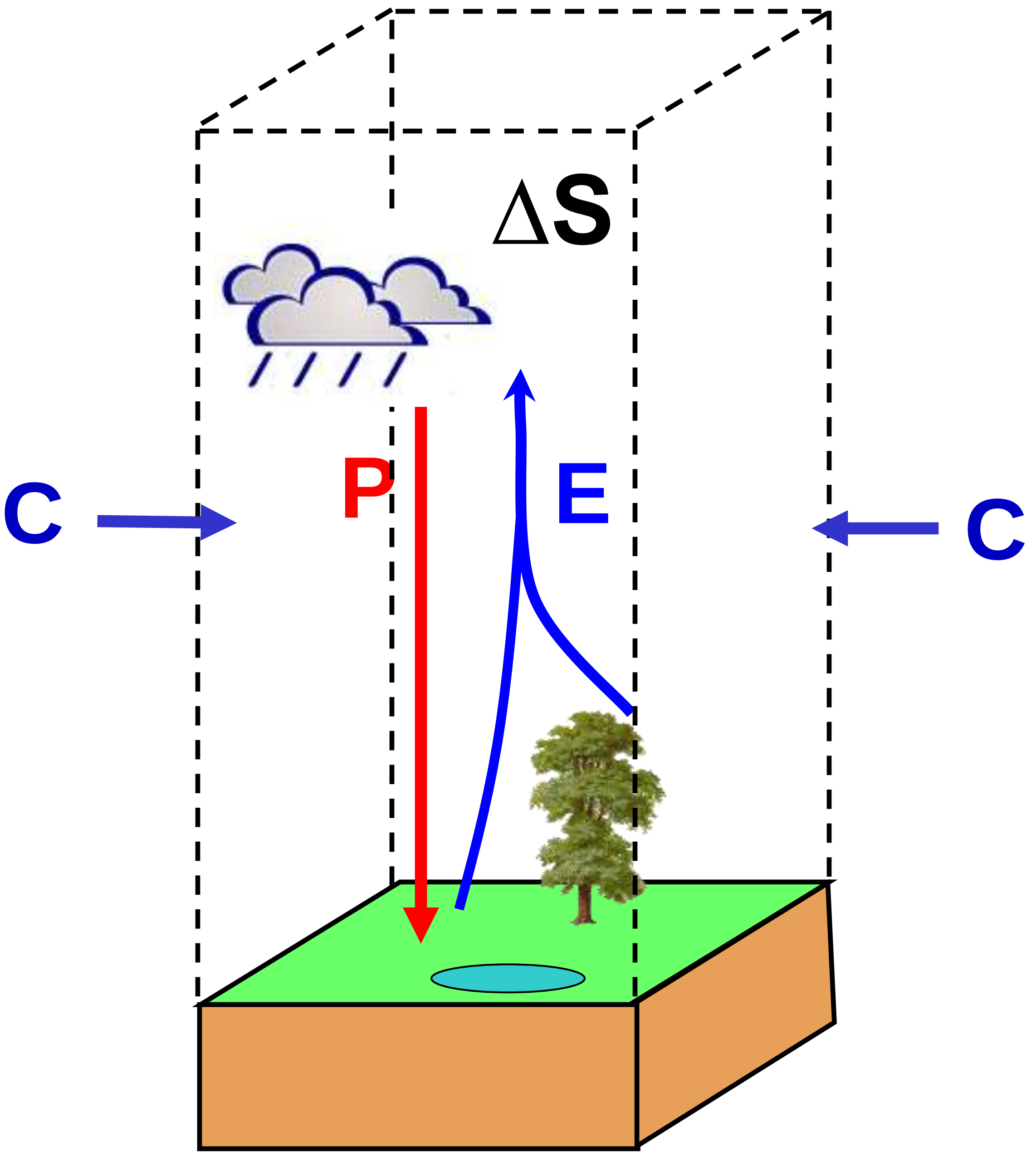
P = precipitation (outflow)

C = **convergence** of atmospheric water. Can be either a net inflow or net outflow depending on sign.

ΔS = change of storage. Usually negligible for time scales more than a few days.

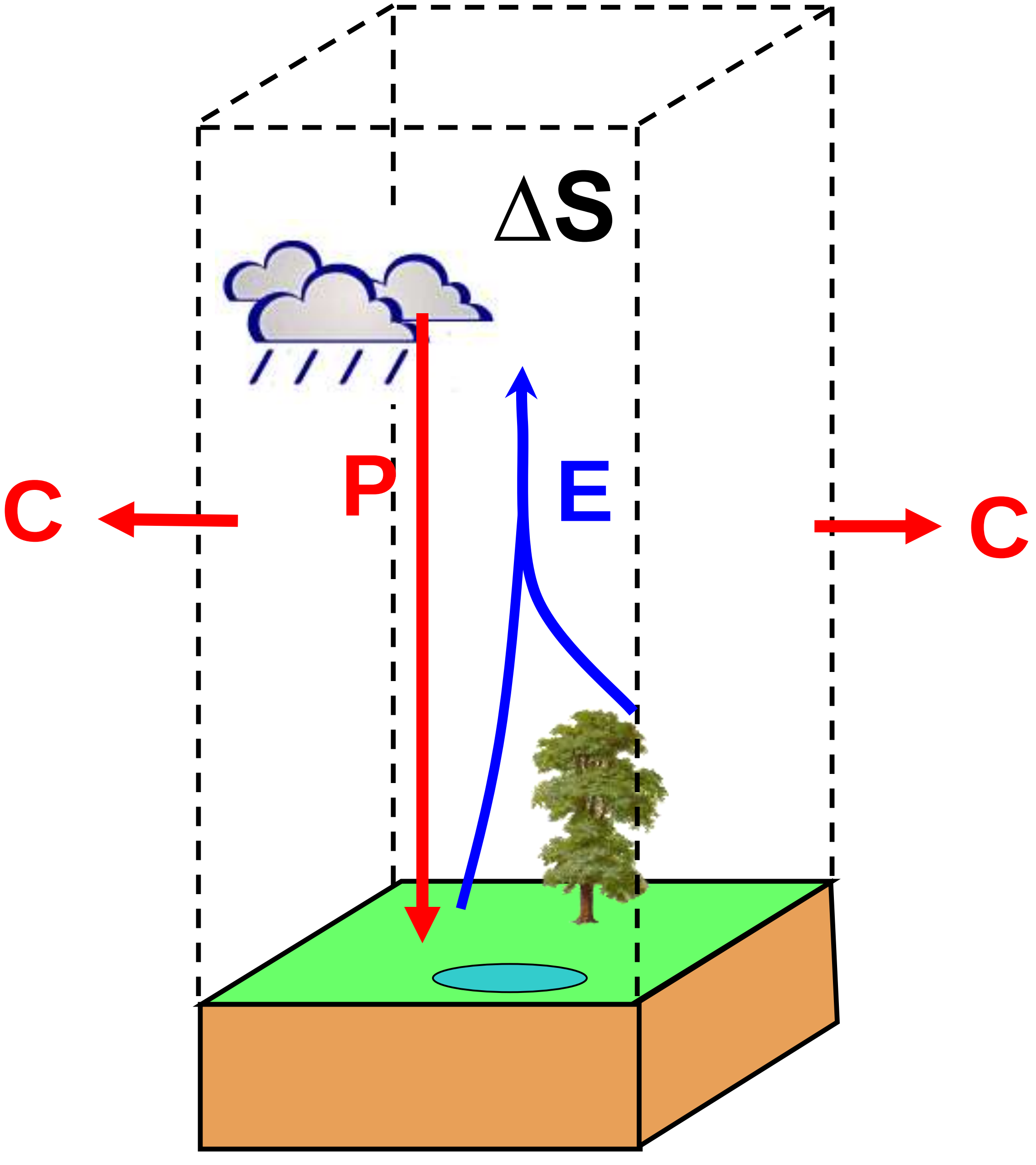
In this case convergence (C) is a net inflow of moisture to the column of air.

Have we discussed a place where this happens?



In this case convergence (C) is a net outflow from the column (i.e., C is negative).

Negative convergence is usually called divergence.

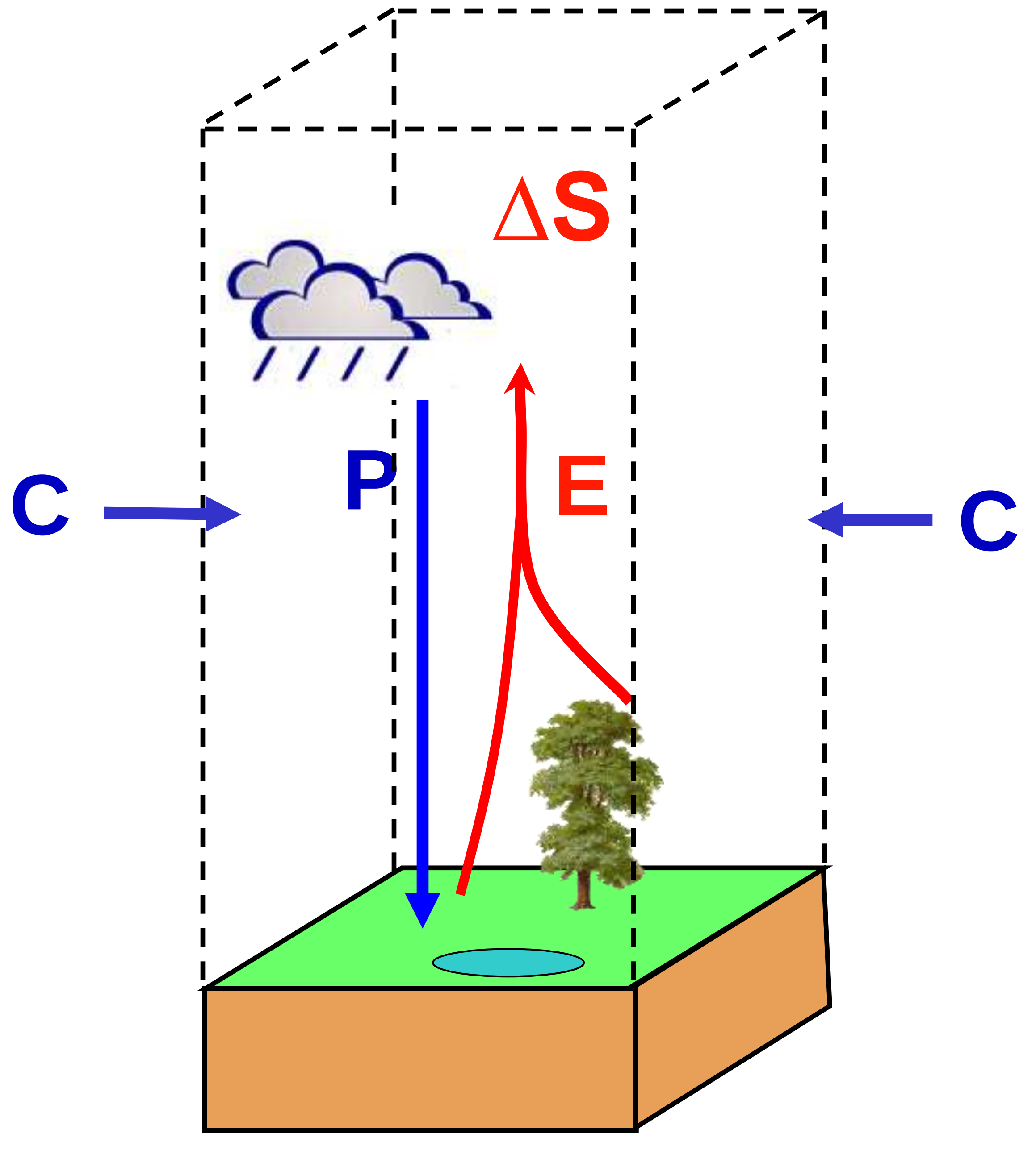


The atmospheric water budget

Is it necessary for annual precipitation to equal annual evapotranspiration **at each individual location** on the globe? Why, or why not?

Is it necessary for annual precipitation to equal annual evapotranspiration when **averaged over the whole globe?** Why, or why not?

For a particular place, if P ≠ E convergence of vapor into (or divergence out of) the column can compensate.



But for the whole globe, there is no other place for water vapor to come from (or go to)!

Global water transfers

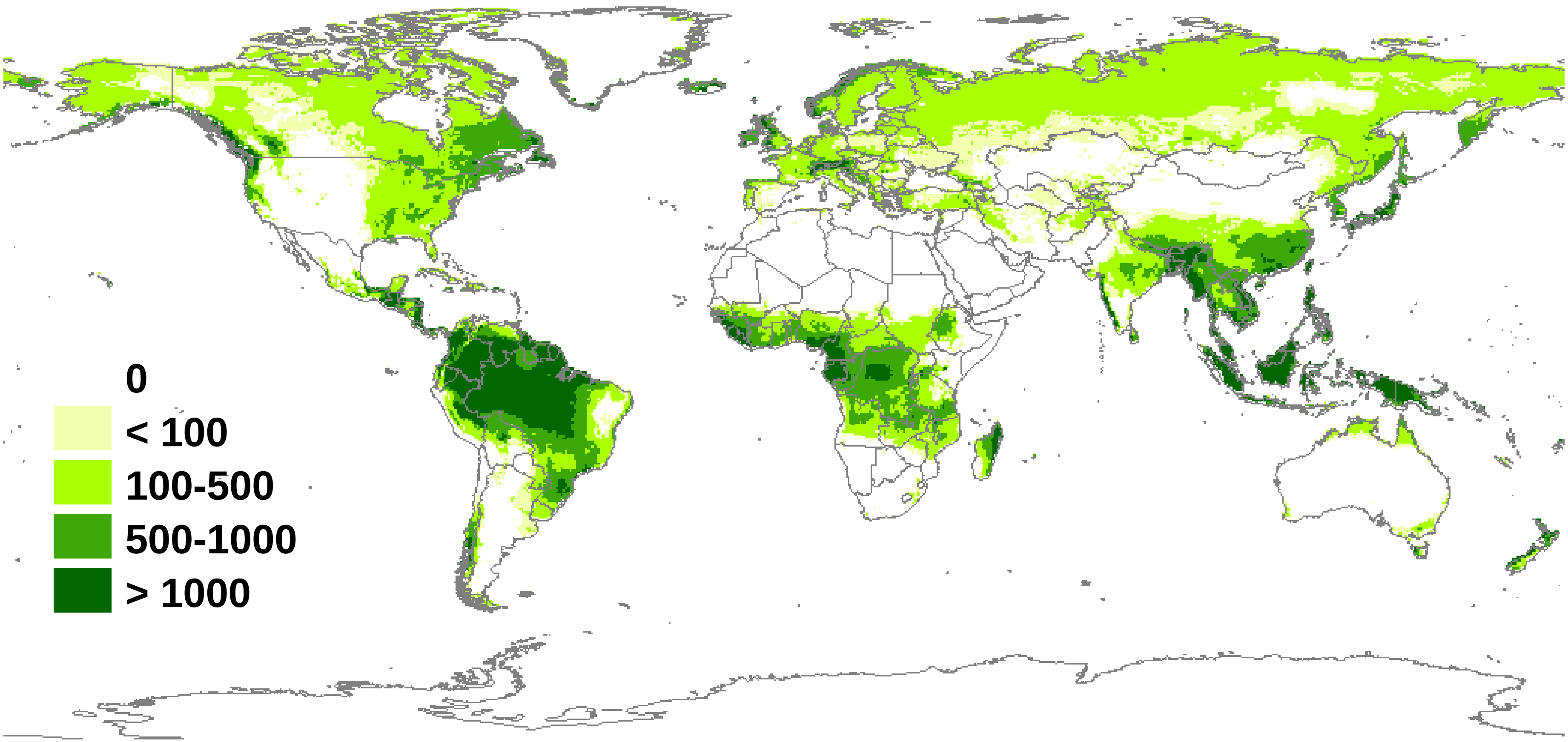
Over oceans more water is lost by evaporation than gained through precipitation.

Over land more water is gained by precipitation than lost by evapotranspiration.

Water transport by wind and **runoff** account for the difference:

- On average, **wind** transports water vapor from oceans to land.
- About 20% of the precipitation over land is removed by **runoff.**
- Over time, the amount of water vapor transferred from oceans to land balances runoff from land to oceans.

Estimated annual runoff (mm per year)



adapted from http://atlas.gwsp.org/

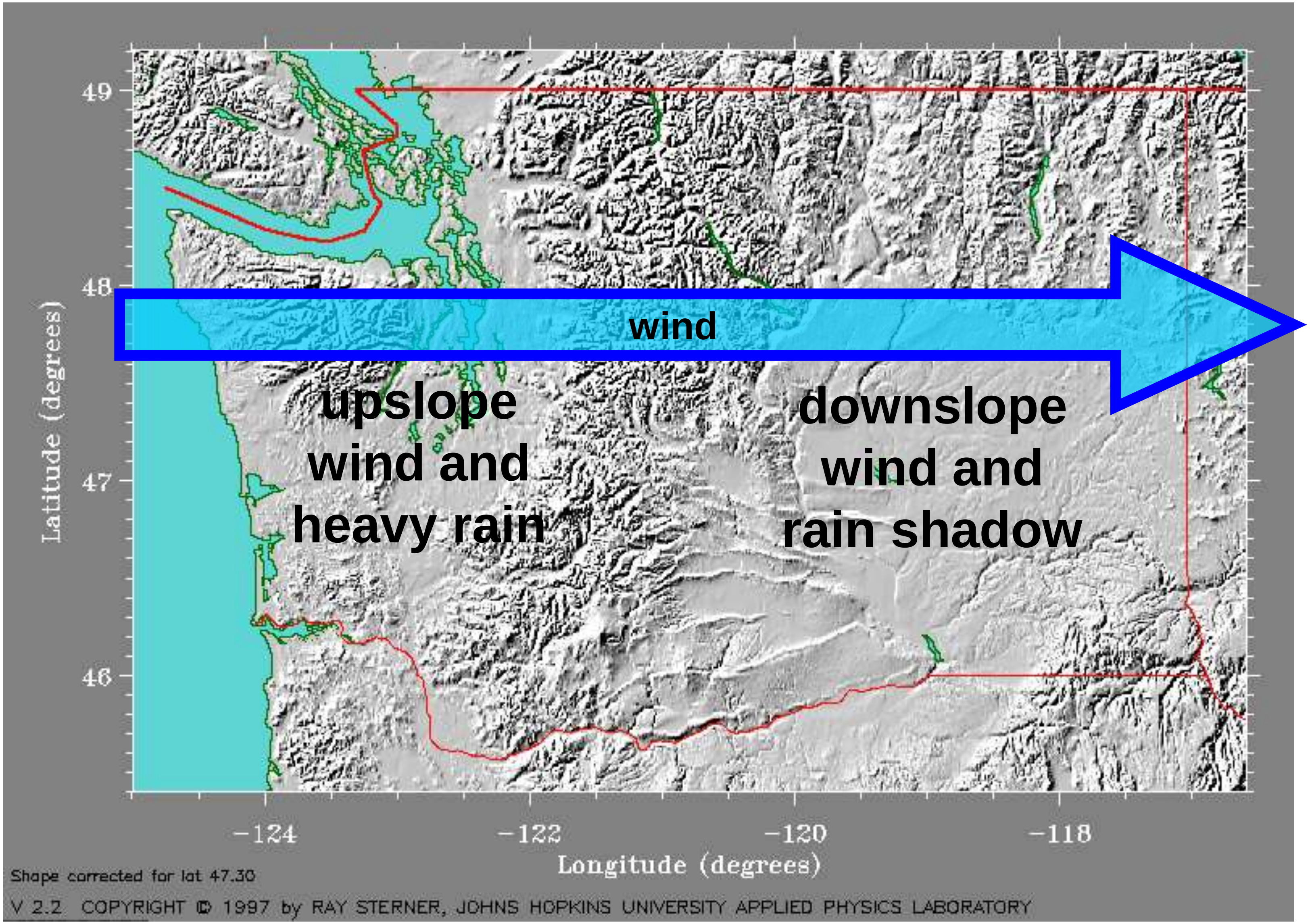
Examples of terrain and coastline effects on precipitation

Monsoons:

- Flow from water to land tends to be warm and moist, promoting precipitation.
- Reversal of monsoon brings cold, dry air from the continental interior.

Orographic lifting (airflow over mountains):

- Mountain height can determine whether precipitation falls as rain or snow.
- Can produce heavy rain on the windward side with dry areas on the leeward.



49
48
47
46
Latitude (degrees)
wind
upslope wind and heavy rain
downslope wind and rain shadow
−124
−122
−120
−118
Longitude (degrees)
Shape corrected for lat 47.30
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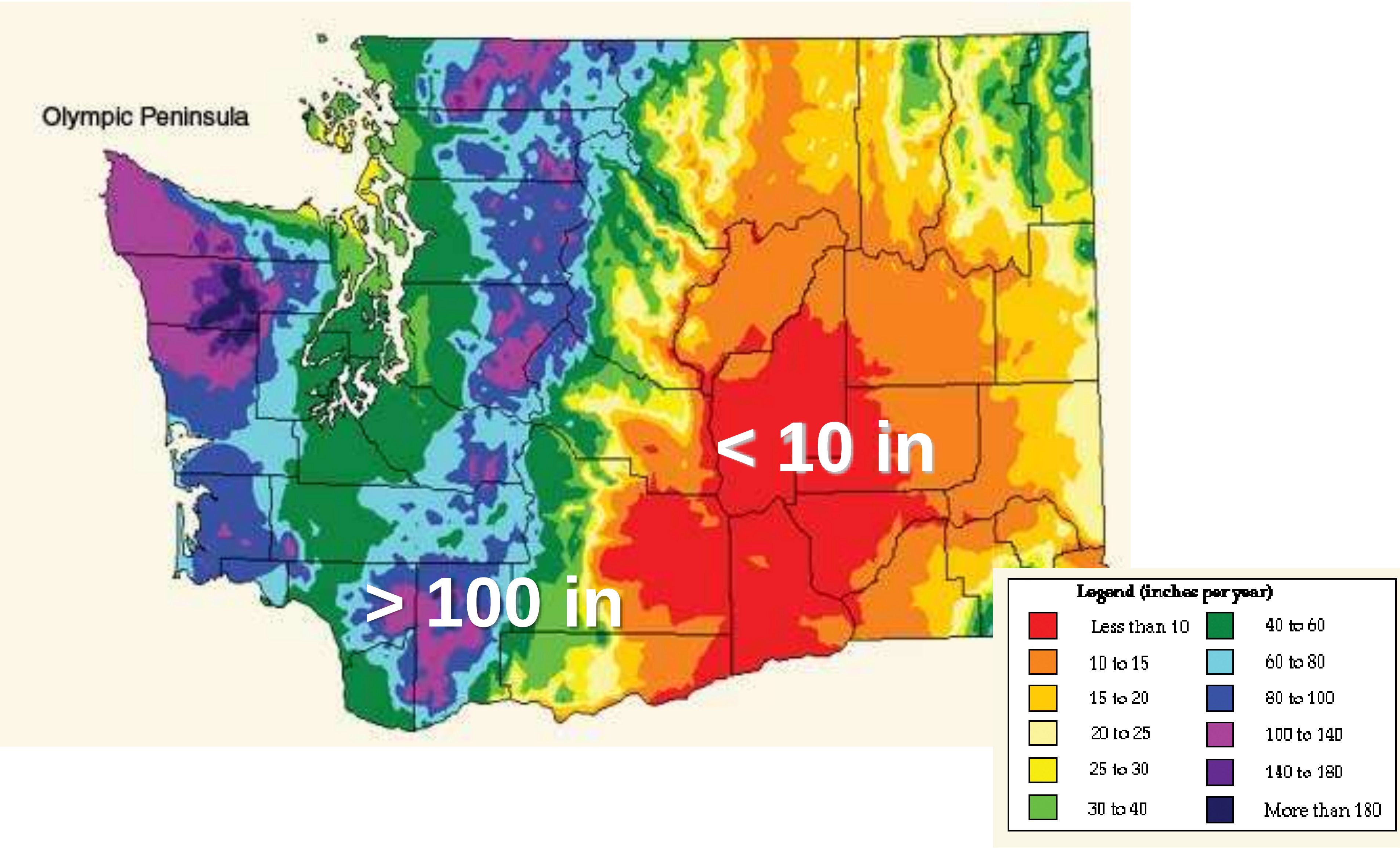

Olympic Peninsula
< 10 in
> 100 in
Legend (inches per year)
Less than 10
10 to 15
15 to 20
20 to 25
25 to 30
30 to 40
40 to 60
60 to 80
80 to 100
100 to 140
140 to 180
More than 180

Terrain and winds

The Andes Mountains run north-south along the west side of South America from about 10º N to 55º S.

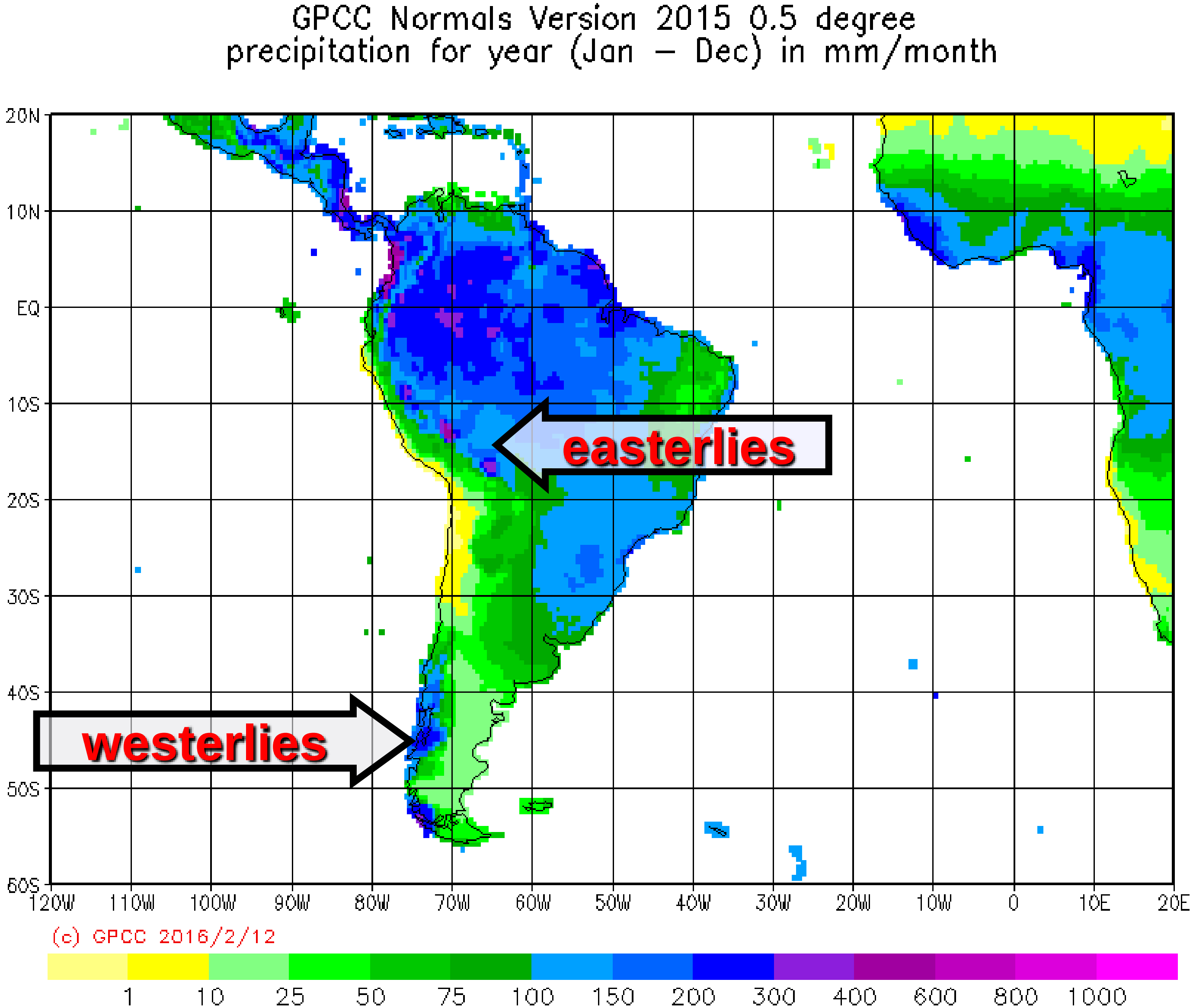
Remember:

Easterly winds prevail in the **tropics** of both hemispheres (from the equator to about 25º N and S).

Westerly winds prevail in the **mid-latitudes** of both hemispheres (between about 30-60º N and S).

How do you expect climatological average precipitation to differ between the west and east sides of the Andes? Consider the whole north-south extent of South America. Why does precipitation vary in this way?

South America precipitation



plotted using http://kunden.dwd.de/GPCC/Visualizer