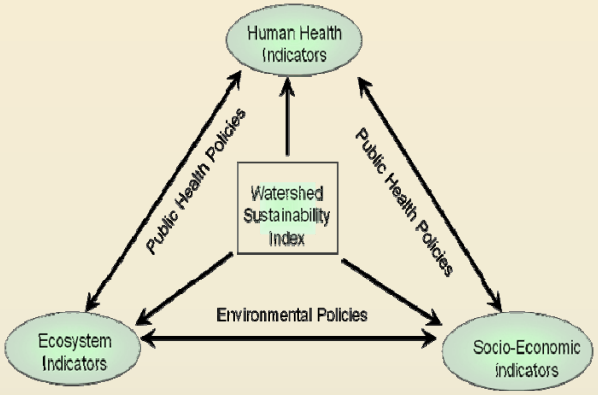
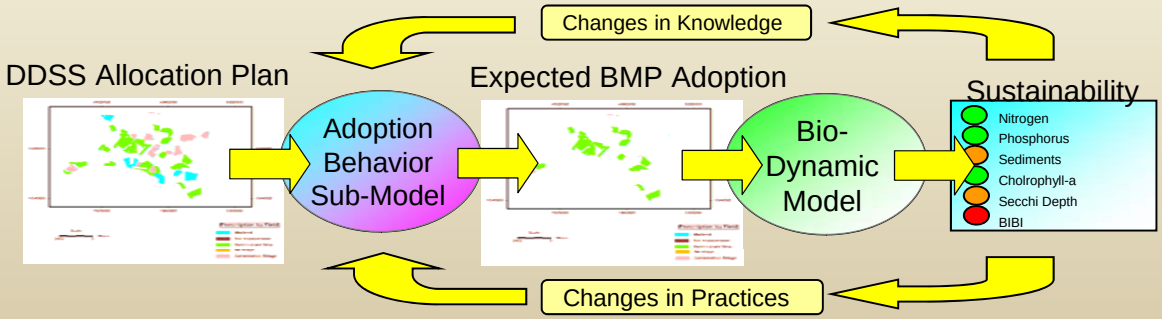
Climate Change and Water Resources

- Energy Dynamics
- Modeling at Watershed Scale
- Landscape & Population Attitude
- Bioindicators for Ecosystem Diagnosis
- Diagnostic Decision Support System (DDSS)
- Climate, Population, Landuse Impacts/Sustainability





Kaye Brubaker, Ali Sadeghi, Victoria Chanse, Paul Leisnham, Hubert Montas, Adel Shirmohammadi

What Does Climate Change Mean for Water Resources?

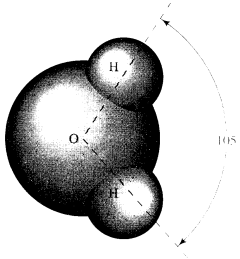
Kaye L. Brubaker
University of Maryland

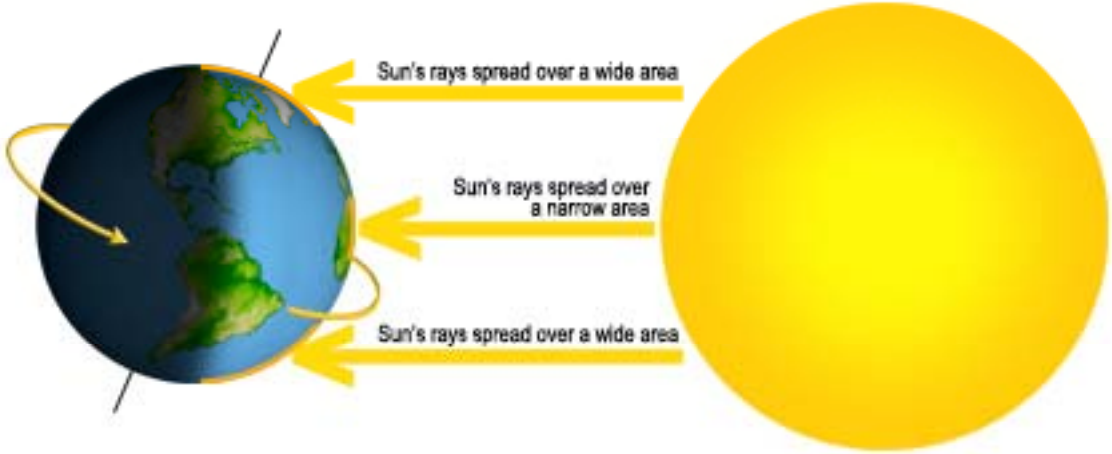
Water, essential to life, plays a critical role in Earth's climate system.

The weather brings the water. But water also plays a large part in driving the weather.

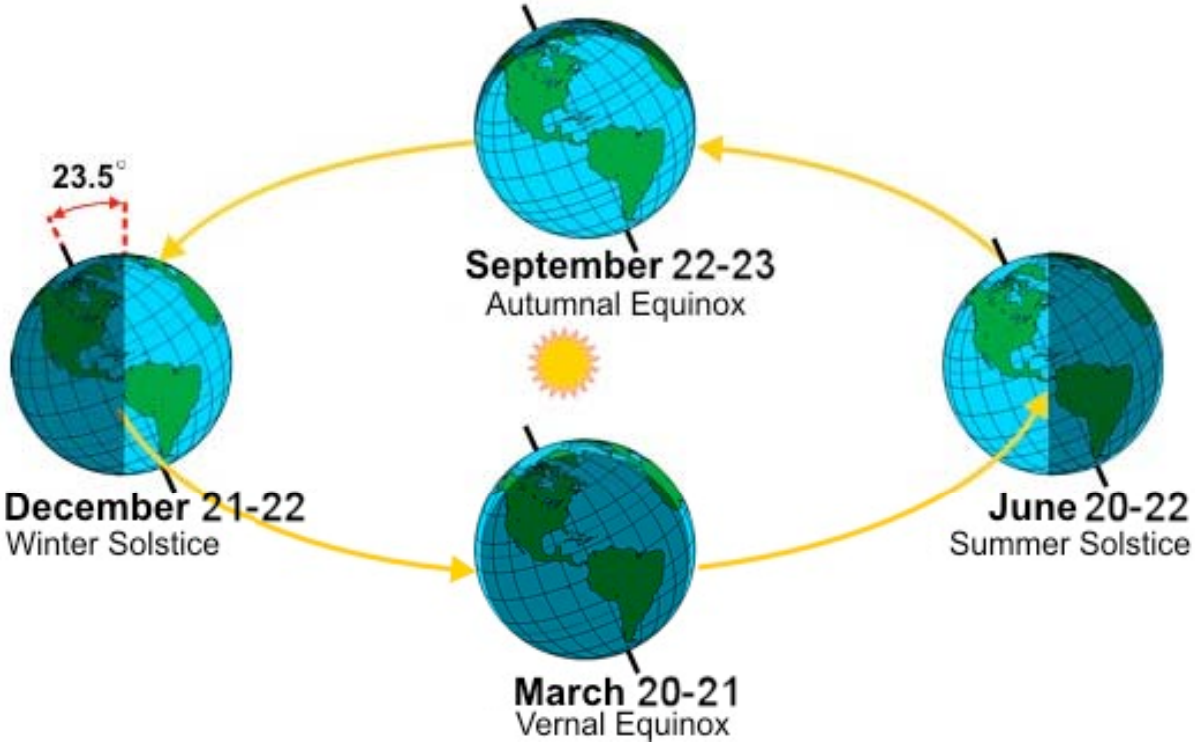
Let's briefly review how the unique properties of this molecule make it so important at the global scale.

Variations in space and time – specifically, trends related to atmospheric composition – will be expressed in variable effects on water resources as the earth's climate system changes.





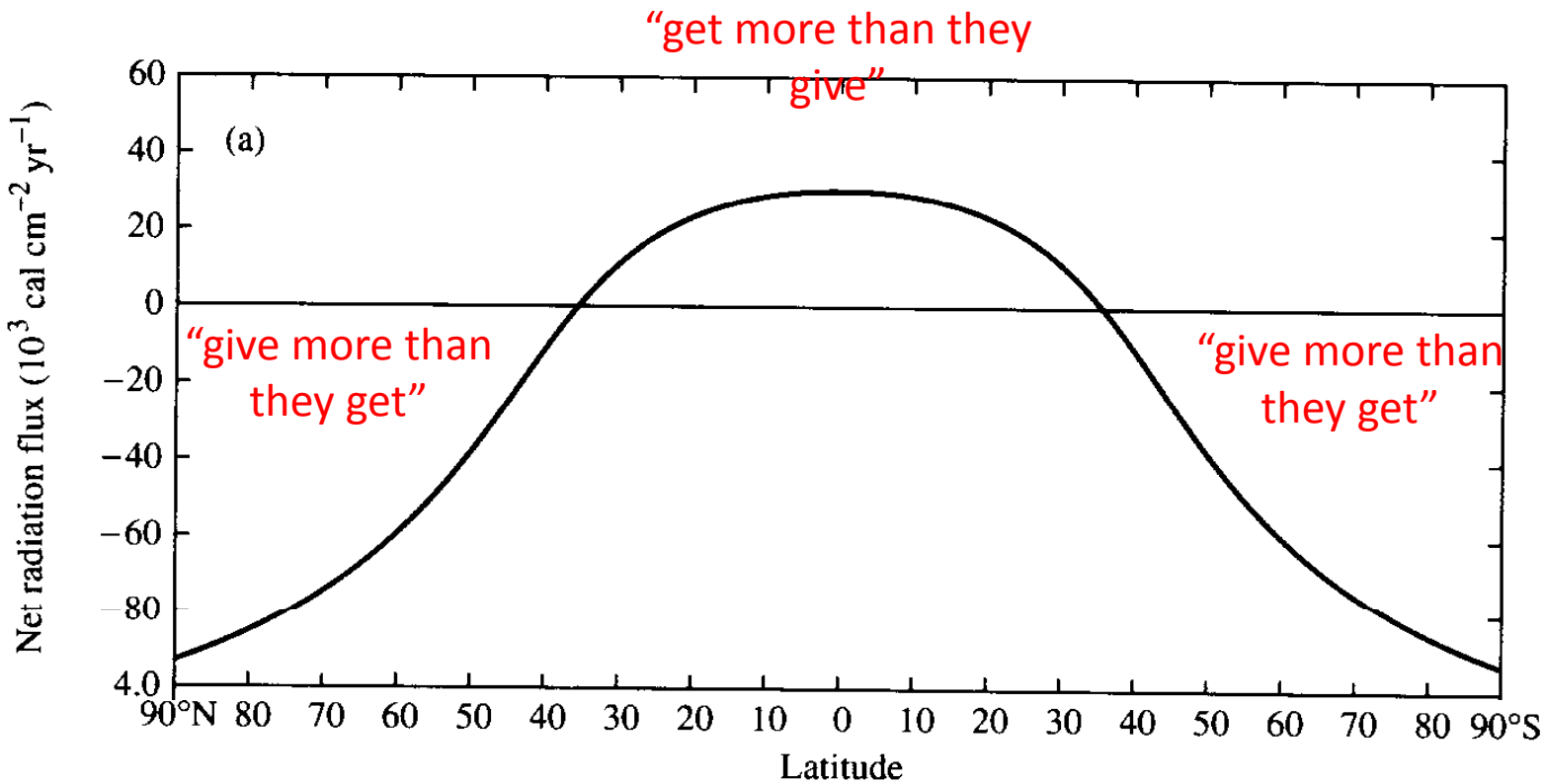
Earth is an unevenly heated rotating spheroid



http://www.lpi.usra.edu/education/skytellers/seasons/images/fig2.jpg

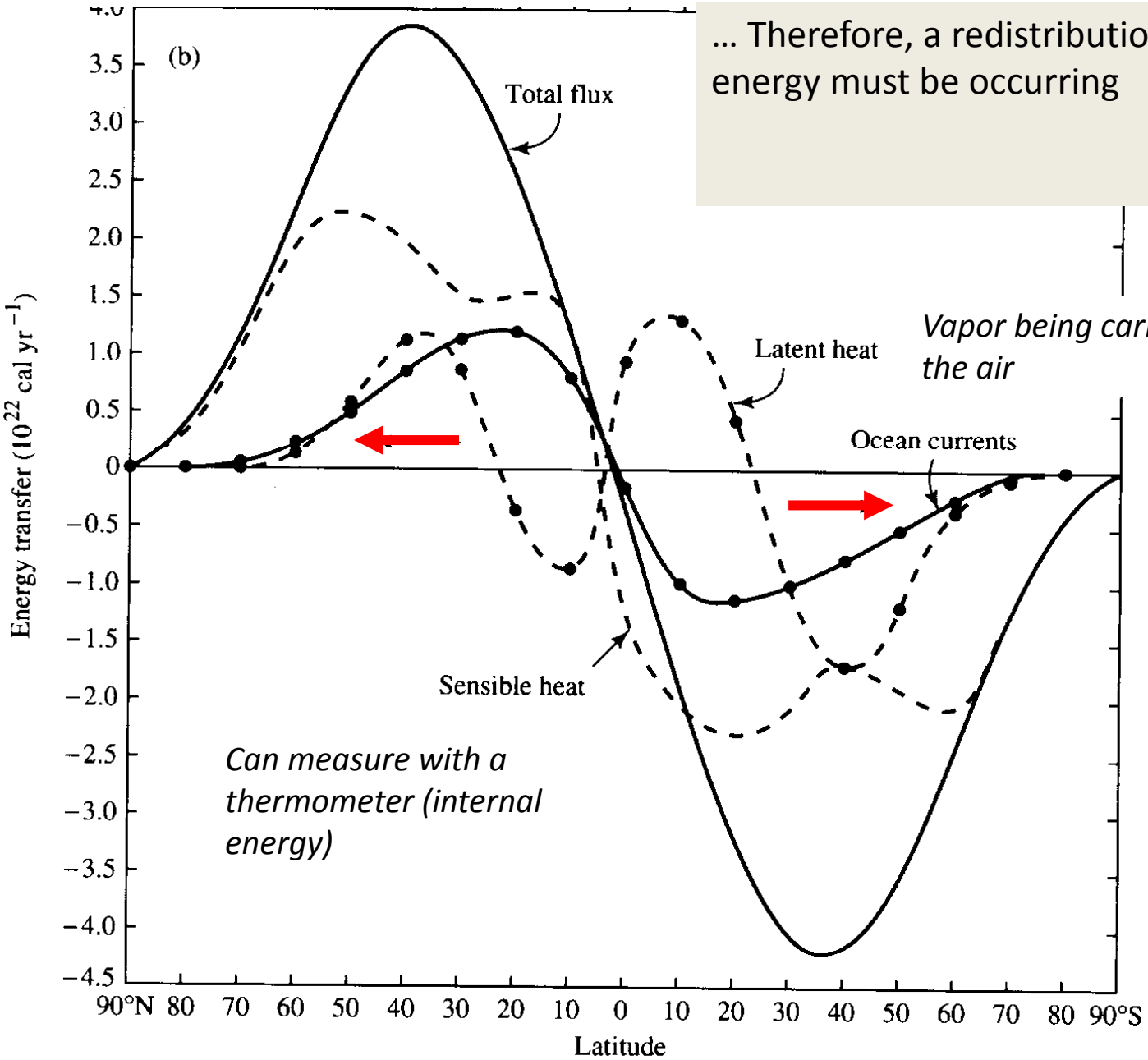
http://www.srh.noaa.gov/images/abq/cli/features/EarthOrbit.png

Radiative Imbalance



Physically, an imbalance cannot be sustained indefinitely…

… Therefore, a redistribution of energy must be occurring



Vapor being carried in the air

Can measure with a thermometer (internal energy)

DRAFT

High Latent Heats of Phase Change

- Energy required to break hydrogen bonds in melting (λ_f) or vaporization (λ_v)
- = energy released in freezing or condensation
- Water's λ_f and λ_v are very high relative to other common substances

$$\lambda_f = 3.34 \times 10^5 \text{ J kg}^{-1} \text{ at } 0^\circ \text{ C}$$

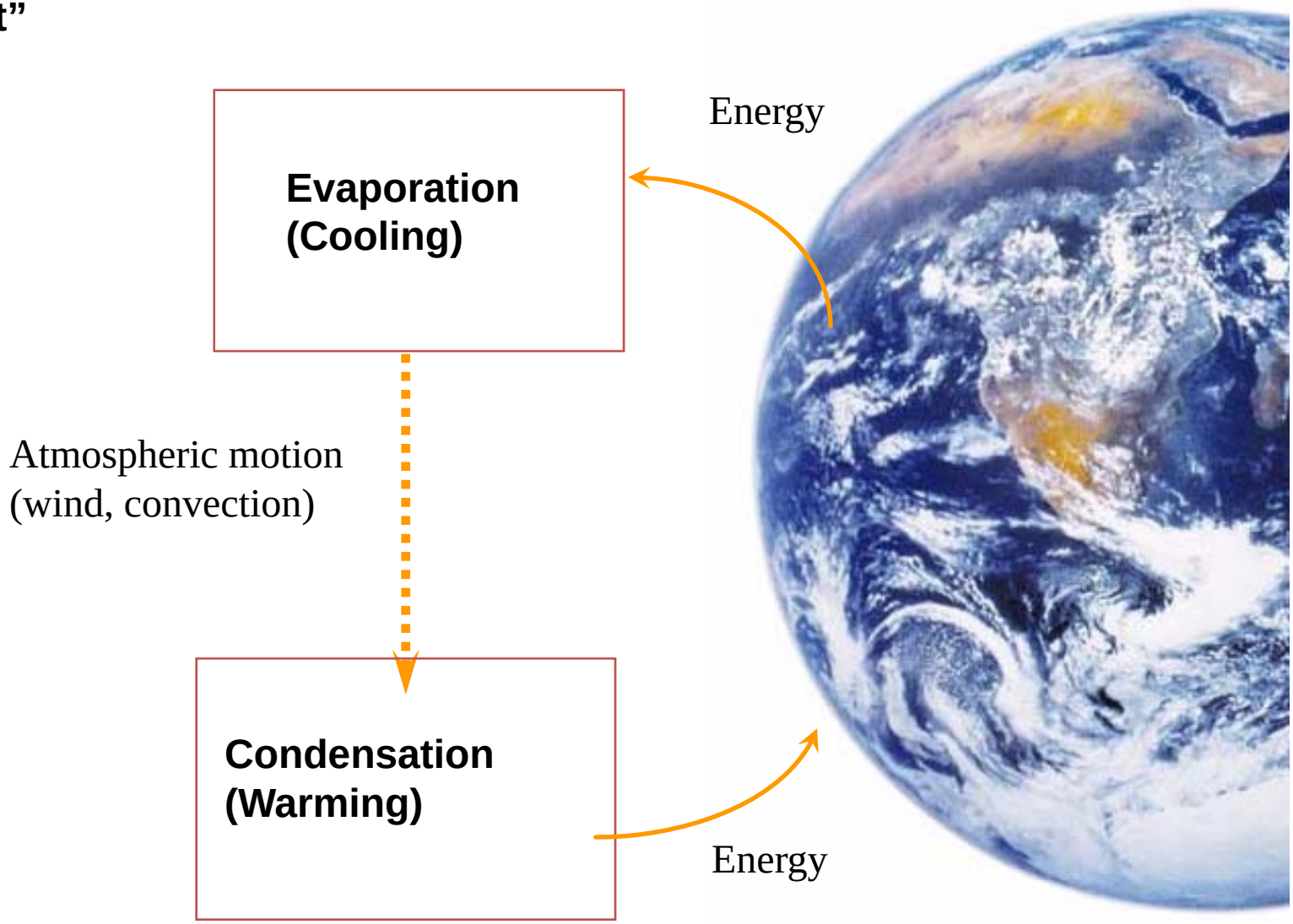
$$\lambda_v = 2.495 \times 10^6 \text{ J kg}^{-1} \text{ at } 0^\circ \text{ C}$$

(decreases w/ increasing temperature)

Latent Heat of Phase Change

- Important role in
  - Heat transport on the global scale (latitudinal)
  - Precipitation formation
  - Vertical (land or ocean to air) energy transport
- Makes water vapor a store of energy, cooling its evaporation site and warming its condensation site

Energy Transport by "Latent Heat"



Thermal Capacity

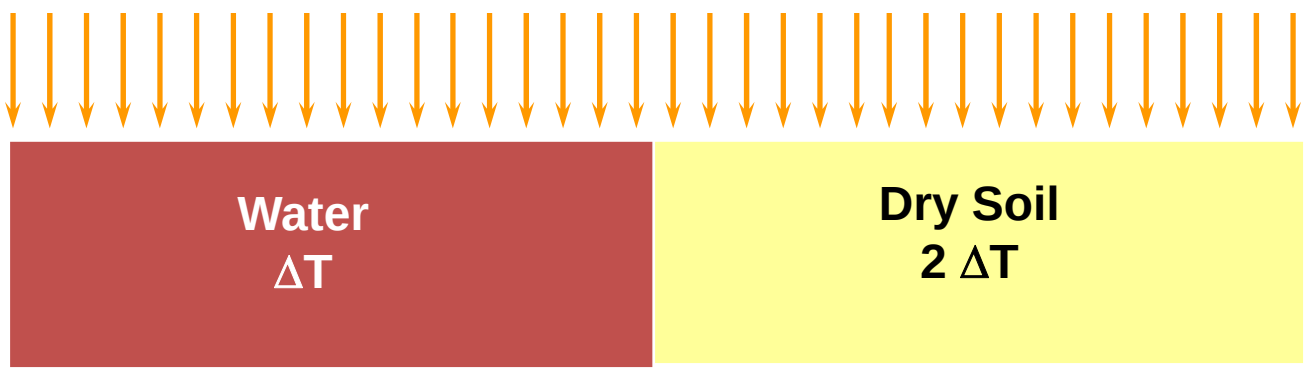
- Temperature represents the vibratory energy of molecules
- In water, much energy must be used to break hydrogen bonds rather than increase vibration
- Result: Thermal inertia. Oceans, other bodies of water (and warm-blooded organisms) can regulate their temperatures

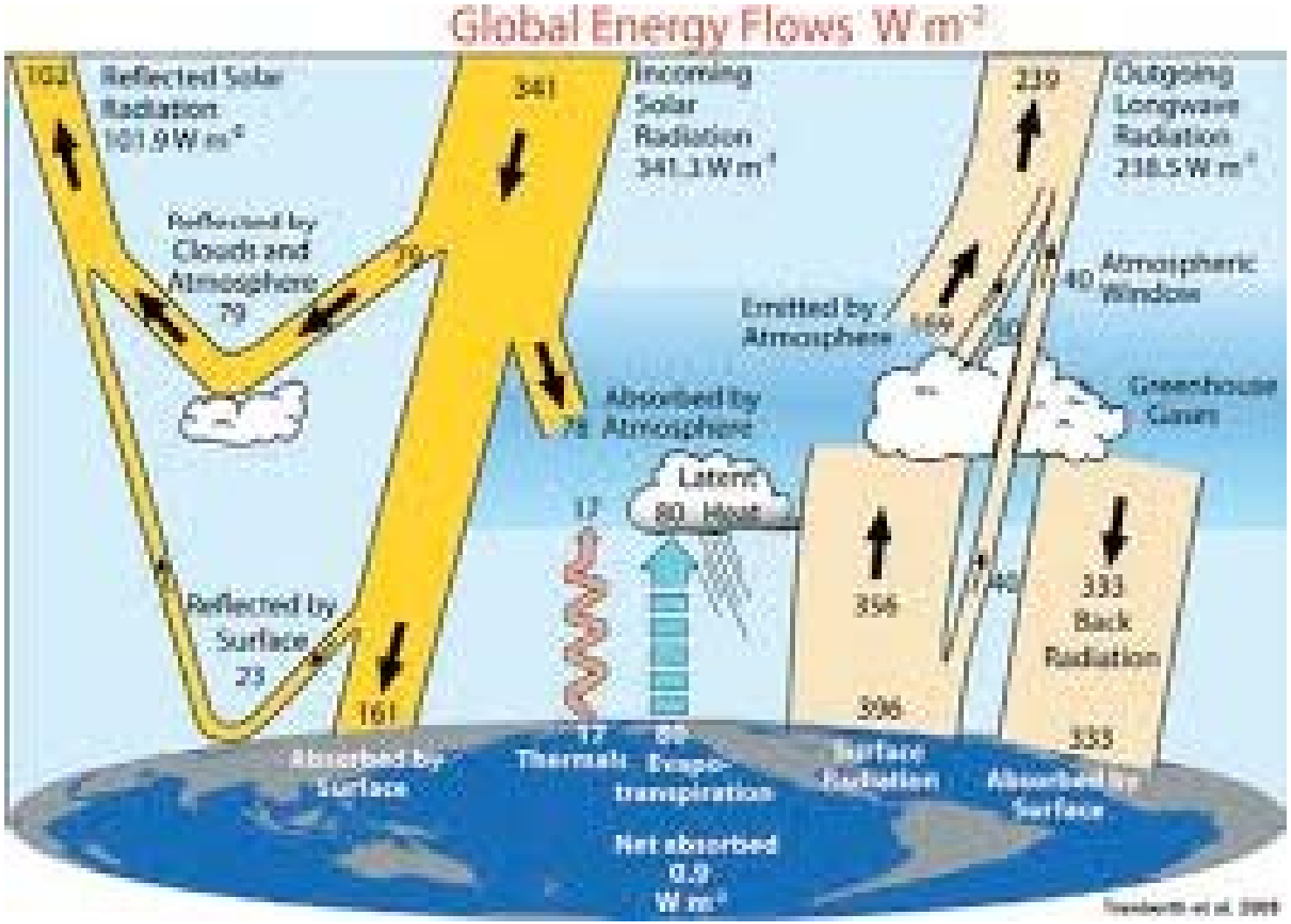
$$C_p = \frac{\Delta H}{M \Delta T}$$

Water: 4216 J kg-1 K-1

Soil: 2000 J kg-1 K-1

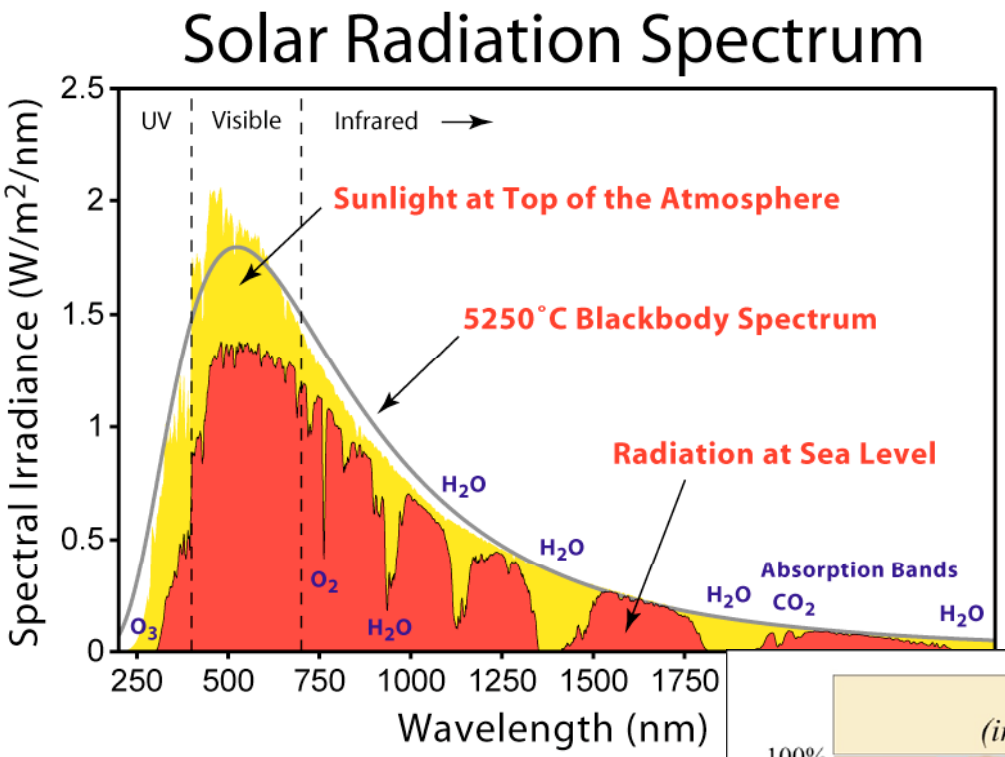
Change in Temperature = $\frac{\text{Energy}}{(C_p)(\text{Mass})}$

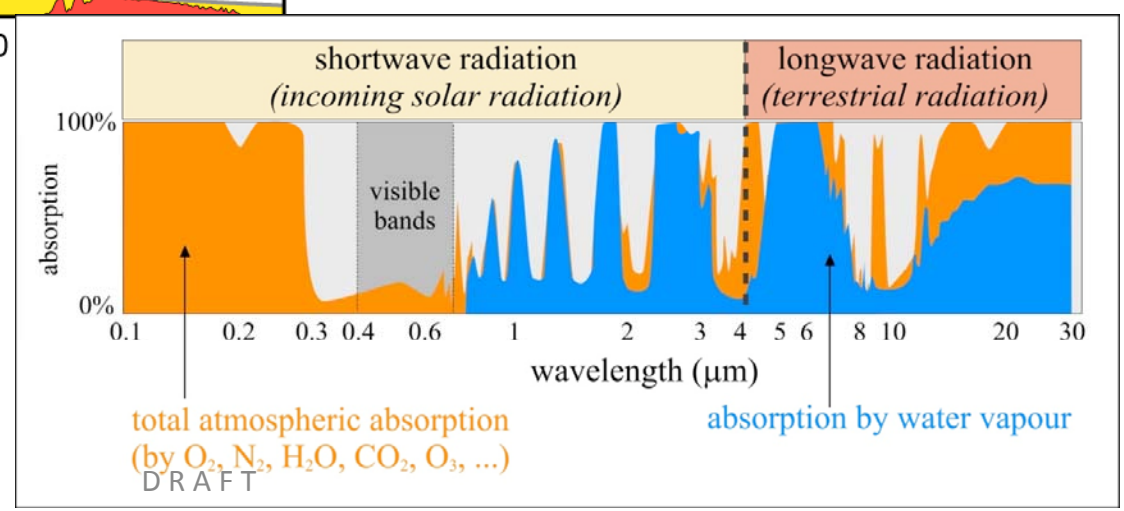




http://www.meted.ucar.edu/tropical/textbook_2nd_edition/media/graphics/global_energy_flows.jpg

Water vapor is the dominant greenhouse gas. The water vapor feedback loop actually makes temperature changes caused by CO2 even bigger.

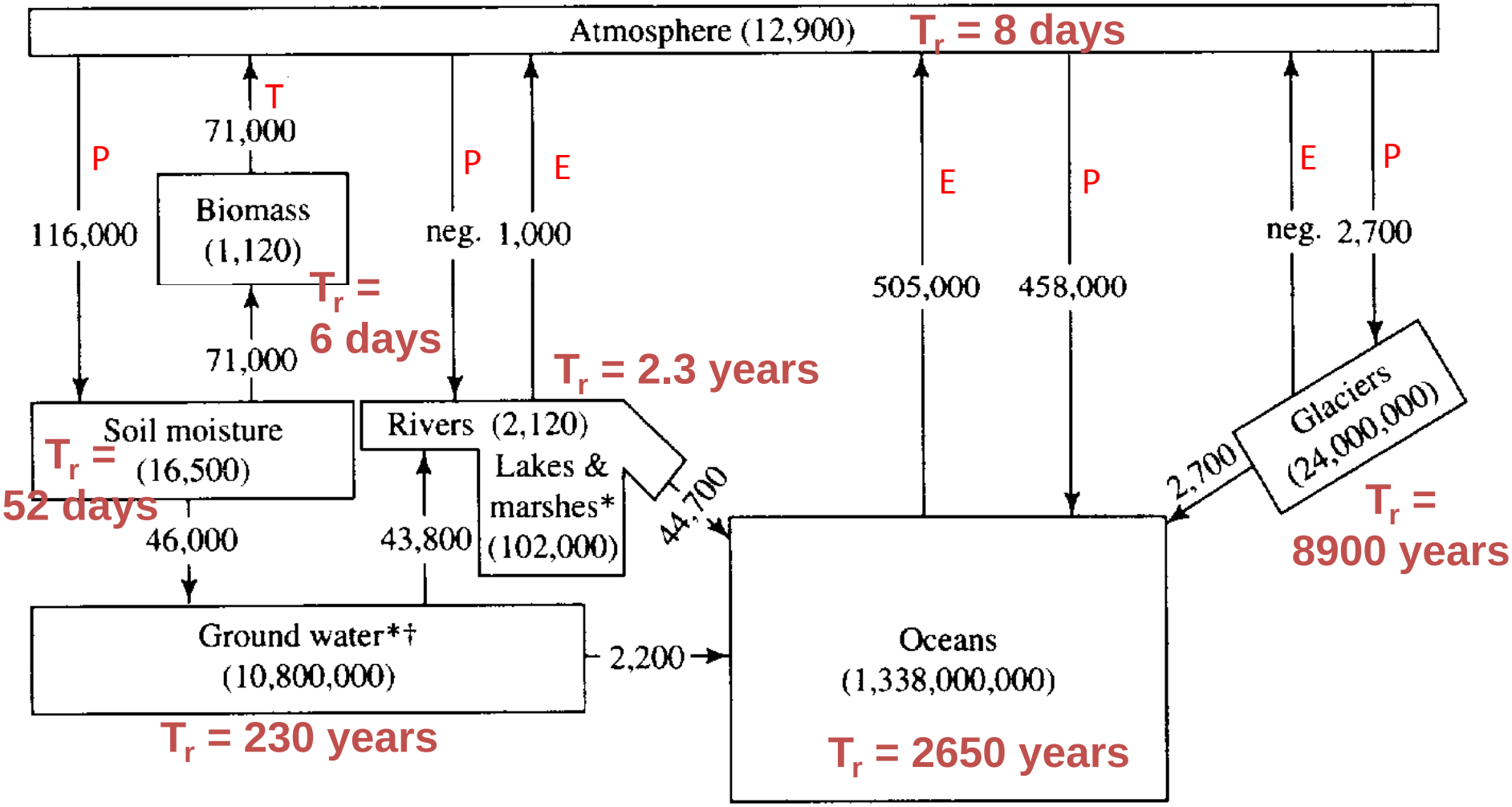




DRAFT

Global Water Stocks (in km^3) and Fluxes (in km^3 yr^{-1})

Average Residence Time (T_r)



*Fresh water only †Includes permafrost

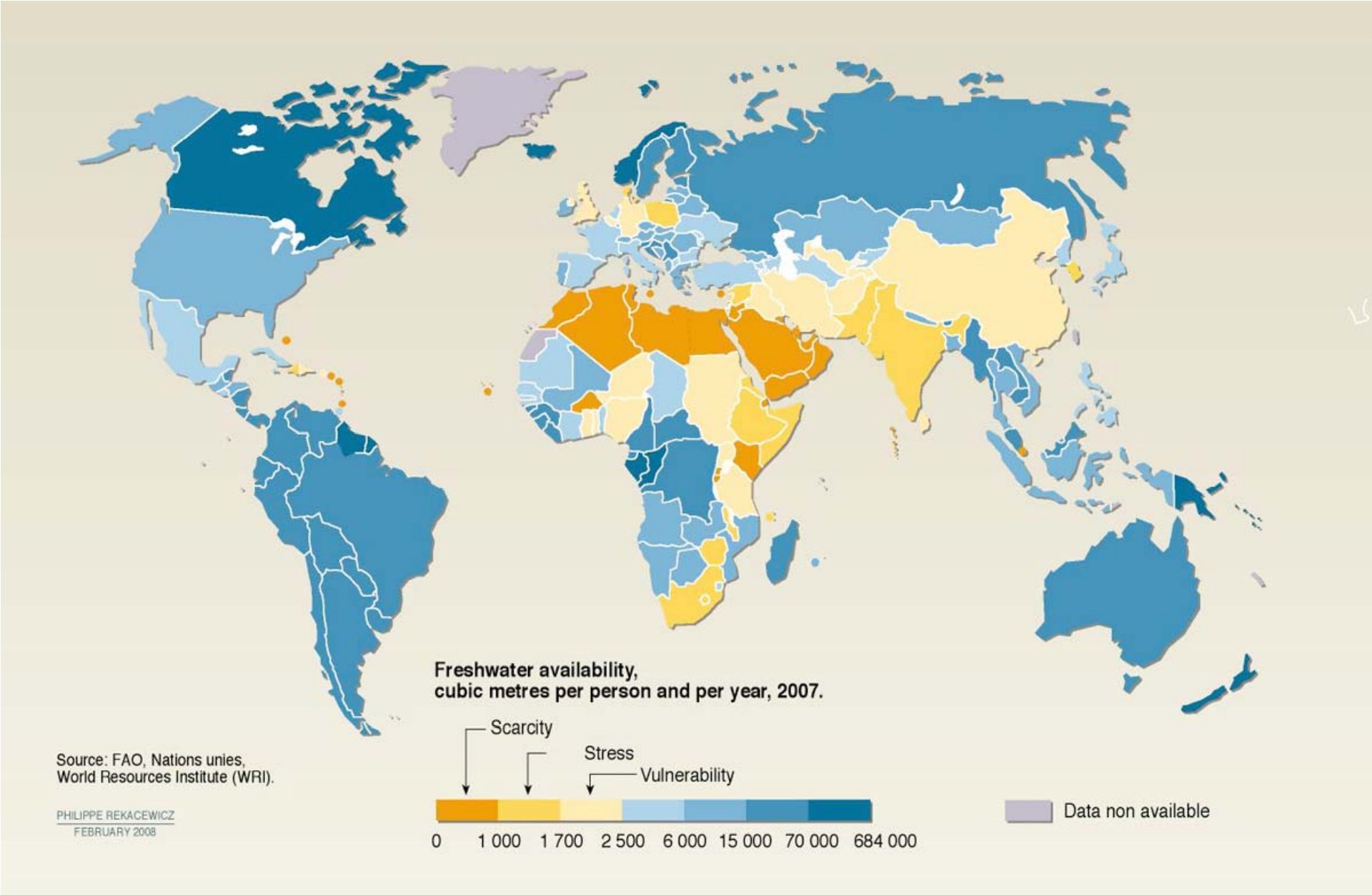
Source: Dingman, 1994

Water Resources

- Total Runoff (RO) from continents – Rivers/lakes and groundwater

$$\frac{(44{,}700 + 2{,}200)\ \mathrm{km}^3\ \mathrm{yr}^{-1}}{7\ \text{billion people}} = \frac{6{,}700\ \mathrm{m}^3\ \mathrm{yr}^{-1}}{\text{person}}$$

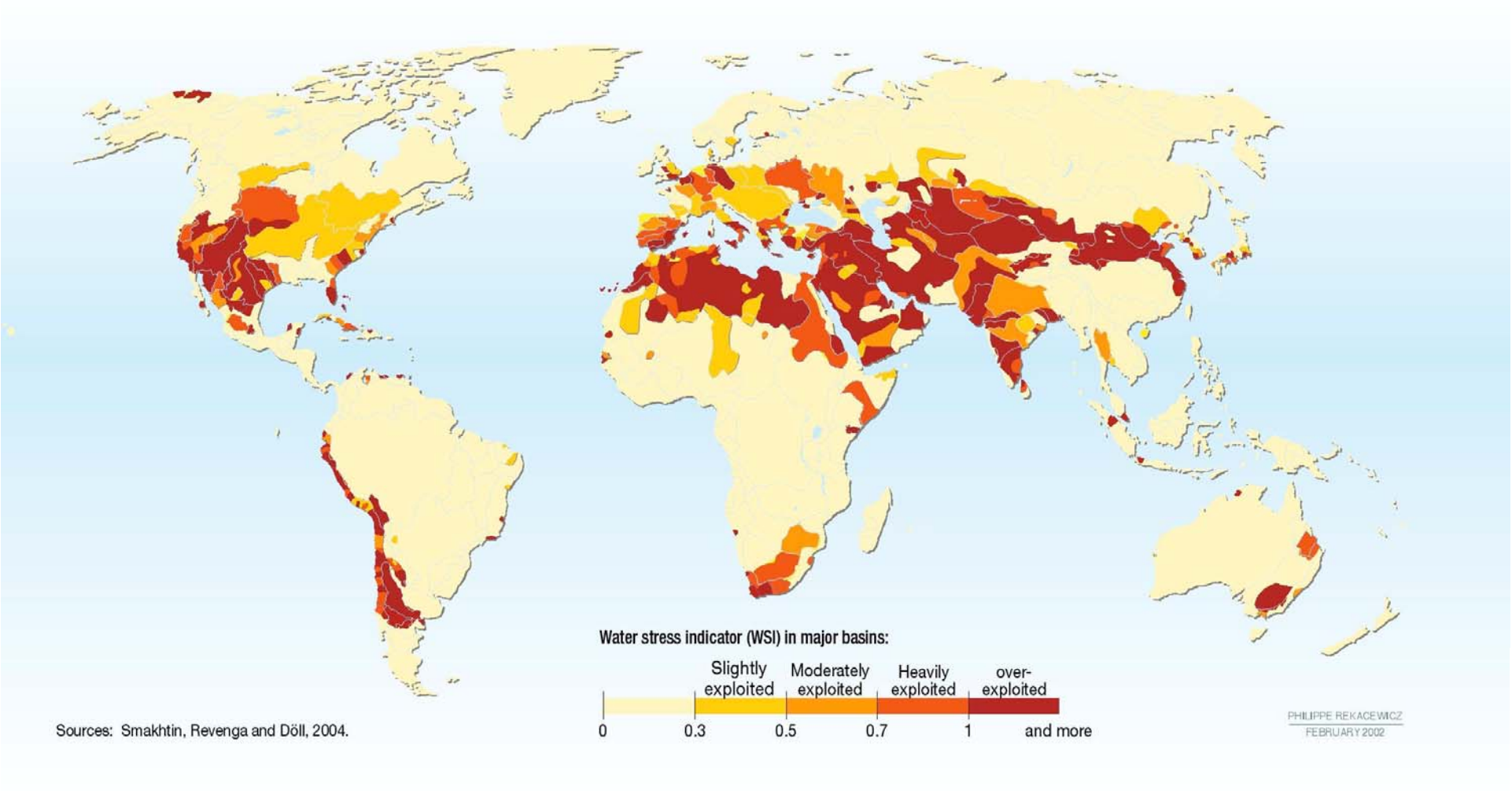
- Current global rate of withdrawal
  - <u>580</u> $m^3\ yr^{-1}\ person^{-1}$
- Developed countries:
  - <u>2,500</u> $m^3\ yr^{-1}\ person^{-1}$



United Nations Environmental Programme
http://www.un.org/waterforlifedecade/scarcity.shtml

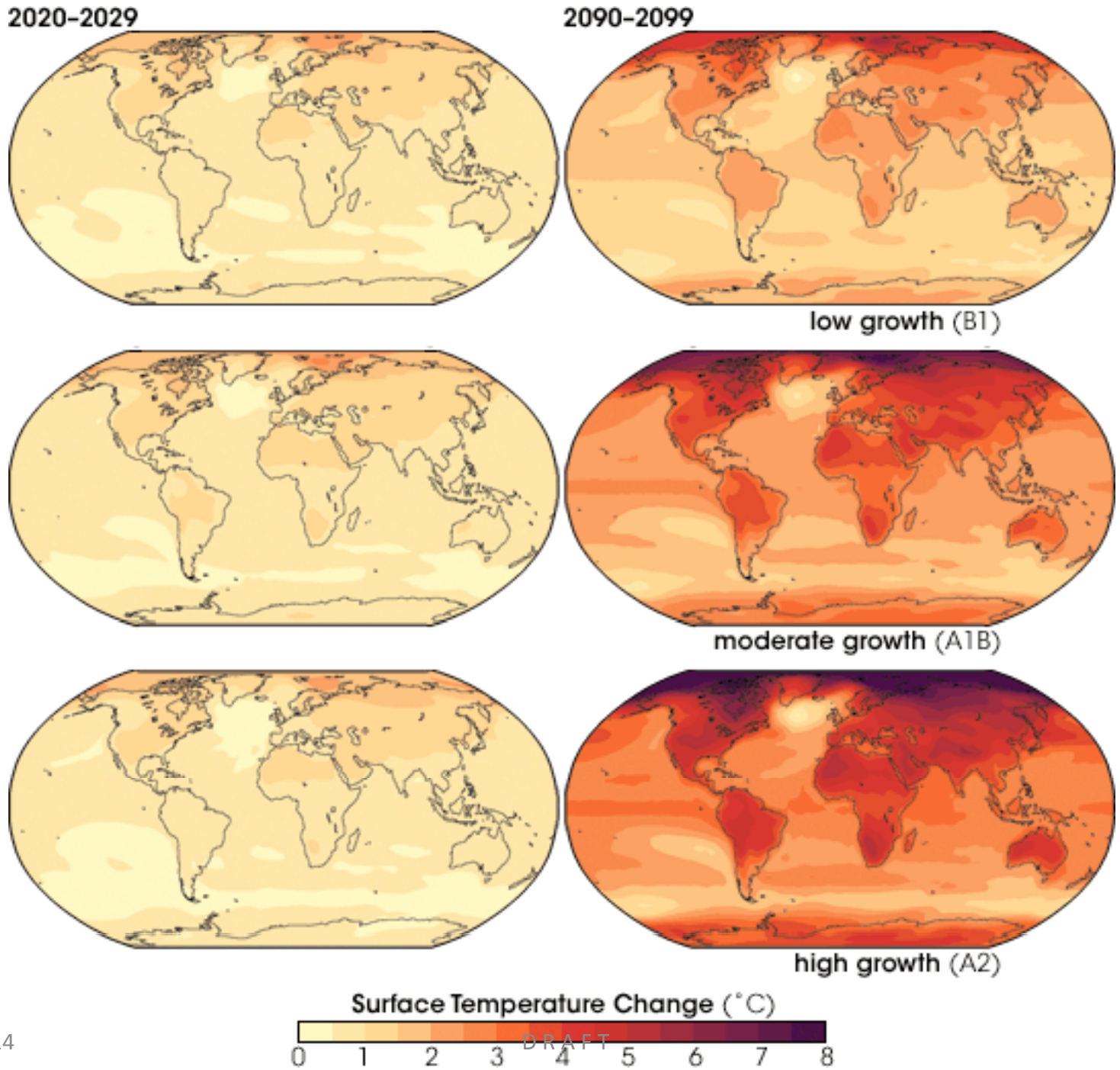
DRAFT

Water Scarcity



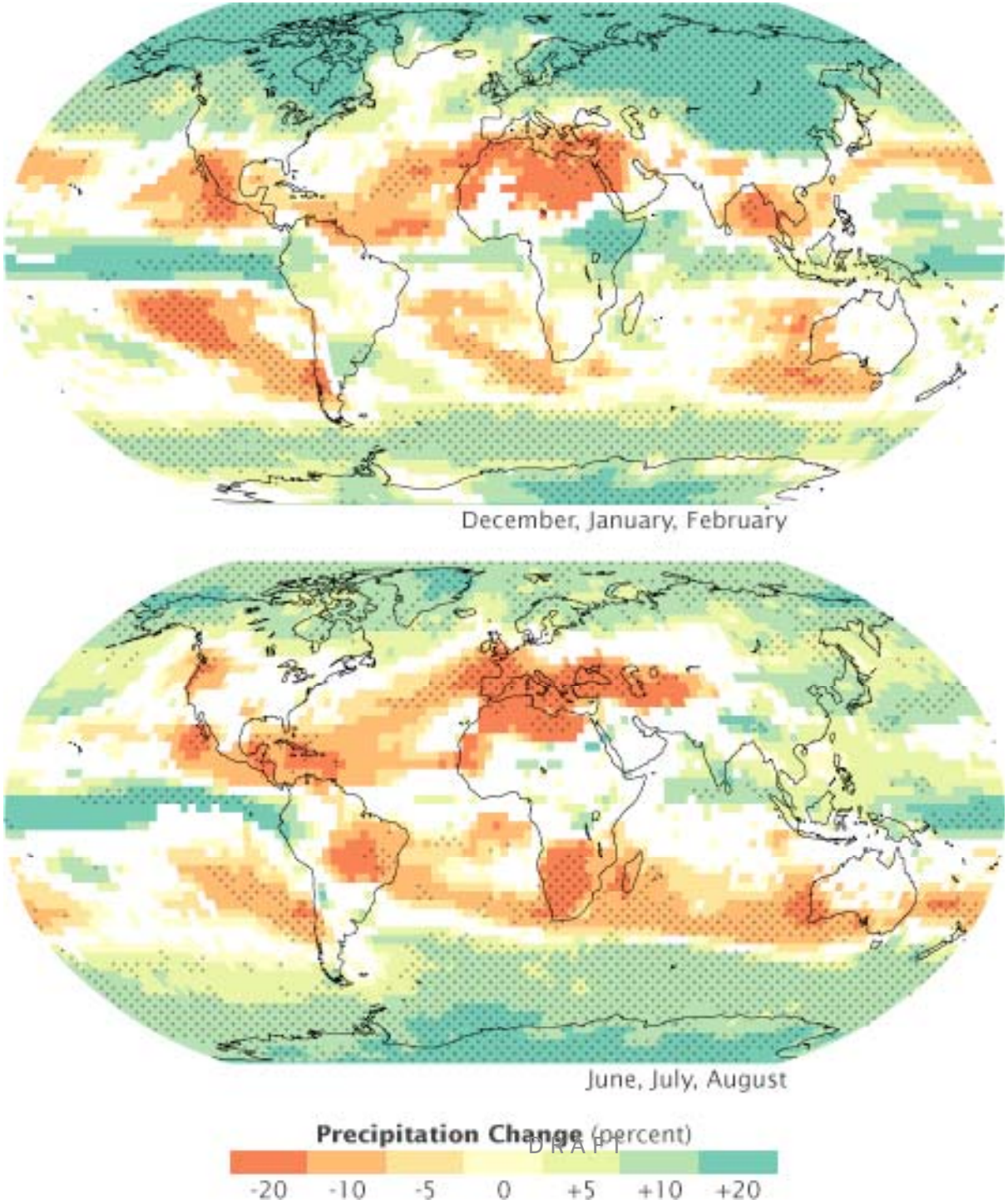
http://www.scienceforthepeople.net/graphics/UNEP_graphics/water-scarcity-index_14f3.jpg

DRAFT



Source: NASA Earth Observatory, based on IPCC Fourth Assessment Report (2007)
http://www.epa.gov/climatechange/science/futuretc.html

DRAFT



Source: NASA Earth Observatory
http://earthobservatory.nasa.gov/Features/GlobalWarming/page6.php

DRAFT

What does climate change mean for water resources?

- Averages are meaningless
  - Natural system is inherently variable and unpredictable
  - Human settlements are variable and unpredictable
- Changes must be understood and assessed regionally; nonetheless,
- The system is connected

Modeling Hydrologic Responses to Climate Change

Ali Sadeghi
USDA-ARS Hydrology & Remote Sensing Laboratory

CBS/AP/ September 26, 2013, 11:40 AM

U.N. panel 95 percent certain climate change is man-made