Topic 22: Anthropogenic Changes and the Atmosphere

Canvas test 9:
topics 21,22, HW7!
due by midnight

short video 18 Ozone Hole

HW#9 due tomorrow

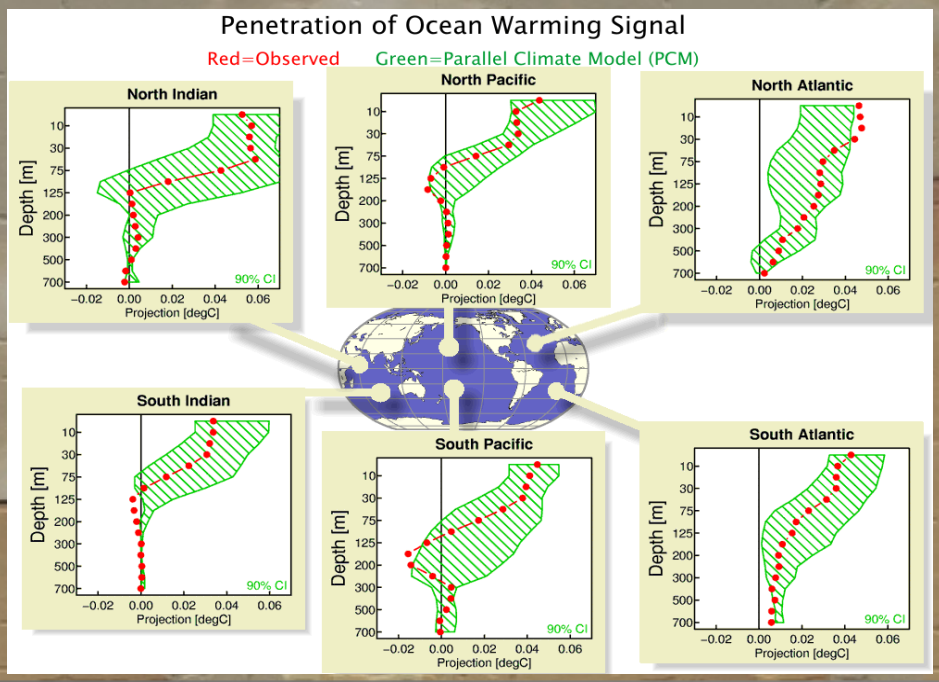
"It is DIFFICULT to get a man to understand something when his SALARY depends upon his NOT UNDERSTANDING IT."
Upton Sinclair

Zoom:
office hour (Laske) 5 pm
discussion (TAs) tomorrow 3 pm
we take attendance for latter

ongoing: please participate in UCSD course review

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



study done 20 years ago

update: warming down to 1000+ m?

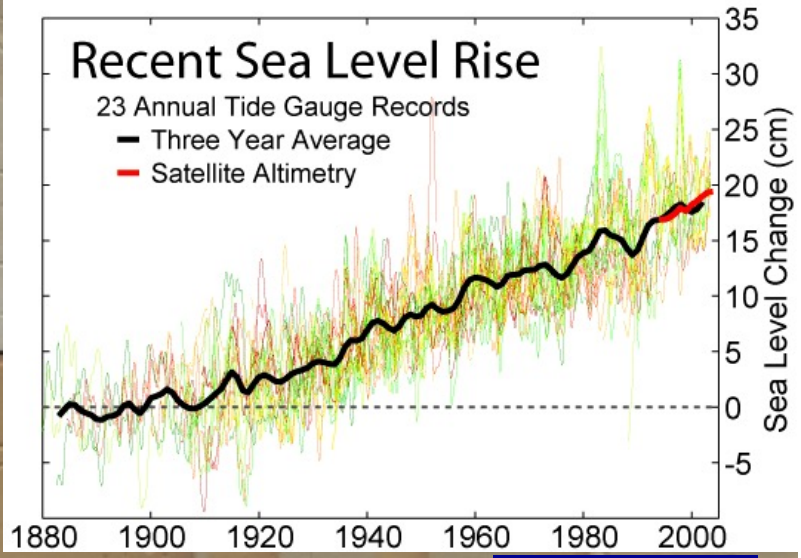
good news: oceans slow down global warming
bad news: oceans already warming
El Niños increasing in strength and frequency?
hurricanes getting stronger/live longer??

The Oceans and Sea Level Rise

rise in last 100 years: 15 cm
about 24 cm since 1880
rate accelerated since 2013

causes of sea level rise
- 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 (??)

Tide Gauge Data



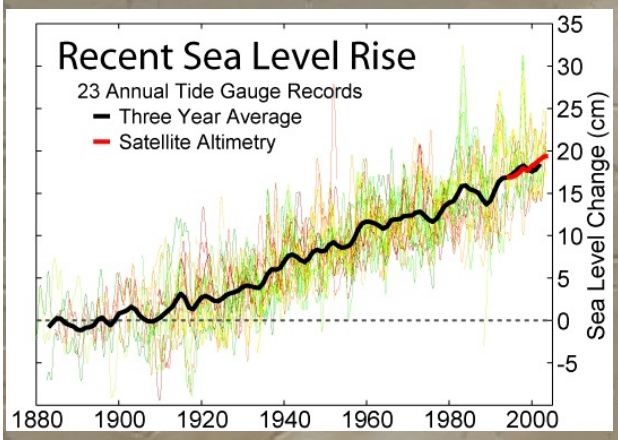
source: IPCC 2014

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

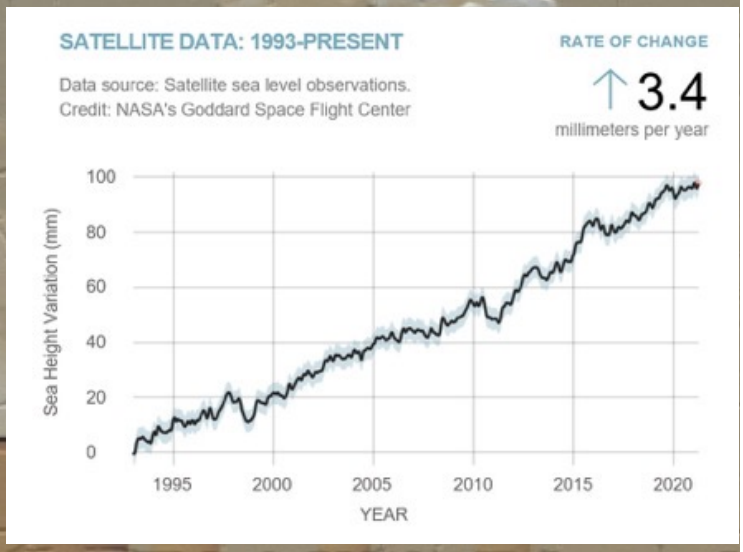
this is not going to happen any time soon
... but ...
1-2 m is to be expected

The Oceans and Sea Level Rise

Recent Satellite Data



source: IPCC 2014



source: wikipedia – figure no longer exists

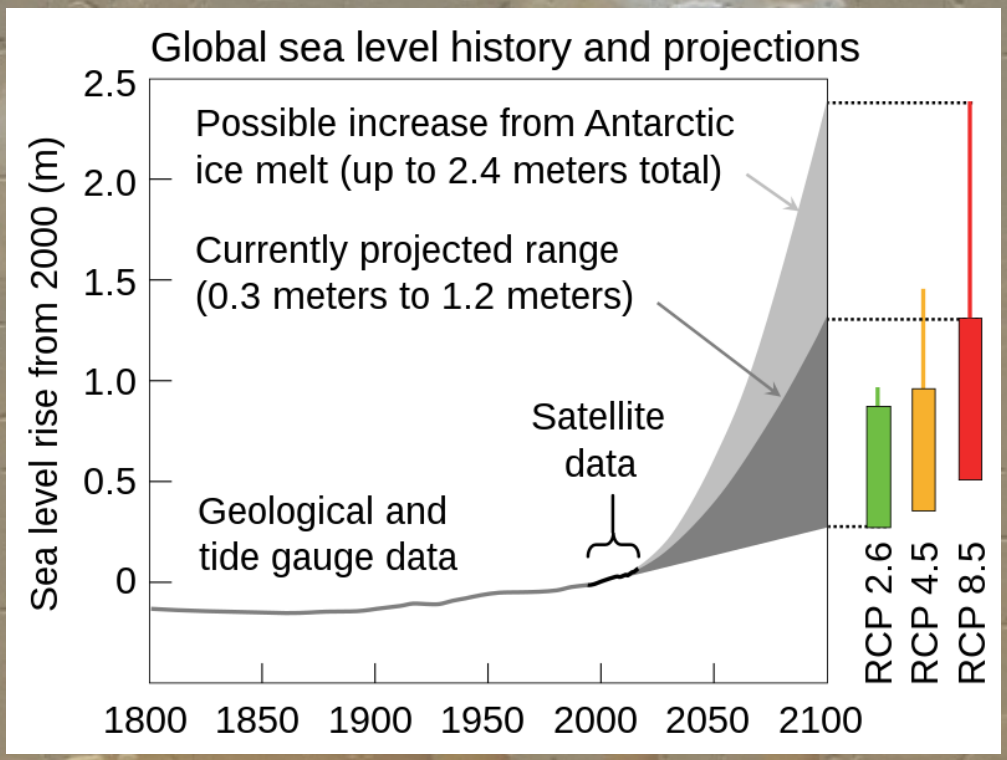
Tide gauge: 24 cm last 125 years
Satellite: 10 cm last 30 years

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

The Oceans and Sea Level Rise

Predictions

- 80-100 cm 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

The Oceans and Sea Level Rise

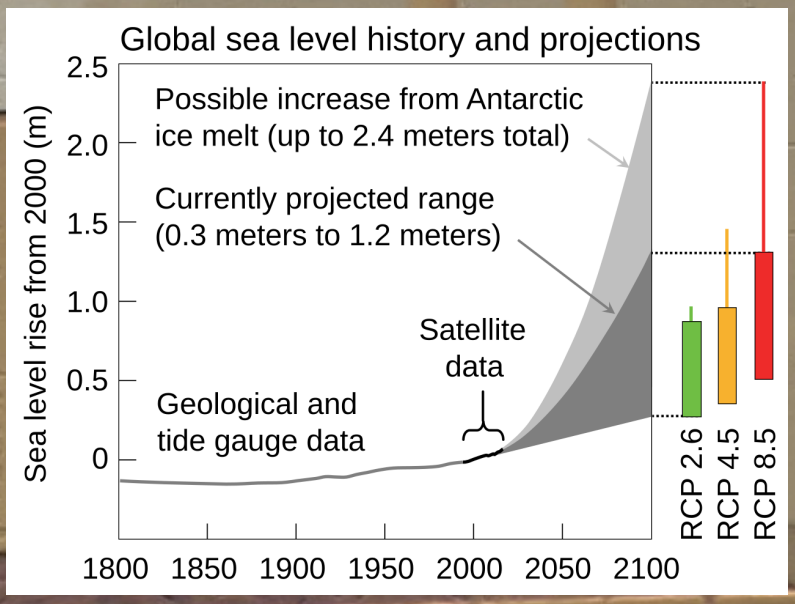
Predictions

- ~~40 - 100 cm (16 - 39 in)~~ 80 – 240 cm
  (class website needs to be updated!)
- *Antarctica still big unknown*
- 100 cm would have serious consequences
- even a small increase causes significant landward migration of coastal estuaries

source: World Watch Institute; wikipedia

For Comparison

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



source: wikipedia

The Warming Oceans and Sea Level Rise

- if sea level rise (1 m by 2100)

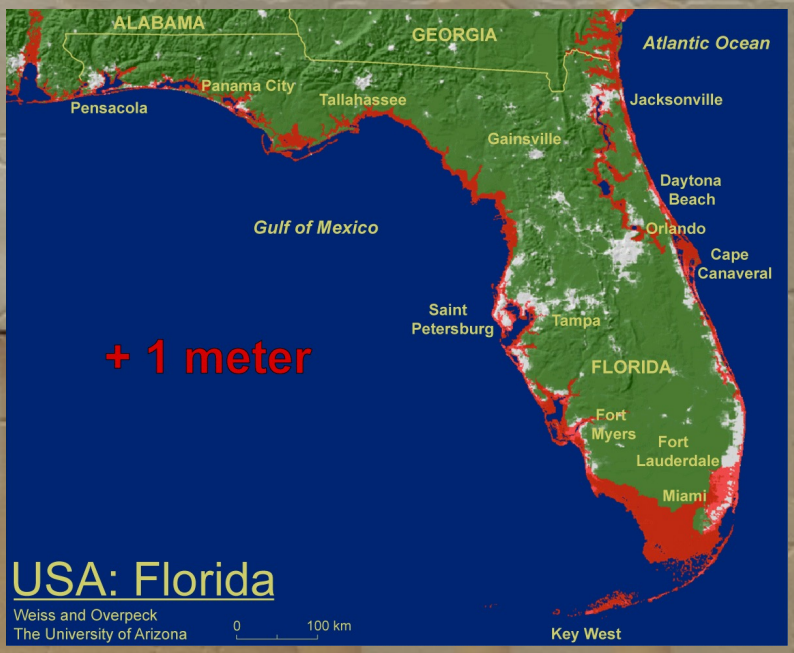
-> costal erosion

-> loss of habitable space

Louisiana,
Alabama
Georgia
Florida

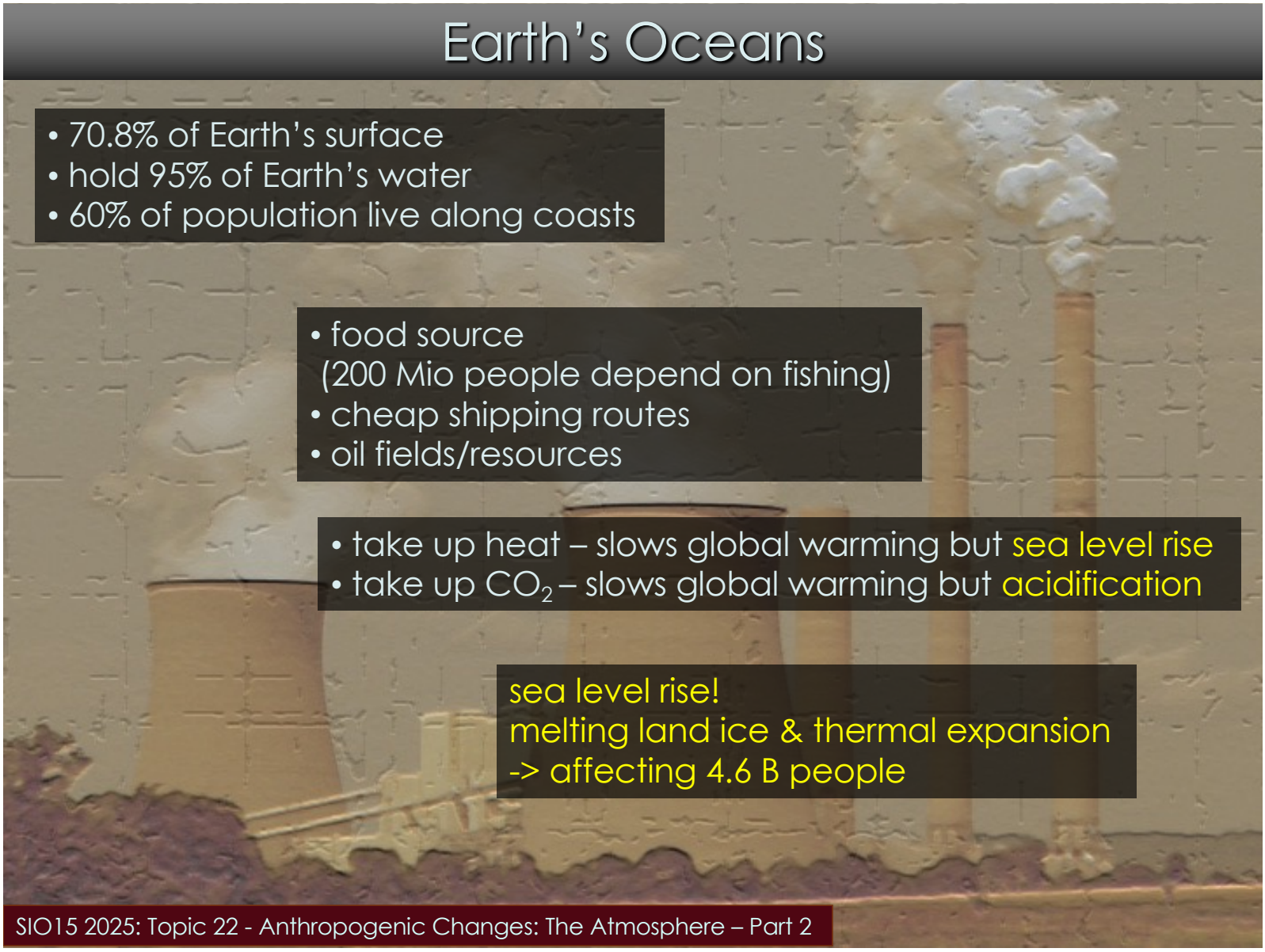
Netherlands
Bangladesh
Maldives
atoll nations

2013 KIRIBATI:
Fiji island purchase



2023 Tuvalu, Fiji, Niue, Solomon, Tonga, Vanuatu:
Port Vila Call for a Just Transition to a Fossil Fuel Free Pacific

Earth's Oceans



- 70.8% of Earth's surface
- hold 95% of Earth's water
- 60% of population live along coasts

- food source
  (200 Mio people depend on fishing)
- cheap shipping routes
- oil fields/resources

- take up heat – slows global warming but sea level rise
- take up CO_2 – slows global warming but acidification

sea level rise!
melting land ice & thermal expansion
-> affecting 4.6 B people

Global Warming and the Oceans

Venice, Italy Dec 1, 2008

- high tides/high winds -> 61 in (topping flood mark: 1.0 m/40 in)
- 66% flooded
- 4th highest since 1872
- highest since 1986
- 1966: 76 in

long-term sea level rise through:

- thermal expansion of ocean water
- melting of ice sheets and glaciers
- local sediment compaction

on top of local short-term threats:

- extreme high tide from 'King tides'
- occasional heavy rain and Alpine run-off

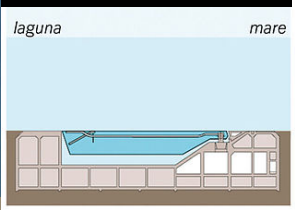
Acqua Alta – Venice – MOSE 2020

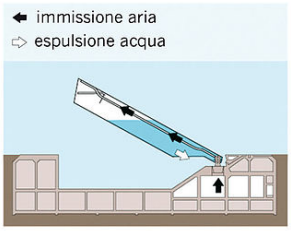
2022 – 204 cm
1966 – 194 cm
2019 – 187 cm
1979 – 166 cm
1986 – 158 cm
2018 – 156 cm
2008 – 156 cm
2019 – 154 cm
1951 – 151 cm
2019 – 150 cm
2012 – 149 cm
1937 – 147 cm

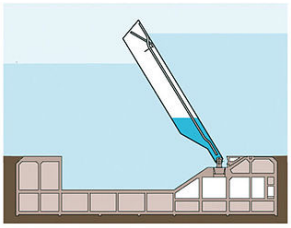
top 12

13 of highest 20 occurred since 2000

78 gates at three lagoon inlets





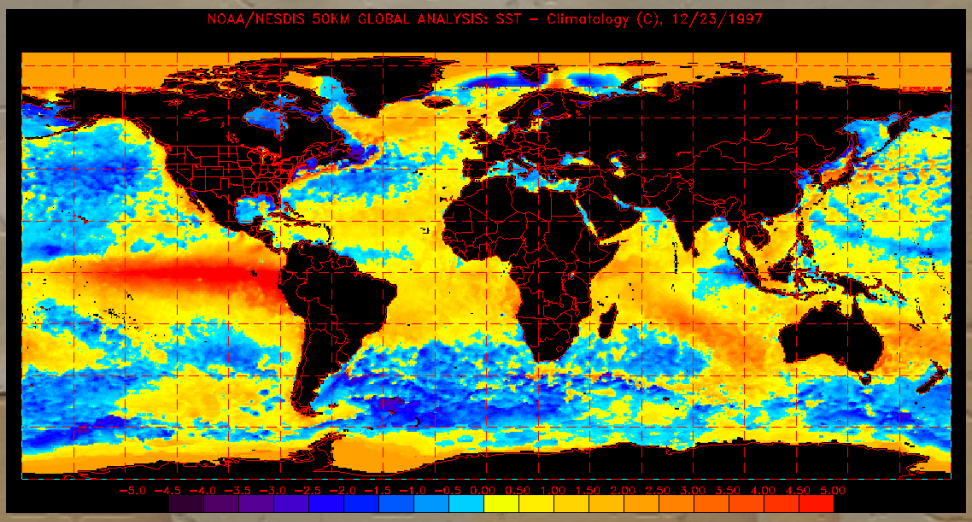


project MOSE (78 gates)
protect Venice for 3 m high tide/flood waters
construction: 2003 – 2021? (7 years late, then 2 years late)
first real test: 7/2020 (baby MOSE deployed 10/2012)
first deployed: 10/3/2020 acqua alta
expected fully functional by end 2025 (formerly end 2021)
cost-overrun: €4.2 B + €1.3B -> €5.5B

source: wikipedia

The Warming Oceans – Food

El Nino:
warm/freshwater on top -> stable layering -> no upwelling -> no food
(e.g. Peru during El Nino as example of things to come)

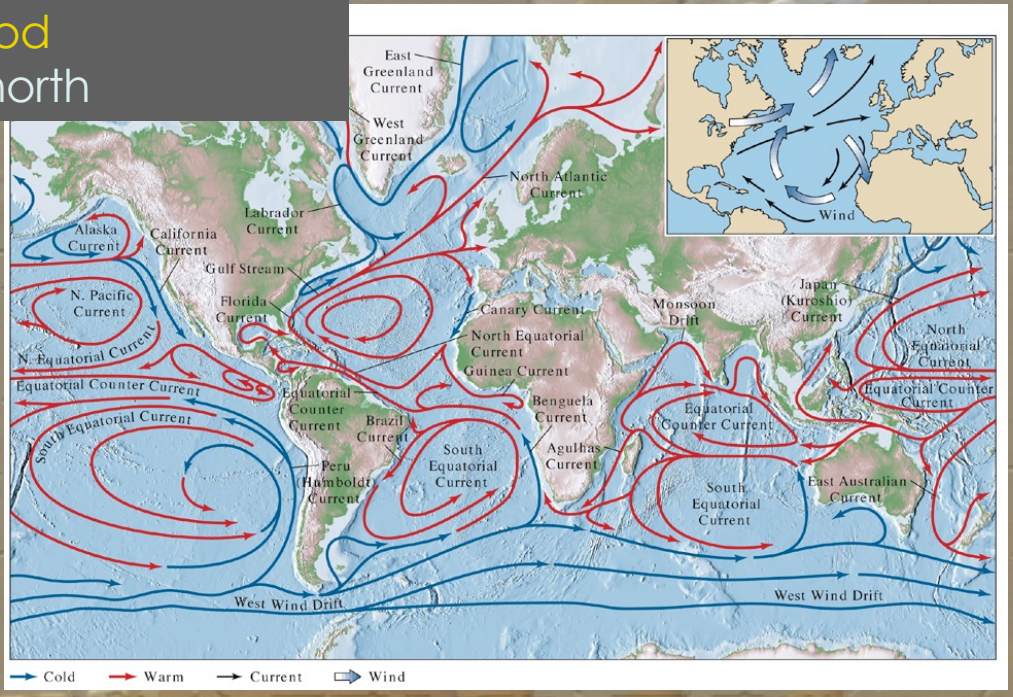


Coastal California – Food, Hurricanes

Weakening California Current:

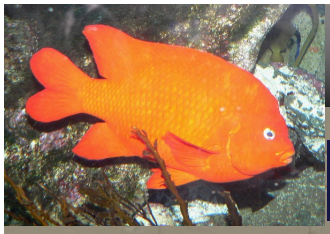
* no upwelling -> no food
* hurricanes advance north

hurricanes weaken when encountering cold water



2018 remnants of TS Fausto -> unprecedented lightning storms S.F.
2023 TS Hilary direct hit S.D. county - first since 1858; Death Valley flood
2025 TS Mario -> CA, AZ flooding; Death Valley flood

California's Kelp Forest



Garibaldi
Cali state fish

giant brown algae
(kingdom protista)

- grows up to 30cm/day to 60m
- needs water < 20°C (68°F)

- important habitat
- resource (iodine, alkali)
- used for things from soap to glass
- alginate thickens ice cream, jelly, toothpaste

The Warming Oceans – Coral Reefs

- coral bleaching if T rises 1-2°C
  corals face multiple threats

2003: 25% gone compared to 1980s
2014: Caribbean –
42+% completely bleached
95% show some bleaching

coral reefs:
"the rain forest of the ocean"
(high biodiversity!)

affected by
- global warming
- acidification
- pollution/pathogens
- physical damage
- freshwater runoff
- sun screen lotion
- predators
- exploitation
- sedimentation

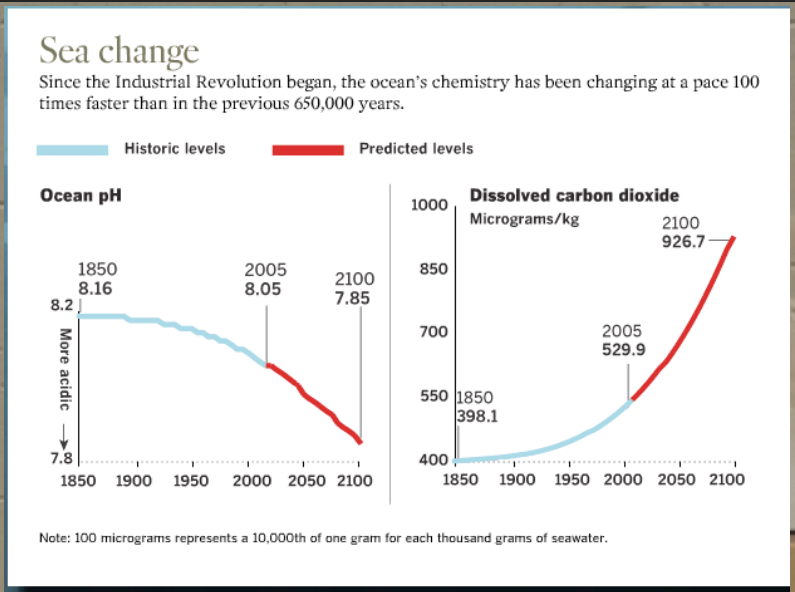
The Role of the Oceans – CO_2

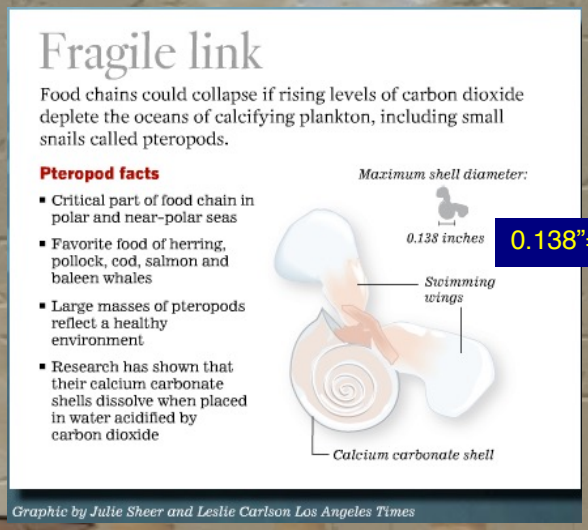
The Story about the Missing CO_2

- 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

Ocean Acidification





0.138"=3.5 mm

- ocean chemistry changes 100 times faster than in last 650,000 yrs
- acidity increased by 30% in 150 years (pH from 8.16 to 8.05)
- projected decrease to pH 7.85 by 2100 (150%)

- cannot produce protecting carbonate shell -> dies ??

interruption of base of food chain - > mass extinction??

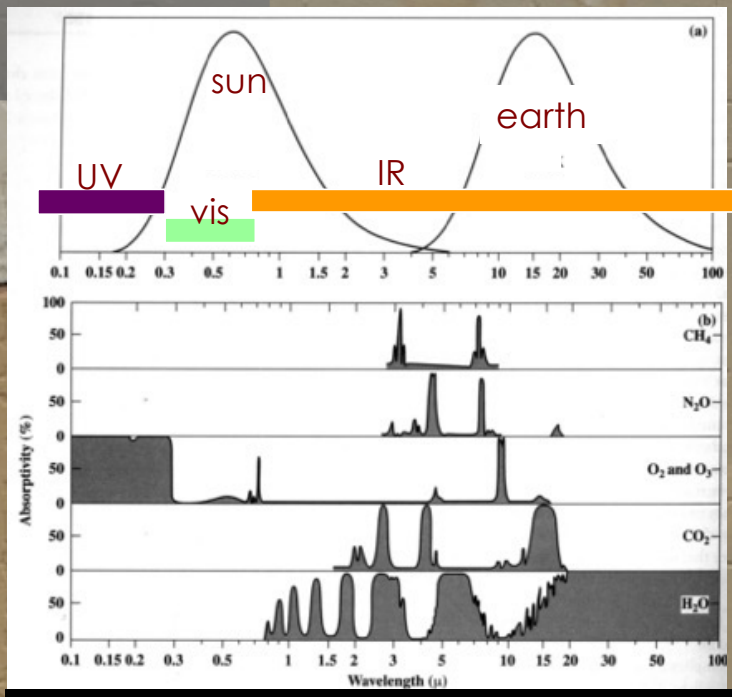
alkaline ←→ acidic

'clean rain' - pH 5.6
'normal rain' - pH 5.5-5.0

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

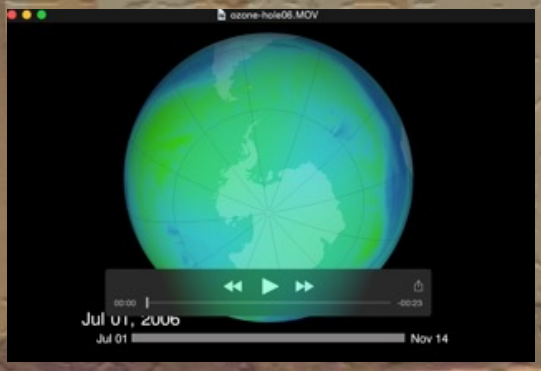
- 10ppm at 20-25km altitude

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

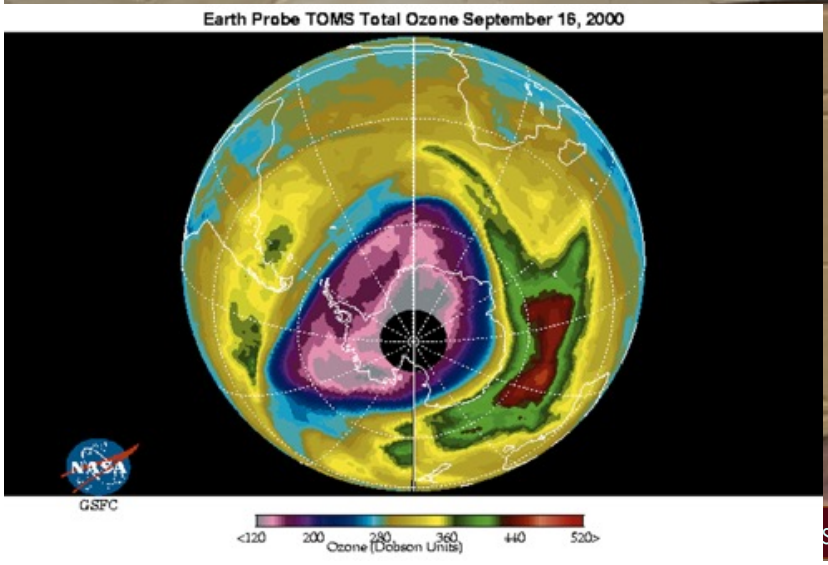
- Ozone greenhouse gas
- Ozone hole NOT related to global warming!

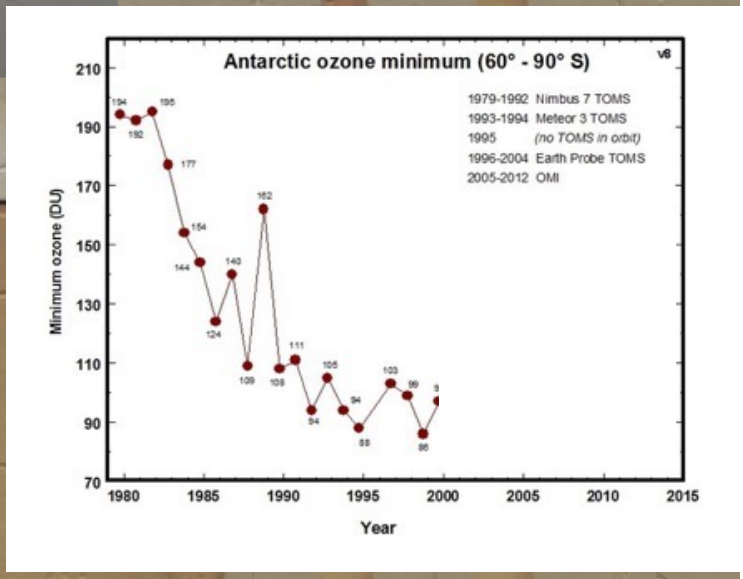


The Ozone Hole

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

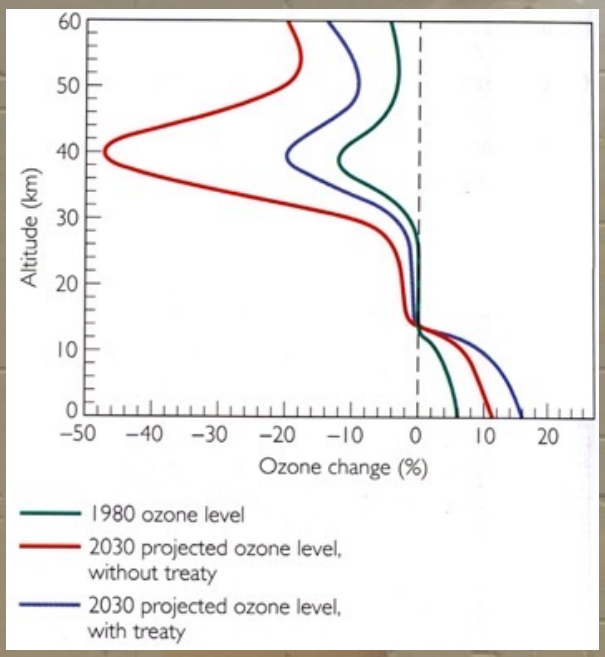
- CFCs (chlorofluorocarbons) not natural
  (refrigerators, air conditioning, spray cans)
  (also greenhouse gas)
- light in stratosphere reacts with CFC
  (Cl then combines with O)



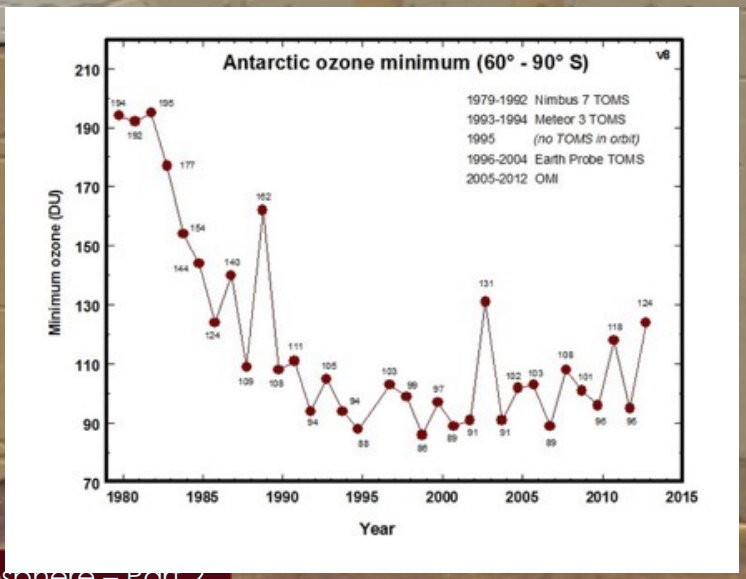


The Ozone Hole – The Montreal Protocol

dire predictions -> Montreal Protocol



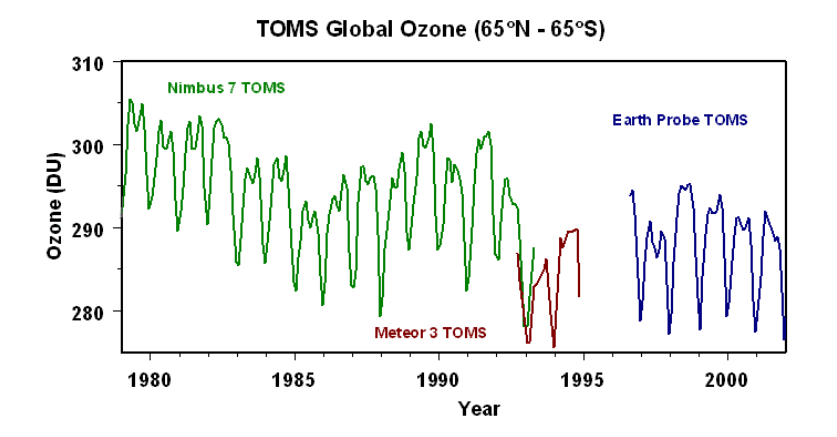
-CFC phased out by 1996 by 140 countries (1987 Montreal Protocol)
- CFC have very long lifetime!
-ozone hole will continue until > 2030
- 2006 ozone hole largest ever
- 2011 deepest Arctic ozone hole ever (40%)



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