Topic 22: Anthropogenic Changes and the Atmosphere

homework 8 online

short video 18 Ozone Hole

test 8: next Monday; includes questions for HW6!

upcoming: please participate in UCSD course review

"It is DIFFICULT to get a man to understand something when his SALARY depends upon his NOT UNDERSTANDING IT."
Upton Sinclair

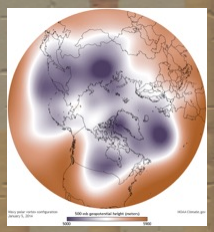
Changes in the Atmosphere – T, GHGs

2015, in the press:
last 13 years all were among 14 hottest ever recorded

2023 hottest recorded year

consequence of global warming:
- uneven warming
- more extreme weather

Anomalous Polar Vortex
-> extreme cold storms



CO_2 Mauna Loa June:

2024: 426.9 ppm

2017 CO_2 increasing even though emission stayed flat
-> point of no return??

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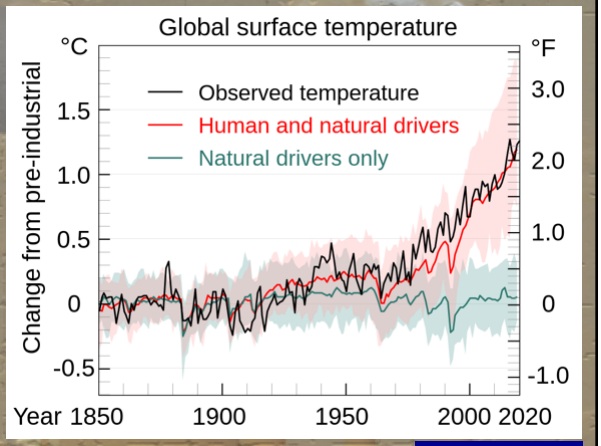
The Global Temperature

this implies that we are beyond the 1.2 °C increase compared to pre-industrial age

dramatic increase in rate of warming since 2010!

Most of this is anthropogenic (most is fossil fuels burning)



source: wikipedia

Nov 2023: temporarily passed +2.0°C

2023: most significant natural driver is El Niño (+0.7°C?)
ONLY TEMPORARY!

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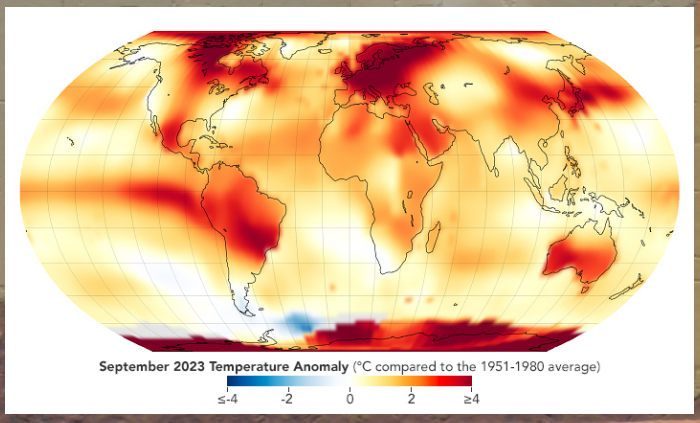
Hot Off the Press 11/20/24

NASA:
2023 hottest recorded year
but 2024 Jun - Aug topped that

potential natural causes for 2024
- El Niño – NO El Niño!
- Hunga-Tonga 2022 (cooling!)
- reduced air pollution – debated
- sun spots cycle? NOT YET
- increase in GHGs (feedback!)



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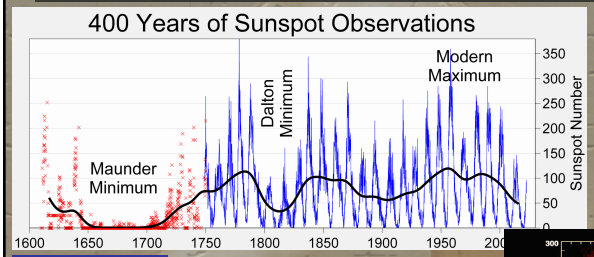
https://earthobservatory.nasa.gov

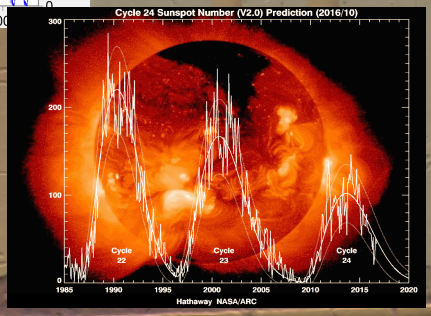
Sunspot Cycle

- 11-year cycle
- changes in solar activity (solar flares; coronal mass ejections)



source: wikipedia

partially EXPLAINS: cooling trend in 1970s

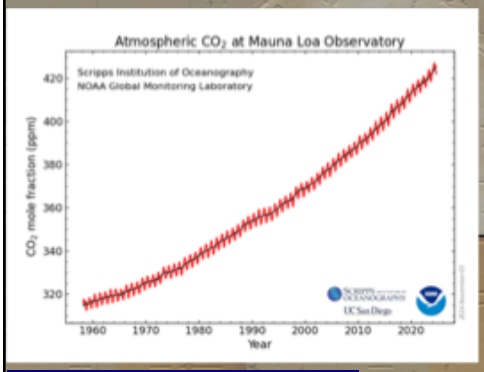


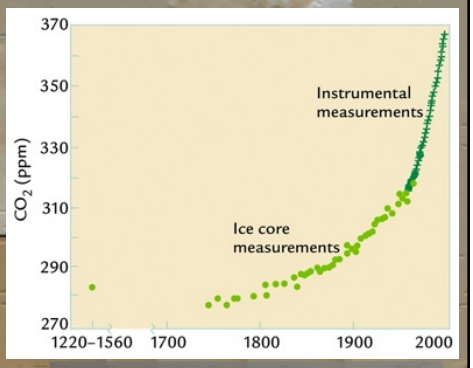
FAILS to explain: warm years in last 20 years
+ will add to T in next 5 years

CO_2 – The Keeling Curve

measures atm. CO_2 at Mauna Loa since 1958
recent CO_2 increase dramatic!

"how do we know it's us?"





https://www.esrl.noaa.gov/gmd/ccgg/trends/

Anthropogenic emissions have increased exponentially

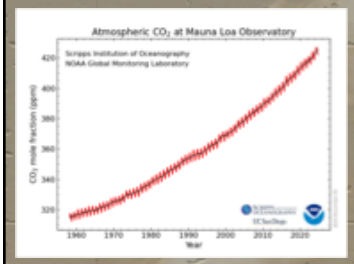
increase from 280 to 420+ ppm in 150 years (50%) ("hockey stick")
CO_2 is greenhouse gas
climate changes can happen rapidly! (over few decades/years)

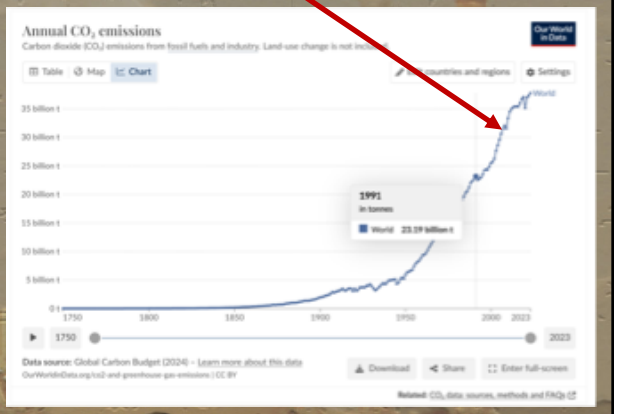
1997 Kyoto Protocol

to stabilize CO_2 at 450 ppm
emissions must fall to levels of 1990 by 2012

this would have given us a 1.5°C increase by 2100

… from pre-industrial levels





we missed that target!

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1997 Kyoto Protocol

1997: to stabilize CO_2 at 450 ppm
emissions must fall to levels of 1990 by 2012
- needed 55% of producers to be ratified
- 2004: ratified after Russia joined; in effect Feb 2005
- 2007: Australia joined leaving
U.S. only industrial country not to join
(has 5% of population but contributes with 25% CO_2)
- developing world allowed to catch up

this would have given us a 1.5°C increase by 2100

… from pre-industrial levels

needs a successor -> COPS since 2009

U.S.: "it hurts our economy"

green: agreed
light green: developing world
red: withdrawn
orange: no intention to ratify
grey: no position

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Post- Kyoto - 2015 Paris Agreement

2007: Inconvenient Truth; Al Gore, IPCC receive Nobel Peace Prize

2009: Copenhagen Accord:
- endorse continuation of Kyoto Protocol
- global increase in T should be less than 2°C (compared to pre-industrial)
- recognize CO_2 increase by deforestation
- U.S. at table for very first time

2°C is more than Kyoto Protocol

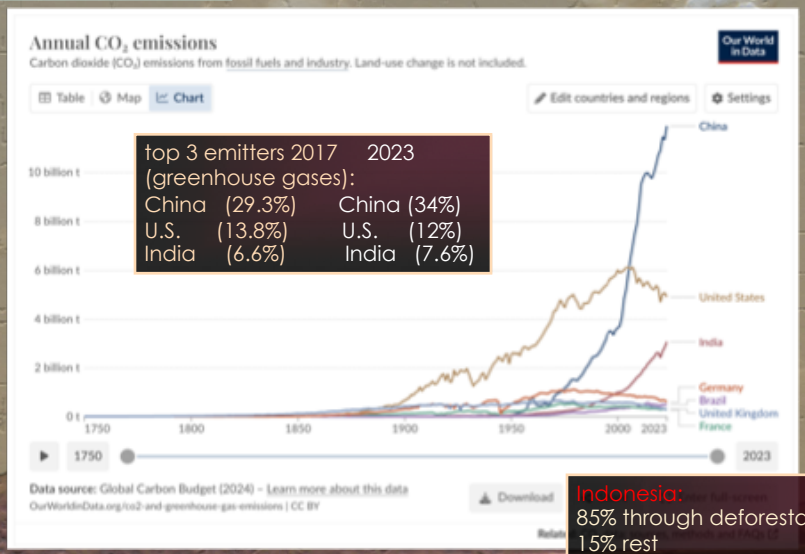
2015 Paris Agreement:
global increase in T should be well below 2°C/toward 1.5°C
193 parties signed; 110 ratified (10/16); in effect Nov 4, 2016
*** China on board ***
For the very first time, U.S. is on board….. until 2017

BIGGEST ISSUES:
- verification that countries fulfill reduction
- doesn't go as far as the Kyoto Protocol
- different countries have different commitments
- U.S. administration 2016-2020 …. 2021+??
- Current pledge falls short of 2°C goal

yearly COP meetings
(conference of the parties)
2024: COP29 in Baku

In the Meantime – Global CO2 Emissions

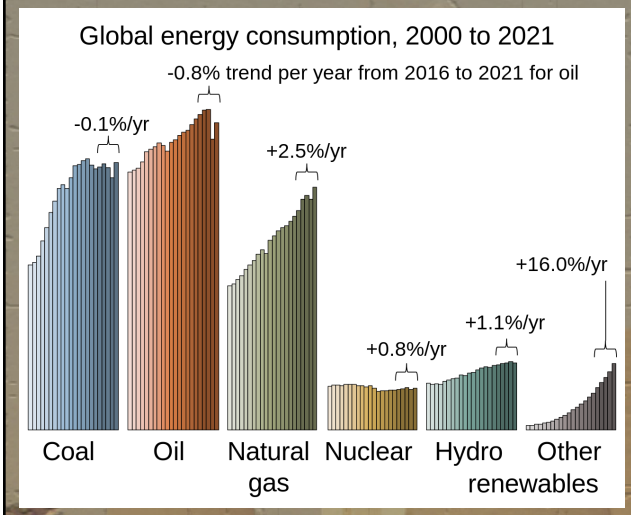
China surpassed USA as top emitter in 2009



top 3 emitters 2017 2023 (greenhouse gases):
China (29.3%) China (34%)
U.S. (13.8%) U.S. (12%)
India (6.6%) India (7.6%)

Indonesia:
85% through deforestation
15% rest
3 overall; #6 by fossil fuels

Anthropogenic CO_2



source: wikipedia

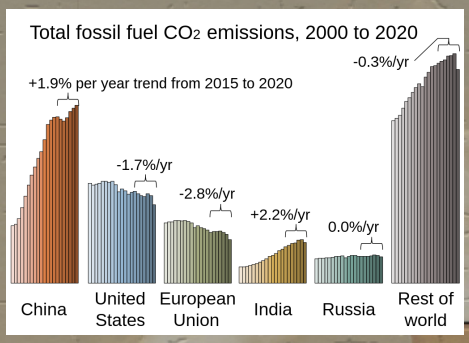
2024: update pending

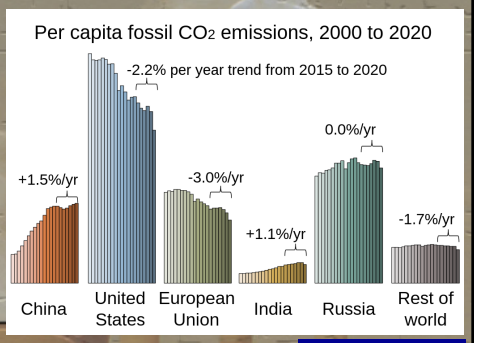
- coal has plateaued (CO_2, SO_2, Mercury)
- natural gas 'exploding' (Europe)

-> "cleaner burning than coal" (but still CO_2, CH_4)

- COVID hiatus/ 2021 increase

Anthropogenic CO_2

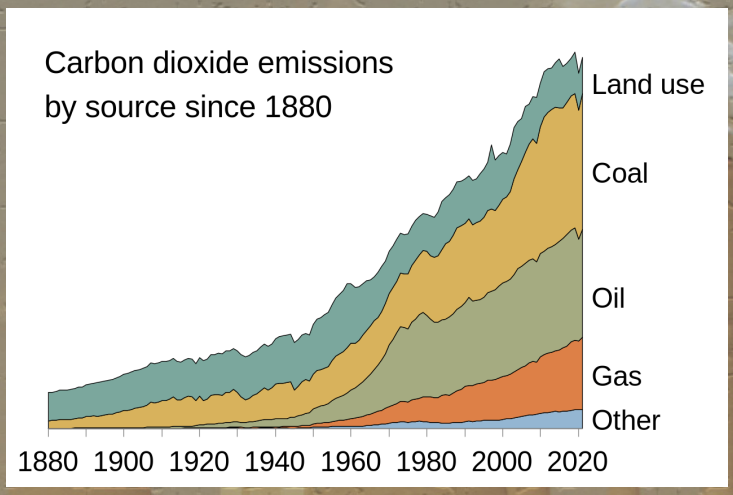




source: wikipedia

- China's explosive increase in coal … initially

Anthropogenic CO_2 – Plateaued 2010s??



2017 CO_2 increasing even though emission stayed flat

residence times:
CH_4 ~ 15 years
CO_2 >> 100 years

source: wikipedia/ 2021 global carbon budget

Global Carbon Project

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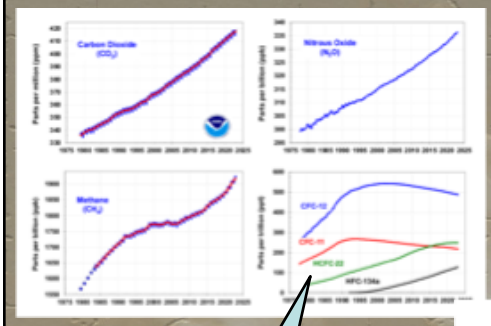
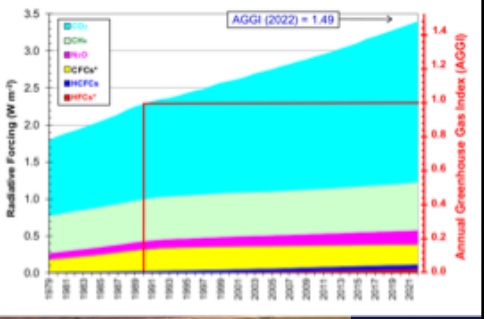
Why still Concentrate on Reducing CO_2?



Greenhouse Gases
- CO_2, CH_4, NxO, FCs increase
- radiative forcing of CO_2 increases most!

residence times:
CH_4 ~ 15 years
CO_2 >> 100 years

HFCs do not harm ozone layer but are greenhouse gases



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source: NOAA

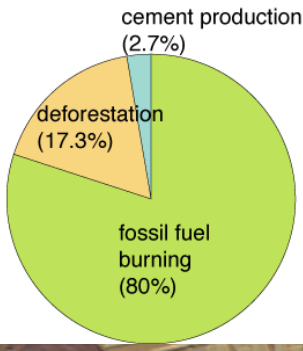
Anthropogenic CO_2

- fossil fuel burning
- deforestation
- cement production

- increase in fossil fuel due to oil/gas
- up to 2009: US contributes 25%
- China's explosive increase in coal

-> CO_2; SO_2; mercury

Human Induced Increase in CO_2

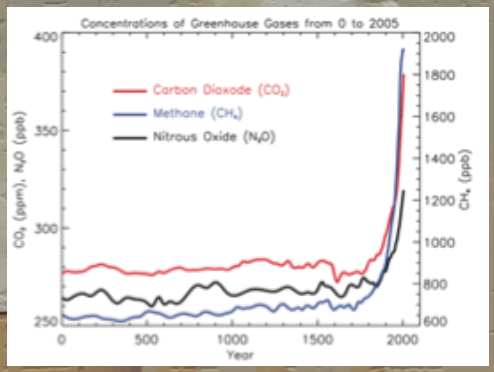


2023 top fossil fuel CO_2 emitters:
- China (34%)
- U.S. (12%)
- India (7.6%)
- EU (6.4%)
- Russia (5.3%)

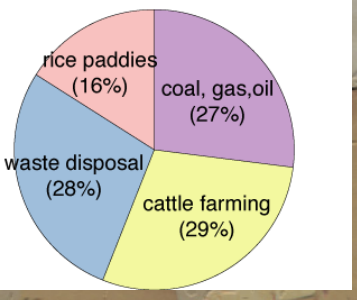
Indonesia #3 ? through deforestation (#6 without deforestation)

Anthropogenic CH_4

- fossil fuel mining/production
- cattle farming
- waste disposal
- rice paddies



Human Induced Increase in CH_4



- also increasing exponentially
- more effective at trapping heat
- short residence time in atmosphere

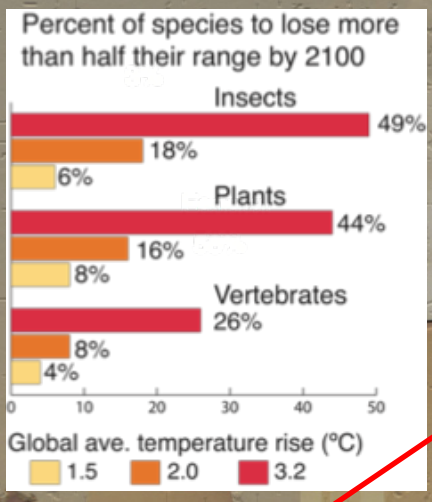
IPCC – Urgent Recommendation

2018: greenhouse emission must be reduced by 45% from 2010 levels by 2030, and 100% by 2050

Implications:
- electricity from coal (currently 40 %) must be reduced to 1-7 %
- renewable energy must increase (currently 20%) to 67 %

IPCC: Intergovernmental Panel on Climate Change

Global Warming - What about the Wildlife?



Science News Jun 2018

- 1.5°C higher than pre-industrial levels increasingly unlikely
- 2.0°C if EVERYBODY sticks with Paris agreement
- 3.2°C or more with even less than business as usual
- plants and insects (POLLINATORS!!) most affected

2018 IPCC report
food shortages, wildfires, coral mass die-offs
- 1.5°C likely reached by 2040 !!
- inundated coastlines, intensifying droughts, poverty
- mistake made earlier: predictions that these effects kick in with a 2.0°C increase by 2040

2024: reached earlier!

The Temperature in the Atmosphere

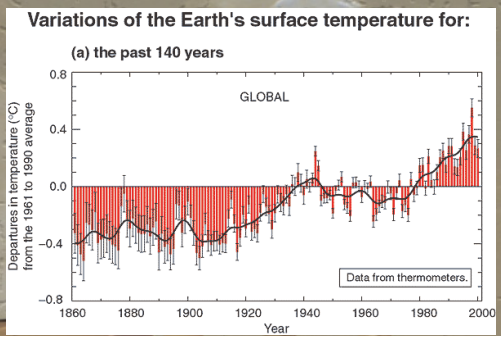
Temperature Increase

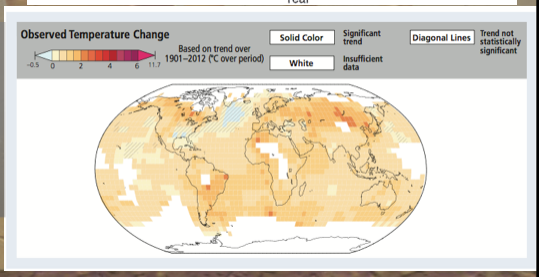
- by ~~almost~~ 1°C in last 140 yrs
- now reaches level of medieval warm period
- heating uneven

Reasons

- millennial warming? (< 0.02°C)
- solar warming (+ 0.2°C?)
- volcanism insignificant

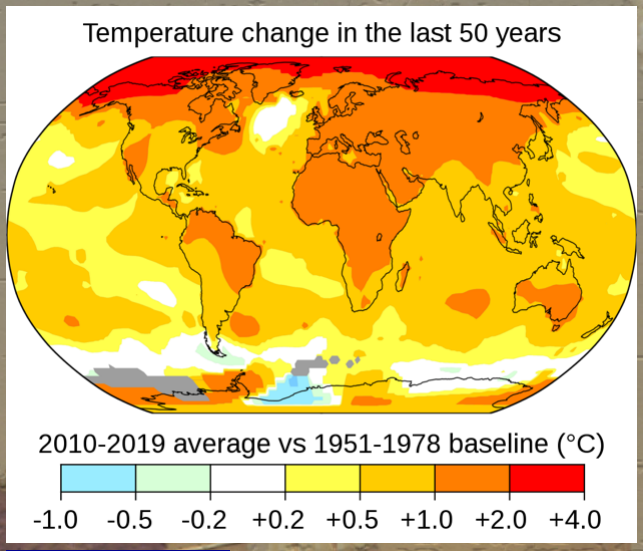
- anthropogenic CO_2 emission (> 0.8°C?)





source: IPCC 2014

The Temperature in the Atmosphere

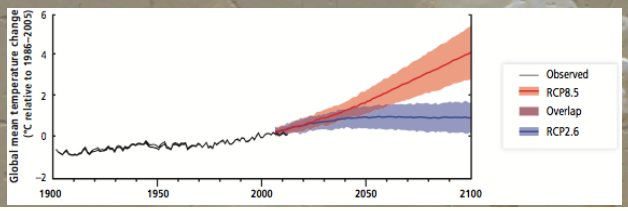


Fastest increase: High-latitude northern hemisphere

source: wikipedia/NASA

IPCC Report 2014: > 1800 pages

source: IPCC 2014



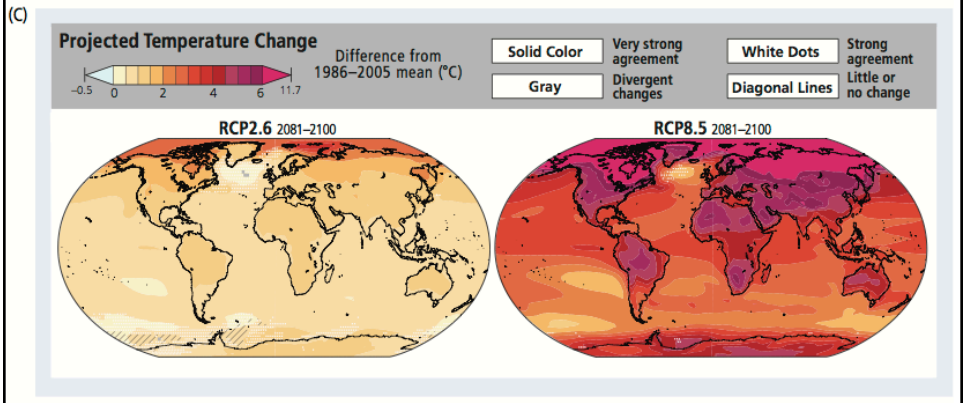
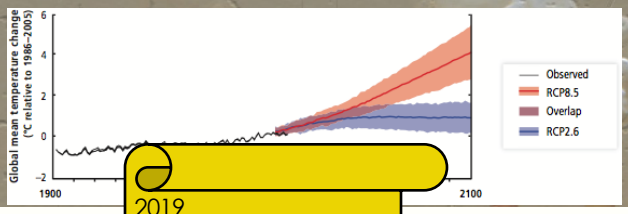


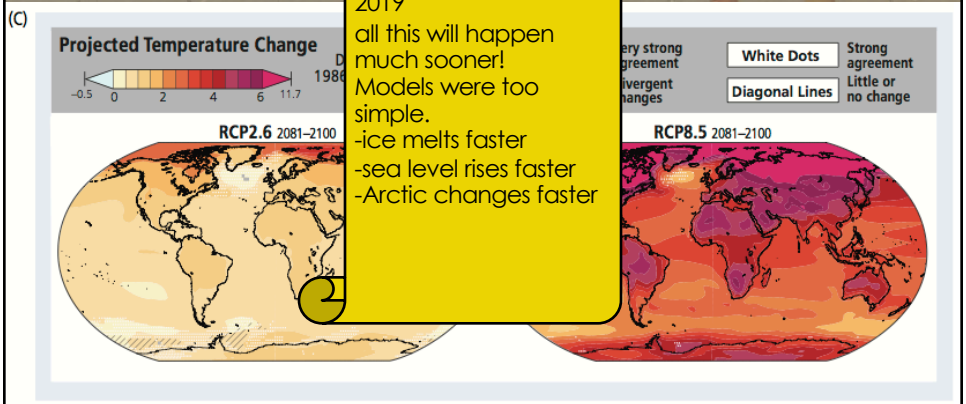
Figure SPM.4 | Observed and projected changes in annual average surface temperature. This figure informs understanding of climate-related risks in the WGII AR5. It illustrates temperature change observed to date and projected warming under continued high emissions and under ambitious mitigation.

IPCC Report 2014: > 1800 pages

source: IPCC 2014



2019
all this will happen much sooner!
Models were too simple.
-ice melts faster
-sea level rises faster
-Arctic changes faster



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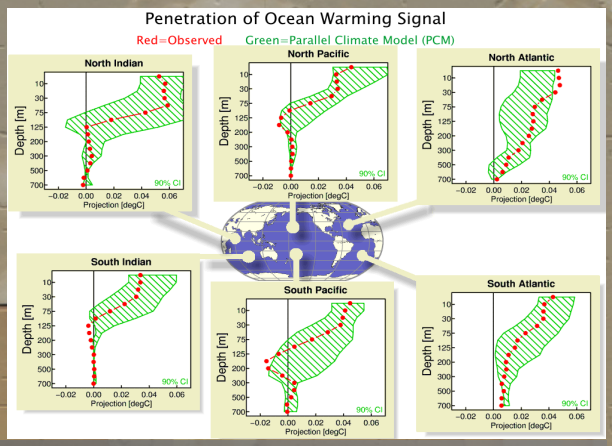
The Role of the Oceans - Temperature

water has high heat capacity – oceans as climate moderators
in last 50 years, 85% of Earth's heat has gone into oceans



good news: oceans slow down global warming
bad news: oceans already warming
->El Niños increasing in strength and frequency

The Role of the Oceans – CO_2

The Story about the Missing CO_2

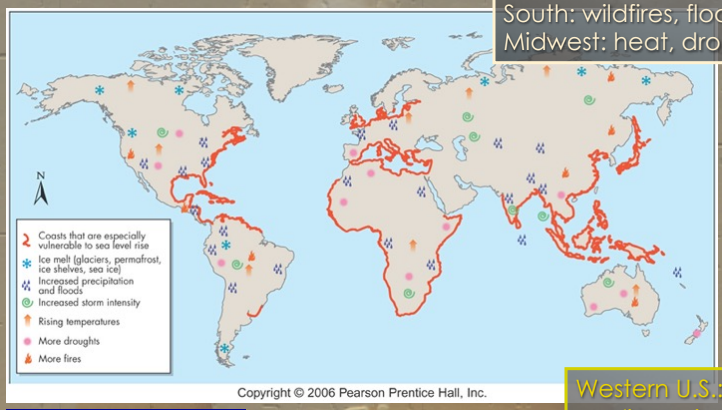
- atmosphere has less CO_2 than humans produced in last 150 yrs
- oceans take up CO_2 → slow warming
- 46% atmosphere; 29% ocean; 7% forest re-growth; 18% other biosphere

good news: oceans take up some of greenhouse gases
bad news: ocean acidification

The Global Consequences of Warming

projected disaster-related impacts

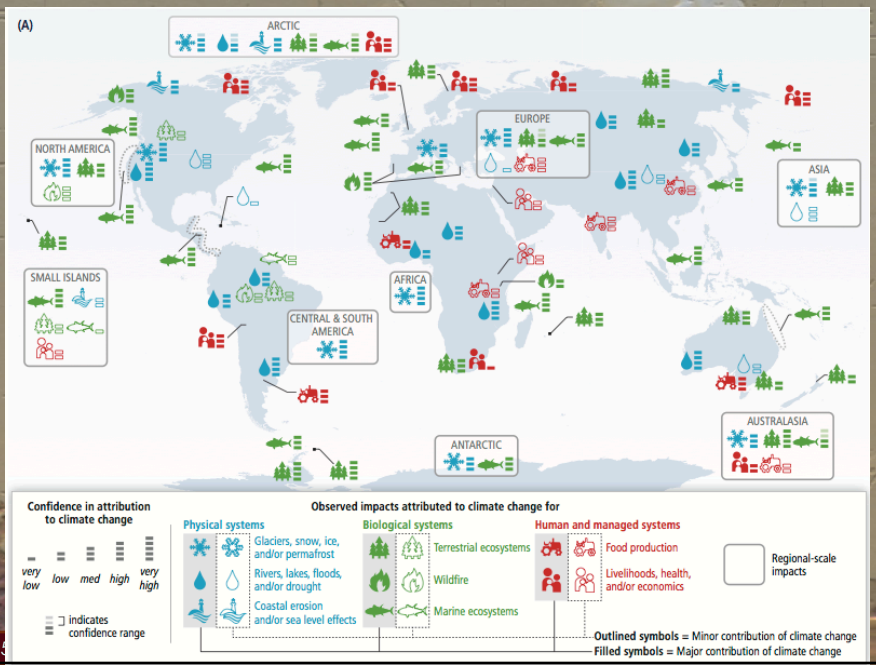
East Coast: flooding and erosion
North: ice melt
South: wildfires, floods, droughts
Midwest: heat, droughts, storms



source: Keller and Blodgett "Natural Hazards" &World Watch Institute

Western U.S.:
-earlier spring
-later fall
-longer dry season
-> increased wildfire risk

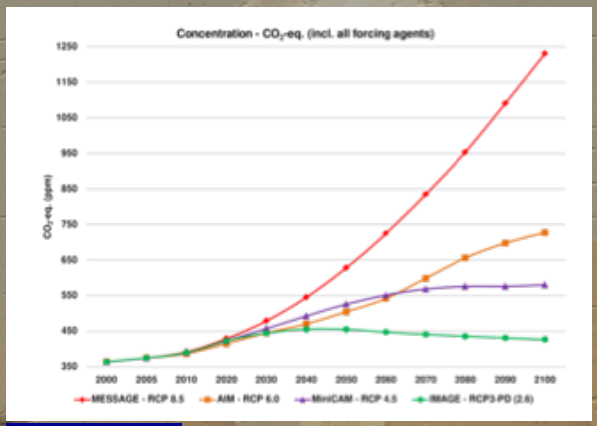
IPCC 2014: 5th summary for policy makers



IPCC Report 2014: > 1800 pages

RCP: Representative Concentration Pathways

U.S. government: "make American coal great again!"
Reality: collapse despite heavy subsidies



source: IPCC 2014

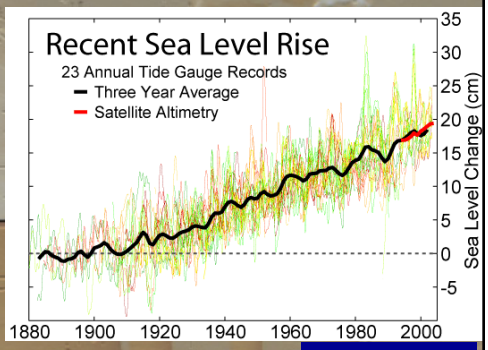
all forcing agents in CO_2 equivalents

RCP 2.6: rigorous emission cut
emission peaks 2010-2020
RCP 8.5: business as usual

The Oceans and Sea Level Rise

Tide Gauge Data

- heating and thermal expansion of upper oceans (30%)
- melting of glaciers (20%)
- melting of G.L. ice sheet (20%)
- melting of A.A. ice sheet (??)



source: IPCC 2014

if all ice sheets melted,
sea level would rise 20-70 m

this is not going to happen any time soon
... but ...
1 m is to be expected

The Oceans and Sea Level Rise

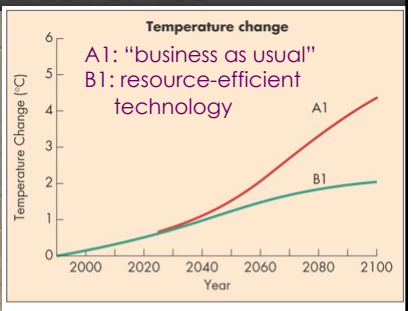
Predictions

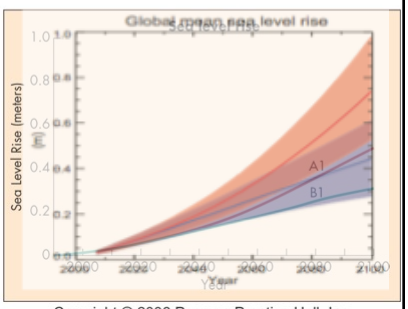
- model predictions: 40 - 100 cm (16 - 39 in)
- even a small increase causes significant landward migration of coastal estuaries
-100 cm will have serious consequences

source: World Watch Institute

For Comparison

- tidal range: up to 12 m/39 ft but typically ~ 100 cm (few ft)
- low pressure in a hurricane can pull up sea surface by 100 cm





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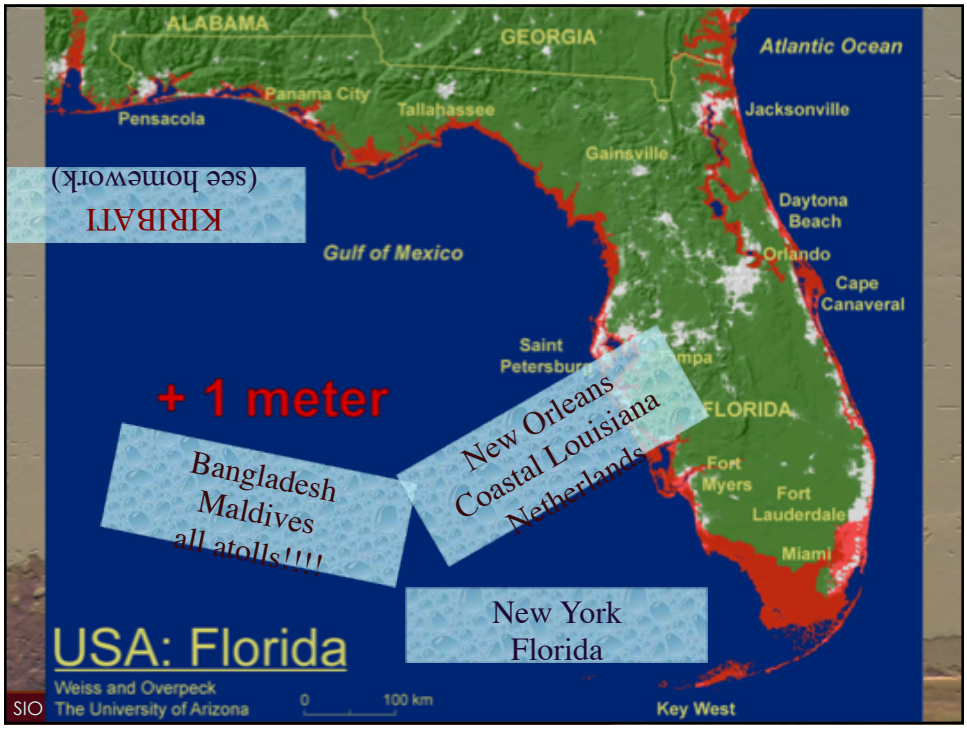
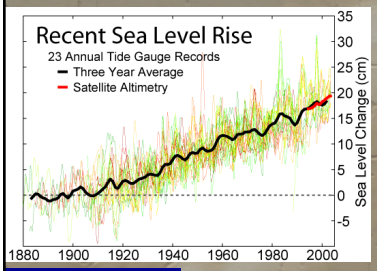
source: Keller and Blodgett "Natural Hazards"

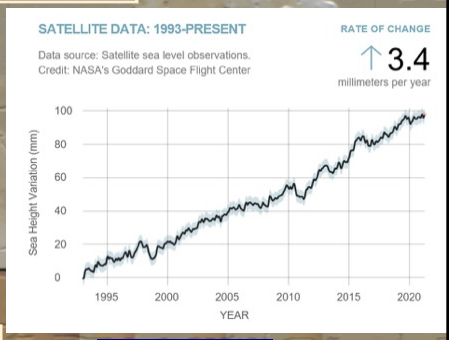


The Oceans and Sea Level Rise

Recent Satellite Data



source: IPCC 2014



source: wikipedia

Tide gauge: 20 cm last 125 years
Satellite: 10 cm last 30 years

- thermal expansion (42%)
- melting of glaciers (21%)
- melting of G.L. ice sheet (15%)
- melting of A.A. ice sheet (8%)

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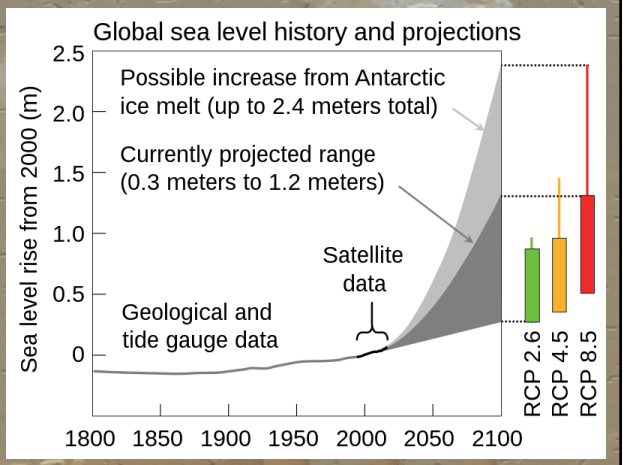
The Oceans and Sea Level Rise

Predictions

- 100 cm may be best case
- 250 cm for "business as usual"



source: IPCC, US Global Change Research Program

RCP2.6: emission peak before 2020
RCP4.5: peak by 2040
RCP8.5: business as usual

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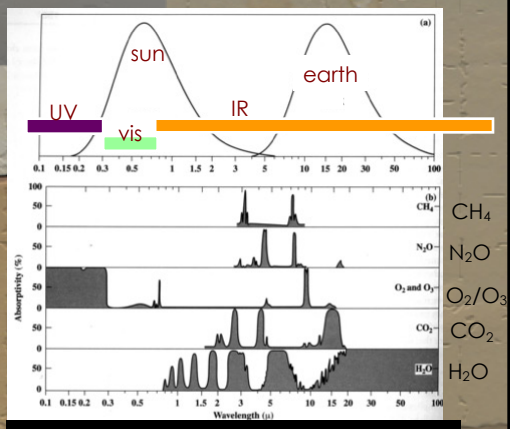
The Ozone Hole: Ozone – O_3

- not released from Earth's interior nor plants
- on ground when NO_x react with sunlight
- in stratosphere when O_2 reacts with sunlight
- pollutant on ground (corrosive and unhealthy)
- UV protector in stratosphere

short video 18



CH_4
N_2O
O_2/O_3
CO_2
H_2O

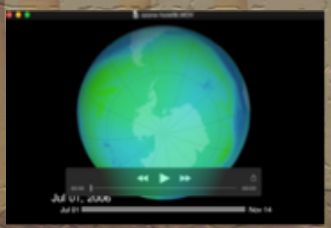
- 10ppm at 20-25km altitude

The Ozone Hole

OZONE, O_3
- not released from Earth's interior nor plants
- on ground when NO_x react with sunlight
- pollutant on ground (corrosive and unhealthy)
- in stratosphere when O_2 reacts with sunlight (10 ppm at 20-25 km altitude)
- UV protector in stratosphere

Ozone hole:
-needs light
-needs very low T
-> springtime phenomenon

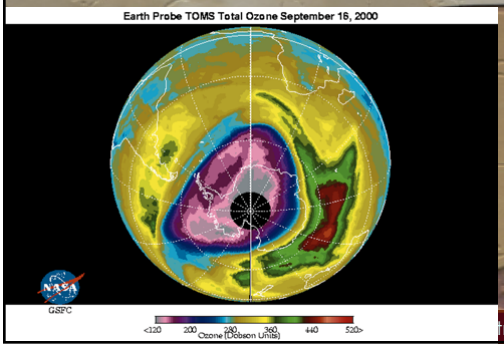
- Ozone greenhouse gas
- Ozone hole NOT related to global warming!

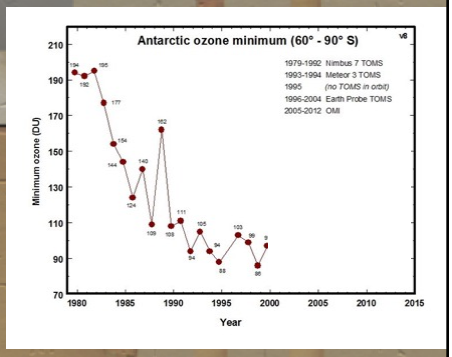


The Ozone Hole

decline first noticed in 1980s
- most severe in early spring

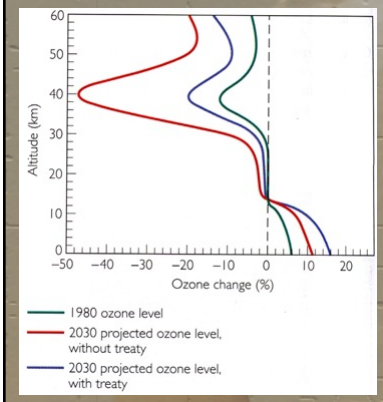
- CFCs (chlorofluorocarbons) not natural
  (refrigerators, air conditioning, spray cans)
  (also greenhouse gas)
- light in stratosphere reacts with CFC
  (Cl then combines with O)





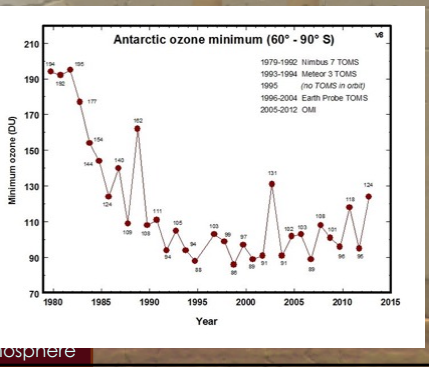
The Ozone Hole – The Montreal Protocol

dire predictions -> Montreal Protocol



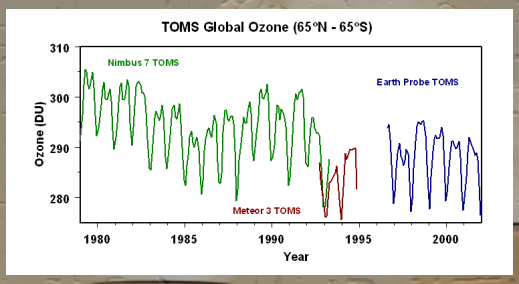
-CFC phased out by 1996 by 140 countries
(1987 Montreal Protocol)
- CFC have very long lifetime!
-ozone hole will continue until > 2030
- 2006 ozone hole largest ever
- 2011 deepest Arctic ozone hole ever (40%)

careful optimism:
2007 Ozone hole was
smallest in decades



The Ozone Hole – A Recovery?

Global Ozone Loss reached Plateau?



... but careful optimism: 2007 Ozone hole was smallest in decades

Deferred to Topic 24