ATOC 4800: Policy Implications of Climate
ATOC 5000/ENVS5830: Critical Issues in Climate and the Environment

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Office Hours: TTh 4:05-5:05pm;
or send email to set up individual meetings

To download articles from the class website: Must use CU VPN from off-campus computer
(https://oit.colorado.edu/services/network-internet-services/vpn)

Discussion/Debate Assignments: see website

Today:
The complex global climate system and the environment: Important concepts & processes

(i)The Global climate system: natural internal climate variability, externally forced variability by "natural forcing" and "anthropogenic forcing";
(ii)Global warming;
(iii) Ozone depletion;
(iv) Tropical deforestation & land use land cover;
(v) Hydraulic fracturing – energy & the environment

A critical thinking question

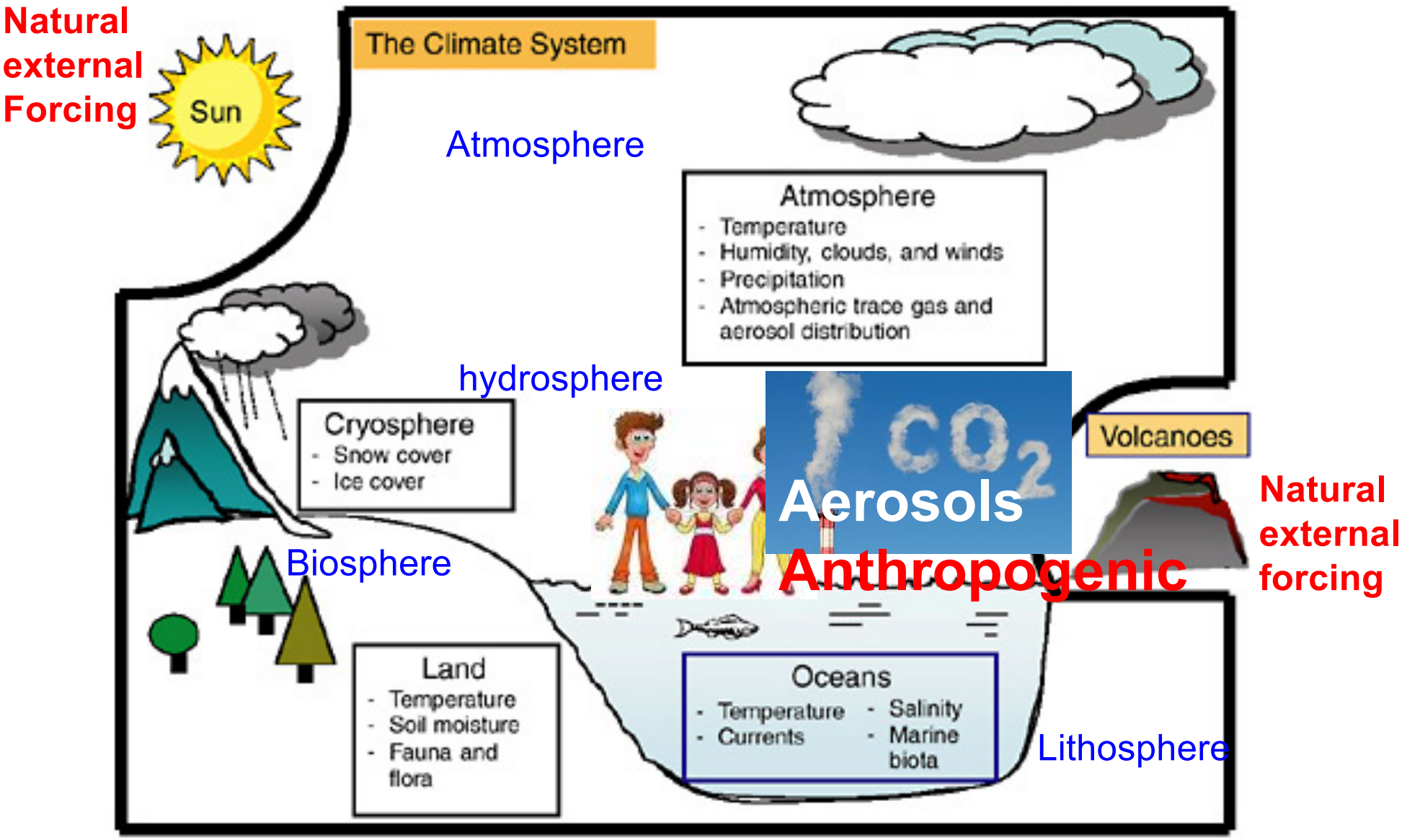
https://www.ehn.org/forest-carbon-sequestration-2649749746.html

The push for standing forest protections in US climate policy
Researchers say "proforestation" policies are the fastest and most effective way to draw excess CO2 out of the atmosphere.

“This difference is particularly relevant as researchers and lawmakers consider the potential for natural solutions—Earth's intrinsic carbon sequestration systems—to be part of large scale climate change mitigation strategies.”

EHN: Environmental Health News

The global climate system



Human affects the “natural, climate system”!

(i) Natural Internal Climate variability & natural external forcing

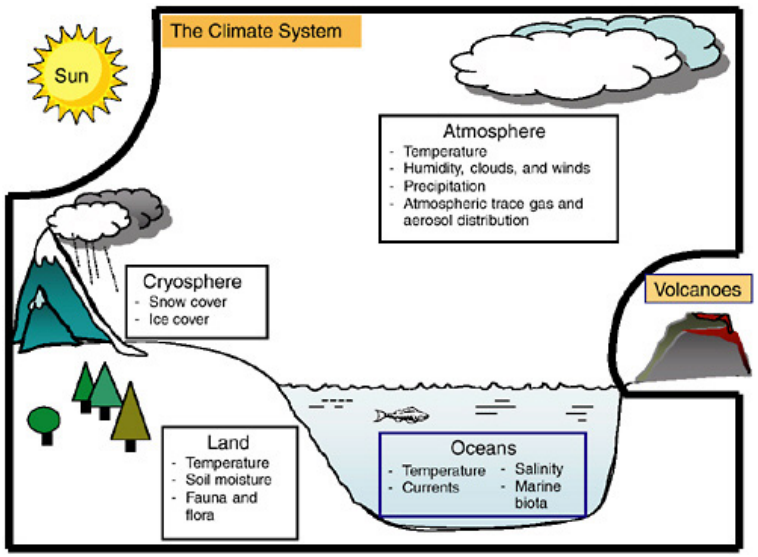
Why does climate vary at various timescales (from seconds to century or longer)?

Externally forced & internally generated in the coupled global climate system.

Natural internally-generated variability: with constant (i.e. not varying with time) external forcing, interactions among the atmosphere, ocean, land and snow/ice & biosphere can induce variability

External forcing (natural):
Solar, volcanoes, etc.;

External forcing (anthropogenic):
GHG, anthropogenic aerosols, land use, etc.



Major natural internal climate variability modes

Natural Interannual variability & climate modes:

The *El Niño and the Southern Oscillation: (ENSO)* in the Pacific – global climate impacts;

The Indian Ocean Dipole (IOD);

The North Atlantic Oscillation (NAO);

The Madden-Julian Oscillation

Decadal variability modes:

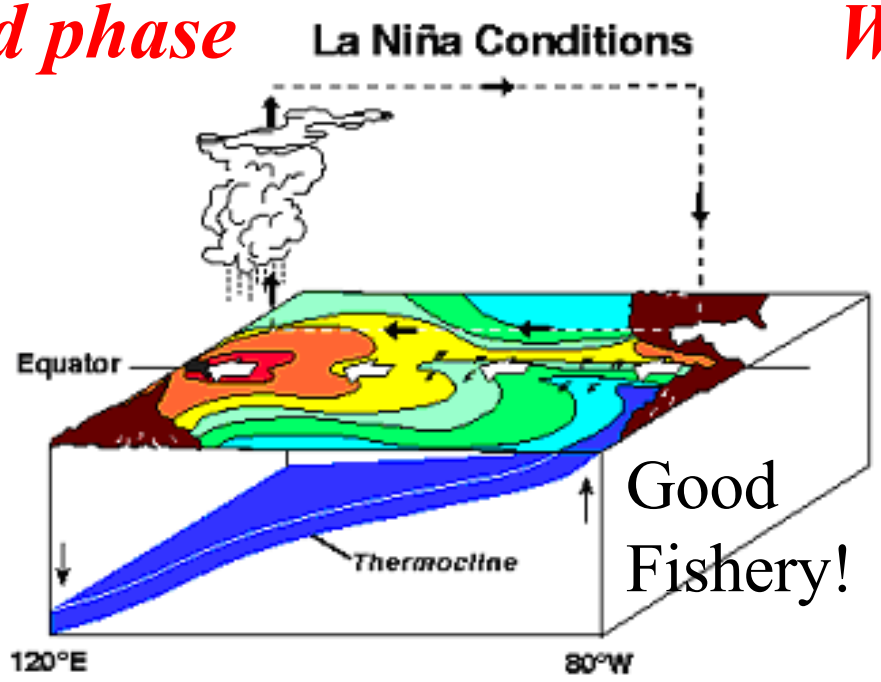
The Interdecadal Pacific Oscillation (IPO): the entire Pacific basin;

Pacific Decadal Oscillation (PDO): primarily in the North Pacific;

The Atlantic Multi-decadal Oscillation (AMO).

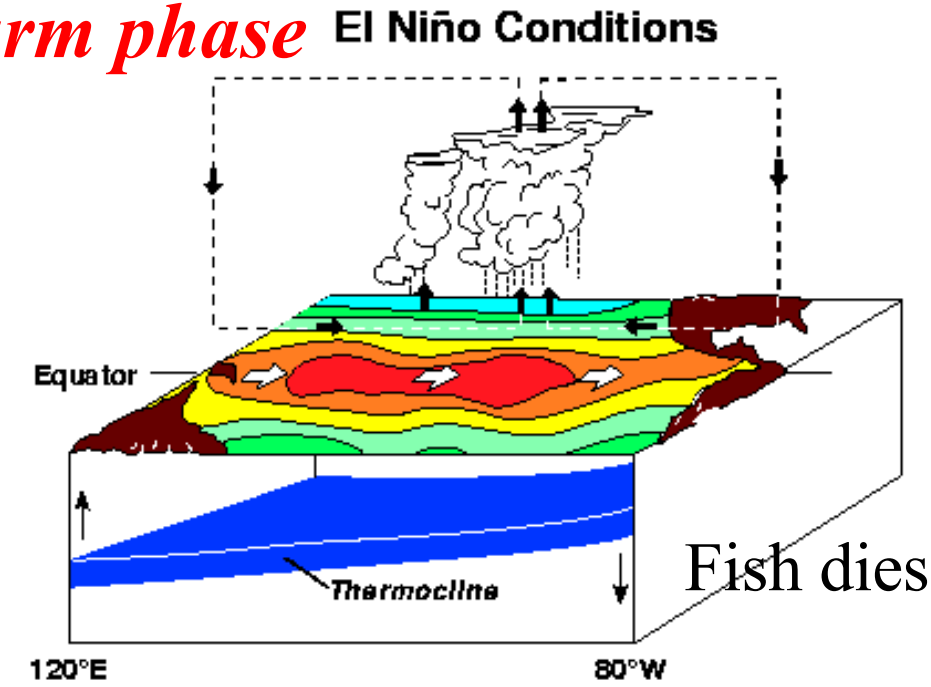
ENSO: Pacific Sea Surface Temperature (SST), winds, precipitation, etc. anomalies (impacts global climate)

Cold phase

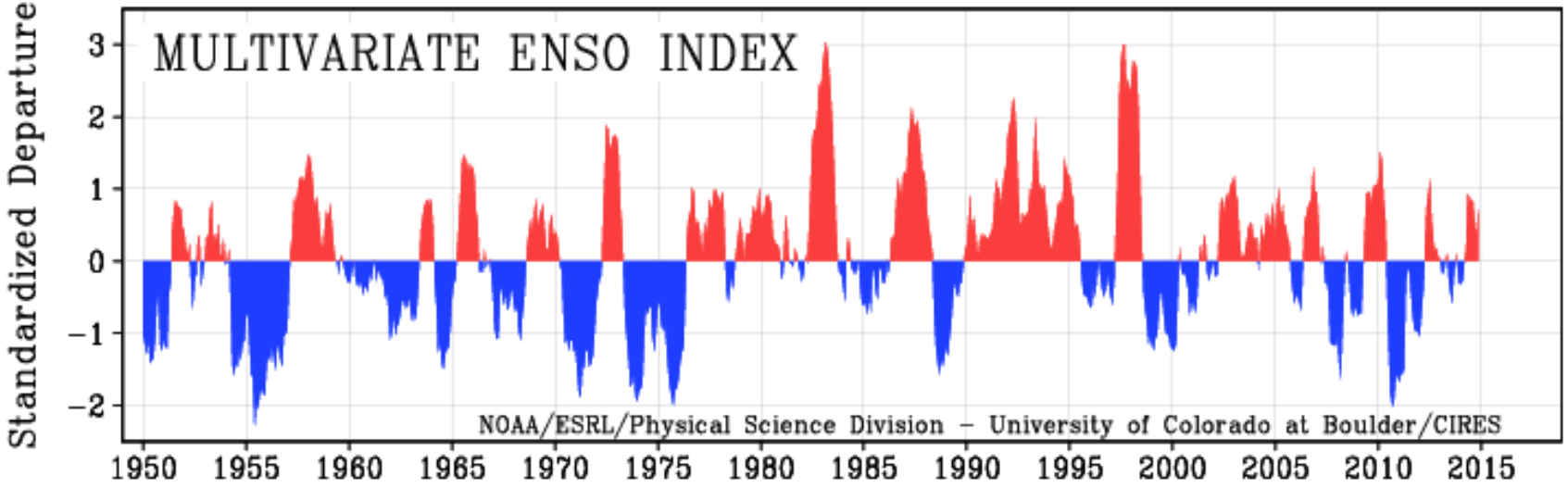


Good Fishery!

Warm phase



Fish dies



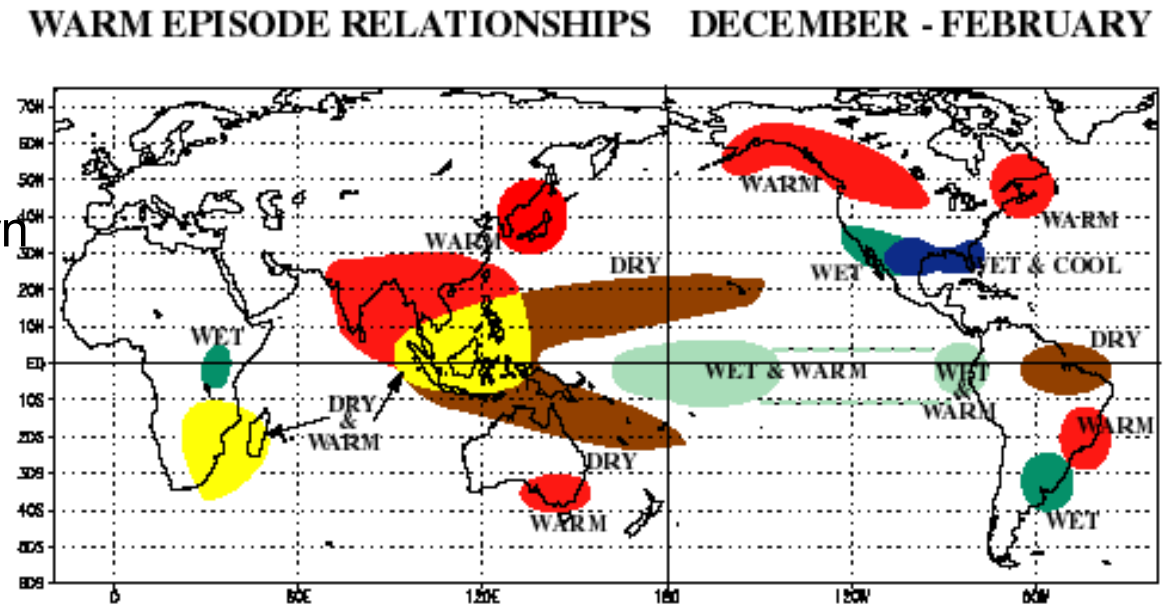
ENSO Climatic Impacts:

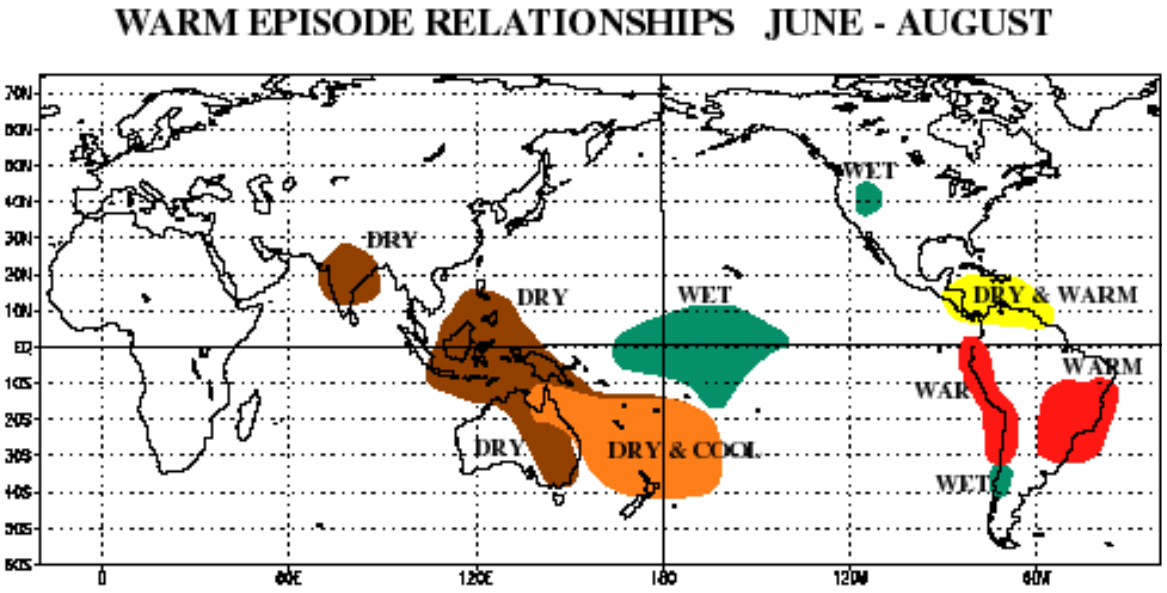
El Nino (warm phase): peak in northern hemisphere winter

Impact: general pattern

Can be different between strong & weak events &

eastern versus central Pacific warming events



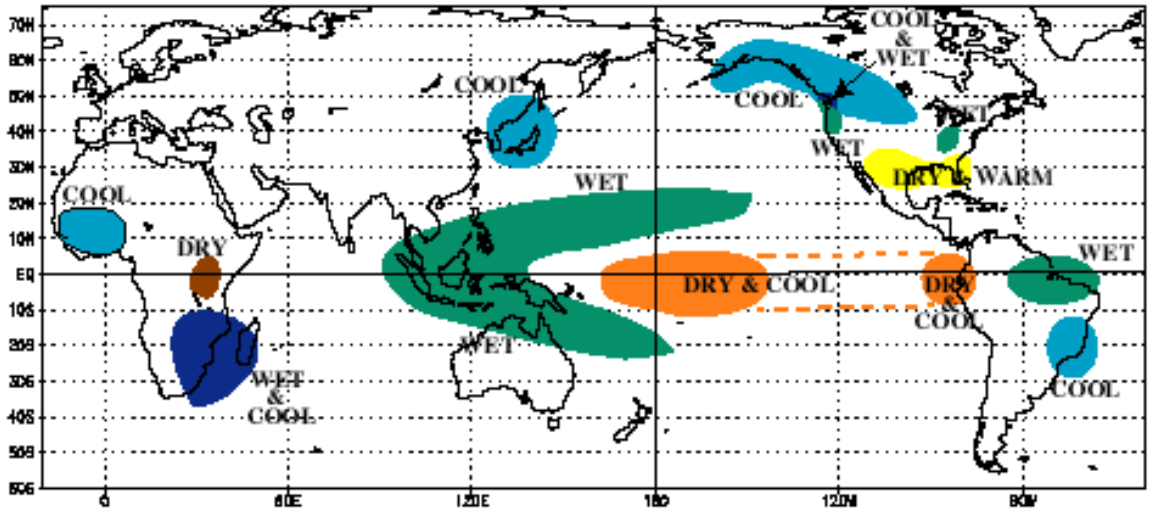


Climate Prediction Center
NCEP

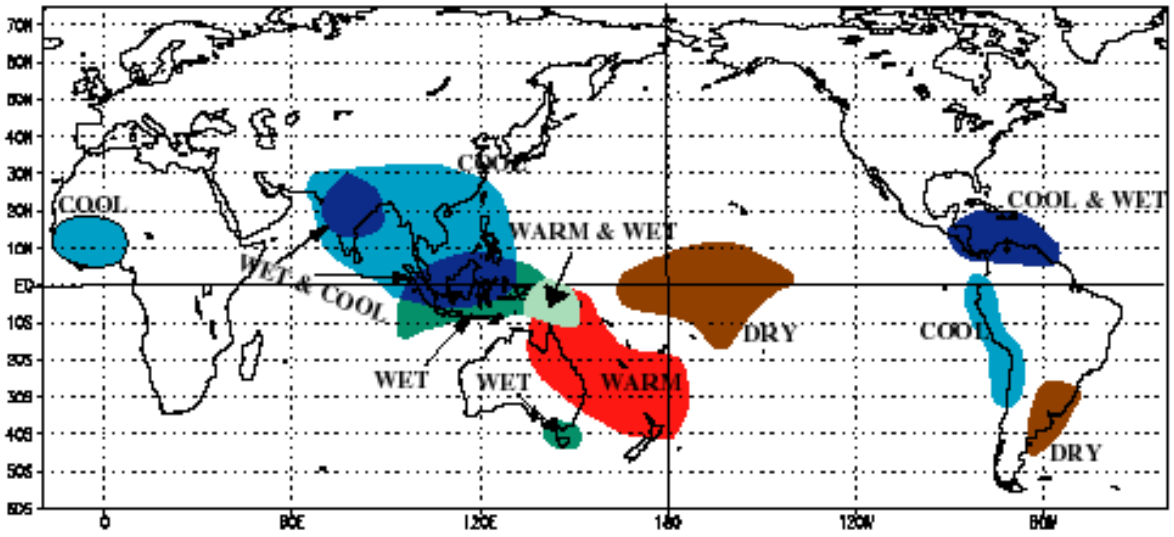
ENSO climatic impacts:

La Nina-cold phase

COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



COLD EPISODE RELATIONSHIPS JUNE - AUGUST



Climate Prediction Center
NCEP

Currently: ENSO Alert System Status: La Nina

https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.shtml

Synopsis: **La Niña is expected to continue through the Northern Hemisphere winter 2020-21 (~95% chance during January-March), with a potential transition to ENSO-neutral during the spring 2021 (55% chance during April-June).**

(b) Example CA: El Nino impact on CA sea level & rain

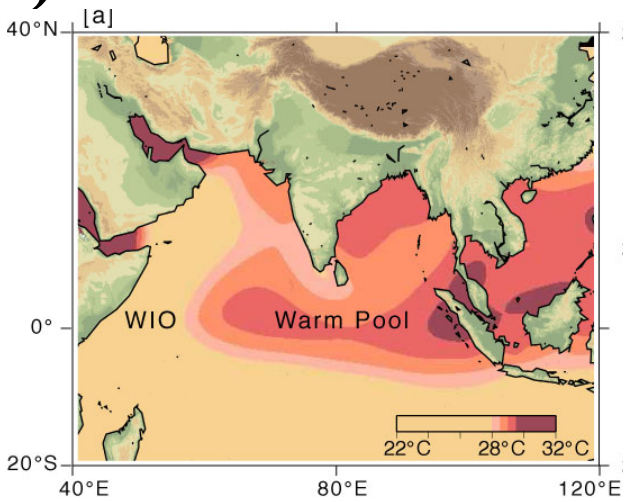
https://www.washingtonpost.com/news/capital-weather-gang/wp/2016/01/06/as-el-nino-reaches-strongest-level-ever-recorded-heavy-rain-engulfs-southern-california/?utm_term=.5de4bfd611b9

2015-2016 strong El Nino: CA & South America sea level rise:

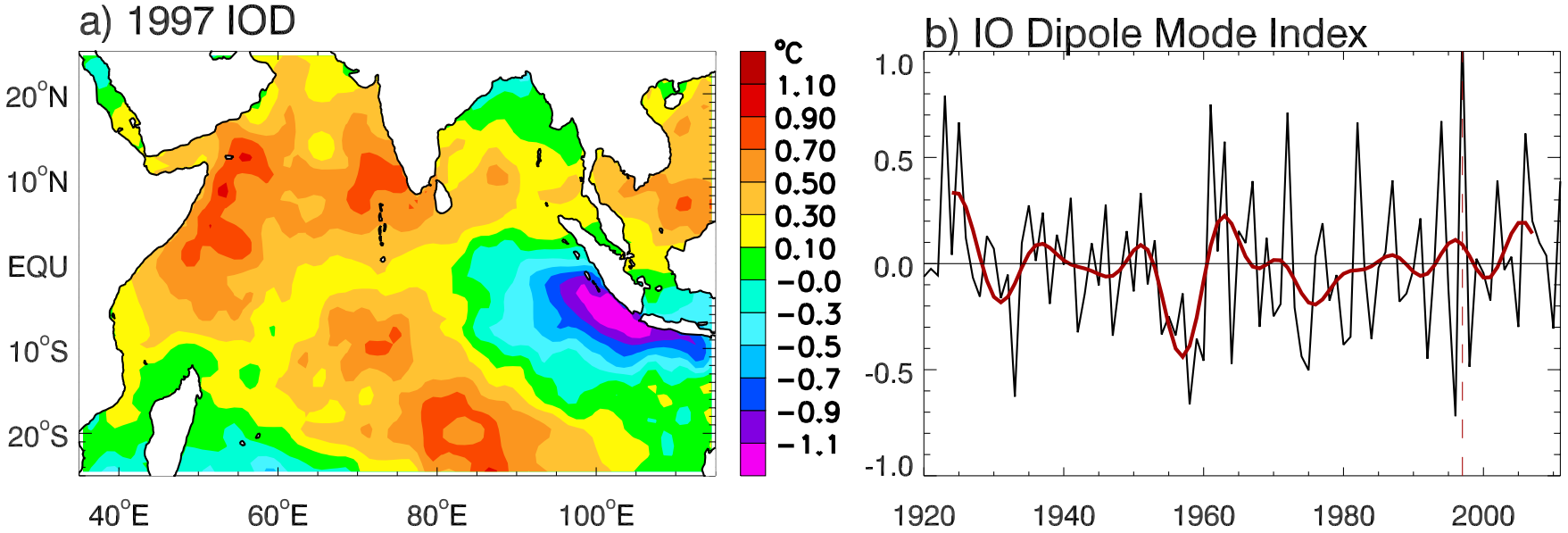
https://svs.gsfc.nasa.gov/30756

Indian Ocean Dipole (IOD): SST anomalies

Normal climatological state of SST:

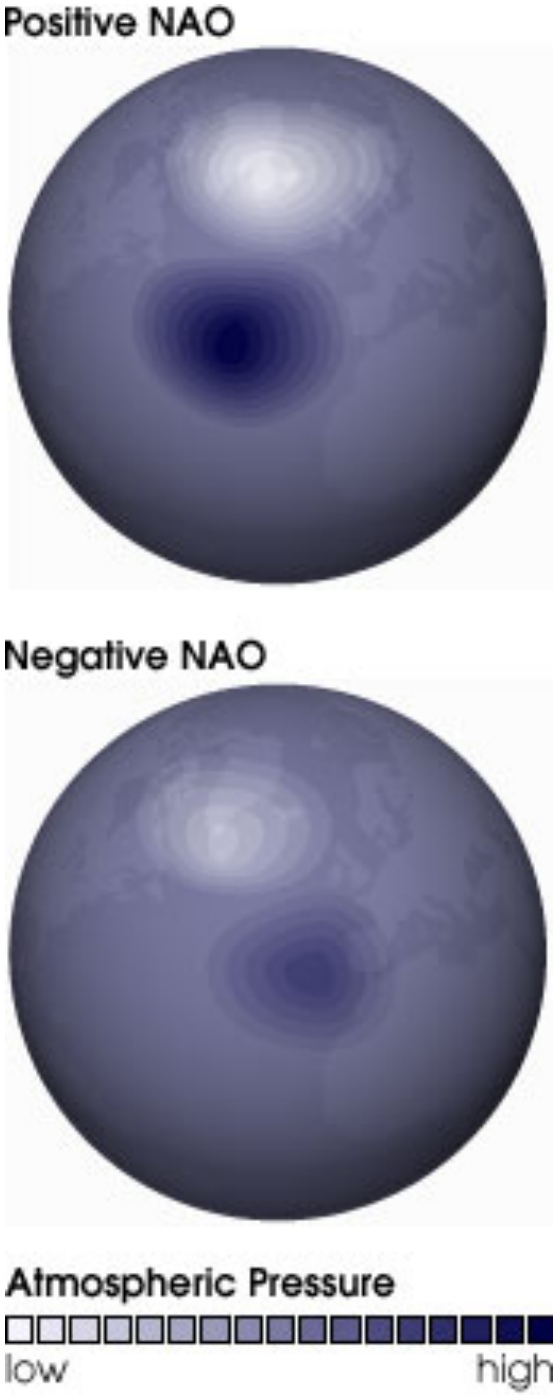


Positive phase of IOD:

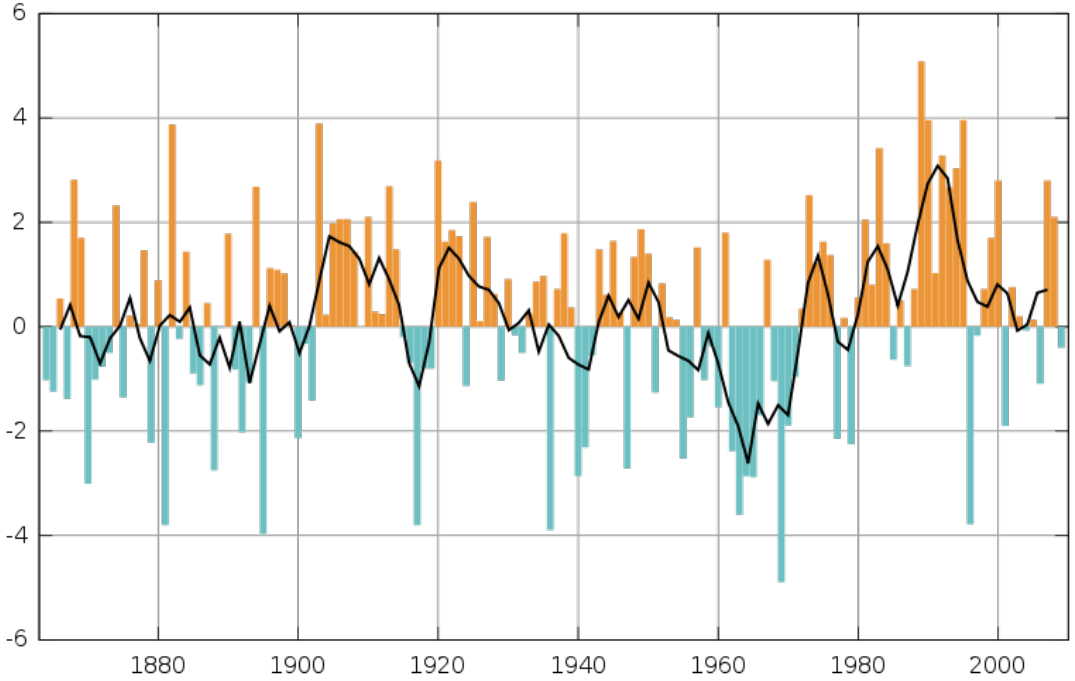


Climatic impacts: East Africa floods, Indonesian drought; When joint forces with El Nino (e.g., 1997-98), it can cause unusually large impact

The North Atlantic Oscillation



Sea Level Pressure: Oscillation between Icelandic low and Azores high; part of Arctic Oscillation, with interannual-decadal timescale Oscillation (no preferred timescale)

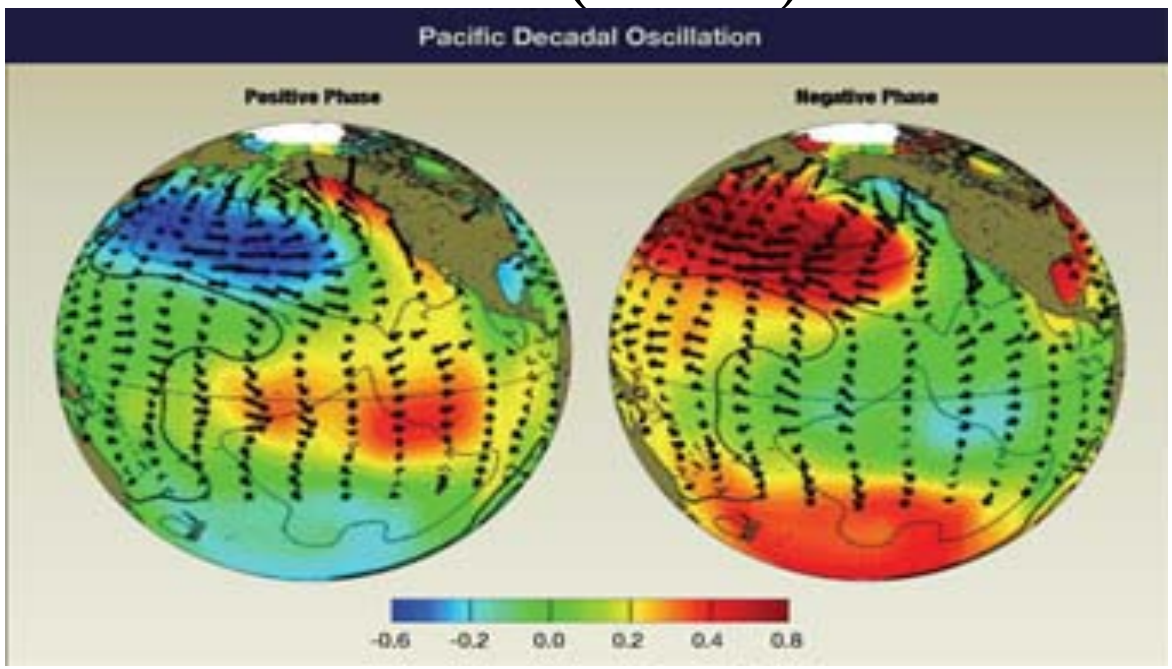


Wintertime NAO index (temporal variability)

Climatic impacts: large impacts on US & European climate, including sea level rise of the Atlantic Ocean

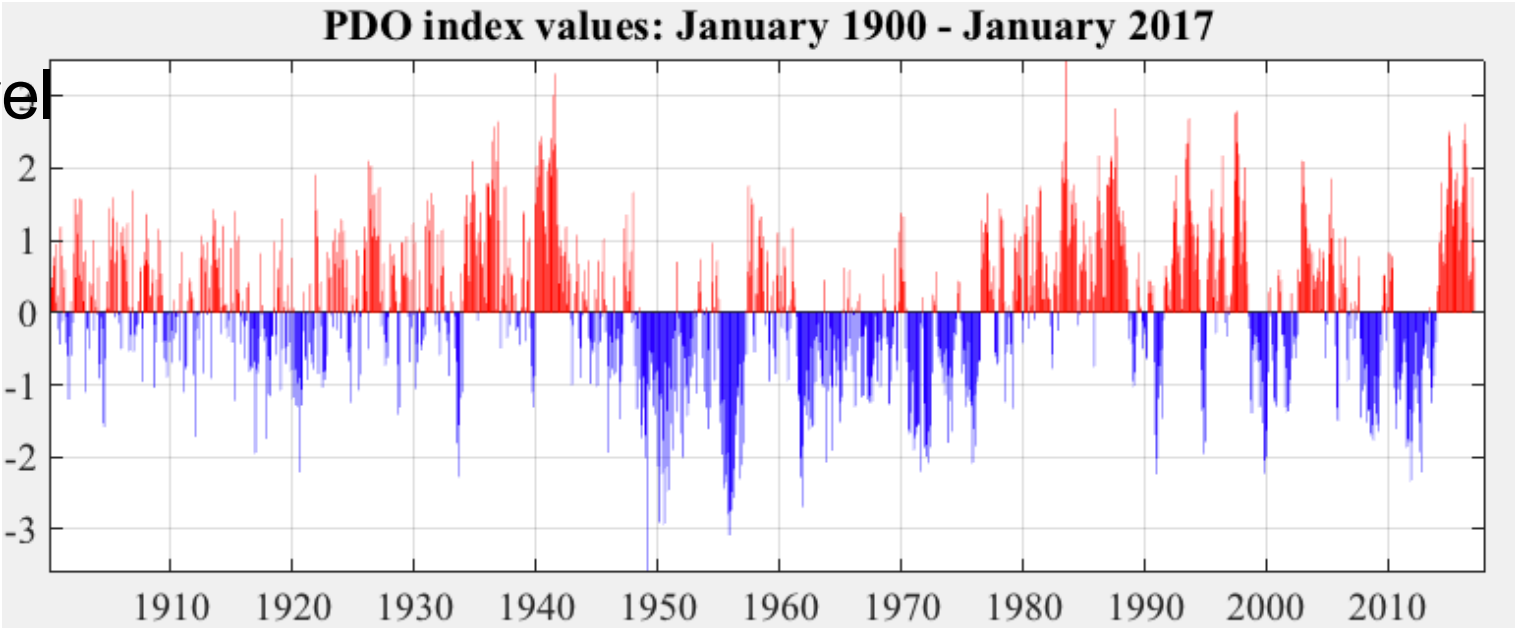
Interdecadal Pacific Oscillation (IPO)/ Pacific Decadal Oscillation (PDO)

ENSO-like,
decadal variability

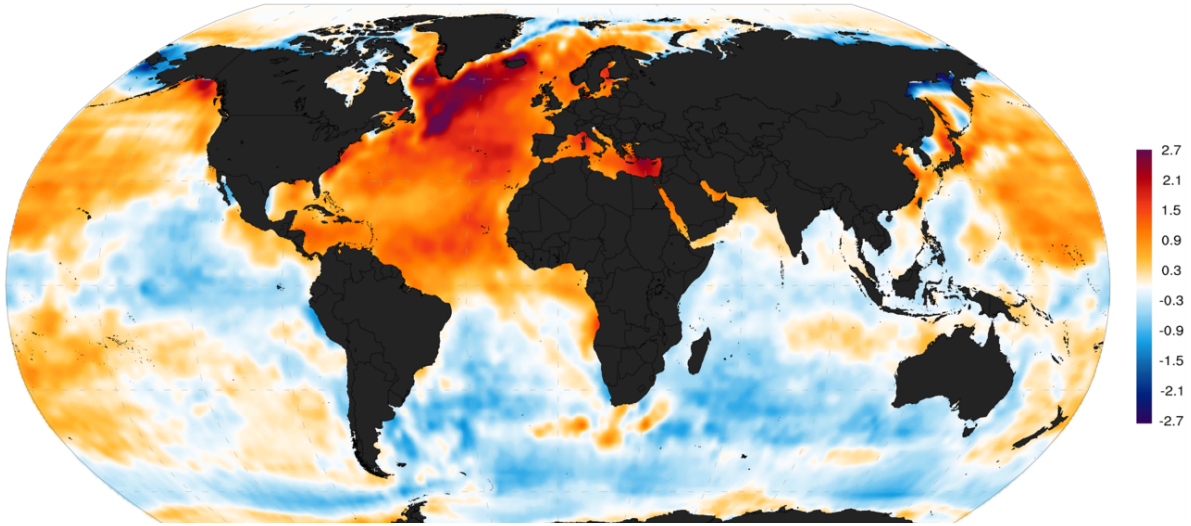


Negative phase IPO:
the recent global surface warming hiatus 2003-2012;

IPO: large impacts on global & regional climate & sea level variability



Atlantic Multidecadal Oscillation (AMO)

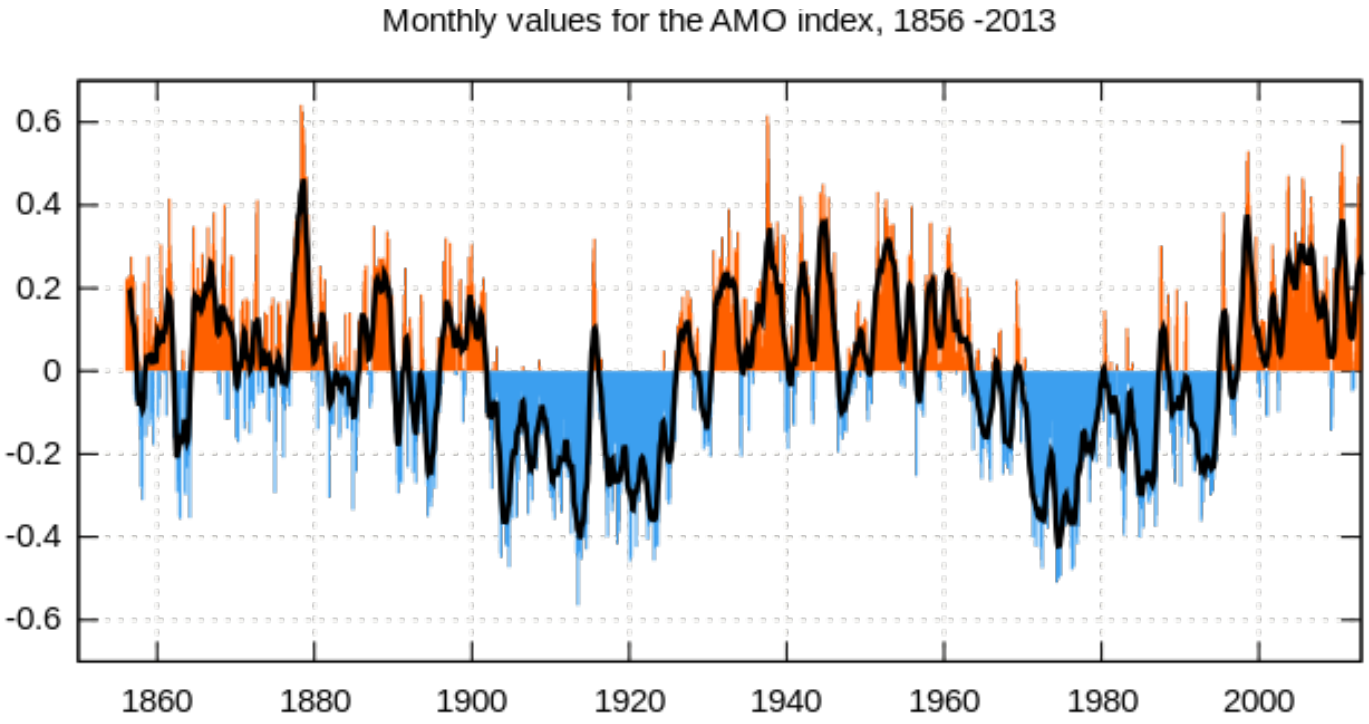


Impacts:

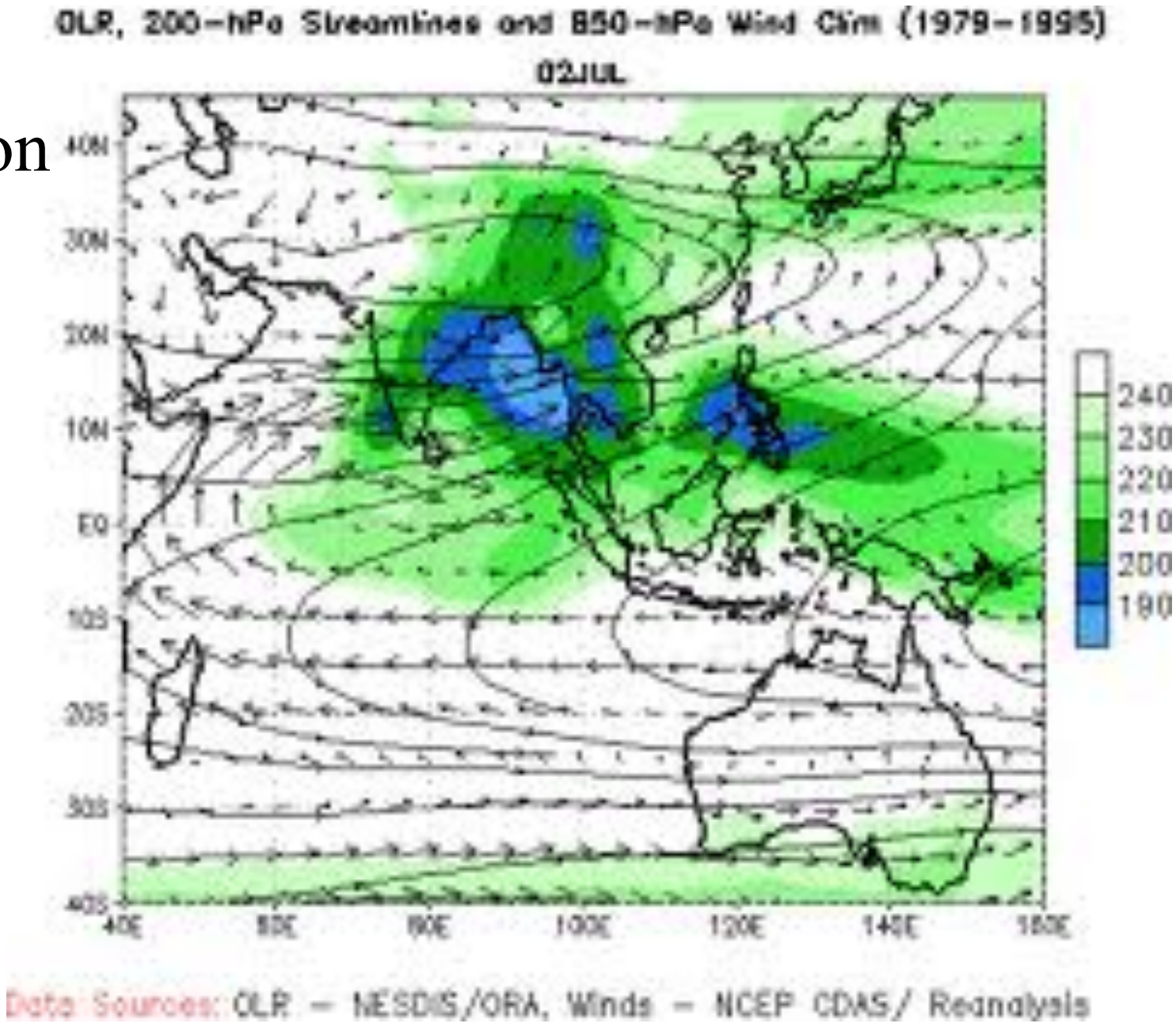
North American Climates;
Hurricanes;
Asian monsoon;

Pacific cold SST – negative IPO;

US east coast sea level



Seasonal:
Asian Monsoon
Wind &
Convection
(OLR –
measures
Tropical deep
convection;
Negative OLR:
Deep convection)



OLR – outgoing longave radiation (satellite data)

Monsoons

India Drought! 2002, 2004: Central Pacific-El Nino: normal rain predicted; but actually severer drought! – economic & societal impacts!

Indian Monsoon Flood.

1997-98 El Nino: Easter Pacific – drought predicted; but actually monsoon rainfall was normal. (Kumar et al. 2006)

Natural external forcing

Solar activities:

Short-term Changes (1's to 1000's of yrs)

Sunspot activities;

Long-term: 10,000yrs and longer

Milankovitch cycles

Volcanic eruptions:

aerosols

Anthropogenic warming

Global climate, the prevailing weather patterns of a planet or region over time, *is being altered by the addition of green house gases to the atmosphere by human –anthropogenic global warming.*

Greenhouse gases are gases that warm a planet's surface by absorbing outgoing *infrared radiation* – radiant heat – and reradiating some of it back toward the surface. This process is called the *Greenhouse effect.*

Greenhouse effect: A natural physical process in all planetary atmosphere that has greenhouse gases.

Table 3-2 Major Constituents of Earth's Atmosphere Today

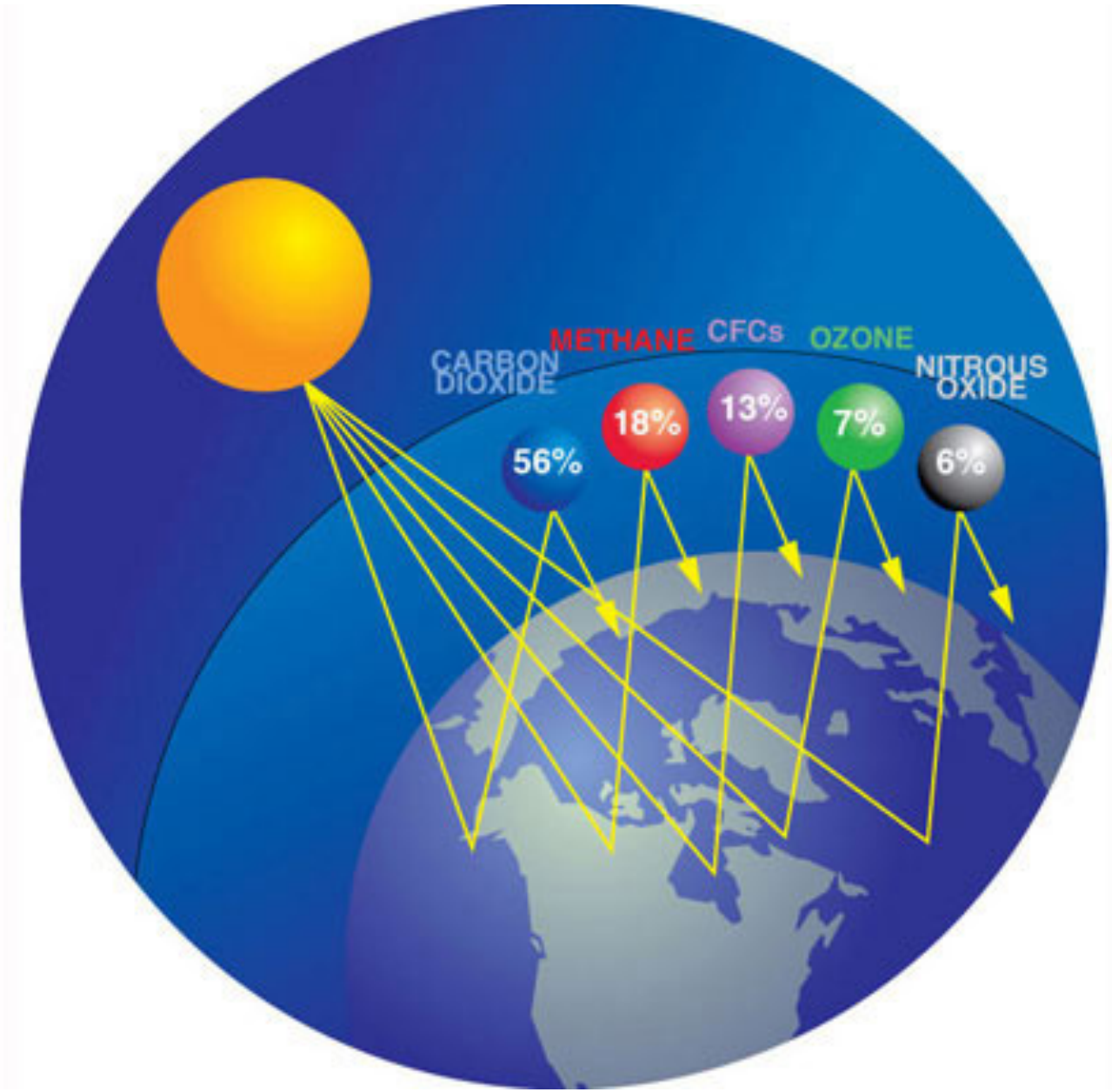
Name and Chemical Symbol	Concentration (% by volume)
Nitrogen, N_2	78
Oxygen, O_2	21
Argon, Ar	0.9
Water vapor, H_2O	0.00001 (South Pole)–4 (tropics)
Carbon dioxide, CO_2	0.039*

Trace gases:

*In 2008.

$$1\% = \frac{1}{100} = \frac{10000}{1000000} = \frac{10000}{1 million}$$

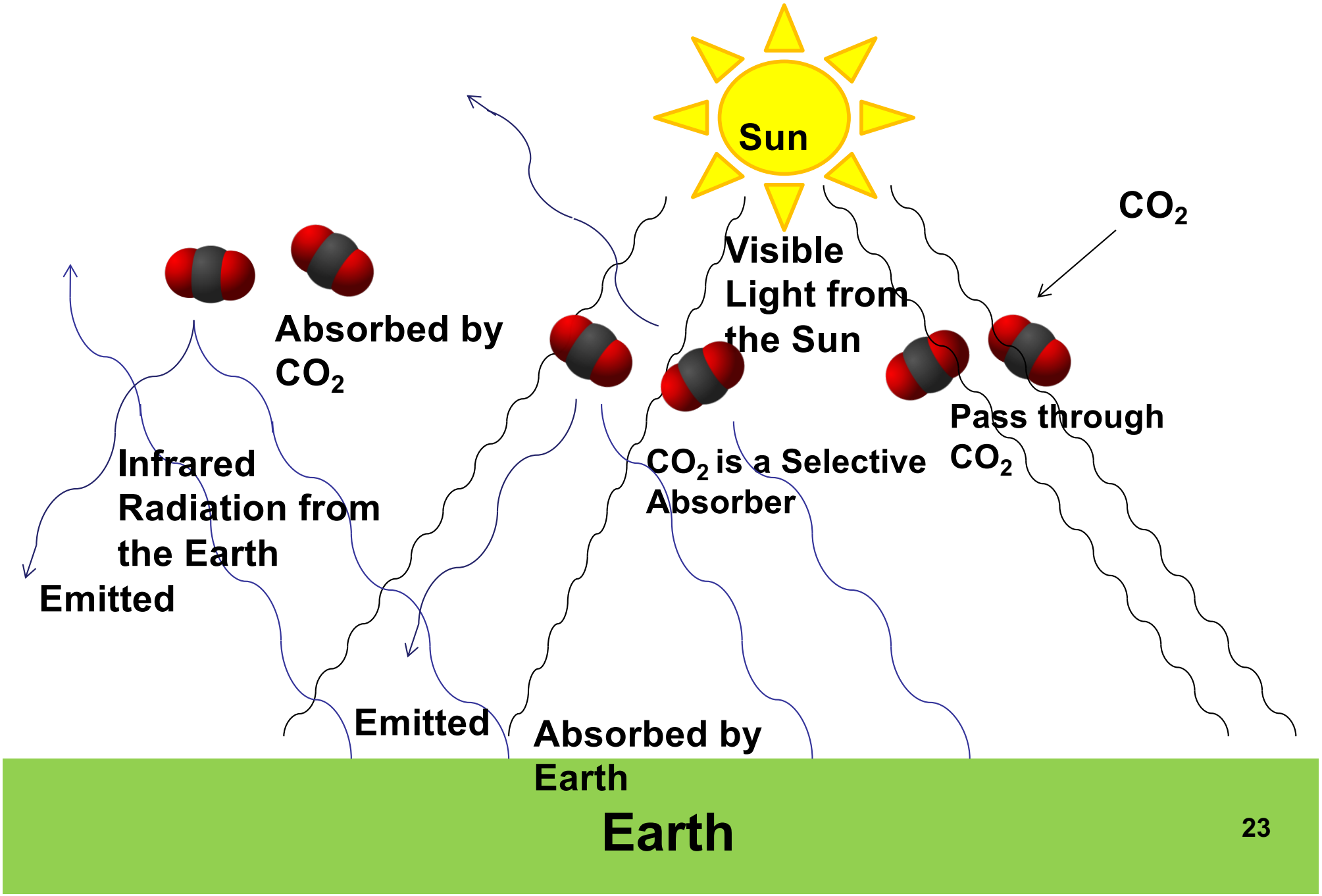
Atmospheric Major greenhouse gases



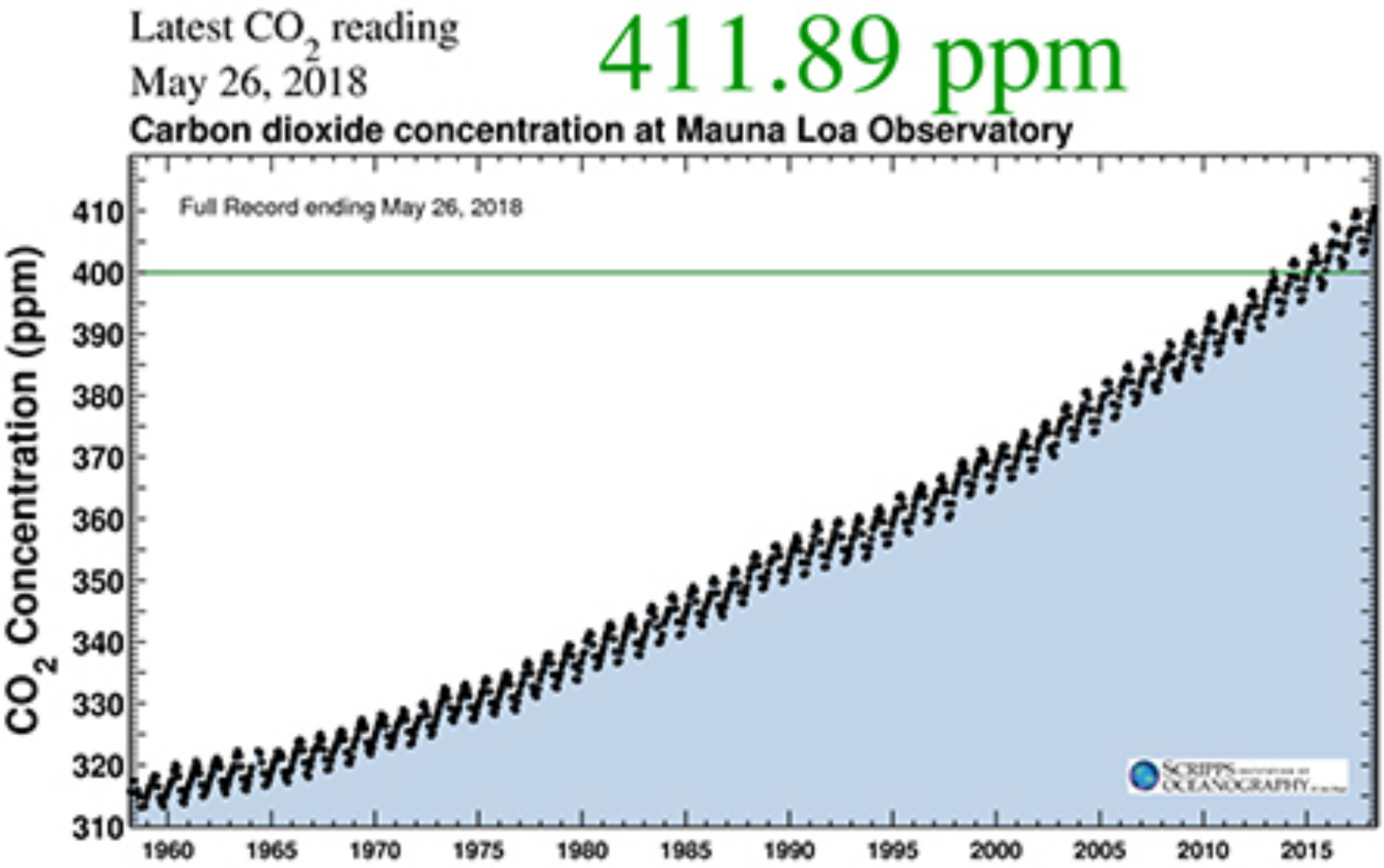
Water vapor is a good GHG; but It does not by itself increase temperatures, since it remains in the atmosphere for a very short time (few days). However,

It amplifies already occurring warming. Increased temperature increases water vapor in the atmosphere.

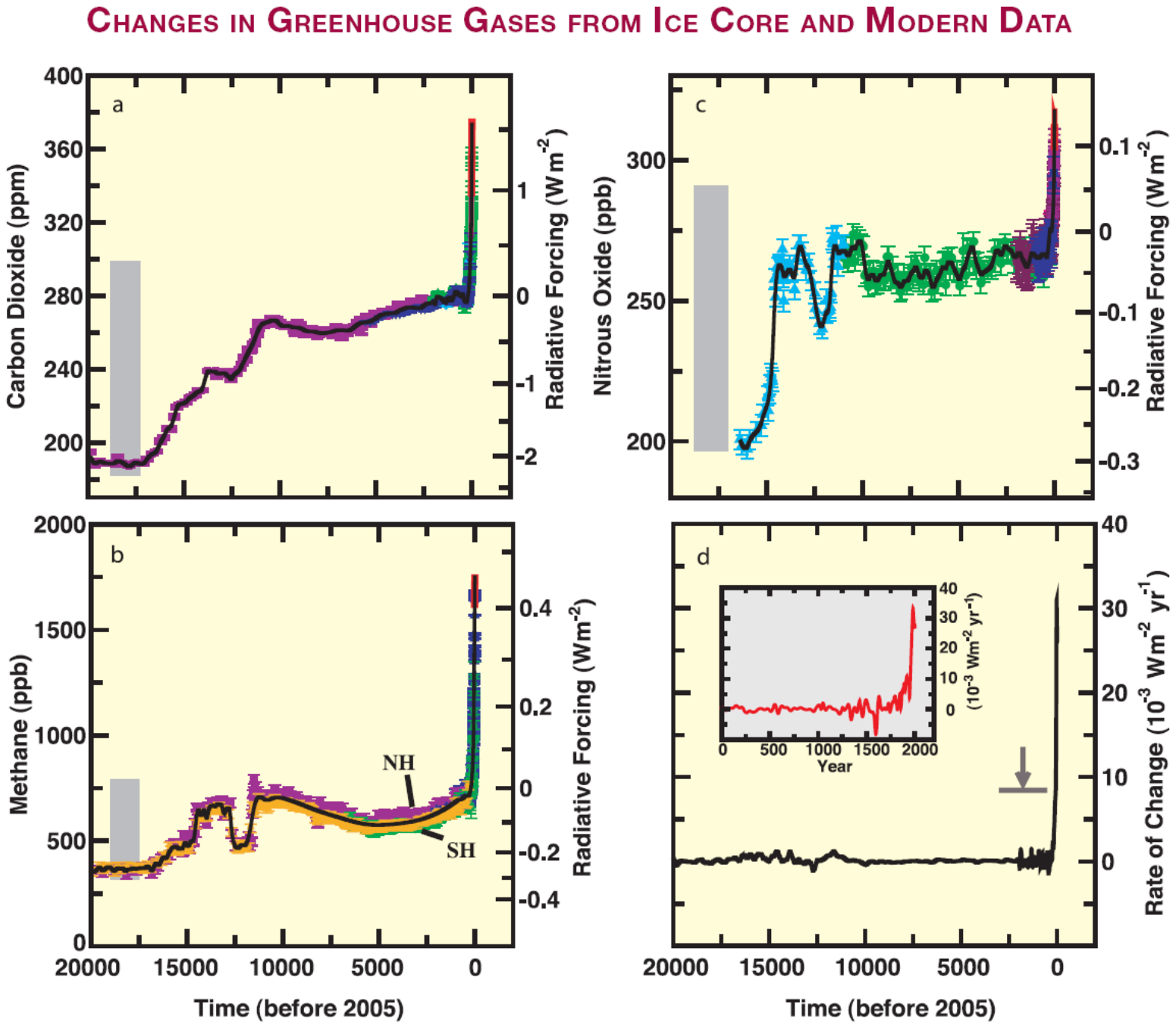
The Greenhouse Effect



The observed GHG (The Keeling curve)



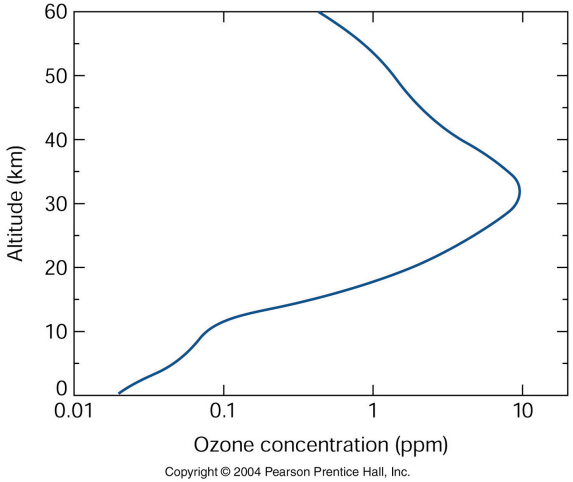
The observed GHG & global warming

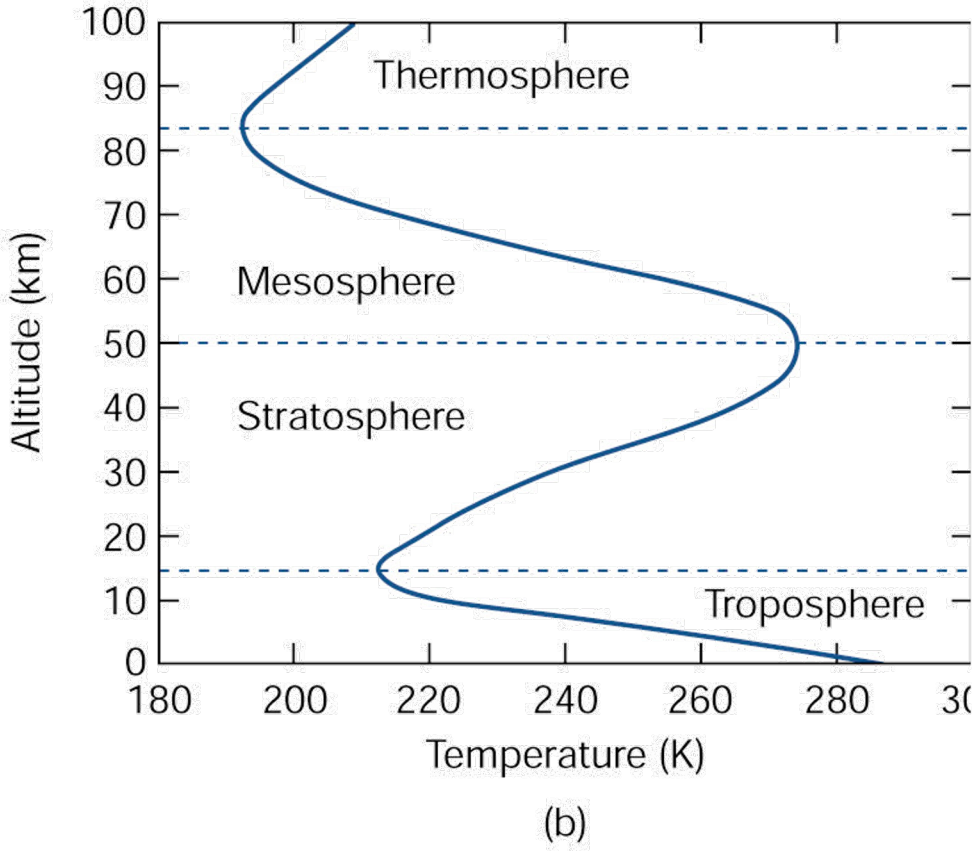


(iii) Ozone layer and Ozone depletion

Ozone layer: a chemically distinct region within the stratosphere (part of the earths atmosphere)

Contains most of the Earth's ozone.



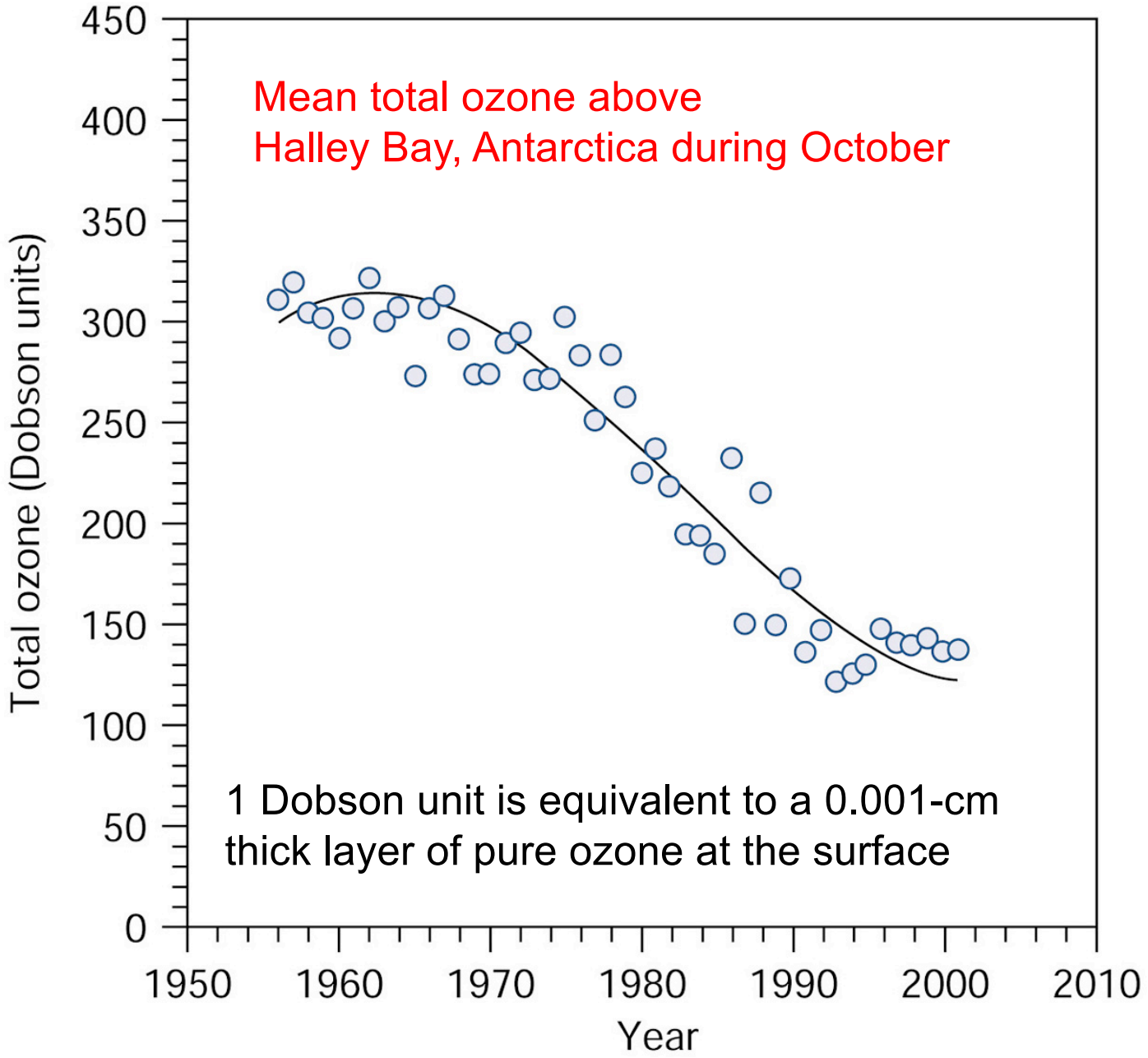


Human impact: Ozone depletion

Ozone layer: Protect Earth's surface from the Sun's Harmful ultraviolet (UV) radiation.

Antarctic ozone hole: In recent decades, a patch of extremely low ozone concentration, is thought to be human origin (freon can destroy ozone)

Observed Ozone Depletion



$$Cl + O_3 \longrightarrow ClO + O_2$$

Chlorine radical

Chlorine monoxide

CFCs (chlorofluorocarbon): transported to stratosphere; break down by UV and become free radicals containing Chlorine. These radicals then break down O3 (rapidly on the surface of polar stratospheric clouds during fall-winter)

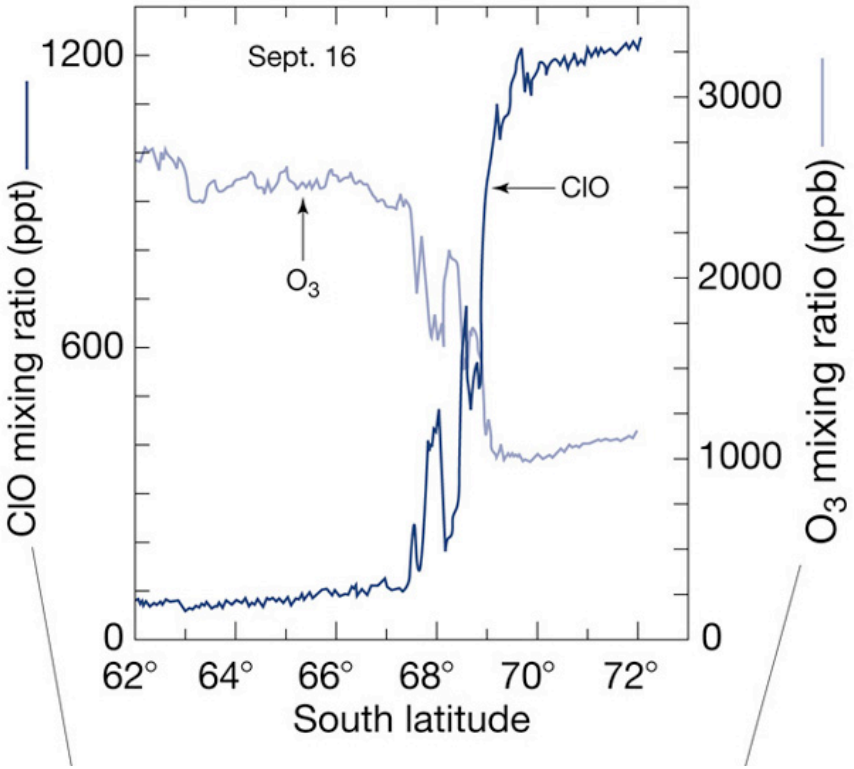


Fig 1-6 Observed Ozone (O3) and chlorine monoxide (ClO). NASA aircraft September 1987.

In 2012, it has been reported that the ozone hole had decreased to the smallest size since 2002. (Comprehensive assessment: healing)

(Ozone hole watch: NASA: https://ozonewatch.gsfc.nasa.gov)

https://believe.earth/en/recovery-of-the-ozone-layer-brings-hope/

(iv) Tropical Deforestation& Land Use/Land Cover Change

Since 10,000 years ago, humans farmed => alter land surface. Tropical deforestation Increases atmospheric CO_2 concentration by 6-17% (Baccini et al. 2012; Nature Climate Change).



We also have northern hemisphere re-forestation in recent years.

Deforestation → lost plant species →
lost of animals and microorganisms that live there.
New species may replace them, but normally the number of species decreases
reduce biodiversity. →

Land use/land change: affects climate:

(v) Hydraulic fracturing & the environment

https://www.youtube.com/watch?v=wrBlr12rVuI