ATMOS 1020 Climate Change

3. Two important climate phenomena

January 27, 2022

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3.1 The El Niño Southern Oscillation (ENSO)

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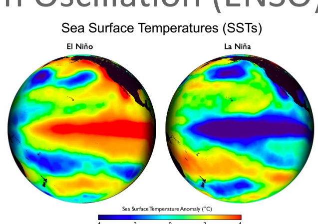
El Niño Southern Oscillation (ENSO)

- Natural irregular oscillation
- Warming and cooling of the equatorial Pacific ocean waters (SSTs)
- Causes global climate variations
- Two states: El Niño and La Niña
- Reason for ENSO
  - instability of the atmosphere-ocean system
  - interplay between
    - atmospheric pressure and winds with
    - oceanic temperatures and currents



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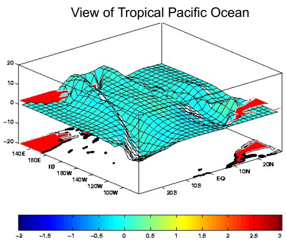
ENSO Computer Animation

- Change of sea level height (undulating surface) and sea-surface temperature (color) for a warm event, followed by a cold event
- Very long oceanic waves play an important role
- The waves are caused by anomalous trade winds blowing over the Pacific



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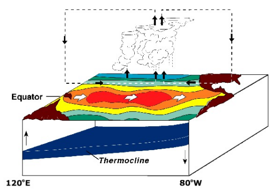
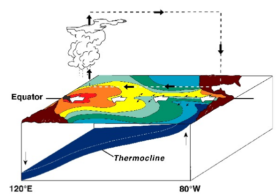
Two Types of ENSO Events

El Niño: Warm ENSO event



- Weak or even reversed trade winds over Pacific
- Central Pacific
  - warm, cloudy, rainy

La Niña: Cold ENSO event



- Strong trade winds over Pacific
- Central Pacific
  - cold, clear, dry
- Western Pacific ("warm pool"):
  - warm, cloudy, rainy

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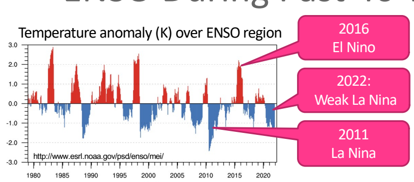
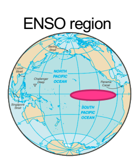
ENSO During Past 40 Years





- ENSO definition: ocean warming or cooling of at least 0.5°C over the east-central tropical Pacific
- El Niño ("the boy", i.e., Christ child): warm phase (red)
- La Niña ("the girl"): cold phase (blue)
- Events occur every ~4 years, last ~1 year, most intense during winter

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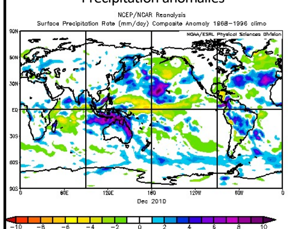
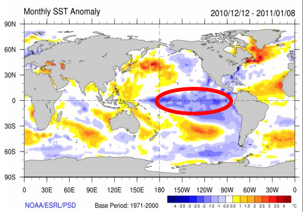
Climate Anomalies

- Climate anomaly
  = difference with respect to the long-term mean
  - an unusual climate condition, e.g., too cold or too wet
- Examples: La Nina during winter 2010/11

Precipitation anomalies



Sea surface temperature (SST) anomalies



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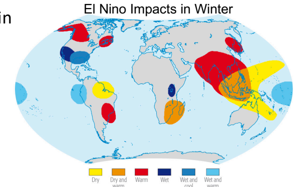
ENSO Impacts

- ENSO causes extreme weather in many parts of the world

El Nino Impacts in Winter



- El Niño impacts
  - northern US and Canada
    - warmer and drier, less snowfall
    - e.g., 2010 El Niño warmed Vancouver during Olympics
  - southern US and Mexico
    - cooler and wetter
  - suppressed hurricane activity over Atlantic
- La Niña impacts are just the opposite

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ENSO & Future Climate Change

- **Very uncertain** how ENSO will change in the future
  - area of active research
- Future changes in ENSO could affect some regions
  - temperature
  - precipitation
  - bleaching of corals

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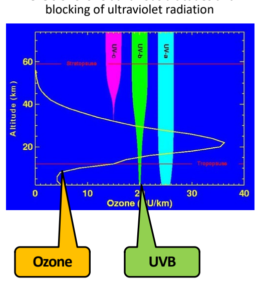
3.2 The Antarctic Ozone (O3) Hole

The Stratospheric Ozone Layer

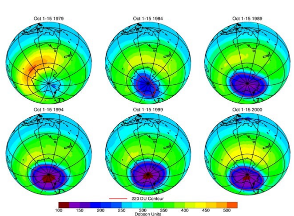
- Radiation from sun contains harmful ultraviolet (UV) radiation (= invisible)
- Most harmful: UVB wavelengths (280–315 nm); skin cancer, cataracts, damage to phytoplankton and plants, reduction of crops
- Stratosphere contains lots of ozone, the so-called "Ozone Layer"
- Ozone (O3) absorbs (removes) most of UVB in a process known as photo dissociation
  - photodissociation: gas absorbs radiation and converts it into heat

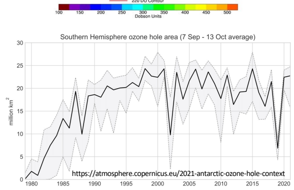
Levels of ozone at various altitudes and blocking of ultraviolet radiation



The Ozone "Hole"

- Satellite observations show a seasonal reduction in stratospheric ozone since 1979
- This is the so-called ozone "hole"
- Mostly in late Winter
- Over Antarctica (up to 70% reduction) during September-October
- To a lesser extent over Arctic (up to 30% reduction) during February-March

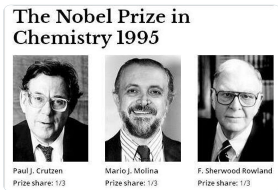




What Causes the Ozone Hole?

- Complicated photochemical reactions …
- Scientists received the Nobel Price for discovering this:

#DYK Chemist José Mario Molina 🇲🇽 together with Frank Sherwood 🇺🇸 and Paul Crutzen 🇳🇱 received the Nobel Peace Prize for their work that warned of the thinning of the Ozone Layer. Molina was the first Mexican-born citizen to receive a Nobel Prize in Chemistry.



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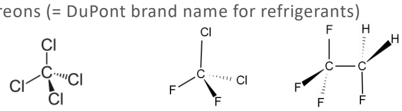
CFCs are Ozone Depleting Substances

- Chlorofluorocarbons (CFCs)
  - made of carbon (C), hydrogen (H), and halogens (Cl, Br, F)
- Example
  - carbon tetrachloride
  - Freons (= DuPont brand name for refrigerants)



Carbontetrachloride   Dichlorodifluoromethane   Tetrafluorethane

  - used as aerosol spray propellant, refrigerants, cleaning agents
- 100% of human origin; emitted at the surface
  - inert; long life time (~50 years); not easily removed from the atmosphere
  - eventually, CFCs reach the stratosphere and stay there for long

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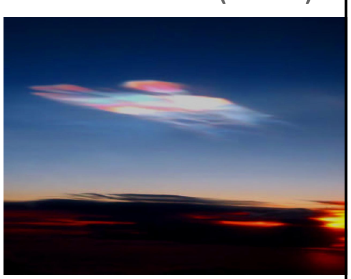
Polar Stratospheric Clouds (PSCs)

- PSCs enable ozone destruction reactions
- Stratosphere is very dry, has rarely clouds
- However, if it gets very cold (below −78°C, -108°F), PSCs may form



- Such conditions occur in the extreme cold of polar winter
- Mostly over Antarctic, to a lesser extent over the Arctic

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How Does Ozone Depletion Work?

- Destruction of ozone (O3) by atomic chlorine
- Chlorine acts as a catalyst; each chlorine breaks down 10,000s ozone molecules before being removed

Three ingredients:

1. **chlorine** (i.e., CFCs) for destruction of ozone
2. **sunlight** for the photodissociation (= breakup) of CFCs, releasing atomic chlorine (Cl)
3. **cold** temperatures for formation of PSCs
    - stratospheric polar vortex with strong winds traps cold air over pole
    - PSCs can form, which then enable catalytic ozone destruction

- These conditions are perfectly met in the stratosphere over Antarctica at the end of polar winter (September-October)
- To a lesser extent over the Arctic (February-March)

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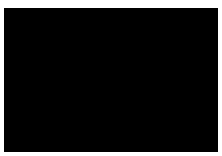
The Antarctic Ozone Hole

- The Antarctic ozone hole is an example of human induced climate change, but it is not global warming
- However:
    - global warming leads to cooling of stratosphere
    - more PSCs may form and create favorable conditions for ozone destruction



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Climate Change or Global Warming?

Terms are often used interchangeably:

- Climate change
  = long-term change in any aspect of climate
    - change in average weather or change in ozone
    - period of change: decades to millions of years
    - may be limited to a region (e.g., Antarctic) or globally
    - natural or anthropogenic
    - often used to downplay anthropogenic influence
- Global warming
  = recent increase in average near-surface temperatures
    - a specific aspect of recent (100 yrs) climate change
    - anthropogenic influence
    - believed to continue in the future

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Solution to the Ozone Problem

- Discovery of the ozone hole led to a ban on all CFCs
- "Montreal Protocol" 1989
  - the most efficient interaction between science and policy to date
- But CFCs are very long-lived
  - Antarctic ozone is predicted to recover by ~2070

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ENVIRONMENT

First Detection of Ozone Hole Recovery Claimed

The feel-good environment story of recent decades—the recovery of the so-called ozone hole—may be passing a major milestone far ahead of schedule. Every austral spring, an ominous "hole" appears in stratospheric ozone over Antarctica. In 1989, international regulations began restricting emissions of ozone-destroying chemicals, such as chlorine-containing refrigerants and propellants. The restrictions quickly capped and then began steadily reducing atmospheric concentrations of those dangerous chemicals.

Although ozone-destroying chemicals have been in decline for a decade now, researchers have long projected that they will not glimpse the first signs that the hole is healing until well past 2020. But for the first time, a group of researchers claims they can already see the ozone hole slowly recovering. Many others, however, say the paper, now in press in *Geophysical Research Letters* (*GRL*), leaves out critical information needed to clinch the case.

No one had been expecting to discern the recovery quite so soon. Scientists thought large, wholly natural, year-to-year variations in Antarctic ozone would obscure any small upward trend. Those natural ozone variations can be traced back through physical and chemical changes in the atmosphere to natural changes in atmospheric circulation. But no one had been able to take those circulation changes into account accurately enough to reveal the underlying ozone recovery.

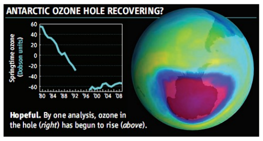
Meteorologist Murry Salby of Macquarie University in Sydney, Australia, and his Australian colleagues think they have nailed down the natural influences on the hole's ozone. In their *GRL* paper, they consider how much of the observed polar ozone variation each spring could be accounted for by changes in two kinds of atmospheric circulation that ultimately influence the amount of ozone destroyed in making the hole each spring. Taken together, the two observed that circulation changes accounted for "virtually all" of the year-to-year changes in springtime Antarctic ozone, Salby and colleagues write.

Subtracting their estimate of the natural changes in ozone from actual changes, the group finds "a clear upward trend since the late 1990s" in the hole's ozone that represents "a systematic rebound." Over the past decade, the rebound has amounted to about 15%, they estimate. "It's a small trend, but it's all we've been waiting for," says meteorologist Lorenzo Polvani of Columbia University. "Now we're actually seeing it."

Some other researchers aren't so sure. "I'm cautiously optimistic," says ozone researcher Paul Newman of NASA's Goddard Space Flight Center in Greenbelt, Maryland, but "I've done these sorts of correlations, and if you vary all the [uncertain parameters] and redo the analysis, you'll get different correlations. They won't look as good." Newman and others want to see a quantitative measure of the uncertainties.

The authors argue that the uncertainty is obviously small. They point to the way their estimate of chemically destroyed ozone closely tracks the amount of chemicals in the hole during the past 30 years. If they had chosen the wrong values, they say, those two trends would not have matched as well. Sorting out just what sort of uncertainty accounting is required should take at least until next October's hole shows up. –RICHARD A. KERR

ANTARCTIC OZONE HOLE RECOVERING?



Hopeful. By one analysis, ozone in the hole (*right*) has begun to rise (*above*).

CREDITS (TOP TO BOTTOM): NASA (IMAGE); M. SALBY *ET AL.*, *GEOPHYSICAL RESEARCH LETTERS*, PAPERS IN PRESS

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