ASTR 380
The Future of Life on Earth

Outline

- Astronomical and geological future
- What if all humans vanished?
- A future with humans

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The Future of Life on Earth

What are the natural limits to the continuation of the human race and life on Earth?

The astronomical future – millions and billions of years
The geological future – millions of years
Changes in the near term… driven by human activity
Survival of “life” versus a technological society
Natural evolution to where?
Technology driven evolution to where?

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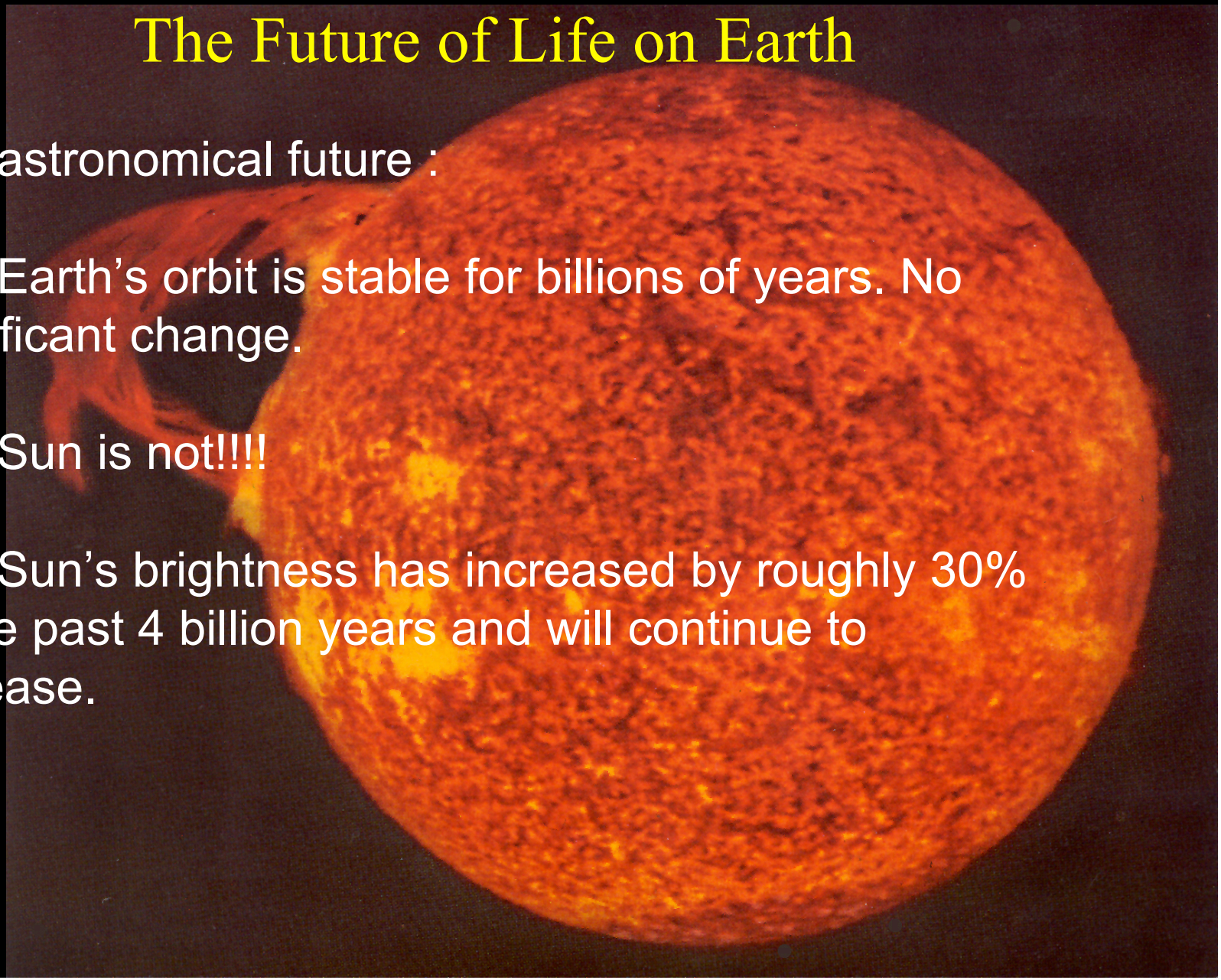

The astronomical future :

The Earth's orbit is stable for billions of years. No significant change.

The Sun is not!!!!

The Sun's brightness has increased by roughly 30% in the past 4 billion years and will continue to increase.

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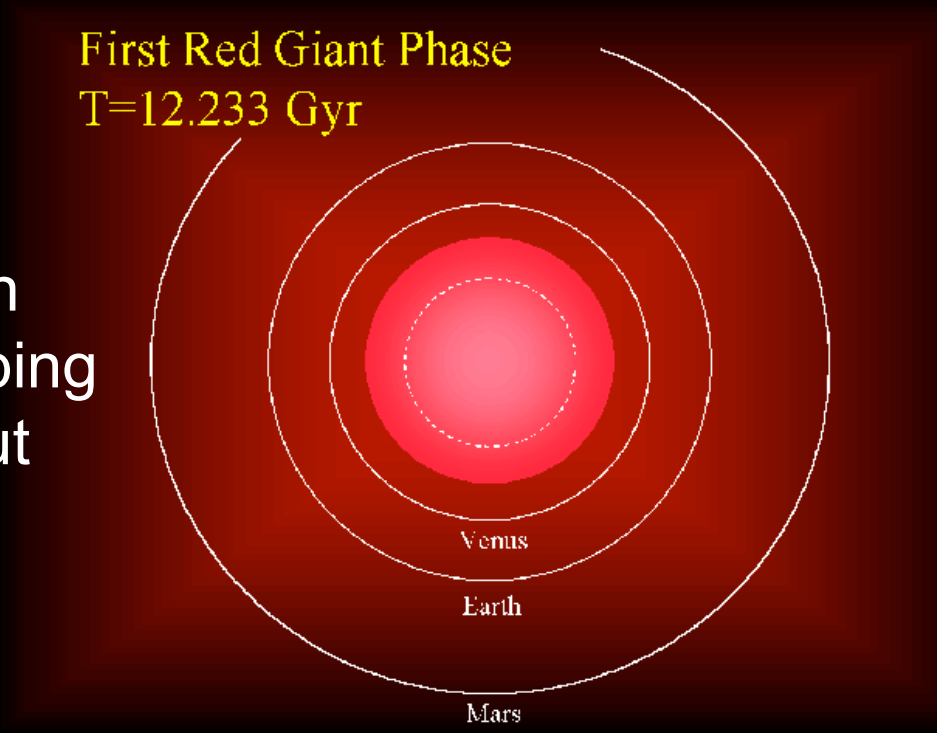
The astronomical future :

Sun's luminosity will be
-- 10% brighter in 1.1 Billion years
-- 40% brighter in 3.5 Billion years
-- 100% brighter in 4.5 Billion years.

In about 5 Billion years, the Sun will become a red giant enveloping Mercury, with a luminosity about 1000 times current!



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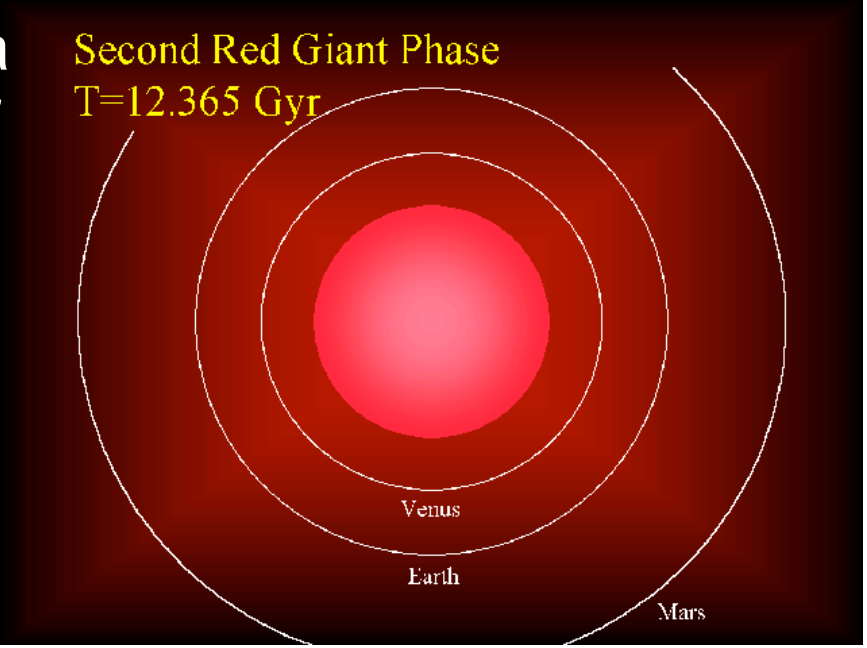
The astronomical future :

At this point, the Sun is blowing out mass in a strong wind and the Earth's orbit moves out.

About 200 Million years later, the Sun swells even further to reach a radius of 1 AU and a luminosity of roughly 5000 solar luminosities!

At this point, the Earth's orbit has moved out to 1.69 AU so it is not engulfed.



Why Does Earth Move Out?

- Conservation of angular momentum
- Sun loses mass from winds during giant phase; down to about 60% of current mass
- Less mass means Earth moves more slowly at a given radius
- To conserve angular momentum, need to move out
- Still won't save us; way too hot!

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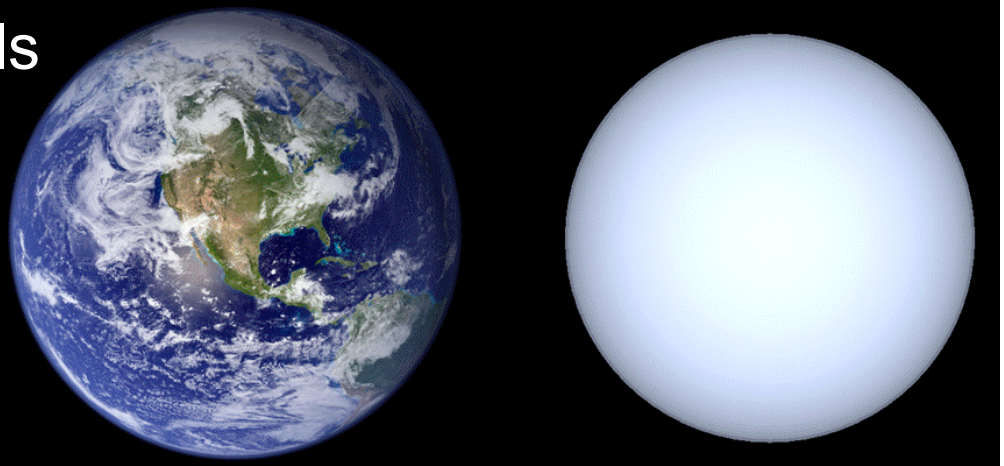
The Future of Life on Earth

The astronomical future :

In the end, the Sun becomes a white dwarf with a mass of 0.51 to 0.58 solar masses.

Earth's orbit is at 1.85 AU.

And the white dwarf Sun cools and becomes less luminous than the sun.



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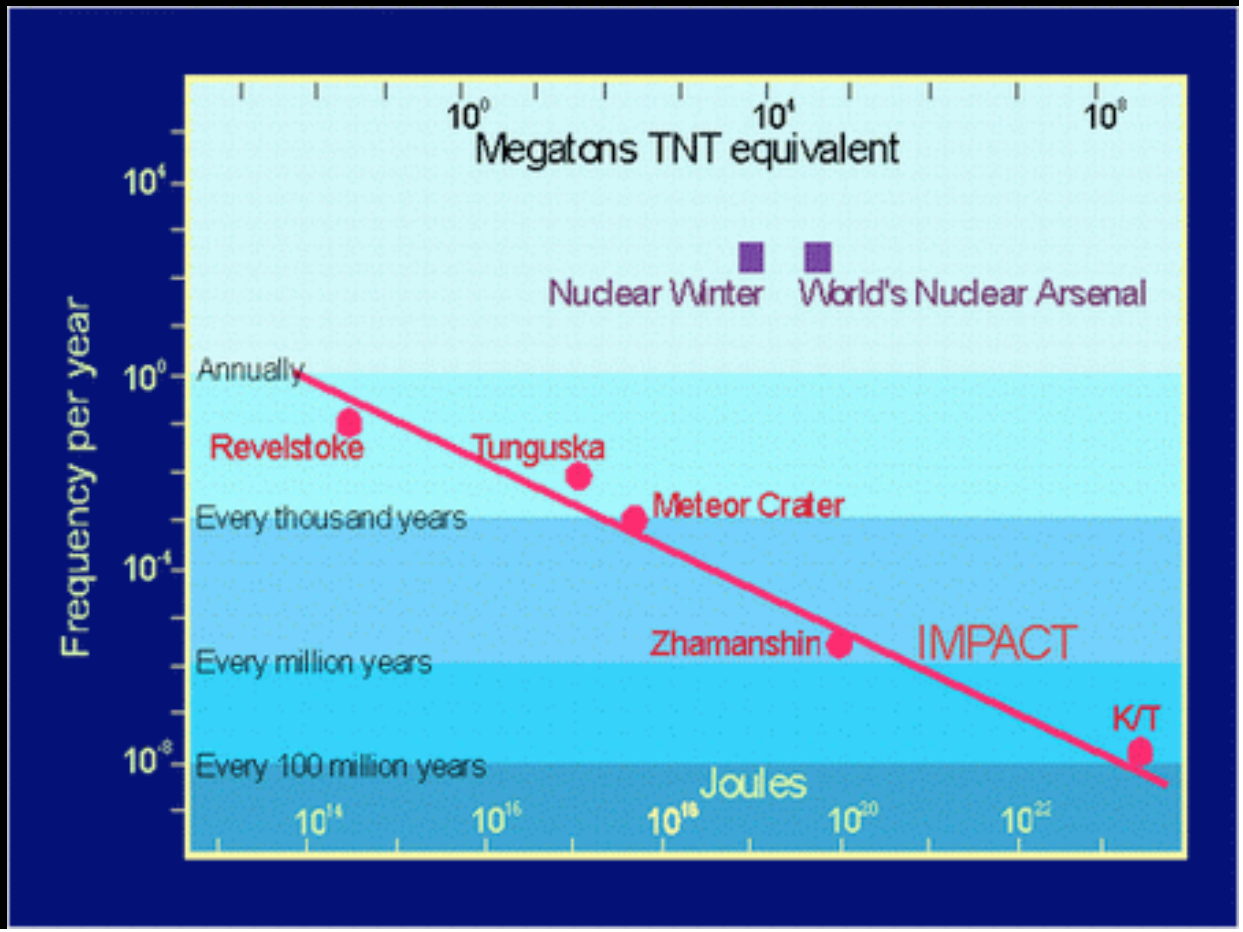
The astronomical future :

More immediate threat: giant impacts!

100 Million years is the magic number…



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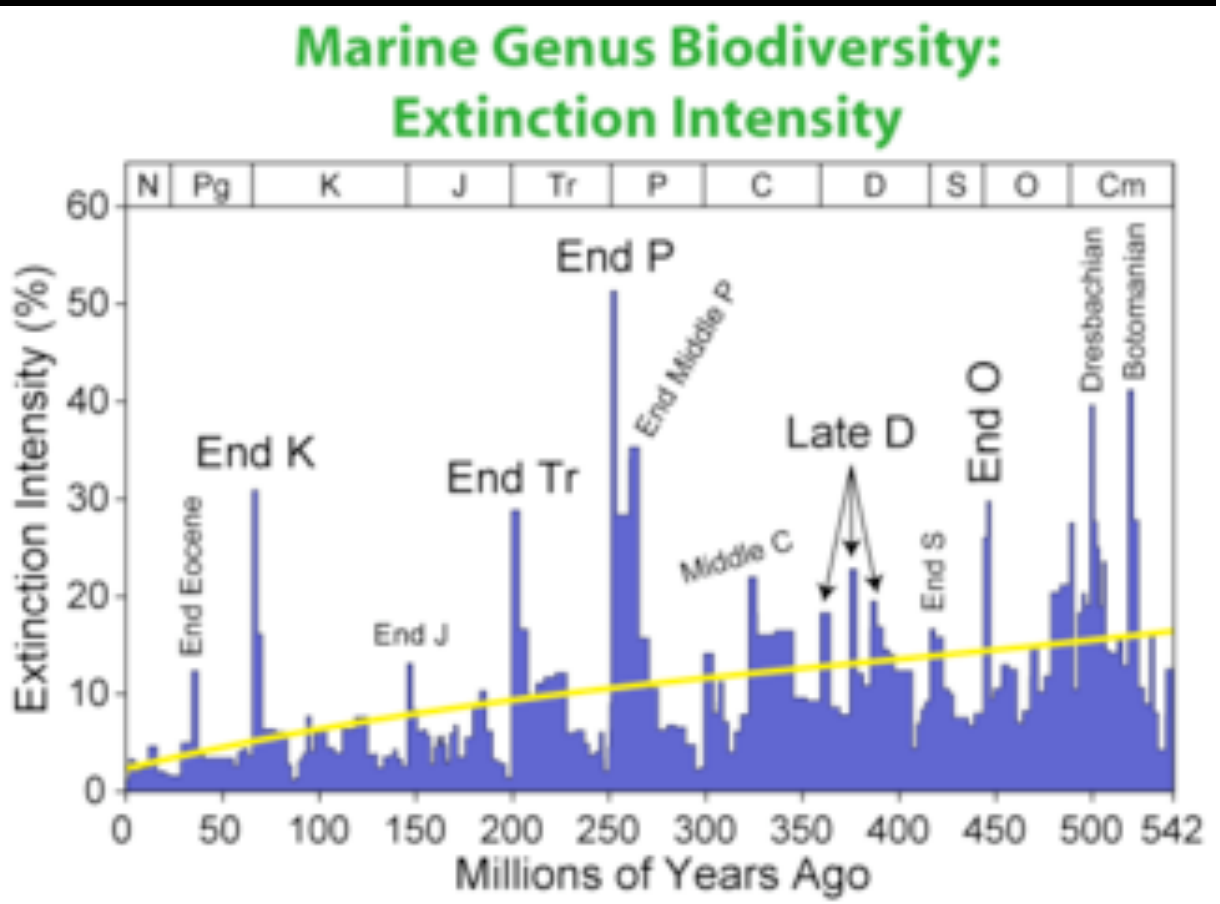
The astronomical future :

Geologic record of mass extinction…. Next one could be next year to 200 Myrs
In the future!

Events reset major
Life forms on Earth

But new life grows



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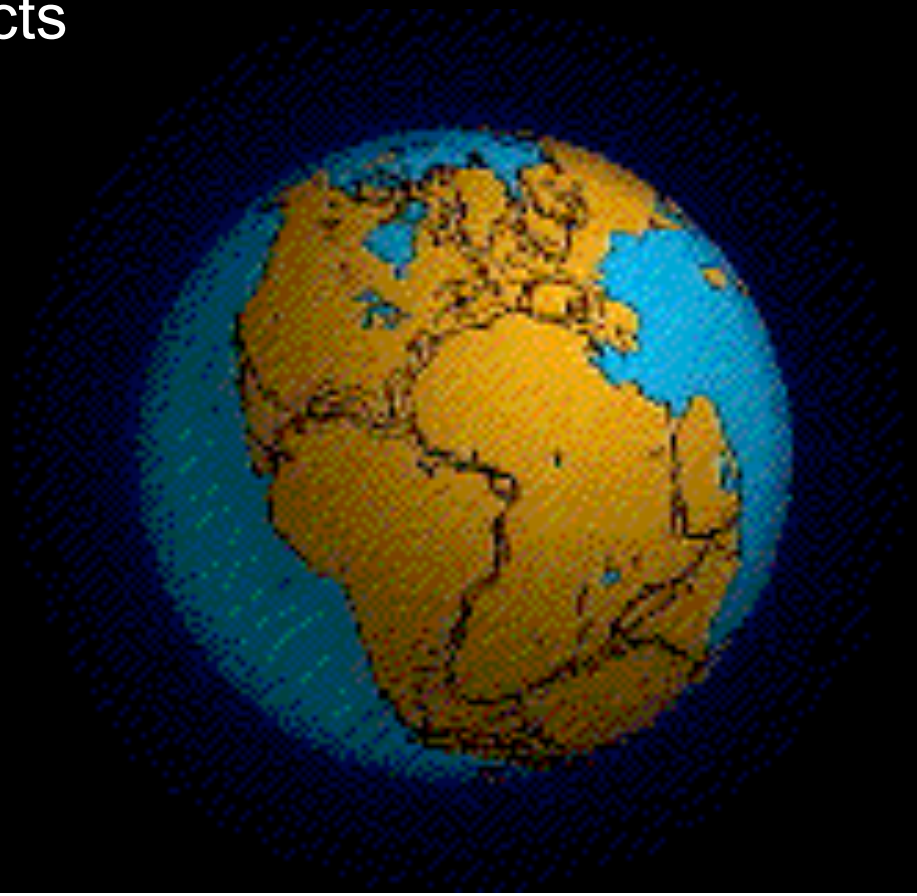
Geological Future: Continents will continue to move!

Position of continents affects
heating of Earth,
interaction of species,
can cause extinctions,
but not usually mass
extinction…..



Will Continents Move As Much?

- Note that as Earth cools, its internal energy diminishes
- Would we therefore expect weaker plate tectonics, hence less continent movement?
- Would this reduce an evolutionary driver?

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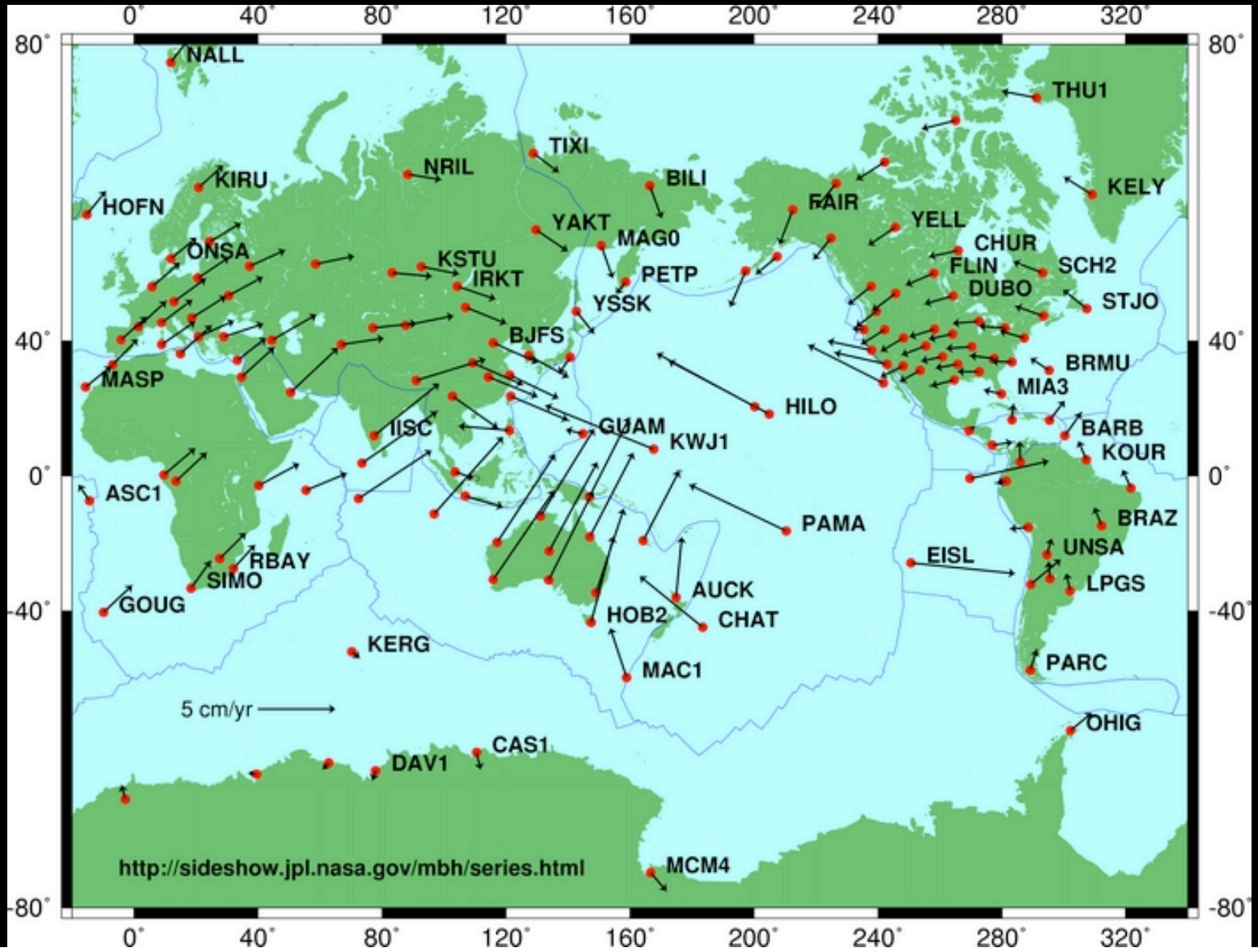

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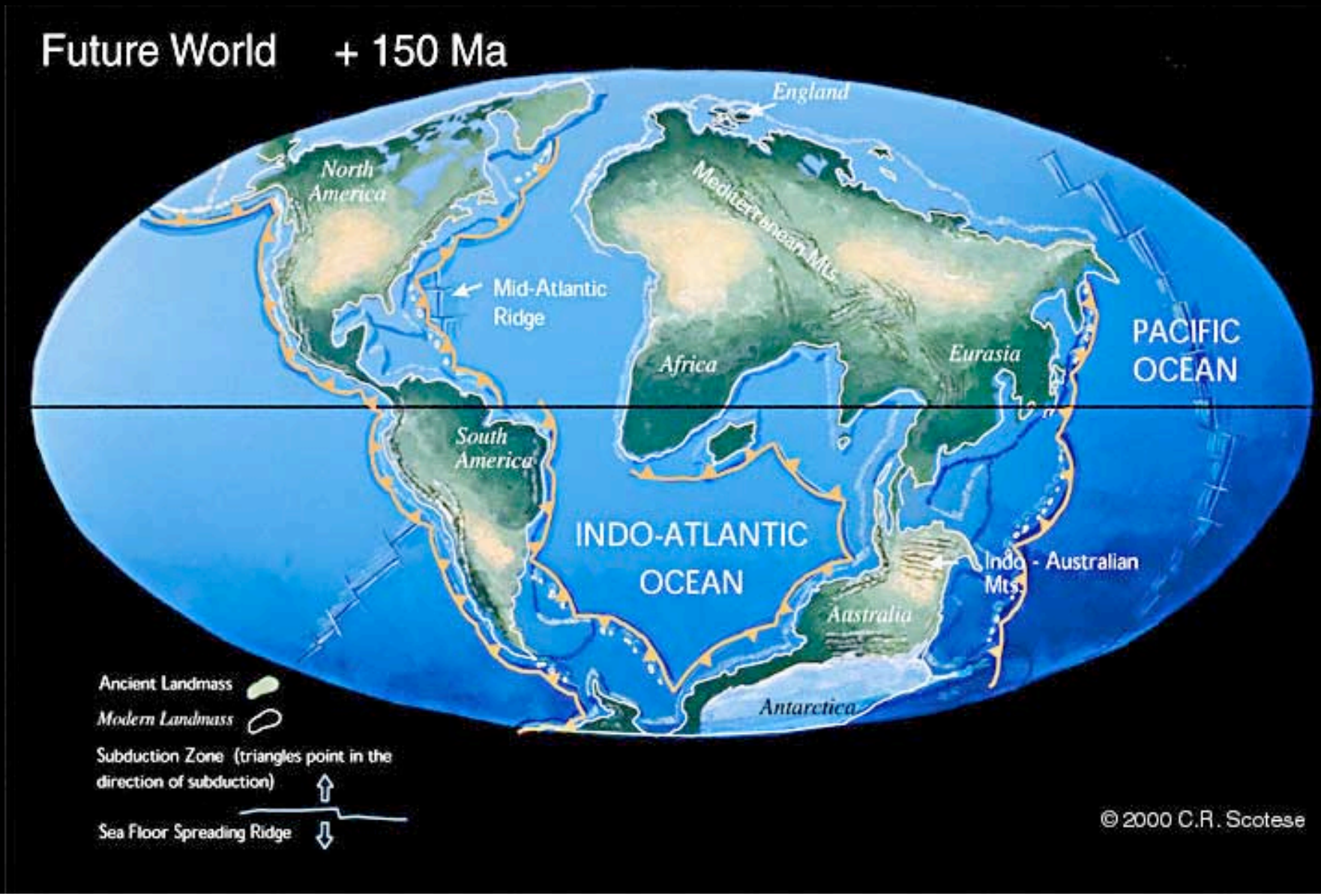


What if we vanished?

- What is our impact on Earth?
- One device to tell: imagine that every human on Earth suddenly vanished
- How long would our structures survive? How long could aliens tell of our presence?
- How would animals and plants respond?

Days to Weeks after Vanishing

- Blackouts due to failure of power stations
- Nuclear plant meltdowns

http://www.lazyenvironmentalist.com/earth%20at%20night.jpg

http://www.ohiocitizen.org/campaigns/electric/2004/ph_three_mile_island500.jpg

Days to Weeks after Vanishing

- Flooding of cities with high groundwater
- Decay of garbage; disease

http://www.eartheconomics.org/projects/HurricaneKatrina/images/large/NewOrleansFlooding.jpg

Months to Years after Vanishing

- Freeze/thaw cycle causes cracking of pavement, buildings
- Exacerbated by plant growth

http://farm4.static.flickr.com/3266/2700573492_ee11c53d1c.jpg?v=0

Example: Angkor Wat

- "Lost" city in Cambodia; capital city of Suryavarman II
- Not active after 1431
- Rapidly overcome by jungle
- Now restored, and national landmark

http://kupukupu73.files.wordpress.com/2009/09/angkor-wat-ruins.jpg

Months to Years after Vanishing

- Buildup of uncollected twigs and leaves in city parks
- Lightning strikes could produce uncontrolled fires
- All wooden buildings destroyed

http://www.wolfkiller.net/Chicago/GreatChicagoFire.JPG

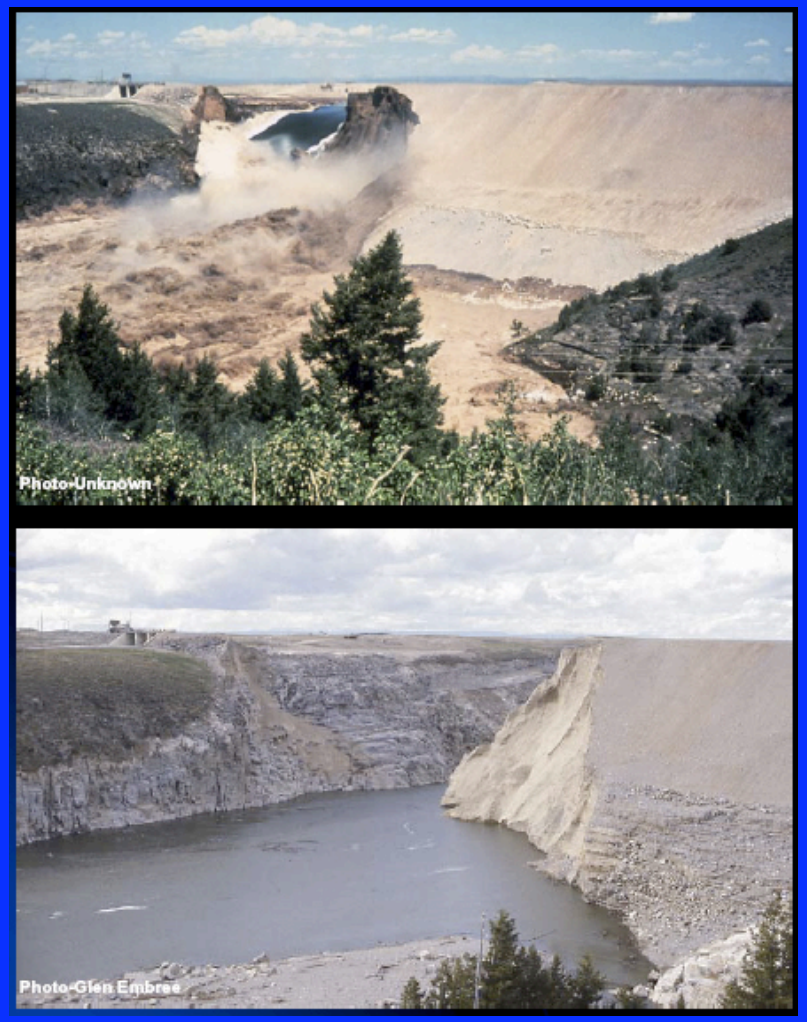
Decades to Centuries after Vanishing

- Skyscrapers anchored in bedrock, but...
- Water corrodes steel beams, streets tilted
- Skyscrapers topple, bring others with them

http://www.ronsaari.com/stockImages/chicago/chicagoSkyline.jpg

Decades to Centuries after Vanishing

- Bridges and dams fail within decades
- Designed to last centuries, but only with maintenance



http://www.searchanddiscovery.com/documents/2005/millard/images/02.jpg

10^3 to 10^6 Years after Vanishing

- Last remaining buildings: stone in dry environments: pyramids 5,000 yr!
- Ice ages would wipe out Northern cities
- Gold, diamonds still fine in this time

http://www.traveladventures.org/continents/africa/images/pyramids3.jpg

10^3 to 10^6 Years after Vanishing

- Our toxic residue dissipates
- Lead in soil (20th century cars) out after 30,000 years
- CO_2 excess out after 20,000 years
- But some plastics such as PVC going strong...

http://blog.lib.umn.edu/evans391/architecture/Garbage_landfill.jpg

Billions of Years after Vanishing

- Most traces gone
- Tectonics reshape Earth, bury remnants
- But satellites still orbit
  Destroyed near Earth, but okay around Mars
- Aliens might think that we evolved on Mars!

http://www.impactlab.com/wp-content/uploads/2008/04/space-debris.jpg

Effect on Animals: The Winners

- Most animals would benefit
- Birds: not breaking necks into buildings! Nesting in skyscrapers
- Mosquitoes: swampy NY, DC
- House cats would become wonderful predators

http://i.pbase.com/u13/petalumadogman/upload/11106749.birdatnightonwindowledge.jpg

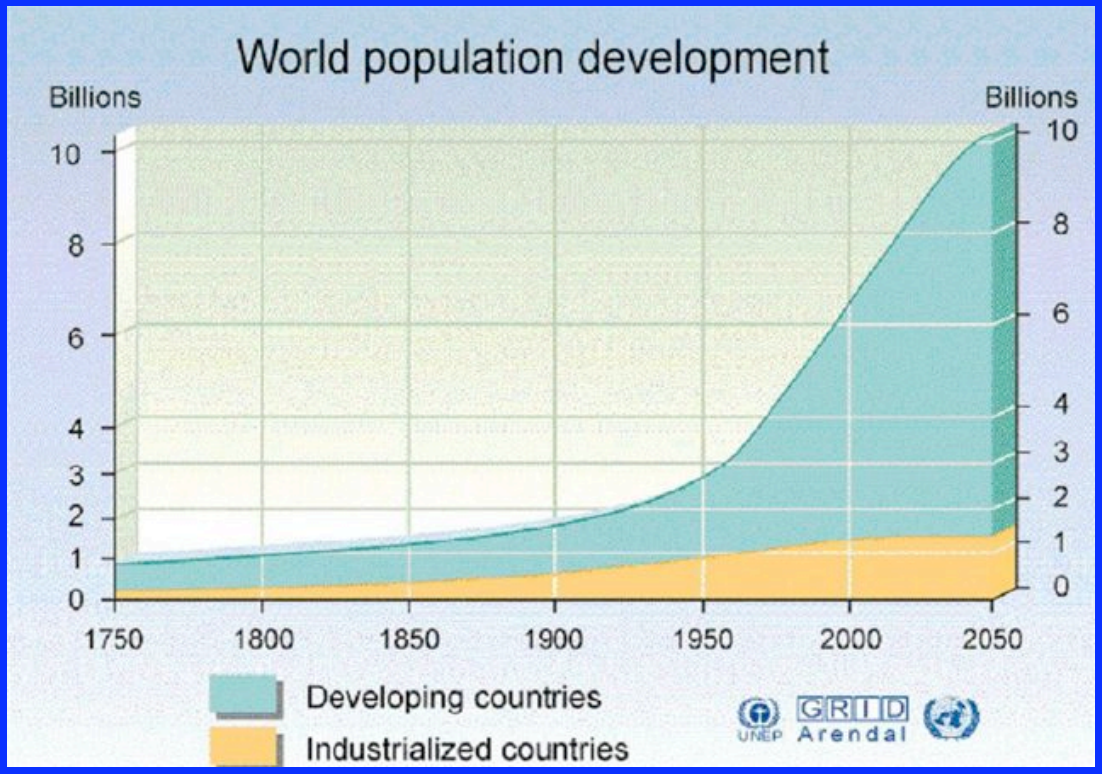
Effect on Animals: The Losers

- Domestic cattle: steak on the hoof for wolves, mountain lions!
- Rats: starve without garbage, eaten by birds
- Cockroaches: no more warmth in winter
- Some endangered birds die without our help

http://www.dkimages.com/discover/previews/754/433723.JPG

Exponential Growth

- Now, future with humans
- Critical fact: exponential growth of population will always dominate
- 1.2% annual growth? By year 2800, 17 trillion people



http://japanfocus.org/images/UserFiles/Image/2456.asahi.jasglobalcontributor/World%20Population%20Growth%20to%202050.JPG

Exponential Growth: "Law of 70"

- Previously, when we considered exponential growth we always used doubling times
- Here, we have another issue: annual growth level is some number of percent; how does this work?
- Simple rule: "Law of 70", which says that if you have growth of x% in some time T, then you will take about (70/x) times T to double
  Example: 1% per year means doubling in 70 yrs
- Also useful: 2^{10} is about 10^3
- I recommend practicing with your calculator

A Comment: Limits on Growth

- Population growth is a tremendous long-term problem for humanity
- And yet, when you point this out to people, they often shrug it off; new resources always available, or maybe we can leave this planet and find more
- In addition, it is ridiculous to imagine unlimited growth of population, so something will intervene
- What is wrong with these perspectives?

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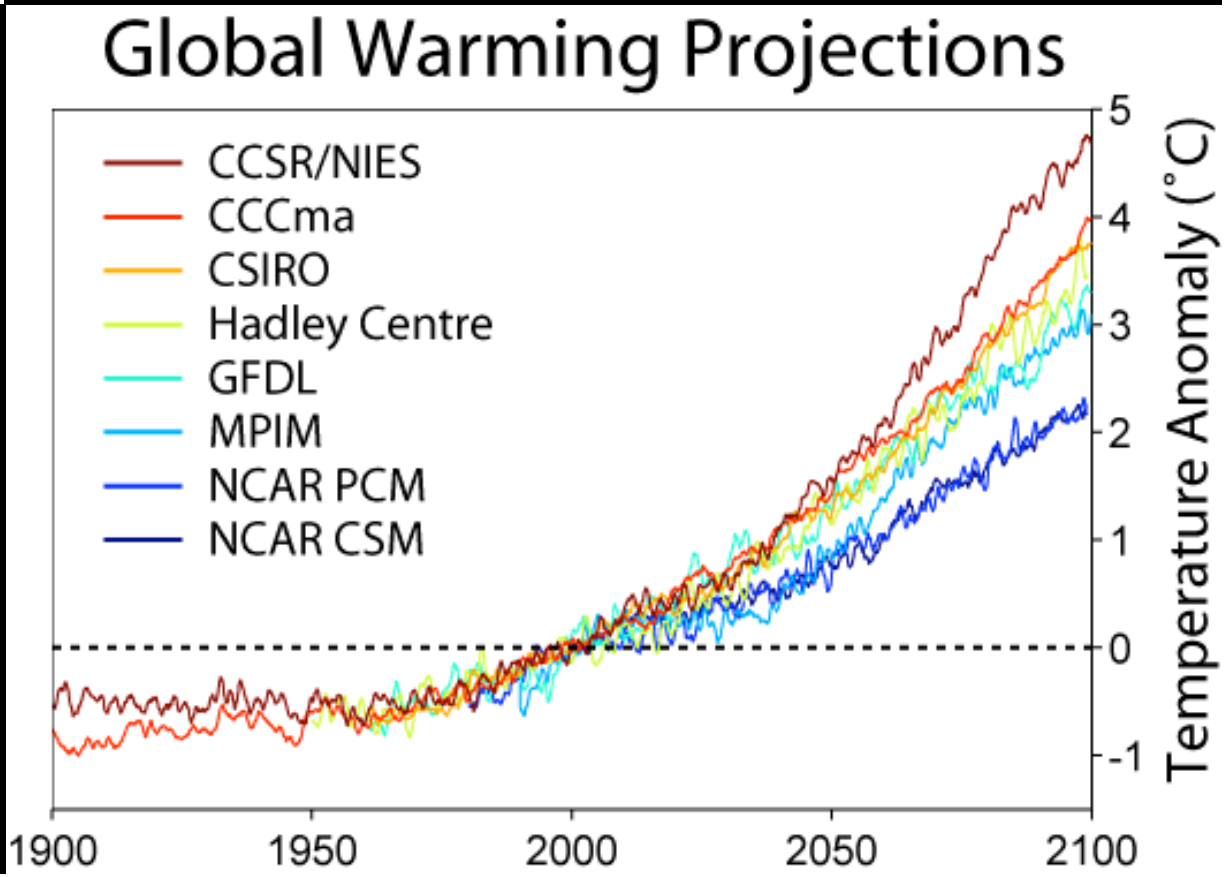
Near-term changes:

Global warming….

Heat, melting ice…

Rising sea level



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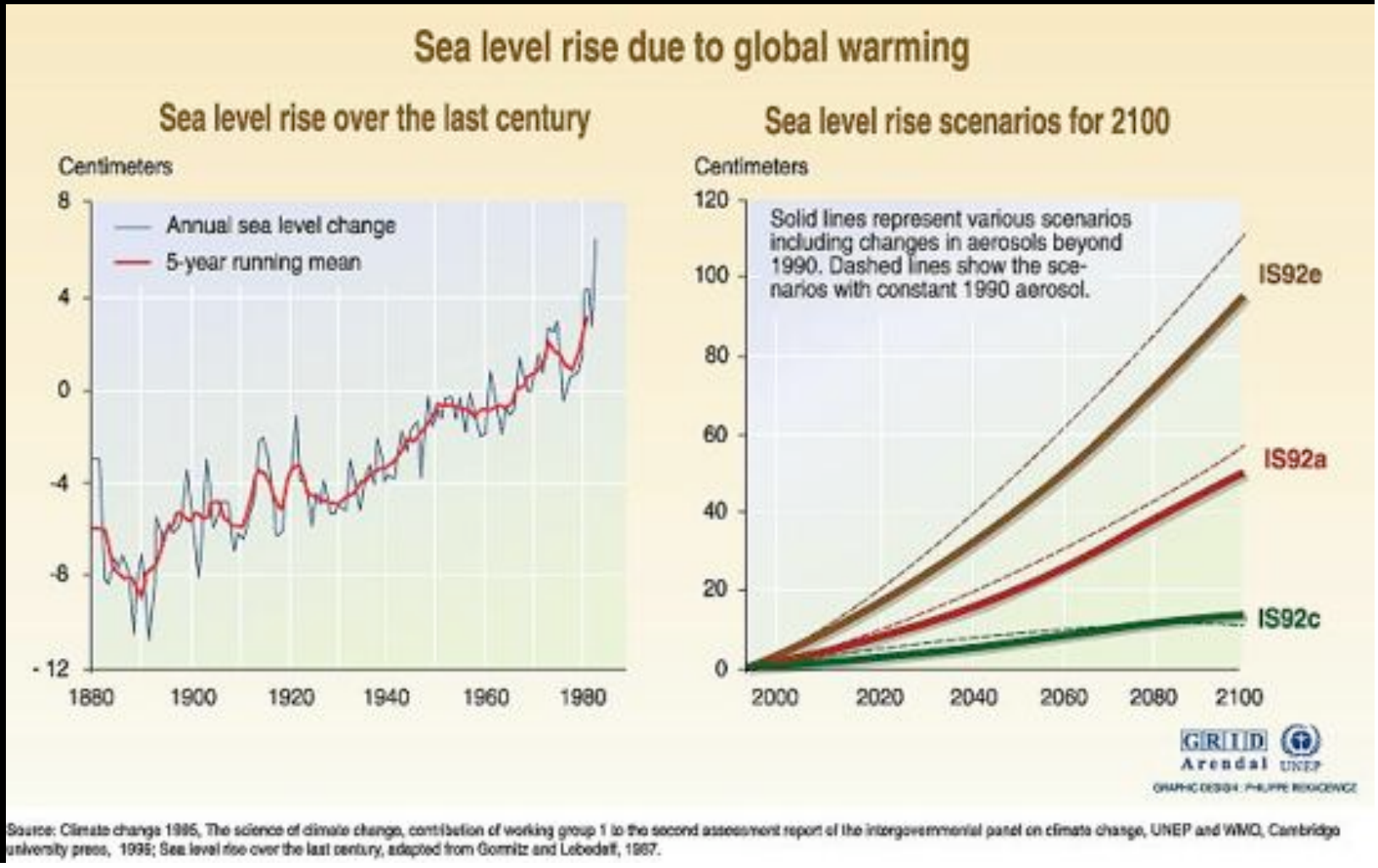
Global warming… sea level rising.



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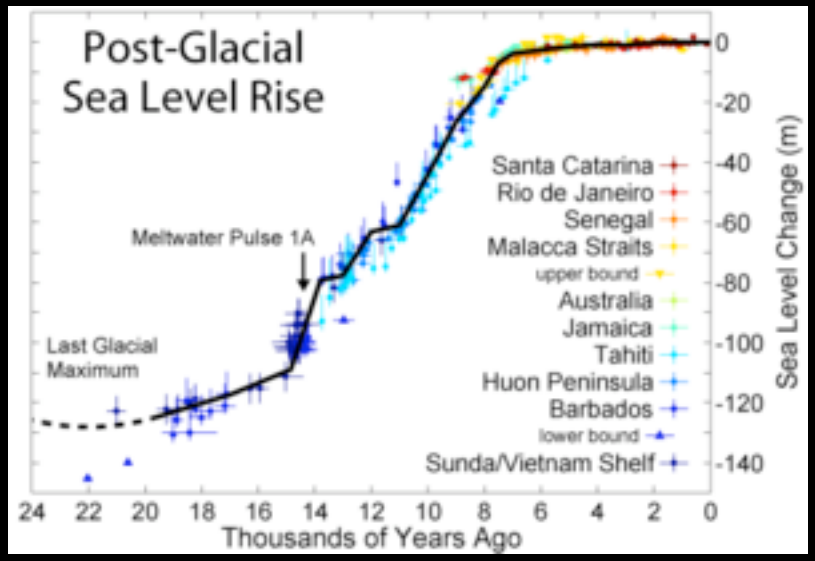
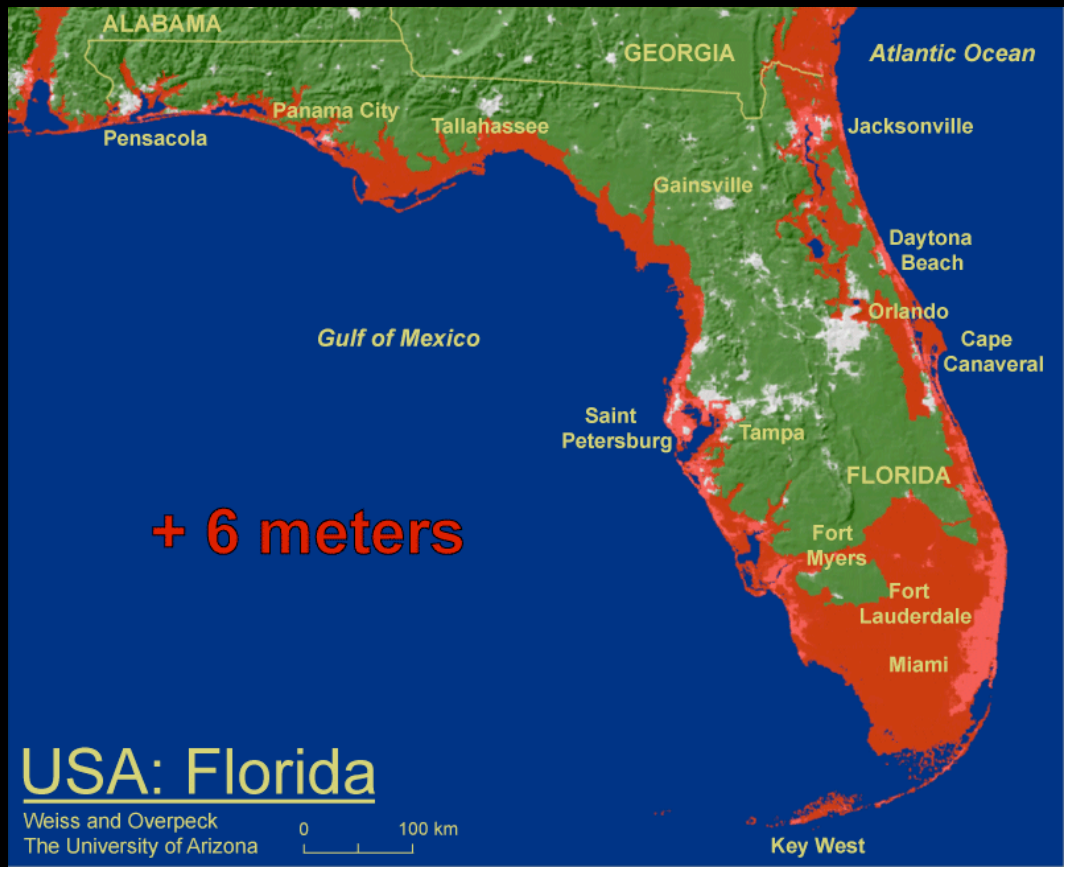
Global warming… sea level rising.

Melting all ice in Greenland would add 7.2 meters to sea level

Melting all ice in Antarctic adds 70 meters!!!





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Global warming… sea level rising…

All of this changes human habitation. May cause wars. Causes widespread suffering…. Over the next 100-500 years…..

But it is unlikely to challenge human domination of the world.

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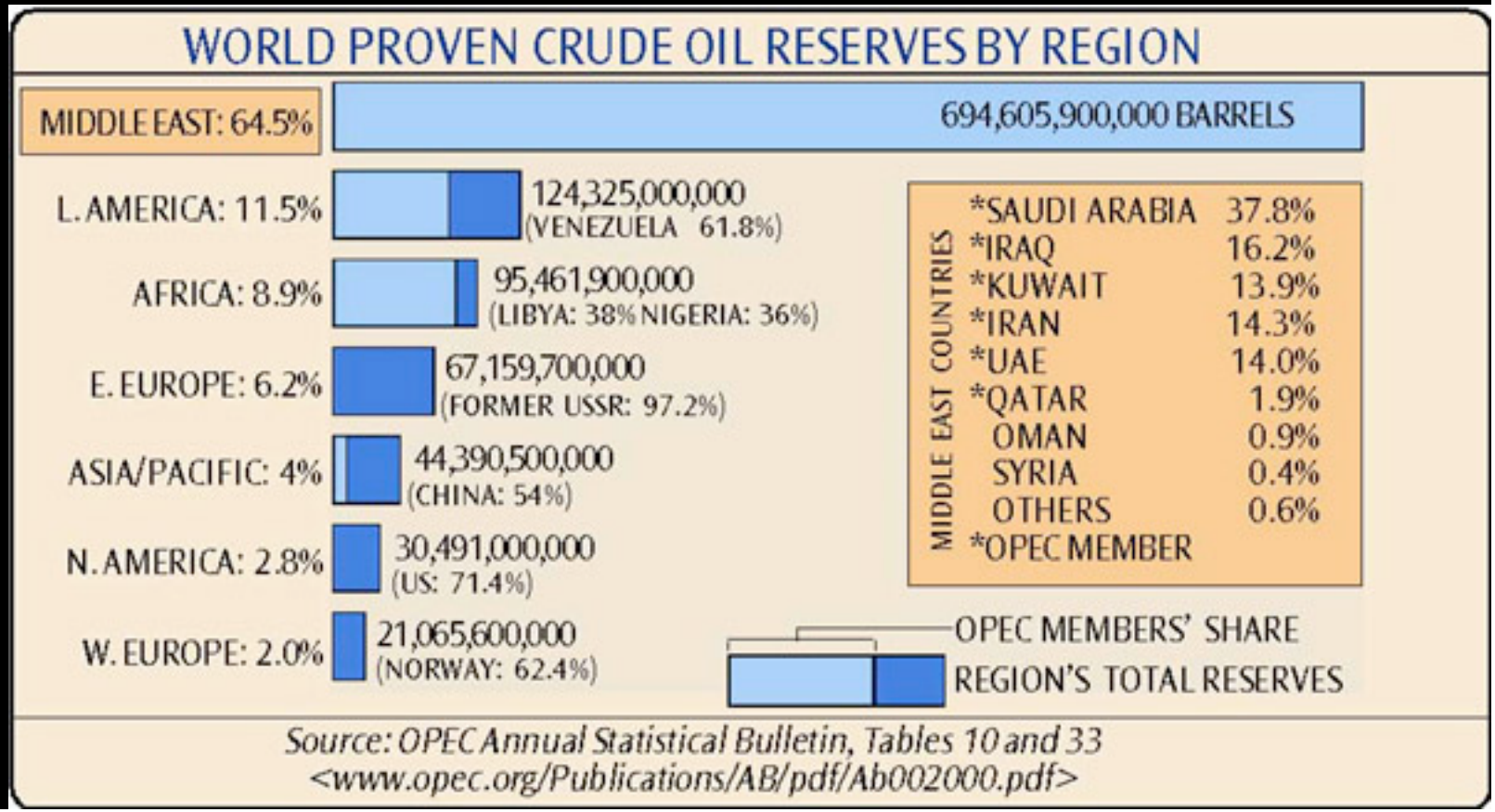
Near-term changes:

Depletion of Energy Resources….



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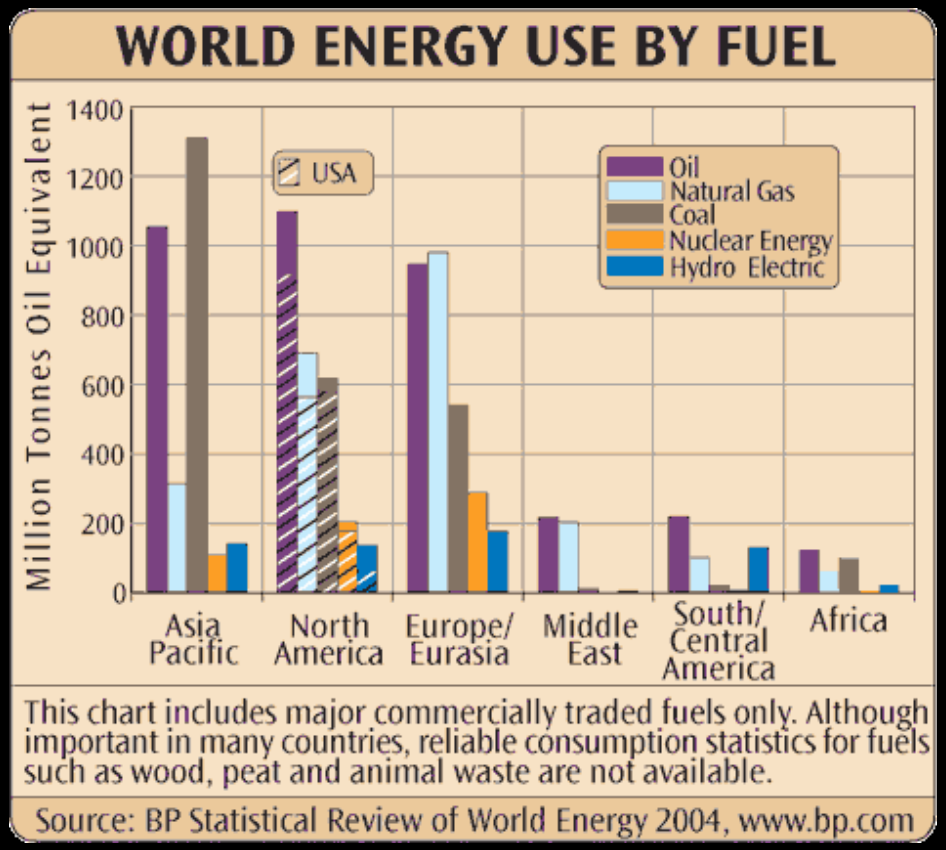
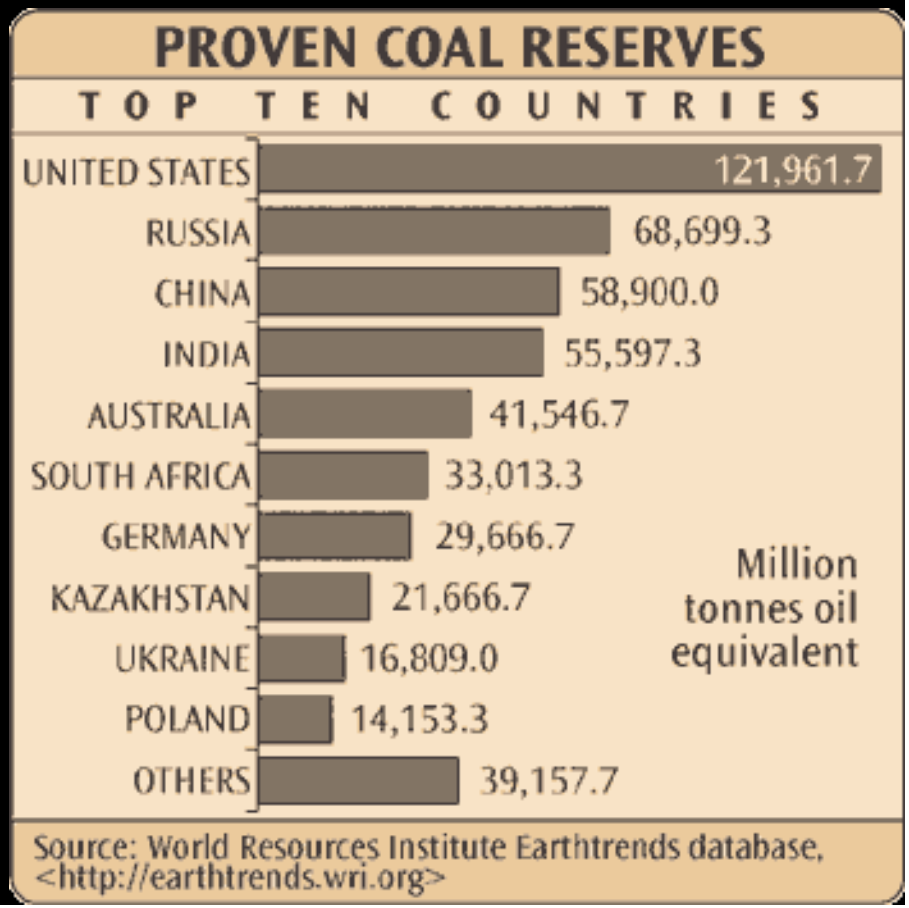
Depletion of Energy Resources….





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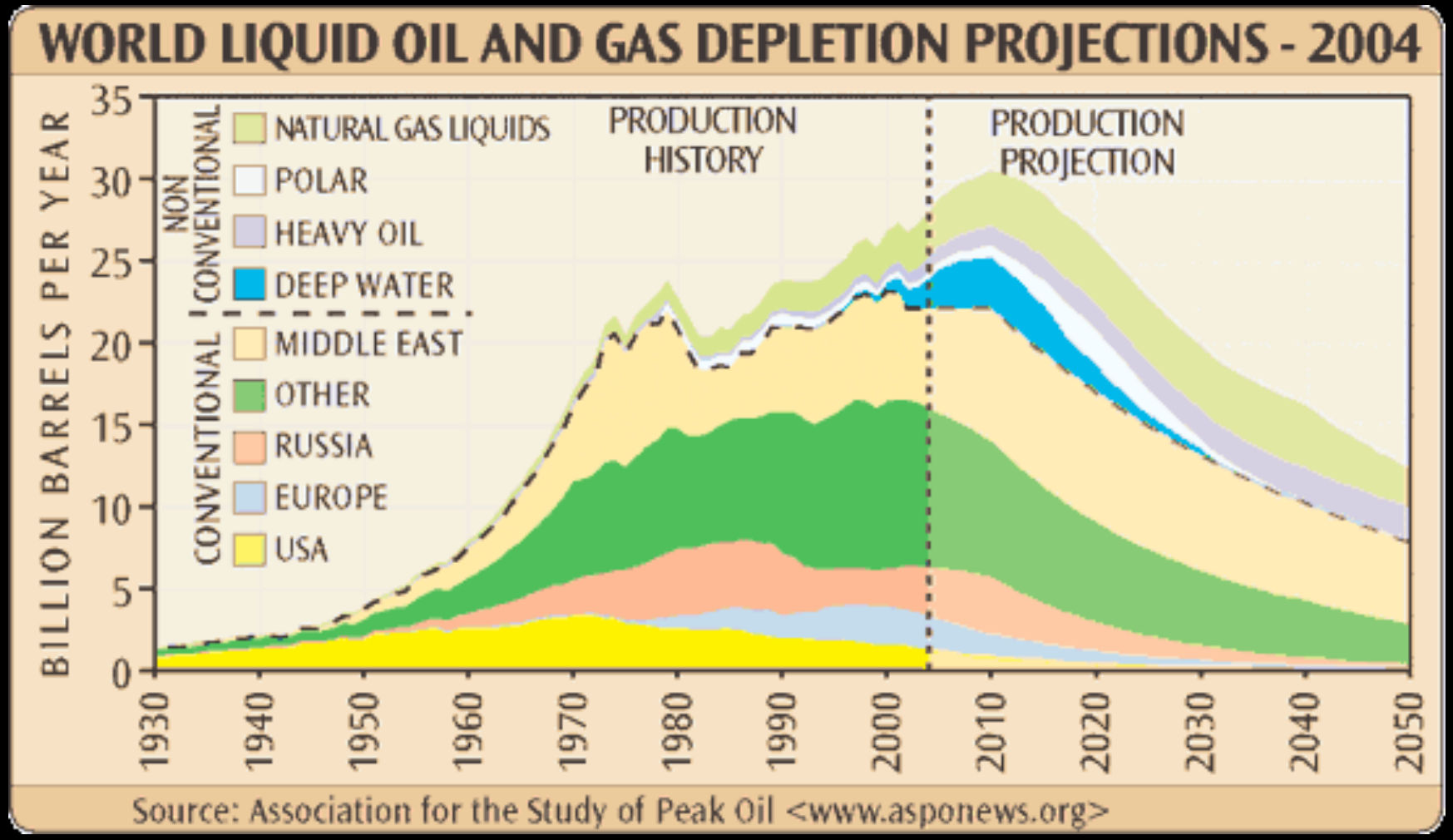
Depletion of Energy Resources….



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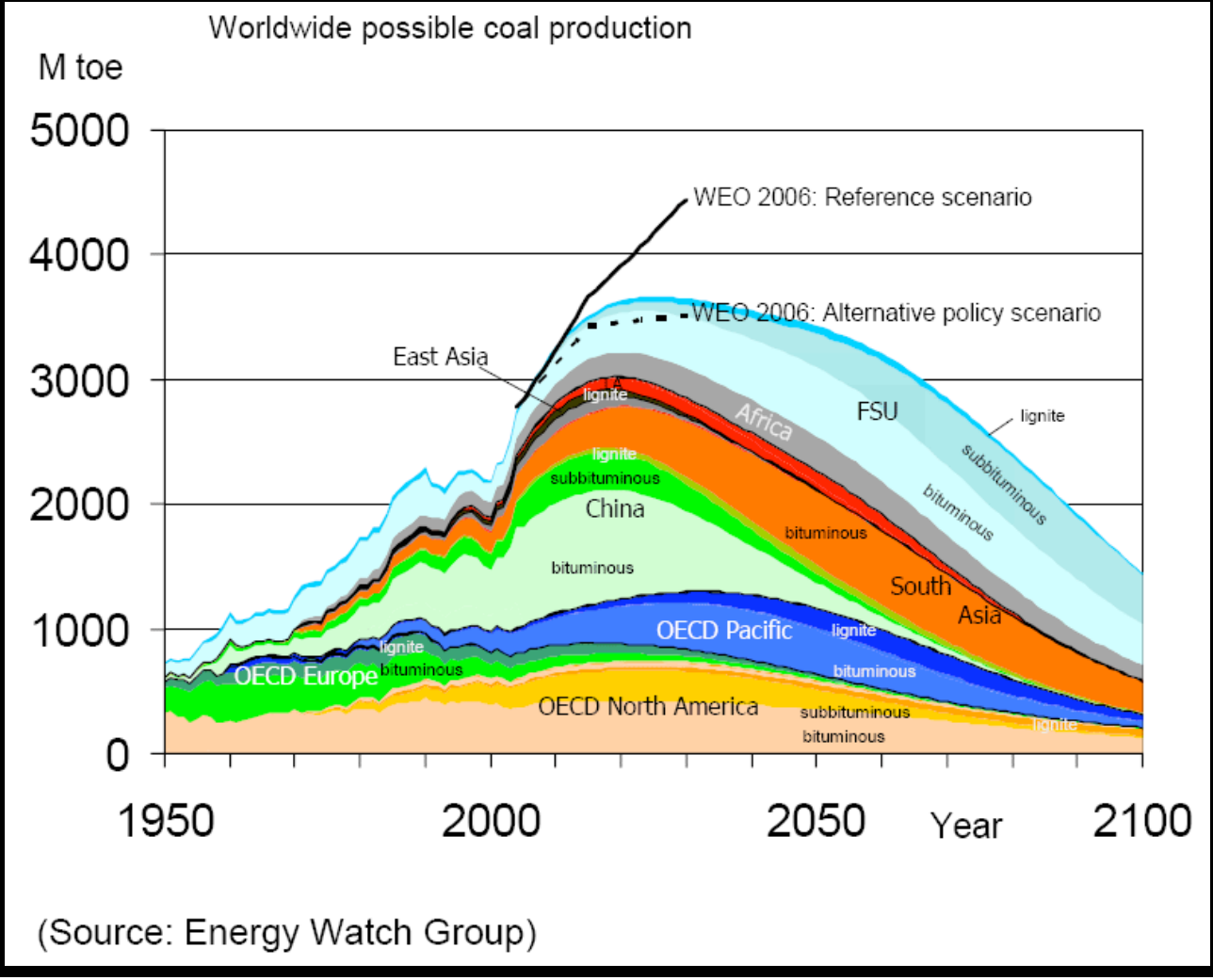
Depletion of Energy Resources….



(Source: Energy Watch Group)

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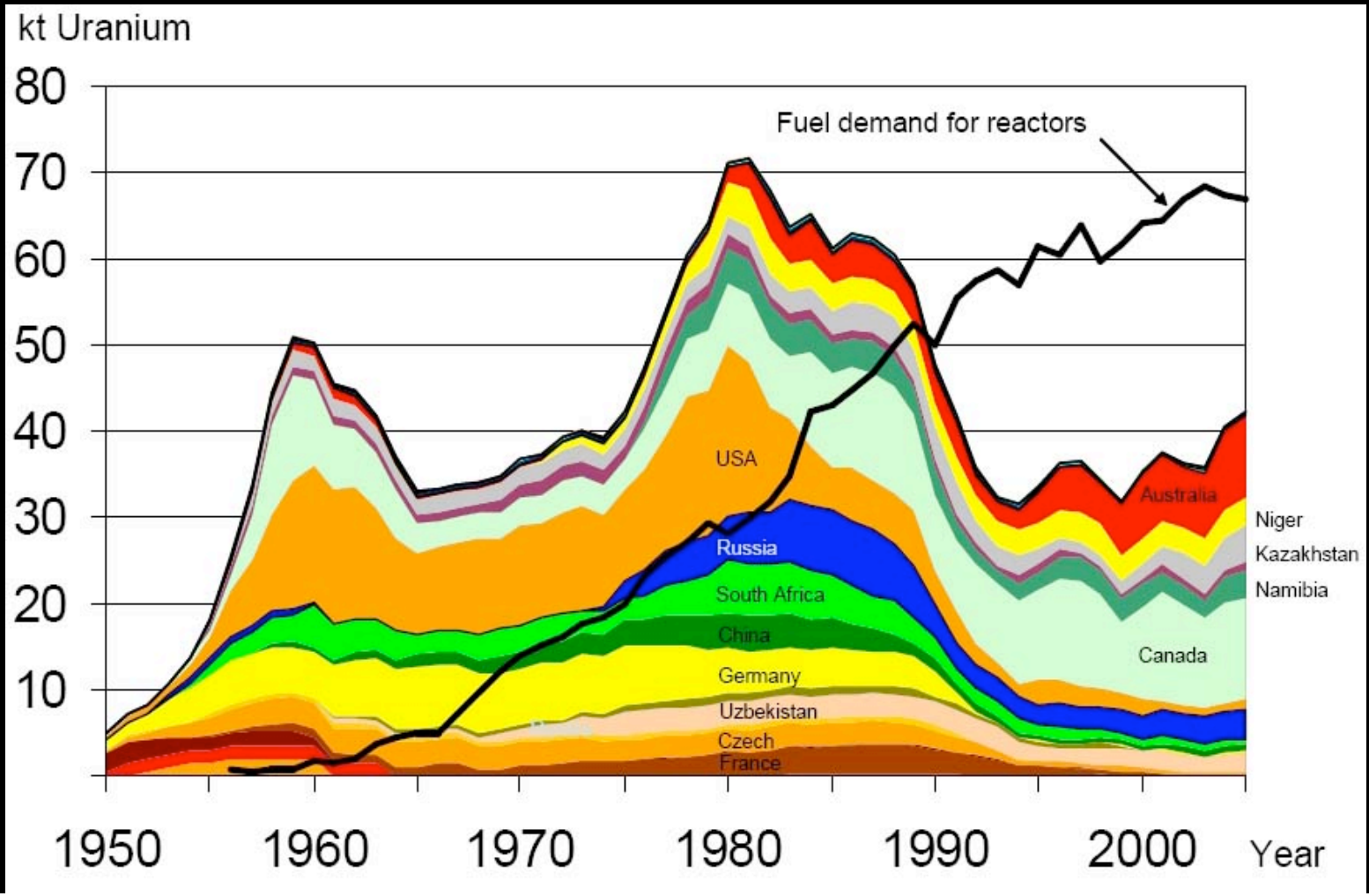
Depletion of Energy Resources….



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Depletion of energy resources….

Current usage estimate: 0.5 zetta Joules (5 x 10^{20} Joules)

Estimated reserves:

fossil fuels: 400 Z-Joules (90% coal)

uranium: 2,500 Z-Joules

We are beginning to feel the costs of limited oil resources. 100 – 200 years for fossil fuels. 1000 years for uranium?

Fusion energy pushes out for many 1000's of year… if it is possible to do with a good energy yield.

Existing energy resources will be depleted.

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Renewable Energy:

Current energy consumption corresponds to 0.01% of the solar energy hitting the Earth.

Solar cells, wind, bio-fuels, and hydroelectric are the main sources of renewable energy.

How will their primary usage change society?

Will there be abundant energy or simply adequate energy?

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Survival of life versus survival of a technological society

Will the Earth have a society engaged in space travel in 1,000 years? 5,000 years? 30,000 years?

Will we continue to develop technology?

If no to both of the above, what are the implications for the possibilities of knowing if other life exists?

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Natural evolution to where?

Genetic evolution of humans will continue.

On the timescale of thousands of generations we will change….

Perhaps on the timescale of decades we will be capable of, and doing, genetic engineering on ourselves…. Selecting for….. What?

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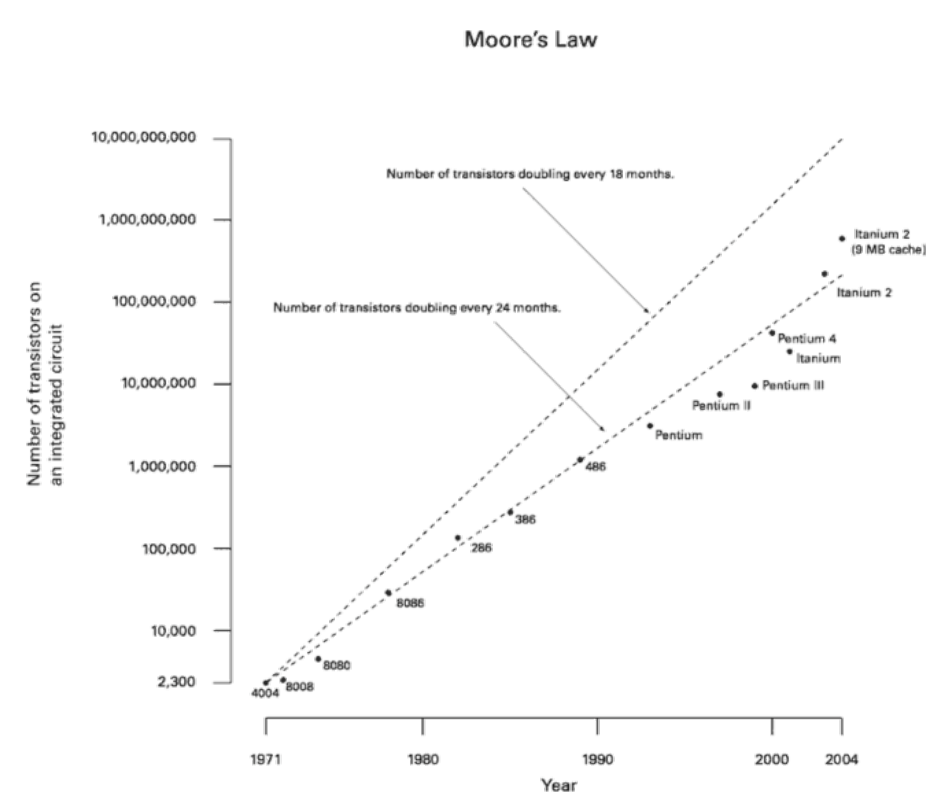
Technology driven evolution to where?

Will computer technology continue at its current rate?

If computer capability doubles every 2 years, in 20 years --- computers will be 1000 times more capable…

Terabytes of RAM

Where could this lead?



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Homo Sapiens have existed for around 250,000 years….

The genus Homo stretches back 2 million years.

In the natural course of evolution, we could easily exist for another few 100,000 years. And evolve into….

Is there a possible event other than a major impact that could end the human linage?

Summary

- Humans have major impact
- Our population growth and desire for resources is causing problems
- Can we break cycle and become self-sustaining?
- Can any technologically advanced civilization do this?