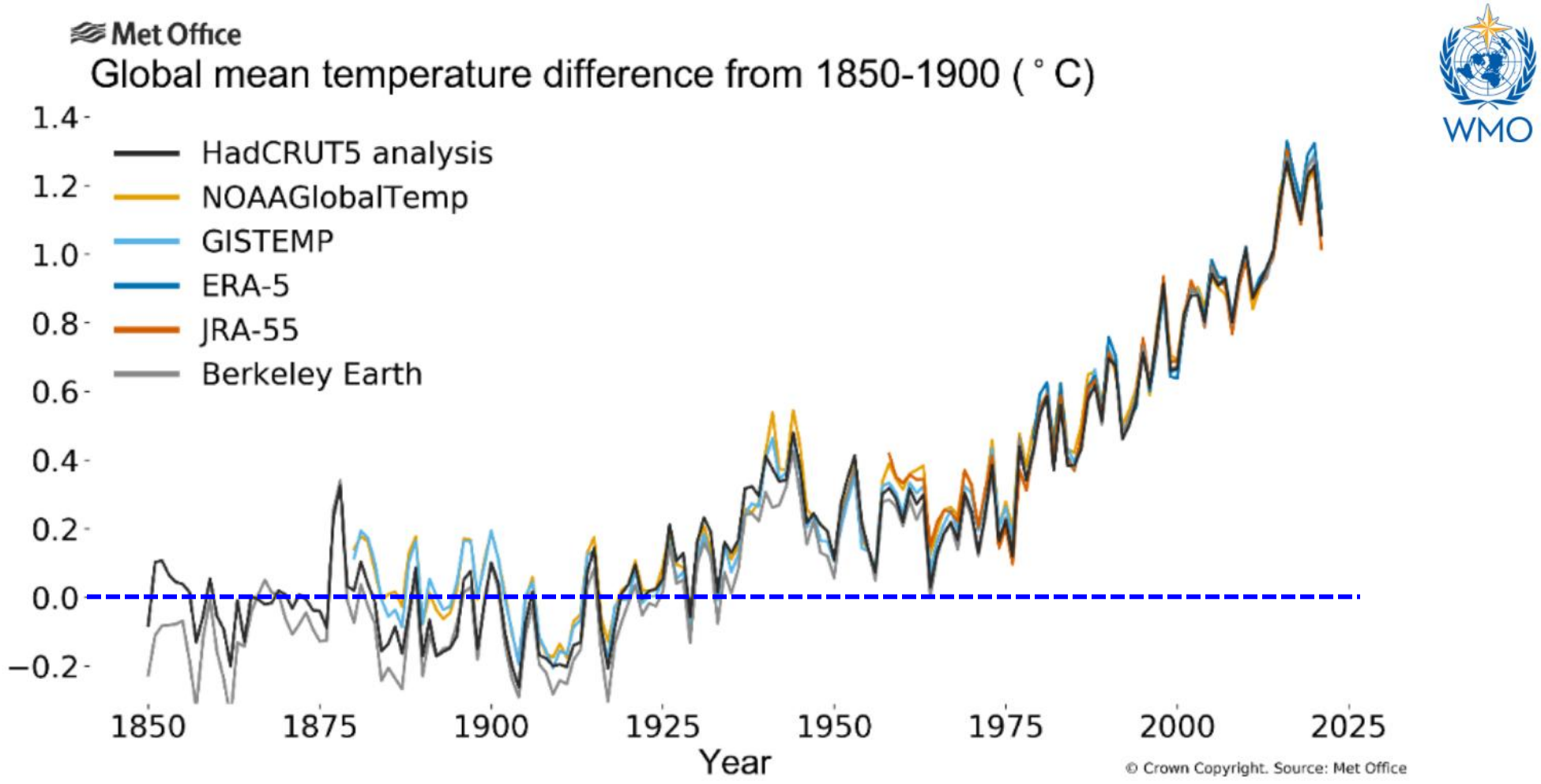
Necessary Foundations & Information on “Climate & Changes”

- About “Modern Climate”
- A few physical foundations (laws)
- Materials in Chapter 1 and Chapter 3
- Global perspective (Chapter 9)
- Class Webpage: http://lees.geo.msu.edu/courses/geo103/
- Lecture notes will be also uploaded to D2L

This class is about "**Modern Climate & Changes**", centered around "global warming"



https://www.rmets.org/news/wmo-provisional-report-state-global-climate-2021

Terminology (will continue a weekly basis)

WMO: World Meteorological Organization is a United Nations specialized agency. It oversees a global network of observation systems—including weather stations, balloons, satellites, buoys, and aircraft—and coordinates the exchange of this data internationally to support weather prediction, climate monitoring, and early warning systems for extreme weather (https://wmo.int/)

Weather is the state of the atmosphere at a particular time, as defined by the various meteorological elements, including temperature, precipitation, atmospheric pressure, wind and humidity.

Climate is the average weather conditions for a particular location over a long period of time, ranging from months to thousands or millions of years. WMO uses a 30-year period to determine the average climate.

American Meteorological Society (**AMS**) defines **CLIMATE**:

- “The slowly varying aspects of the atmosphere-hydrosphere-land surface system.”

- “It is typically characterized in terms of suitable averages of the climate system over periods of a **month or more**, taking into consideration the variability in time of these averaged quantities.”

American Meteorological Society (AMS) defines **WEATHER**:

- "The state of the atmosphere…as distinguished from climate, weather consists of short-term (minutes to days) variations in the atmosphere."

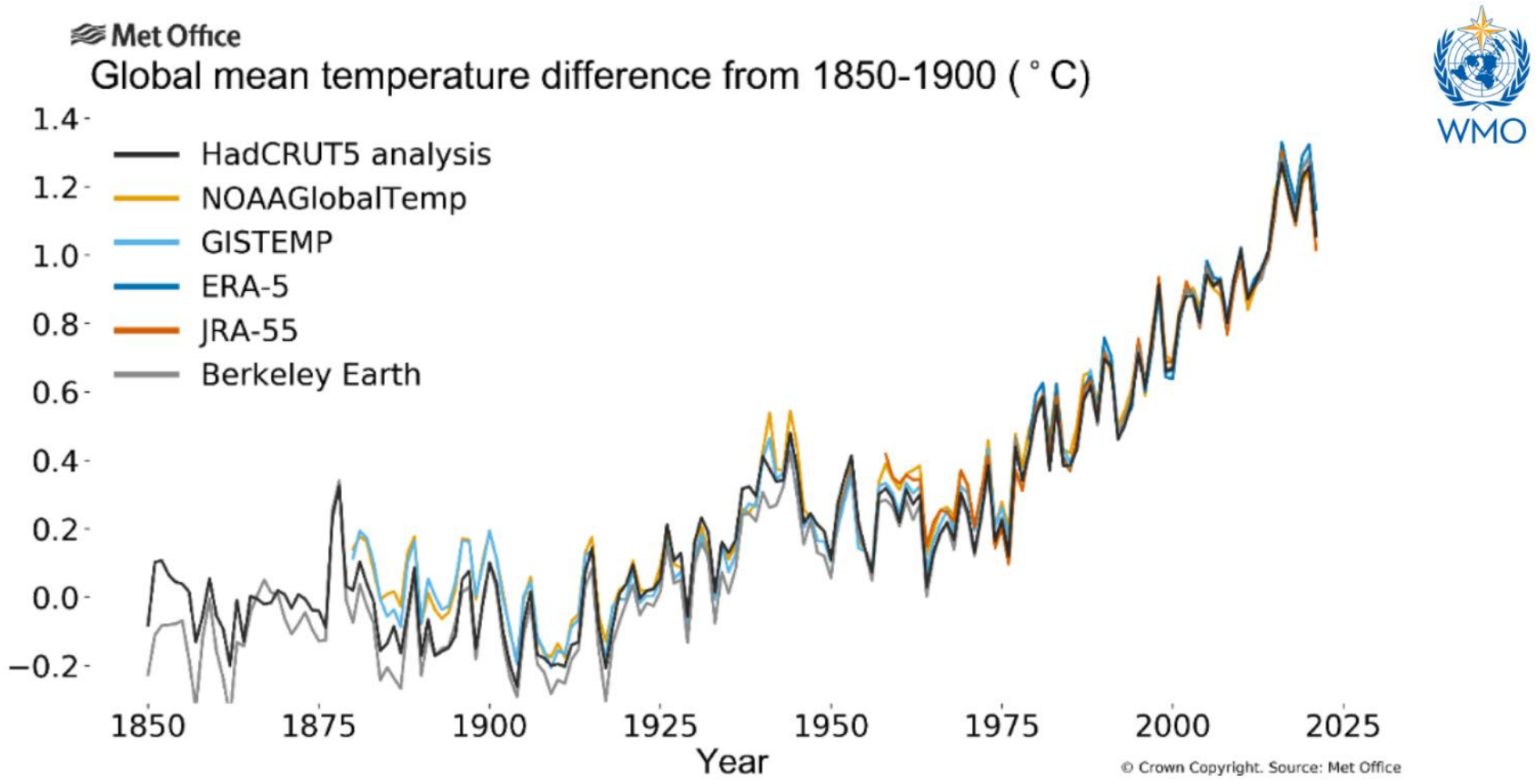
Mark Twain, summed it up more concisely:

- "Climate is what you expect…weather is what you get."

American Meteorological Society (AMS) defines **CLIMATE CHANGE**:

- "Any systematic change in the long-term statistics of climate elements (e.g., temperature, pressure, or winds) sustained over several decades or longer."

- Rate of the change
- Oscillations
- Anomalies
- Cyclic phenomenon



Variables and Units (will continue as needed)

Climatic Variables

- Temperature
- Precipitation
- Humidity
- Pressure & VPD
- Radiation (PAR)
- Wind (speed & direction)
- Visibility & Turbidity
- Cloud (cover, type)
- Soil moisture
- Snow cover & depth
- Surface albedo (reflectivity)
- Sea level
- Ocean salinity
- …

English Unit vs International System of Units (SI)

1. Temperature

Fahrenheit (°F): not an SI unit, but used in the U.S., UK, and other countries

Kelvin (K): the SI base unit for thermodynamic temperature.

Celsius (°C): commonly used in daily life and science; related to kelvin by

$$T(°C) = T(K) - 273.15$$

$$°C = (°F - 32) \times 5/9$$

$$°F = (°C \times 9/5) + 32$$

Quick calculations

What is the temperature of an object in English Unit and SI?

Object	English (°F)	SI (°C)	SI (K)
Earth surface	?	?	~288 K
Sun's surface	?	?	~5,500 K
Normal human body	?	36.5	X
Water boiling temperature	?	100	X
Ice temperature	?	0	X
Temp in Lansing	35	?	X
Room temperature	72	?	X
			X

English Unit vs International System of Units (SI)

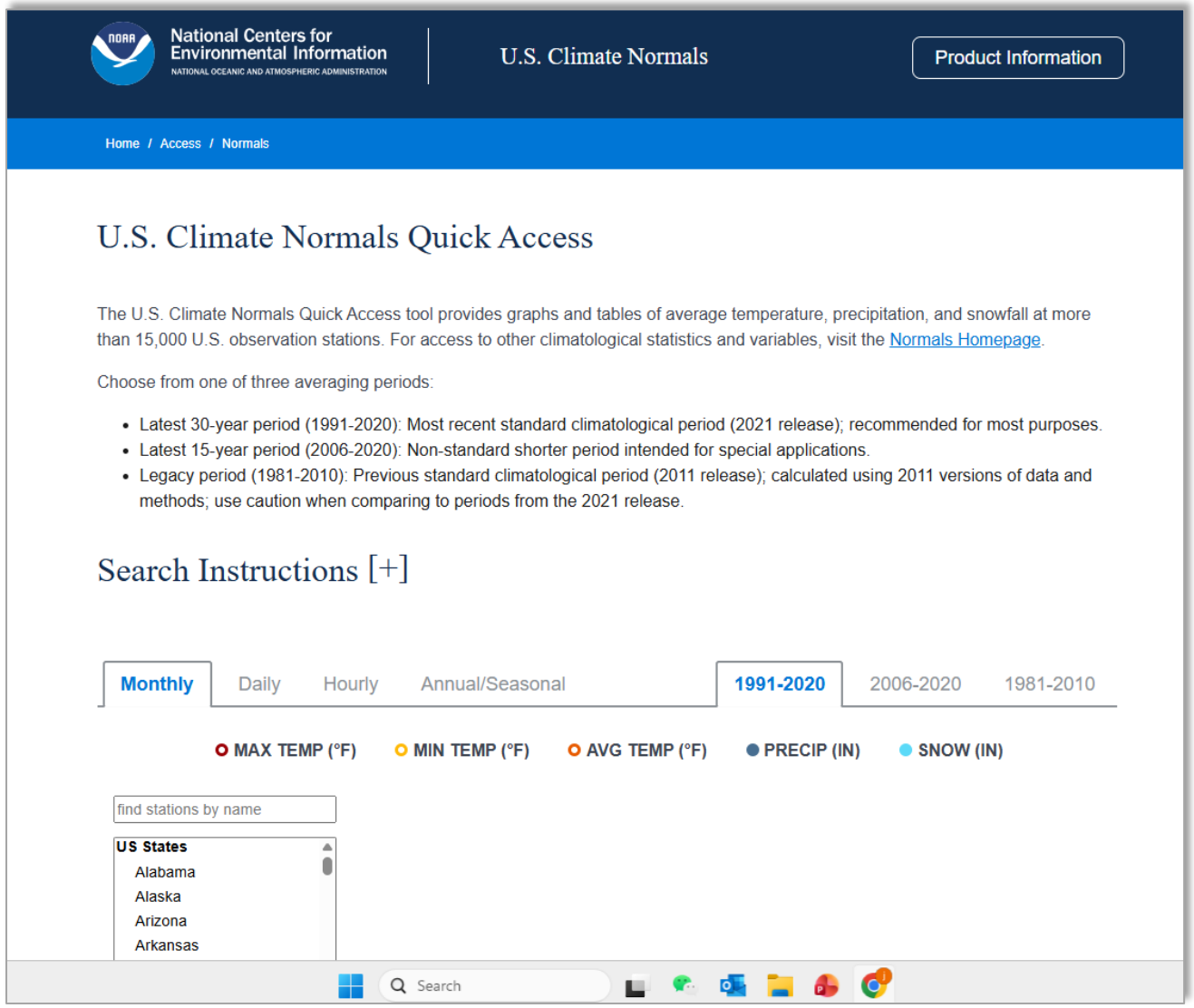
2. Length, Area, & Volume

1 inch = 2.54 cm
1 m = 3.28 ft
1 mile = 1.61 km
1 ha = 2.47105 acres
1 acre = 0.404686 ha
1 yard = 0.9144 m
1 m = 1.09361 yards
1 m^3 ≈ 1.30795 yd^3
1 yd^3 ≈ 0.764555 m^3
1 bushel = 8 gallons
1 U.S. gallon ≈ 3.78541 liters
1 U.S. bushel ≈ 35.24 liters
1 Board feet = 1 ft × 1 ft × 1 in
= 144 cubic inches

Object	SI (°C)	En. Unit (inch)
Rainfall	800 mm/year	? Inches/year
Snow fall	? m/year	210 ft/year
Wind speed	? km/hour	20 miles/hour
Water in Lake Michigan	~4,918 km^3	? ft^3
Visibility in Lansing	? km	10 miles
Timber production	150 m^3/ha/year	? Bushels/acre
Corn yields	? m^3/ha	180 bushels/acre

NOAA: National Oceanic and Atmospheric Administration (USA):

https://www.ncei.noaa.gov/access/us-climate-normals/



Physical Foundation

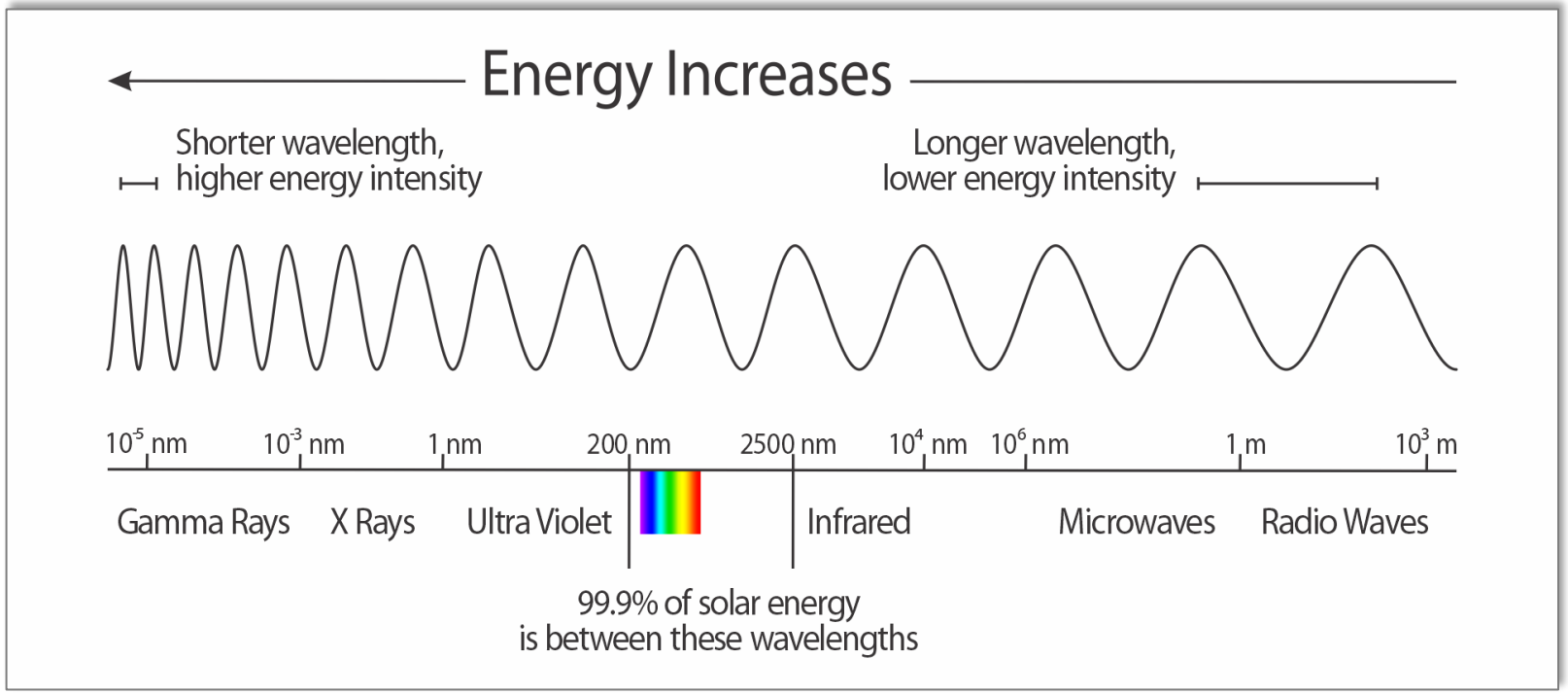
Energy

- Amount: Joule (J)
- Rate of energy use: Watt

- 1 W=1 J/s
- 1 Wh=3600 J
- A 60 W bulb on for 1 minutes:

$$E = 60\ W \times 60\ s = 3600\ J$$

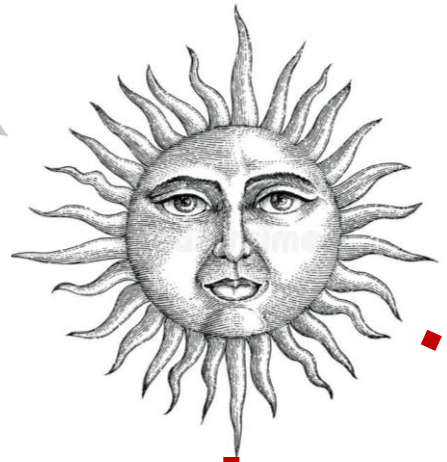
Wavelength



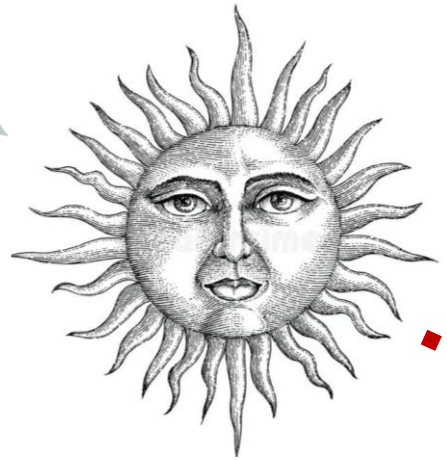
Energy Flux

Amount per unit area: W/m^2

https://www.rmets.org/news/wmo-provisional-report-state-global-climate-2021



Amount of energy received per unit area is called solar constant (c) = 1361 W/m^2



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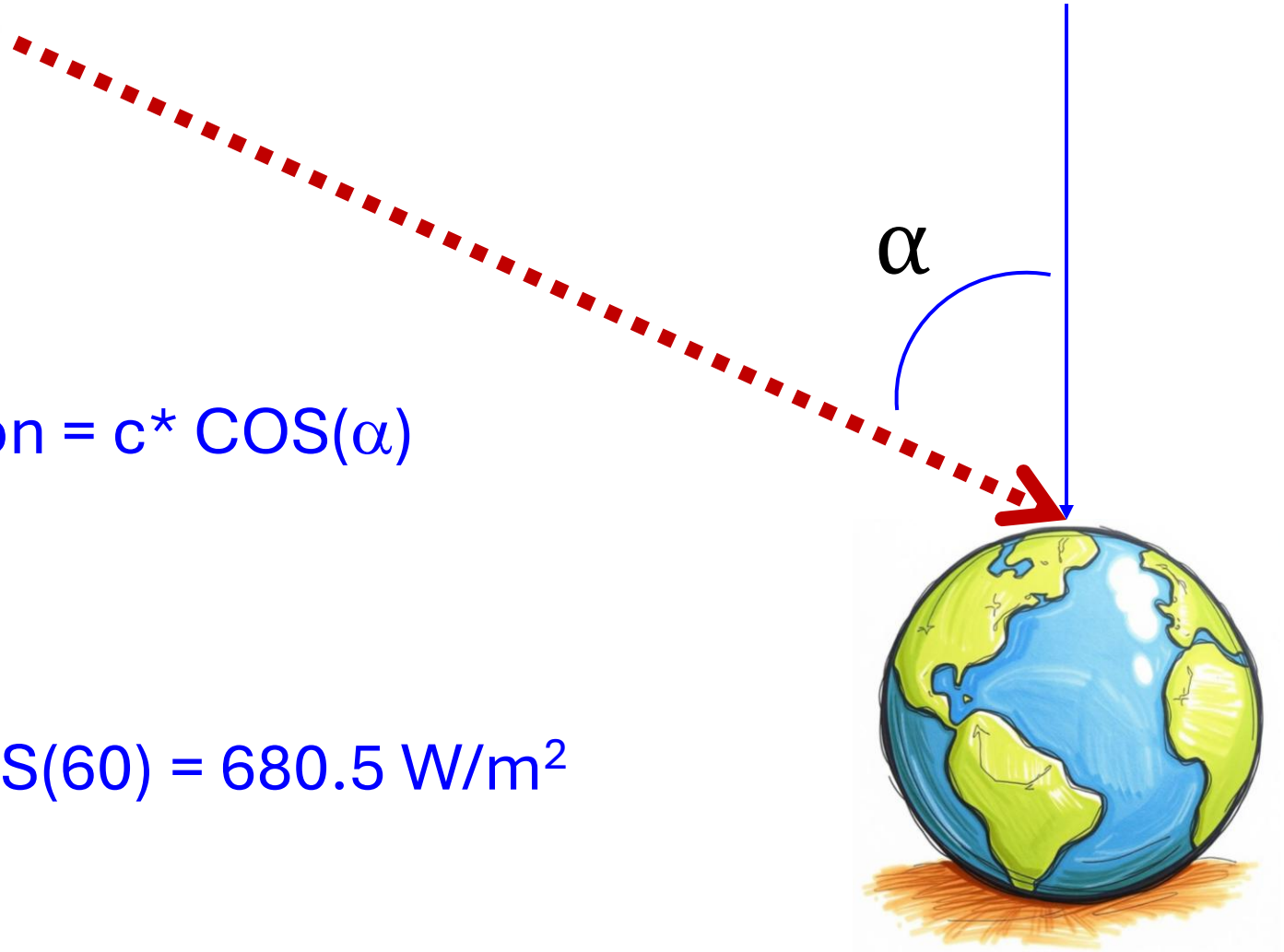


Actual radiation = c* COS(α)

α =60 degree

R_t = 1361*COS(60) = 680.5 W/m^2

Blackbody Theory

Any object with a temperature higher than absolute zero (-273.15 °C) emits energy.

Stefan–Boltzmann Law

The total energy (E) radiated from an object is proportional to the 4th power of its temperature (T), with σ as the emissivity (i.e., Stefan–Boltzmann constant):

$$E = \sigma \cdot T^4$$

$\sigma = 5.67 \times 10^{-8}\ W \cdot m^{-2} \cdot K^{-4}$

Grey Body: actual emissivity (ε)

$$E = \varepsilon \cdot \sigma \cdot T^4$$

- A perfect blackbody: ε = 1
- Real materials: 0 < ε < 1

Wien's Law: describes how the **peak wavelength** of radiation emitted by a blackbody shifts with temperature.

$\lambda_{max}=2898/T$

where:

- λ_{max} = wavelength of maximum emission (micrometers, µm)
- T= temperature in Kelvin

The Sun

- $T \approx 5800$ K

$$\lambda_{max} \approx \frac{2898}{5800} \approx 0.5\ \mu m$$

Peak in **visible light (green)**.

Earth

- $T \approx 288$ K

$$\lambda_{max} \approx \frac{2898}{288} \approx 10\ \mu m$$

Peak in **thermal infrared**.

Planck's Radiation Law describes the electromagnetic radiation emitted by a black body in thermal equilibrium at a given temperature. This is described by :

$$E = \frac{h \cdot c}{\lambda}$$

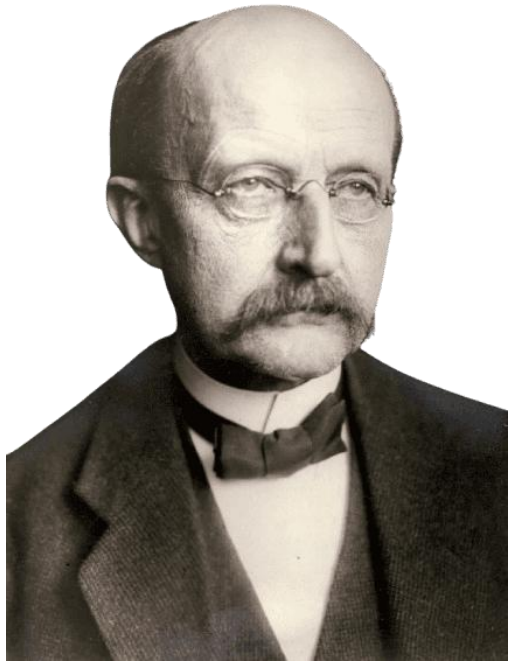
h = Planck's constant; $6.62607015 \times 10^{-34}$ joule/s (J/s)

λ = frequency of radiation (nm)

c = speed of light (m/s) = [299,792,458 m/s]

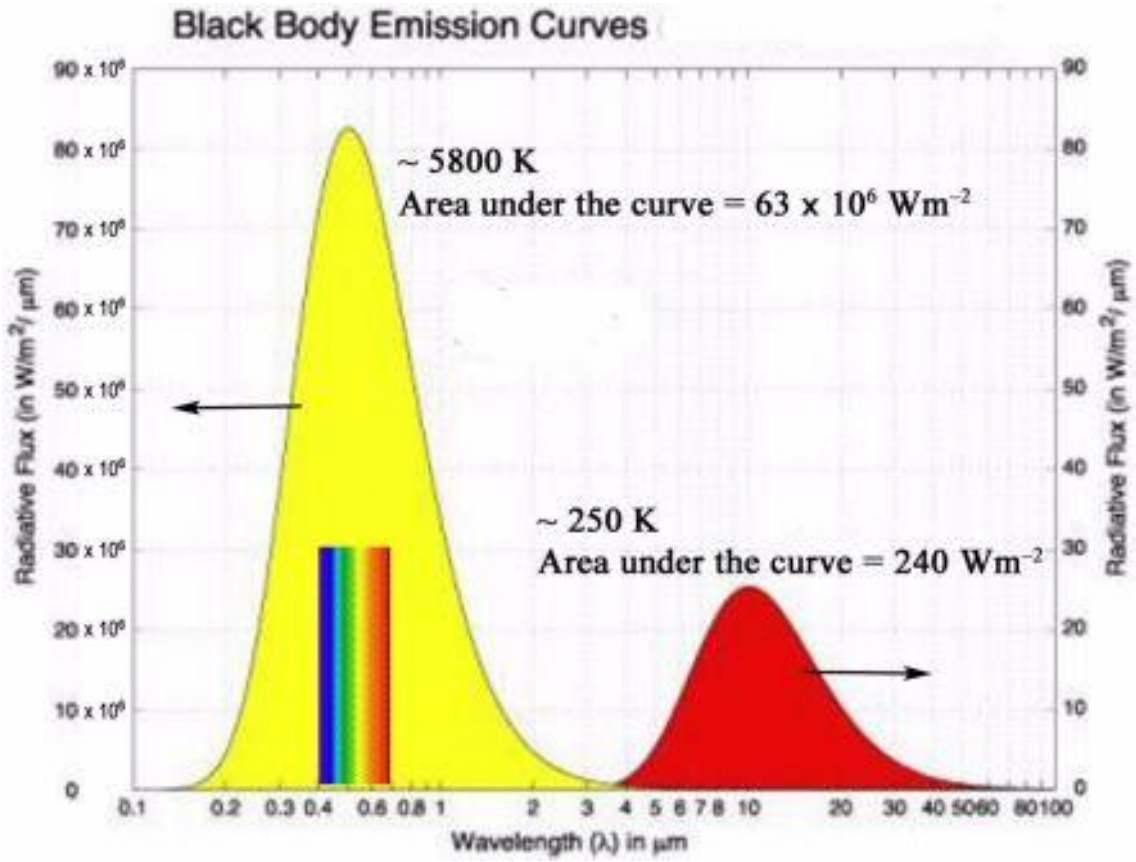
≈ 3.00×10^8 m/s
≈ 300,000 km/s
≈ 186,282 miles/s

Planck's Law is a mathematical relationship formulated in 1900 by German physicist Max Planck to explain the spectral-energy distribution of radiation emitted by a blackbody (a hypothetical body that completely absorbs all radiant energy falling upon it, reaches some equilibrium temperature, and then reemits that energy as quickly as it absorbs it).



1) Radiant emittance from the sun (T = 6000 K) varies from 0.2 nm to 3.0 μm and peaks at spectra of ~0.55 μm, with most energy coming from a wavelength of 0.3-0.7 nm (>50%). These wavelengths are loosely called "shortwave radiation" or "visible light").

2) The Earth's (T = 288 K) peak emittance is 9.5-10.0 μm. In sum, Earth's temperature is mostly maintained by the balance of incoming shortwave radiation from the sun and outgoing longwave radiation from the Earth.

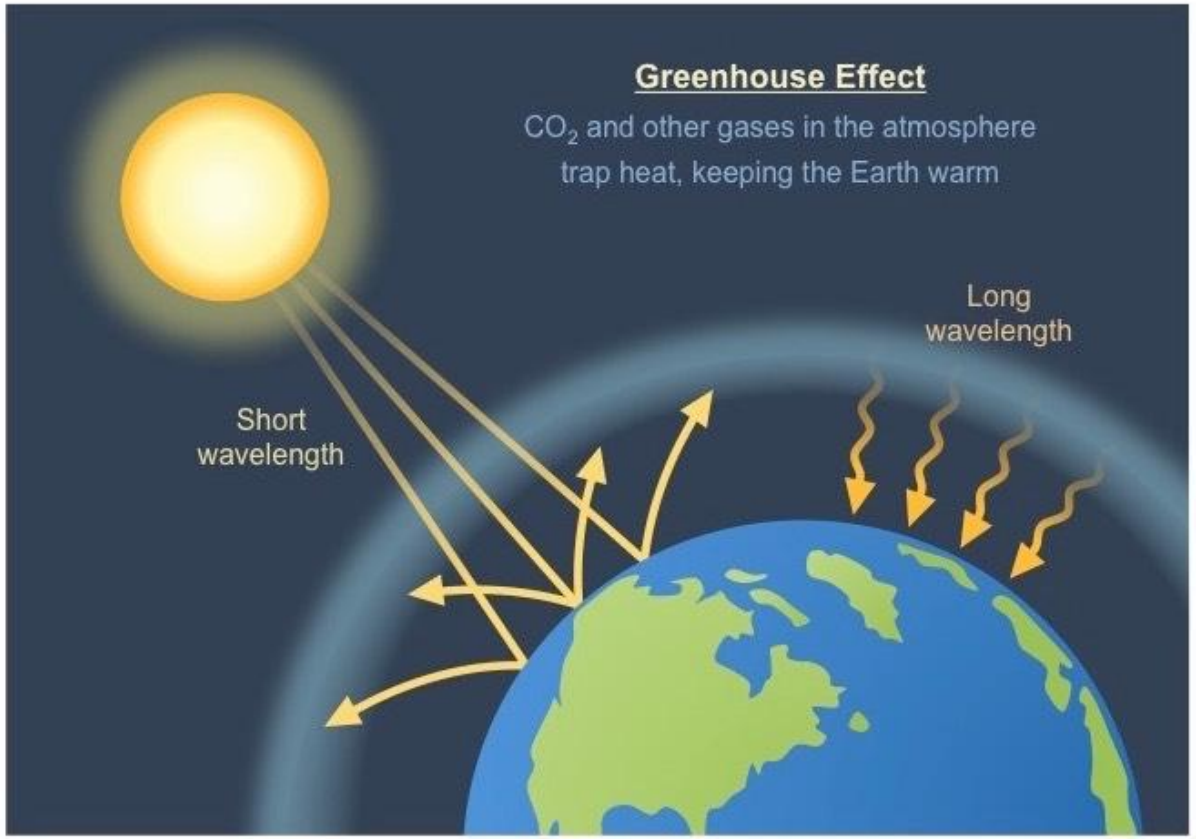


https://www.pinterest.com/pin/561964859722645297/

Why is temperature increasing?

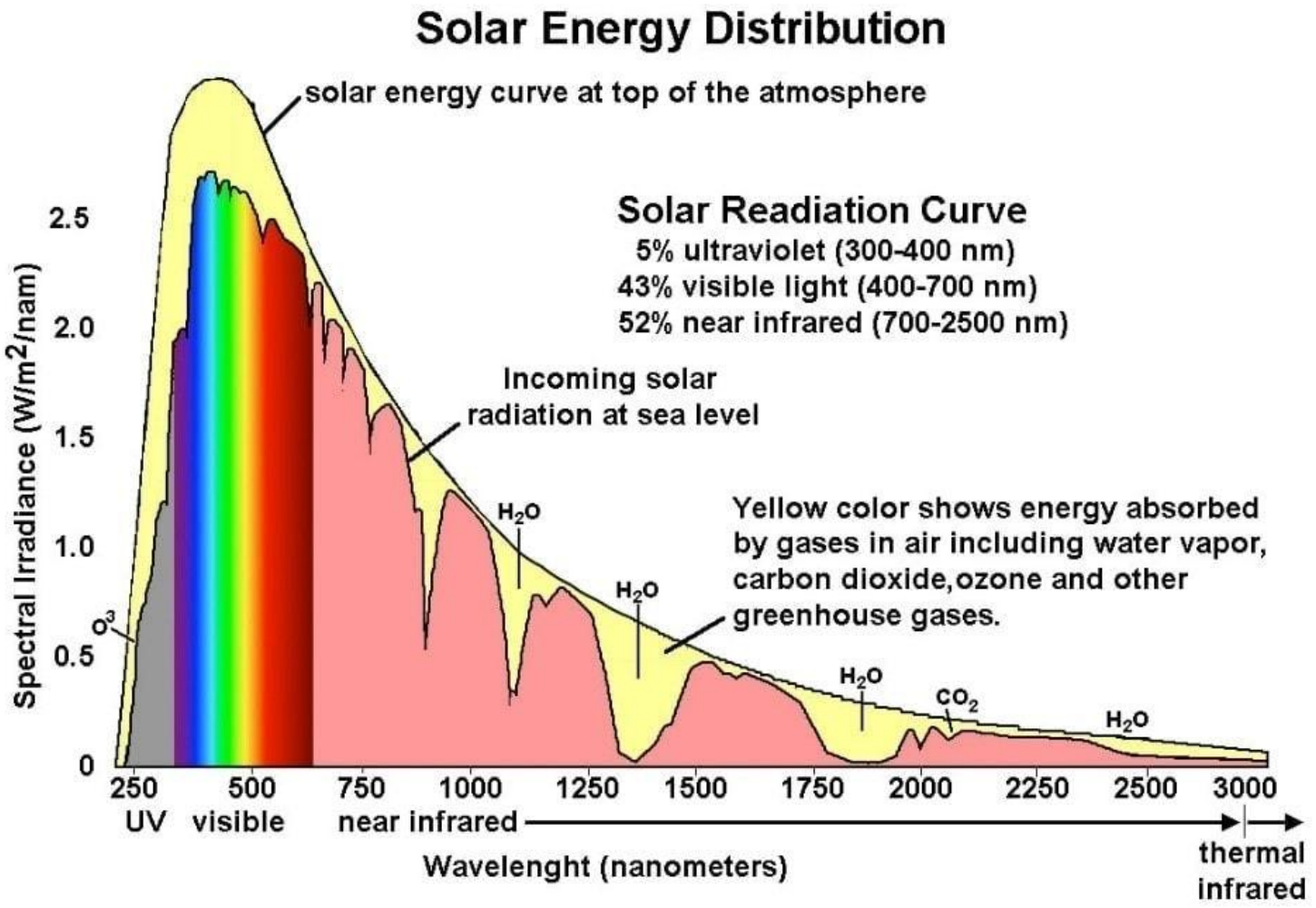
NASA Video: https://www.youtube.com/watch?v=bk6mCWfVtbw

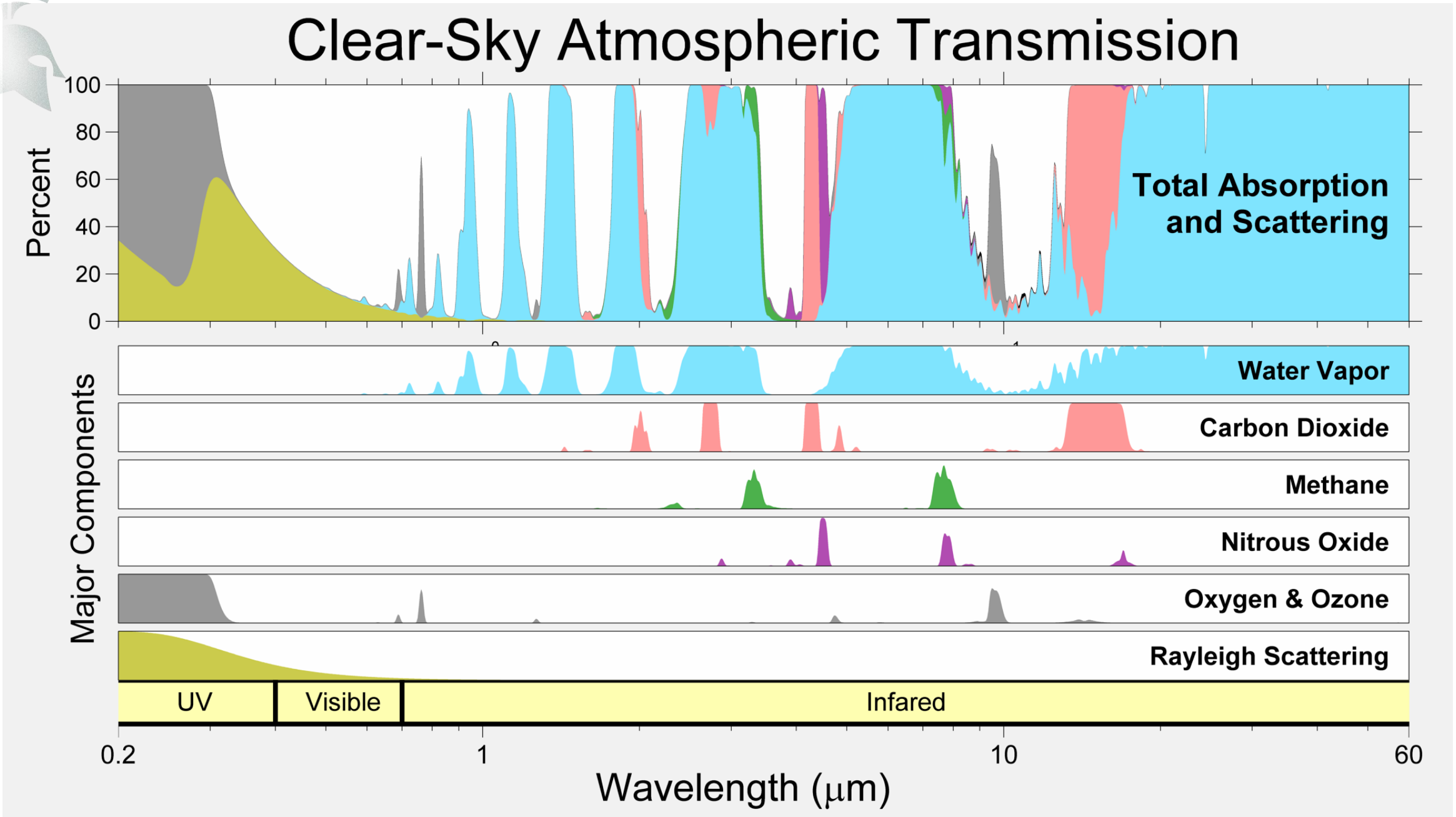
"Earth climate is fundamentally an energy balance that resolves energy inputs from solar radiation and ultimate loss of energy to the universe. These two streams of energy occur at very different bands of the electromagnetic spectrum, short-wave radiation from the sun, and long-wave radiation to the universe. Climate change boils down to understanding this energy balance."



https://ib.bioninja.com.au/standard-level/topic-4-ecology/44-climate-change/greenhouse-effect.ht

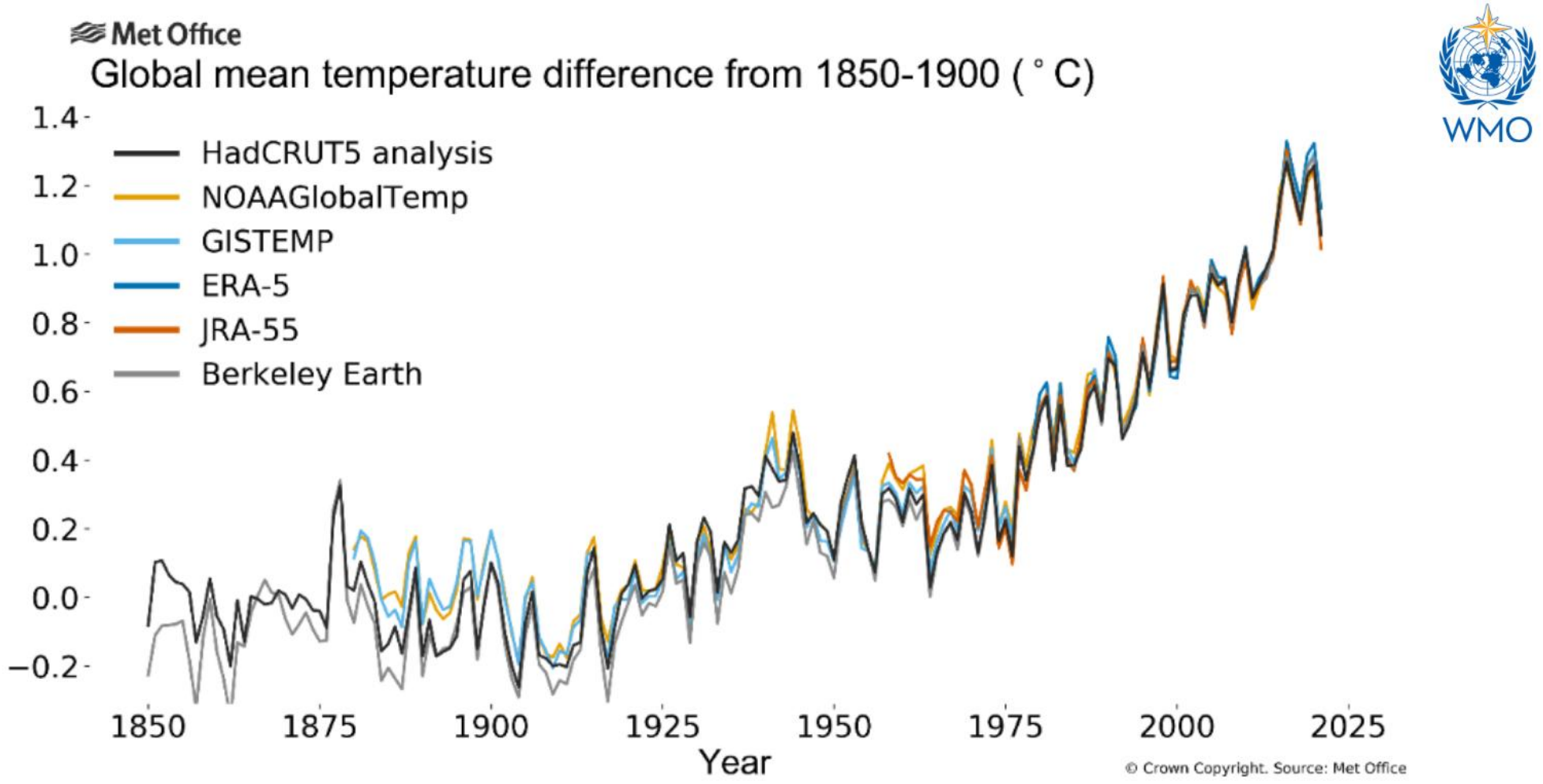
Earth's atmosphere is composed of many gases and particles. Nitrogen (~78%) and oxygen (~21%) are the two major chemical species. Other species, including water, argon, CO_2, etc., account for <1%.




Clear-Sky Atmospheric Transmission
Percent
100
80
60
40
20
0
Total Absorption and Scattering
Major Components
Water Vapor
Carbon Dioxide
Methane
Nitrous Oxide
Oxygen & Ozone
Rayleigh Scattering
UV
Visible
Infared
0.2
1
10
60
Wavelength (μm)

Chen, J. 2020

Widely accepted theory on global warming because more energy is trapped due to the changes in atmospheric gases.



https://www.rmets.org/news/wmo-provisional-report-state-global-climate-2021

Temperature-Dependent Sex Determination -- TSD

- The sex of most turtles, alligators, and crocodiles is determined after fertilization. The temperature of the developing eggs decides whether the offspring will be male or female.
- If a turtle's eggs incubate <81.86 °F, the turtle hatchlings will be male. Otherwise >87.86° F, the hatchlings will be female.
- The warmer the sand, the higher the ratio of female turtles. Increased temperatures could result in skewed and even lethal incubation conditions, which would impact turtle species and other reptiles.

https://oceanservice.noaa.gov/facts/temperature-dependent.html

Global Connections: Dairy production in Kazakhstan

PM Mamin holds extended meeting on livestock development

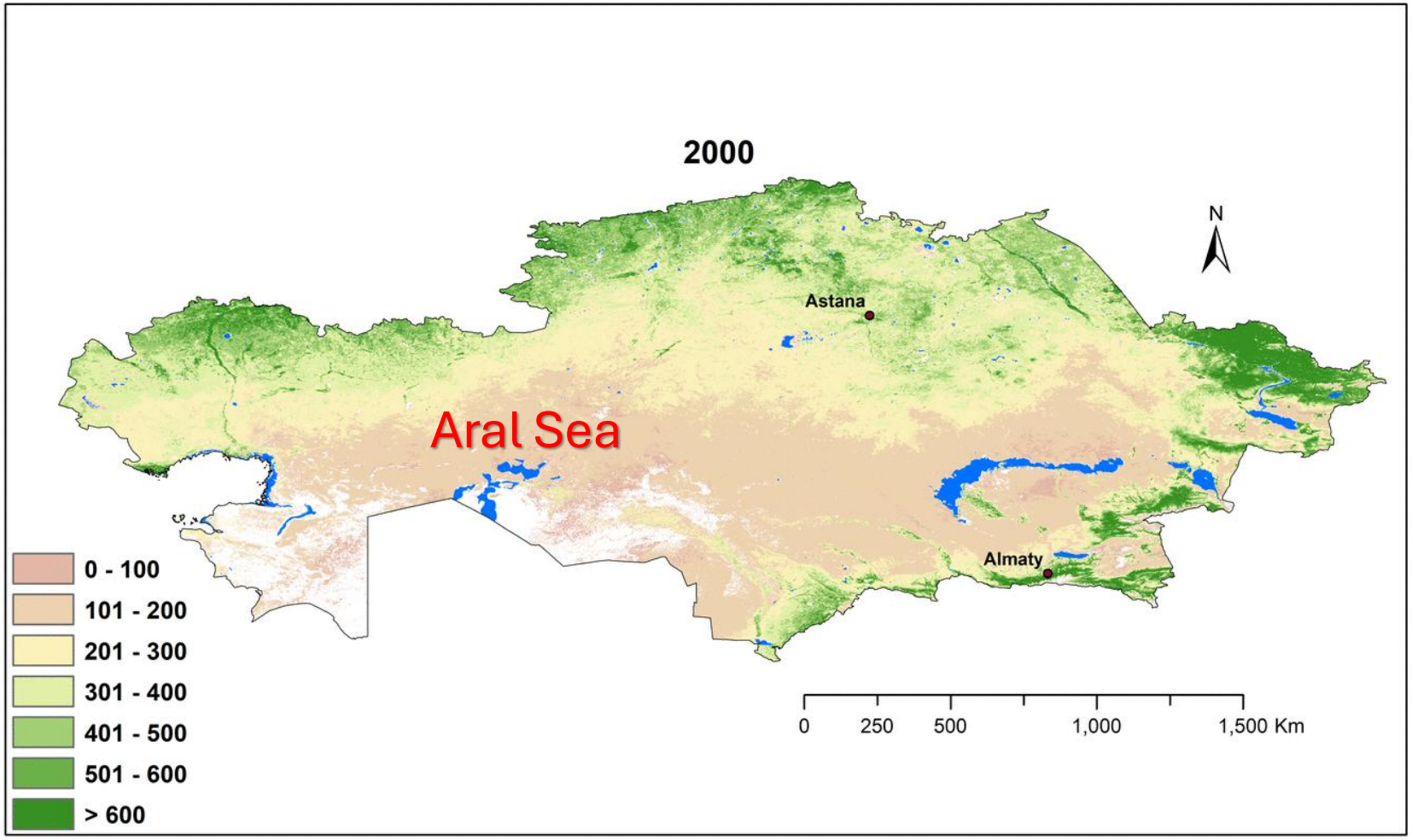
25 December 2019 19:05 Share in:

NUR-SULTAN. KAZINFORM - Prime Minister Askar Mamin chaired a meeting on the development of beef cattle breeding.

- A sectorial program for the development of livestock farming is being implemented in the framework of the State Agro-Industrial Complex Development Program for 2017-2021.
- Kazakhstan is planning to increase the volumes of its meat exports by 2.5 times.
- The main importers of the meat products are Russia, Azerbaijan and Iran.
- Residents of Turkey, the United Arab Emirates, China, Russia and Iran are interested in the meat products from Aral Sea.

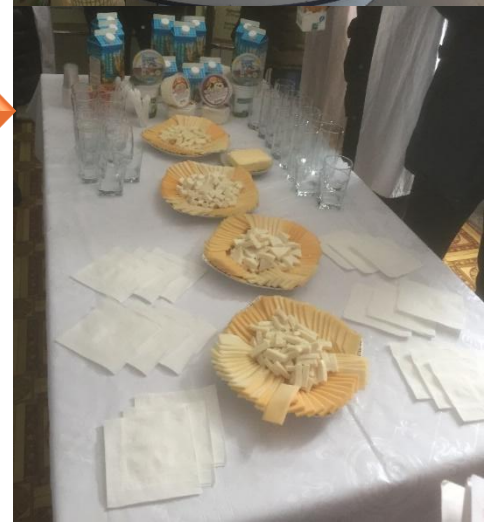
Are there enough NPP to support this large livestock?

Dynamics of net primary production (NPP) of the ecosystems in Kazakhstan from 2000 through 2014



Field Trip to Kostanay – a boarding region with Russian

Modern facility and equipment from Italy, Germany, Japan, others



The Tale: Russian Food Table

1) So the reason for more crop/livestock is to satisfy Russians' food table

2) Italy, Japan, China and others all help

3) Russia needs import diary products regardless of its large lands

4) Economic depression in Russia

5) USA & NATO Countries imposed sanctions on Russia

In 2014 & 2022, Russia interfered Ukraine

Are USA & NATO countries responsible for the shrinking pace of Aral Sea, at least partially?

Or Shall we blame Russians – an easy target

Putin was never a fully-fledged climate chang
Addressing a climate conference in 2003, Put
warmer weather so people spend less on fur

Bloomberg Opinion

Technology & Ideas

Even Putin Is Now Worried About Climate Change

Russia has dropped its doubts about joining the Paris accords.

https://www.bloomberg.com/opinion/articles/2019-09-24/putin-is-finally-worried-about-climate-change

By Leonid Bershidsky

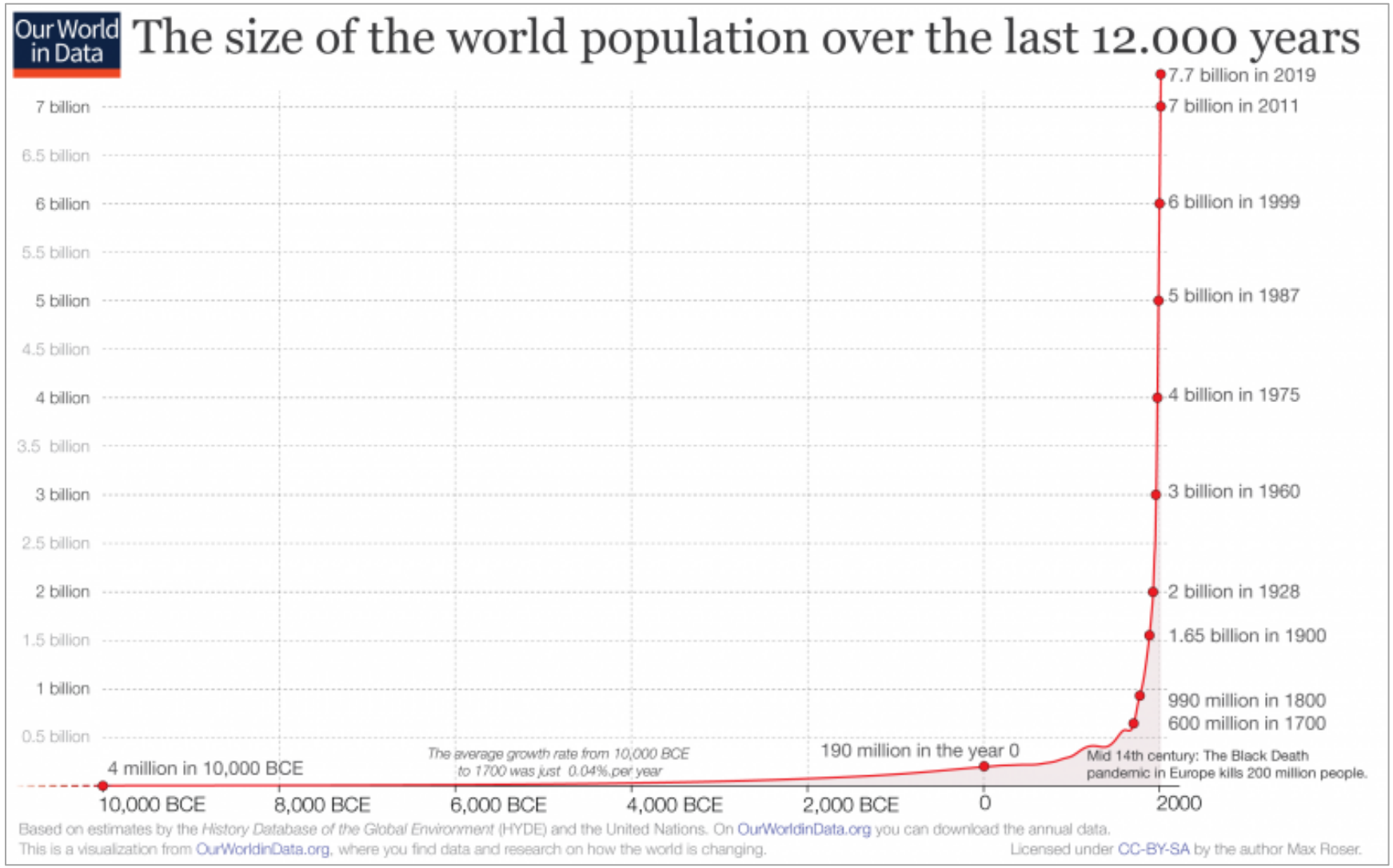
September 24, 2019, 12:00 AM EDT *Corrected September 24, 2019, 3:01 AM EDT*

Russian bears. *Photographer: Alexey Nikolsky/AFP/Getty Images*

Leonid Bershidsky is Bloomberg Opinion's Europe columnist. He was the founding editor of the

After years of procrastination, Russia, the world's fourth-biggest greenhouse gas emitter, has officially joined the Paris climate agreement, which it signed in 2016. It shows that President Vladimir Putin's views of climate change are

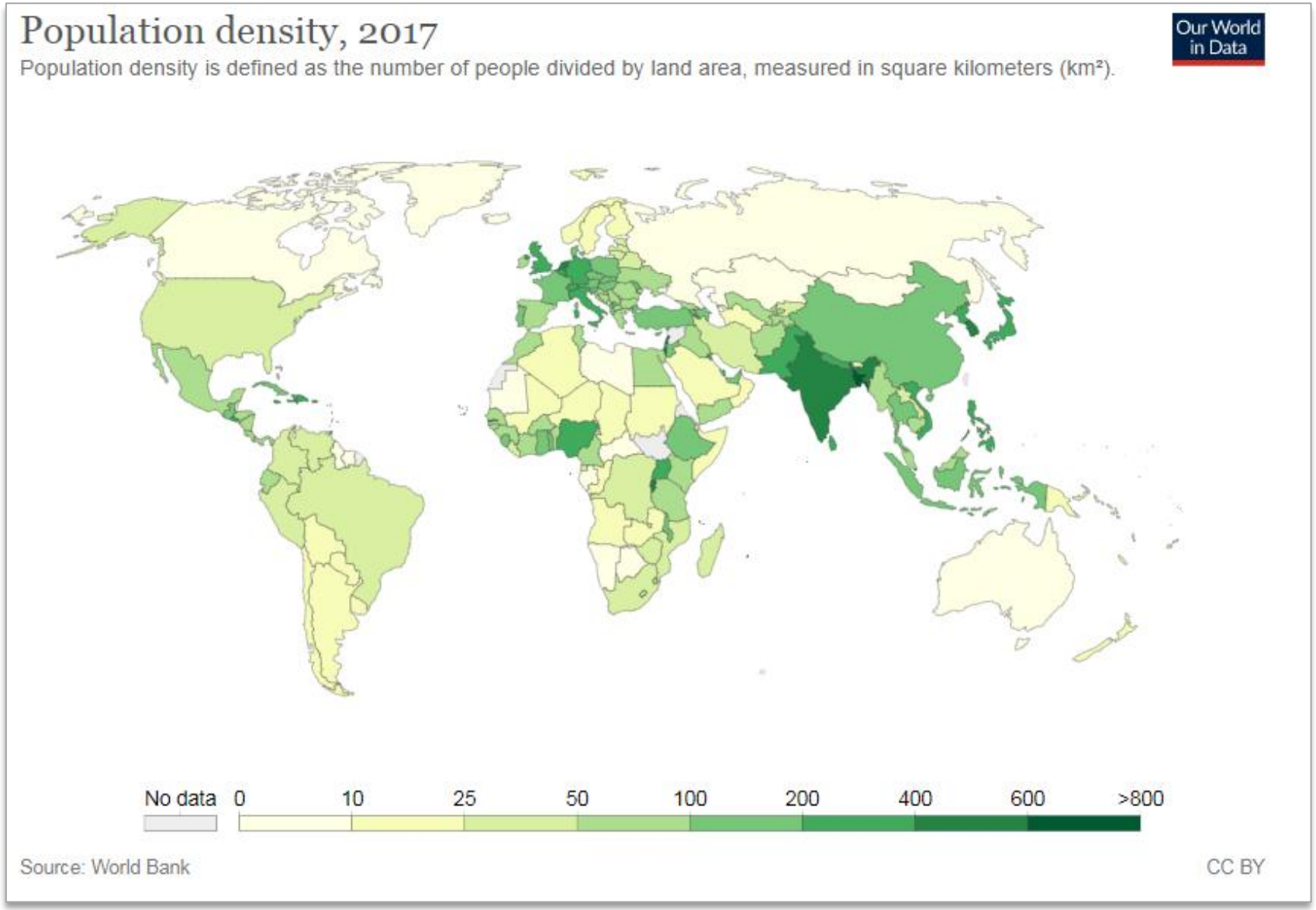
Complex Interconnections: Global Population and growth



https://ourworldindata.org/world-population-growth

Complex Interconnections: Global Population – uneven distribution

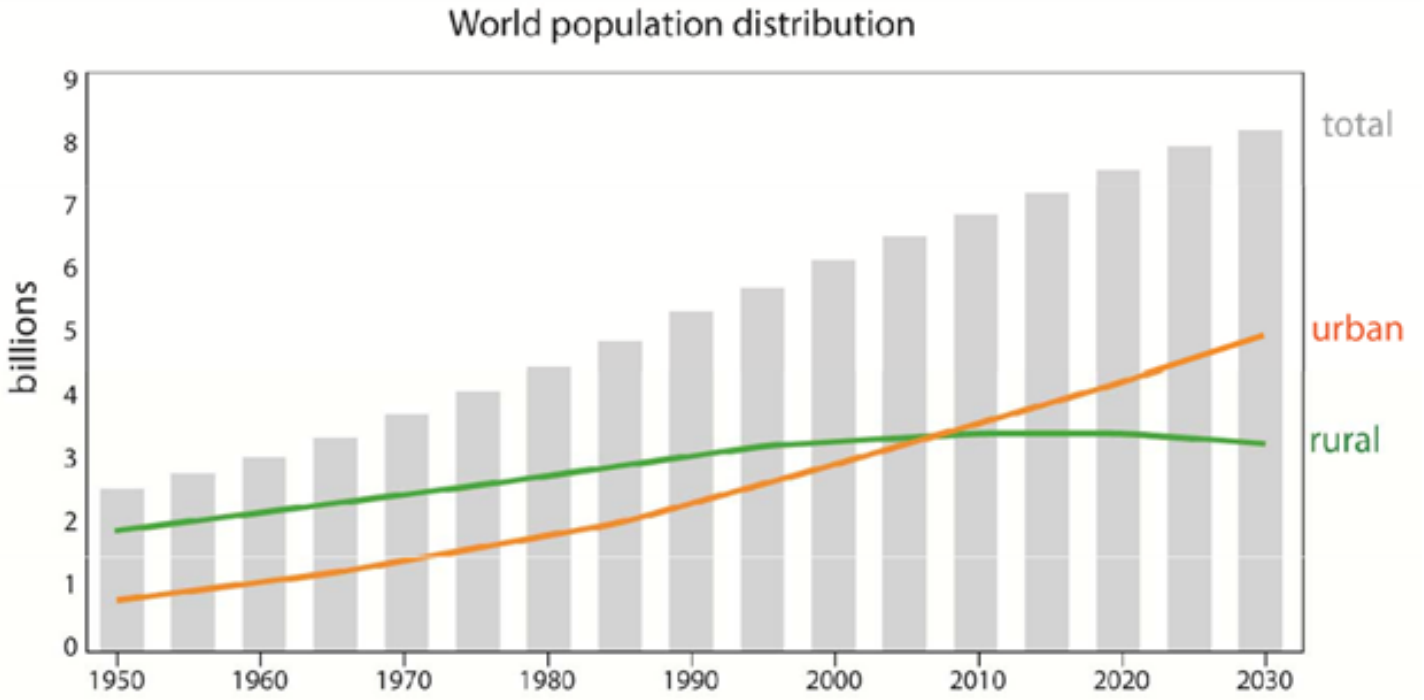
People in developing countries wants the same living standards of Americans!

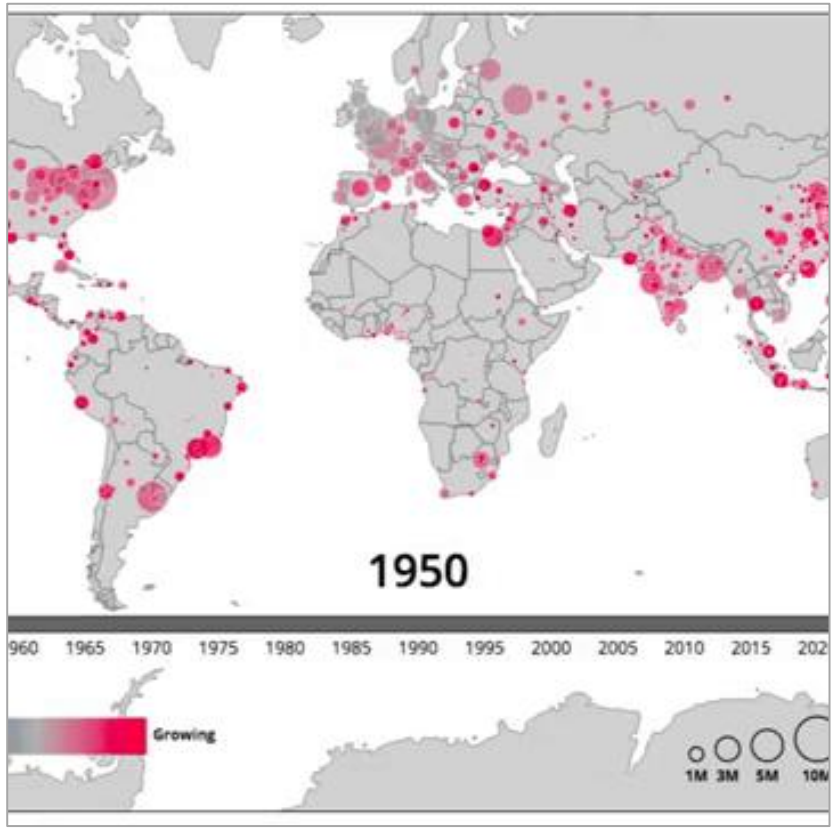


https://ourworldindata.org/world-population-growth

Complex Interconnections: Urbanization

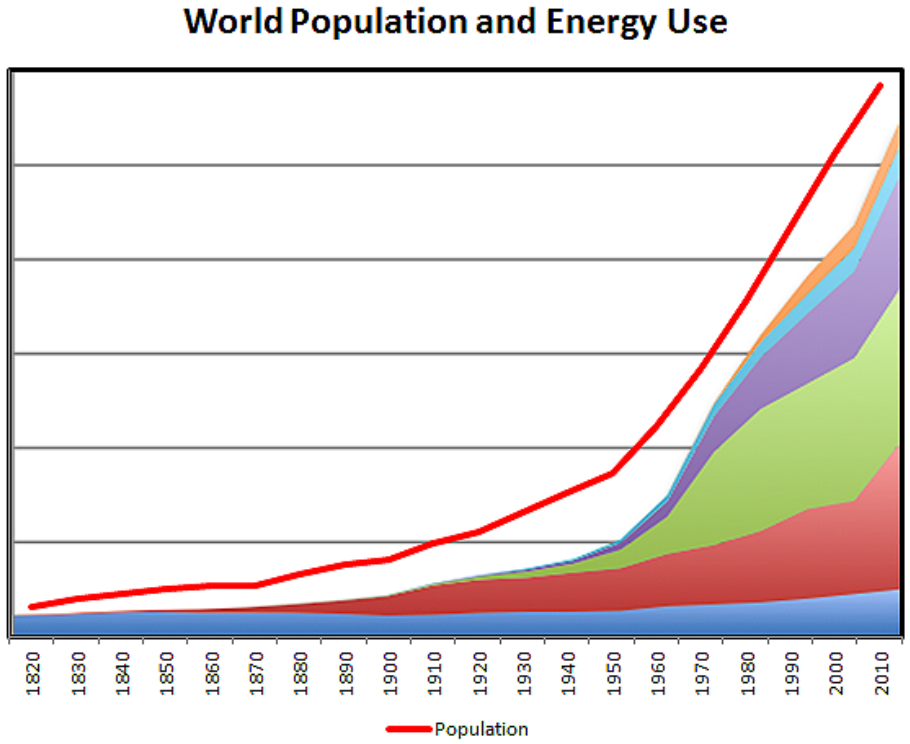
By 2050, ~70% people will live in urban!

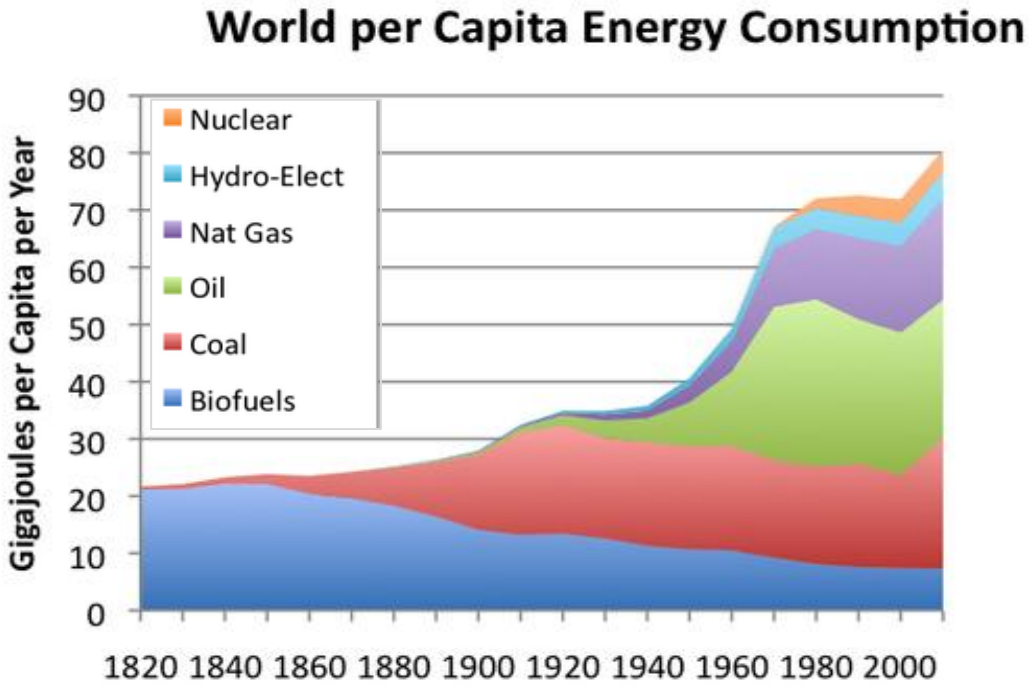




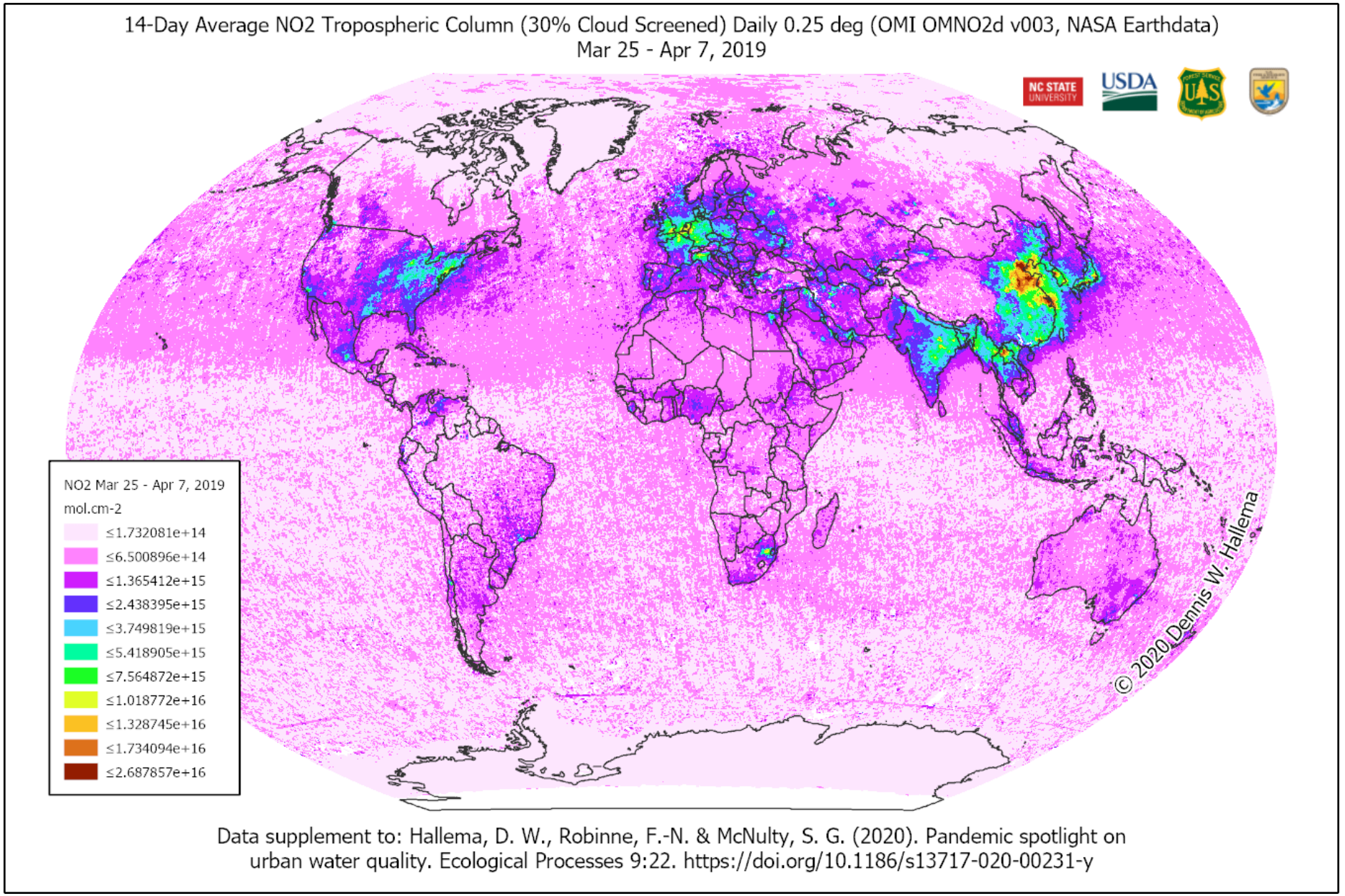
https://www.mathematica.org/commentary/global-urbanization

The world's energy demand is rising!



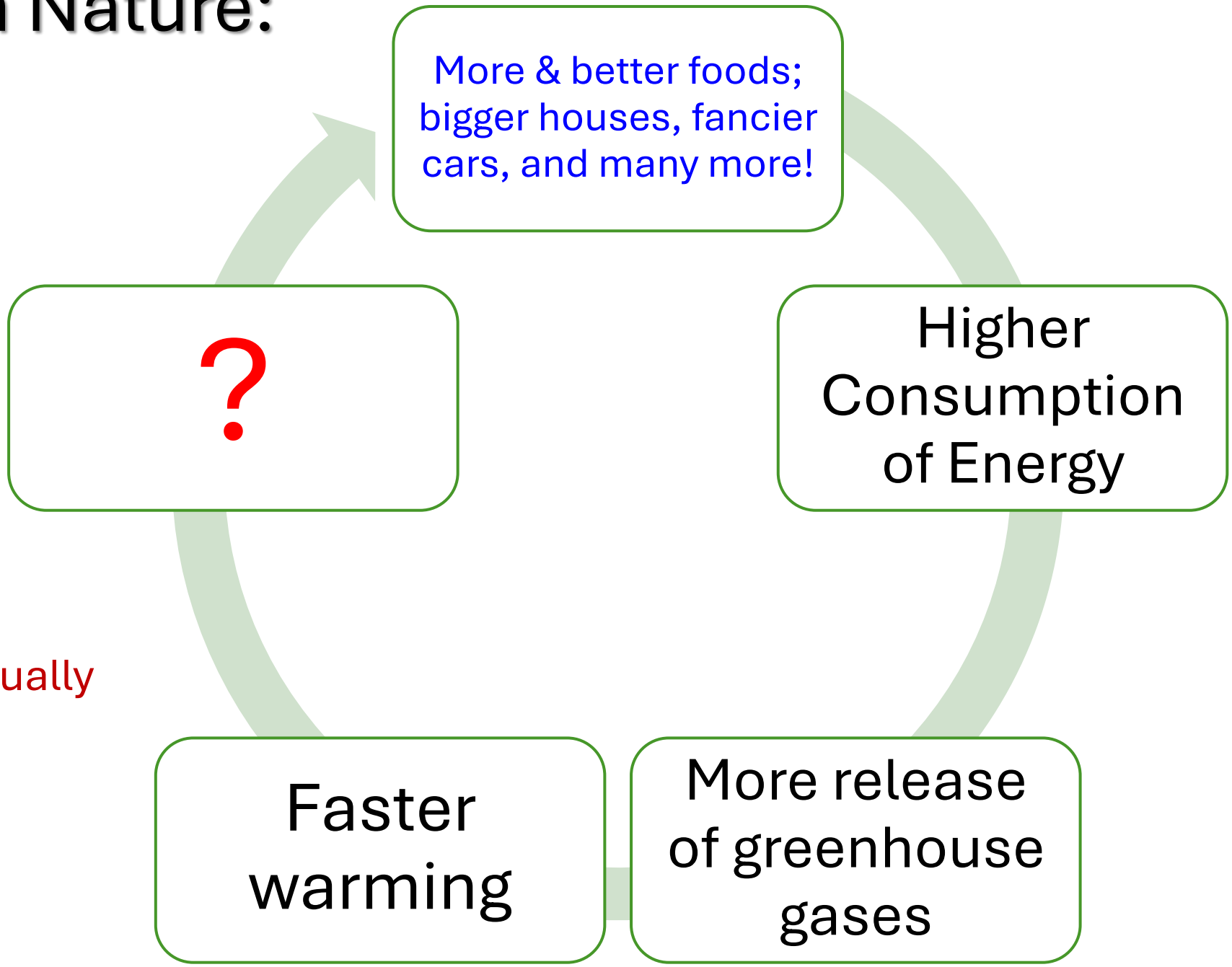


- Nearly 40% of total U.S. energy consumption in 2012 was for residential and commercial buildings;
- Energy consumption has grown exponentially in developing economies (e.g. China, India);
- Governments have pushed a shift from fossil fuels to renewable energy sources, such as solar energy, wind power and biofuels;
- Oil and gas remain the major primary energy sources to power the world’s industries.



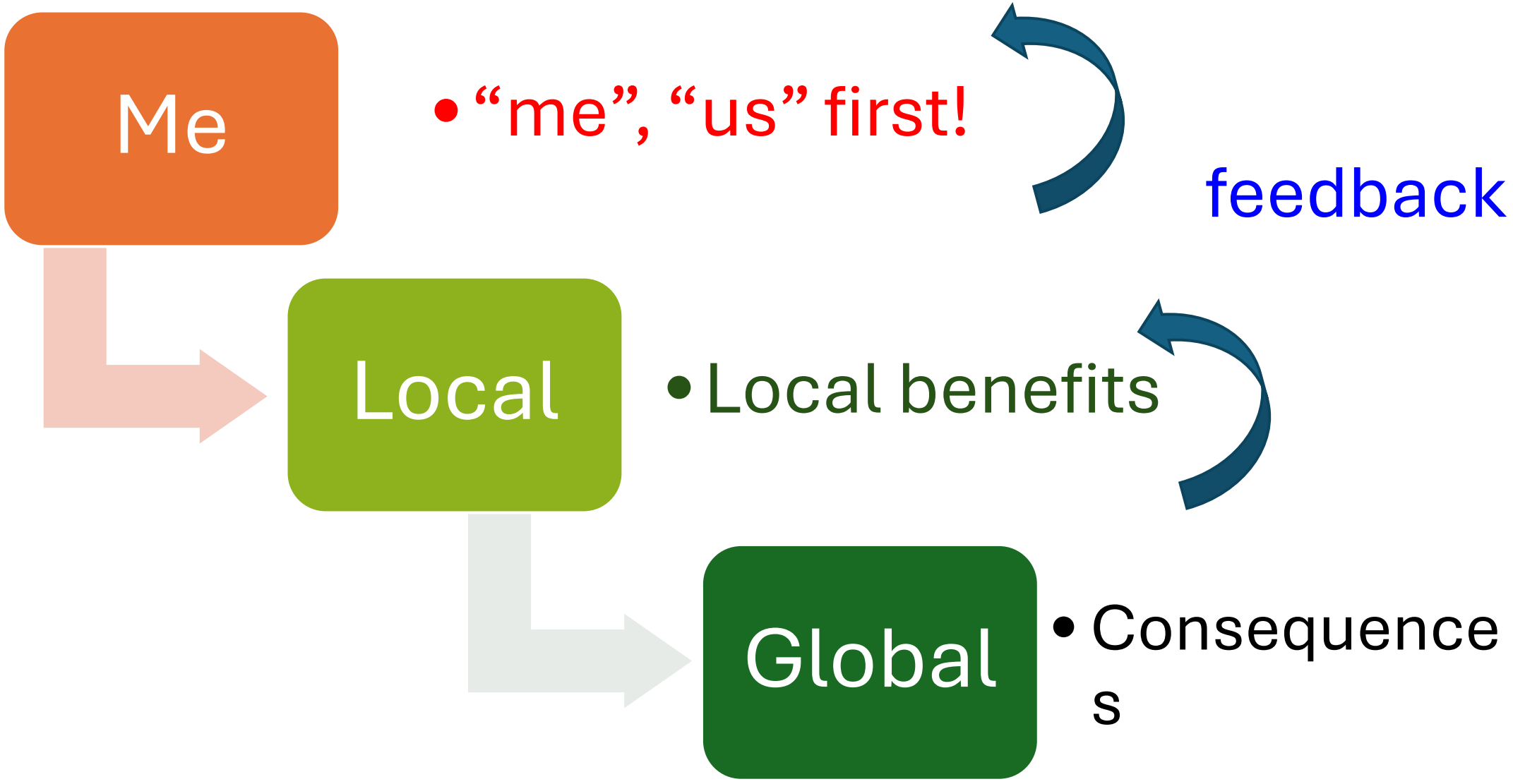
Hallema, D. W., Robinne, F. N., & McNulty, S. G. (2020). Pandemic spotlight on urban water quality. *Ecological Processes*, *9*, 1-3.

Human Nature:



- A positive feedback
- System collapses, eventually

Human Nature



In sum,

1. Globalization is an unavoidable process for now and for the future
2. The changes, including climate, will have consequences (mostly negative so far) on ecosystems, societies, and people
3. Both the causes and consequences are complex and can be remotely connected
4. Solutions are more than just adaptation and mitigation, with education and awareness as the foundational needs for now!

Next Lecture (Jan 21 & 26, Wed)

Ch 1: An Introduction to the Climate Problem

1.1. What is Climate?
1.2. What is Climate Change?
1.3. A Coordinate System for the Earth
1.4. Why You Should Believe This Book
Terms
Problems