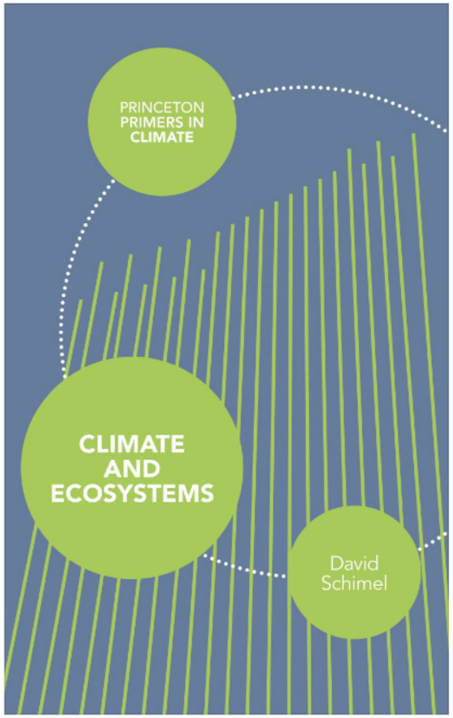
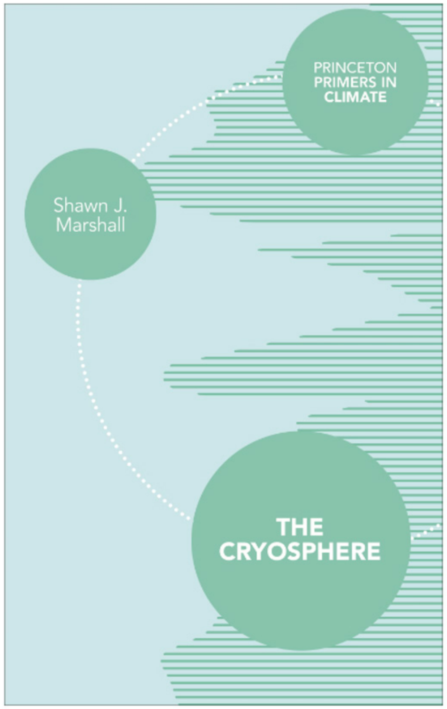
Ecosystems and Cryosphere Introduction

AOSC 680

Ross Salawitch

Class Web Sites:
http://www2.atmos.umd.edu/~rjs/class/fall2022
https://umd.instructure.com/courses/1327017





Lecture 21

17 November 2022

Student Projects

- Each student will provide an 18 minute (12 to 15 slide) presentation on a research project, either 2, 6, or 8 December 2022
- Presentations will be in the same order as the discussions of the Princeton Primers in Climate (PPC) readings, to provide some level of proper "spacing"
- Those presenting towards the end of the PPC readings encouraged to get started soon on your research project
- Each student will also submit a 6 to 8 pages single spaced (not including reference list or figures) paper, on the same project**, due at the class meeting that follows the in-class project presentation (or Mon 12 Dec for those presenting on 8 Dec)**
- Project should be ***new work for this class*** but can be related to your dissertation or some other topic in which you've had prior interest
- Would like students to provide a **2 to 3 sentence description** of your research project by a week from today, by replying here: https://umd.instructure.com/courses/1327017/quizzes/1551279
- Happy to speak and/or exchange email with students about possible projects
- For emails, most appreciated if subject can begin with "AOSC 680:"
- **If given a complete draft of your paper at least 7 calendar days prior to due date, I will provide back an edited "mark-up" you can use as input for final submission**

AGU Journal Abstract Requirement

AGU ADVANCING EARTH AND SPACE SCIENCE

Abstract

The abstract (1) states the nature of the investigation and (2) summarizes the important conclusions. The abstract should be suitable for indexing. Your abstract should:

- Be set as a single paragraph.
- Be less than 250 words for all journals except GRL, for which the limit is 150 words.
- Not include table or figure mentions.
- Avoid reference citations unless dependent on or directly related to another paper (e.g., companion, comment, reply, or commentary on another paper(s)). AGU's Style Guide discusses formatting citations in abstracts.
- Define all abbreviations.

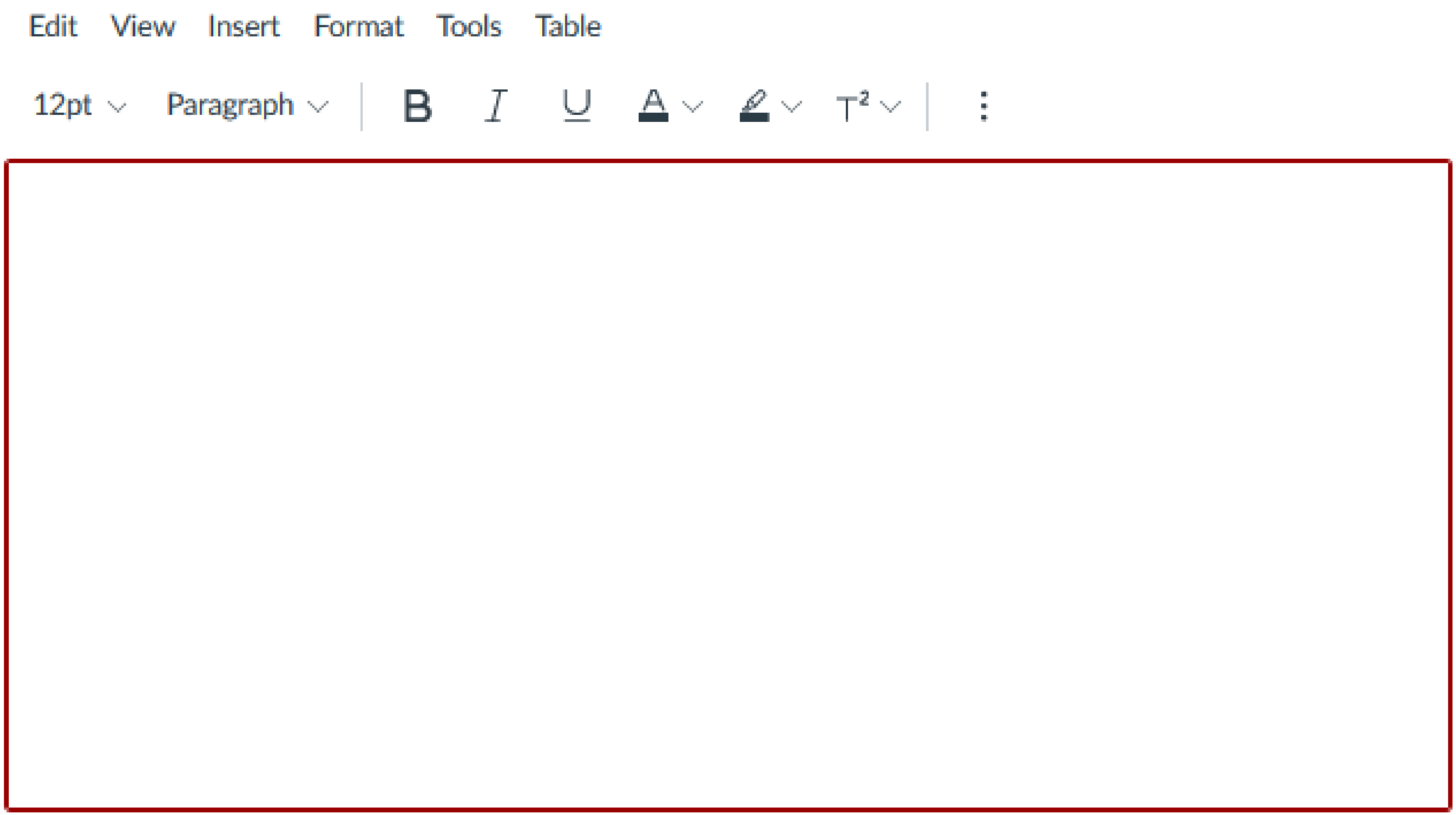
New requirement for your Research Paper: you must include an abstract, between 150 and 250 words, that will appear just after the paper title and your name of the first page of the submitted document, that summarizes the content of your paper for an interested, perspective reader.

In other words: please express: a) the high level elements of your research paper that you believe a reader will be interested in learning more about, should they decide to read the paper, as well as: b) the high level elements of your paper a reader should "take away", should they not have time to read the rest of the manuscript.

https://www.agu.org/Publish-with-AGU/Publish/Author-Resources/Text-requirements#abstract

Chapter 1: The Cryosphere

Describe with specificity (i.e, write a sentence or two description and include the page number or section heading) something you learned that you consider to be both new and interesting, from Chapter 1 of The Cryosphere by Shawn J. Marshall.



https://press.princeton.edu/books/paperback/9780691145266/the-cryosphere

New Paper Links Cryosphere and Ecosystem

Article | Open Access | Published: 10 November 2022

Spatially consistent microbial biomass and future cellular carbon release from melting Northern Hemisphere glacier surfaces

Ian T. Stevens, Tristram D. L. Irvine-Fynn, Arwyn Edwards, Andrew C. Mitchell, Joseph M. Cook, Philip R. Porter, Tom O. Holt, Matthias Huss, Xavier Fettweis, Brian J. Moorman, Birgit Sattler & Andy J. Hodson

Communications Earth & Environment **3**, Article number: 275 (2022) | Cite this article

368 Accesses | **128** Altmetric | Metrics

Abstract

Melting glacier ice surfaces host active microbial communities that enhance glacial melt, contribute to biogeochemical cycling, and nourish downstream ecosystems; but these communities remain poorly characterised. Over the coming decades, the forecast 'peak melt' of Earth's glaciers necessitates an improvement in understanding the state and fate of supraglacial ecosystems to better predict the effects of climate change upon glacial surfaces and catchment biogeochemistry. Here we show a regionally consistent mean microbial abundance of 10^4 cells mL^{-1} in surface meltwaters from eight glaciers across Europe and North America, and two sites in western Greenland. Microbial abundance is correlated with suspended sediment concentration, but not with ice surface hydraulic properties. We forecast that release of these microbes from surfaces under a medium carbon emission scenario (RCP 4.5) will deliver 2.9×10^{22} cells yr^{-1}, equivalent to 0.65 million tonnes yr^{-1} of cellular carbon, to downstream ecosystems over the next ~80 years.

https://www.nature.com/articles/s43247-022-00609-0

Preface, Climate and Ecosystems

FORT COLLINS, Colo. — Well, by golly! Who would've guessed?! The first brewery to ever open up in Fort Collins was actually Budweiser! Strange, huh? After all, Fort Collins is sort of like a craft brewery mecca!

It's true, though. The Budweiser Brewery opened its doors in 1988, nearly 2 decades after Fort Collins lifted its law on prohibition.

See, even though prohibition ended nationally around 1933, Fort Collins had its own local prohibition law in place until 1969.

It is kind of odd it took close to 20 years for a brewery to open in Fort Collins after prohibition ended though, ya know?

Photo by Drew Smith

https://kdvr.com/news/unique-2-colorado/budweisers-big-claim-to-small-colorado-town/

10

A NEW HUMAN NEED: STUDY OF GLOBAL CHANGE

Human activity is now causing significant changes on a global scale within the span of a few human generations. The burning of fossil fuels, for example, is injecting carbon dioxide into the atmosphere at unprecedented rates. The atmospheric concentration of this gas has increased by nearly 25 percent since the Industrial Revolution, and by over 10 percent since 1958 alone; at this rate it will double within a century. Carbon dioxide is transparent to sunlight entering the atmosphere but blocks the flow of heat radiated outward from the Earth's surface, thus creating a "greenhouse effect" that produces a net warming trend. On the basis of the present rate of increase in atmospheric carbon dioxide, climate models predict an average global increase of at least 2°C in surface temperature during the next century—an increase comparable to that experienced since the last Ice Age 18,000 years ago—together with marked shifts in precipitation patterns. There are also continuing increases in a number of other "greenhouse gases," including methane, chlorofluorocarbons, and tropospheric ozone; although the concentrations of these trace species are presently much less than that of carbon dioxide, they are rising much more rapidly. Their effects can also be more pronounced: molecule for molecule, chlorofluorocarbons produce 10,000 times the greenhouse effect of carbon dioxide, in addition to depleting stratospheric ozone.

Moreover, the daily needs of nearly half the world's people for fuel and nourishment are reducing the Earth's vegetation and the productivity of marginal agricultural land. Because of these economic and cultural forces, the extent of the Earth's forest cover has decreased substantially since 1950. Since much of the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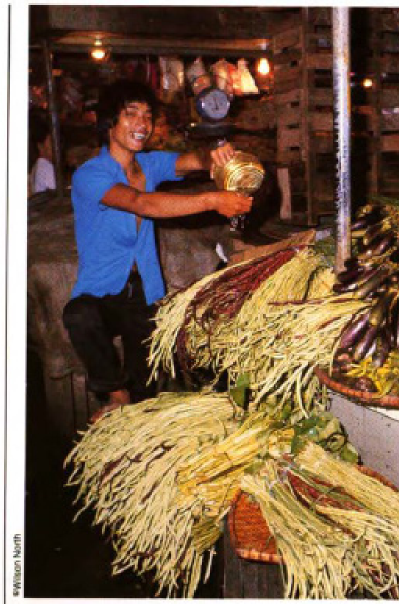
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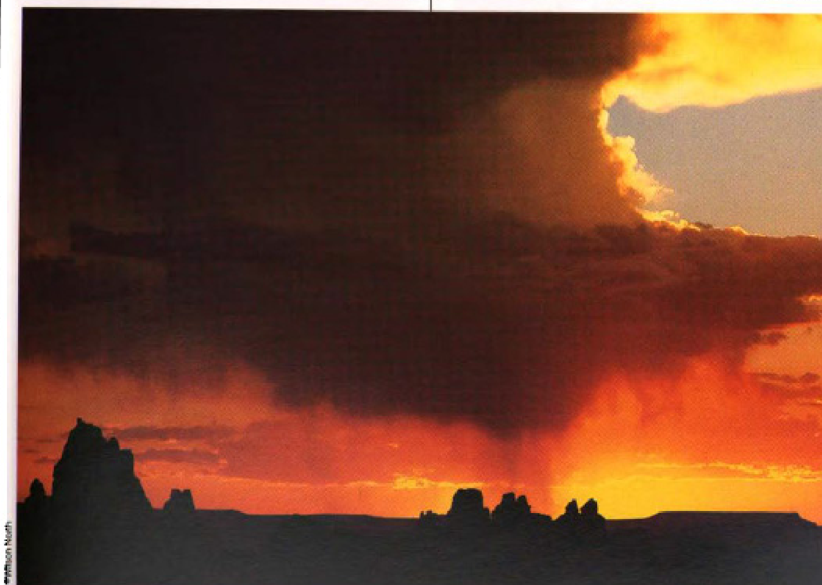
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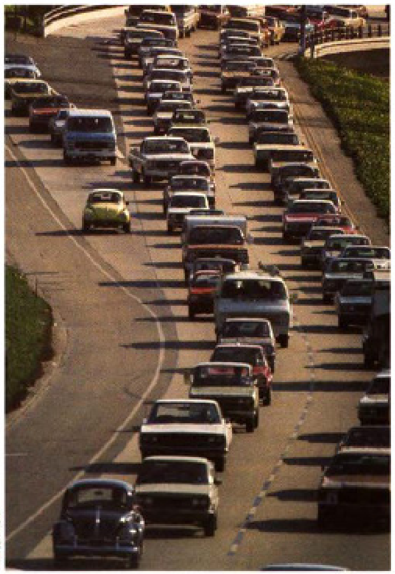
11

https://nap.nationalacademies.org/download/19210

Earth System Science: Overview: A Program for Global Change (1986)

12

deforested land is planted to other vegetation, and since substantial afforestation may be occurring at northern midlatitudes, the net effect on carbon-dioxide balance remains unclear, but such changes are almost certain to alter the ecology of the land in a variety of ways. For example, the clearing of tropical forest, often by burning, is reducing the world's greatest reservoir of plant and animal diversity. In marginal agricultural areas, overcropping of the land and uncontrolled animal grazing may be turning productive soil into desert, a major source of dust that in turn can affect atmospheric properties and climate.



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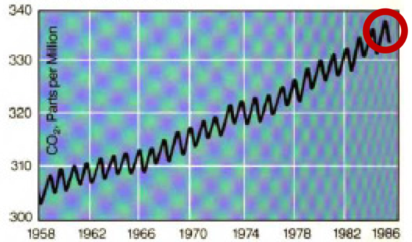
All of these human-induced changes are difficult to assess and measure accurately, but it is already evident that they are playing a role in shaping present and future global conditions. Now is the time to document these processes on a global scale and to identify the causal relationships among them, while there is still time to respond effectively.

Observed increase in atmospheric carbon dioxide, resulting in part from human activities.



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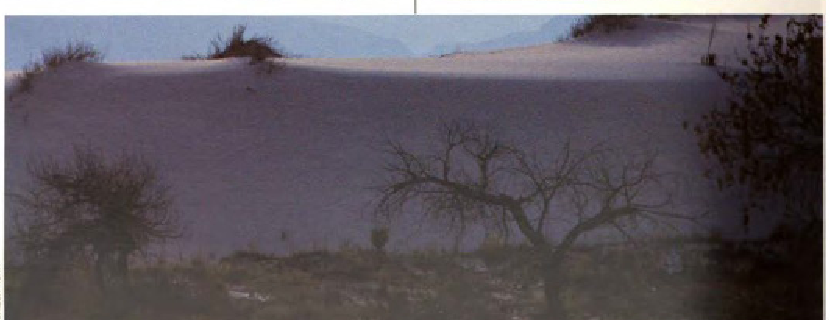

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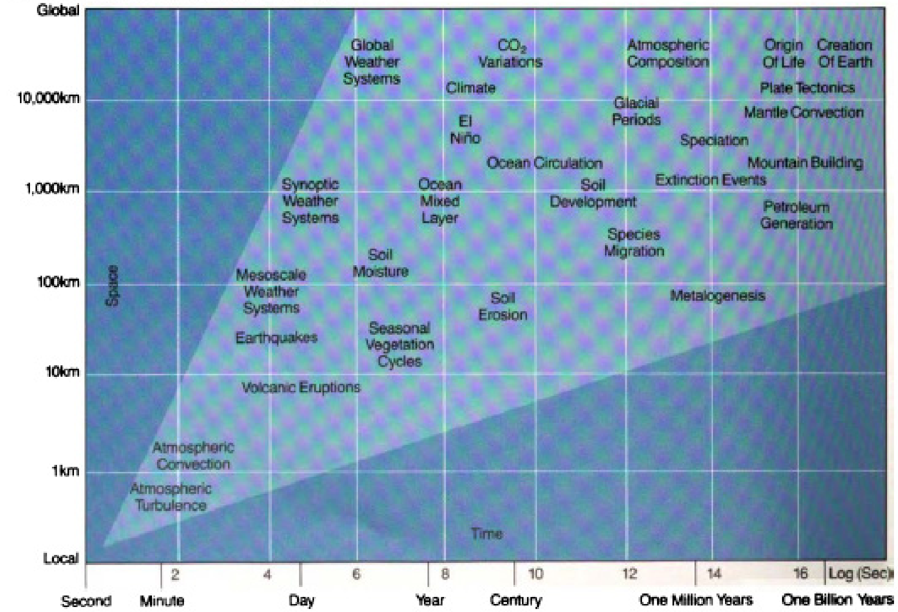
The geological record has long been studied

Figure 1. EARTH SYSTEM PROCESSES: CHARACTERISTIC SPACE AND TIME SCALES



Membership, Earth System Sciences Committee

Francis P. Bretherton, *National Center for Atmospheric Research (Chair)*
D. James Baker, *Joint Oceanographic Institutions Inc.*
Daniel B. Botkin, *University of California at Santa Barbara*
Kevin C. A. Burke, *NASA Lunar and Planetary Institute*
Moustafa Chahine, *Jet Propulsion Laboratory, California Institute of Technology*
John A. Dutton, *Pennsylvania State University*
Lennard A. Fisk, *University of New Hampshire*
Noel W. Hinners, *NASA Goddard Space Flight Center*
David A. Landgrebe, *Purdue University*
James J. McCarthy, *Harvard University*
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Earth System Science: Overview: A Program for Global Change (1986)

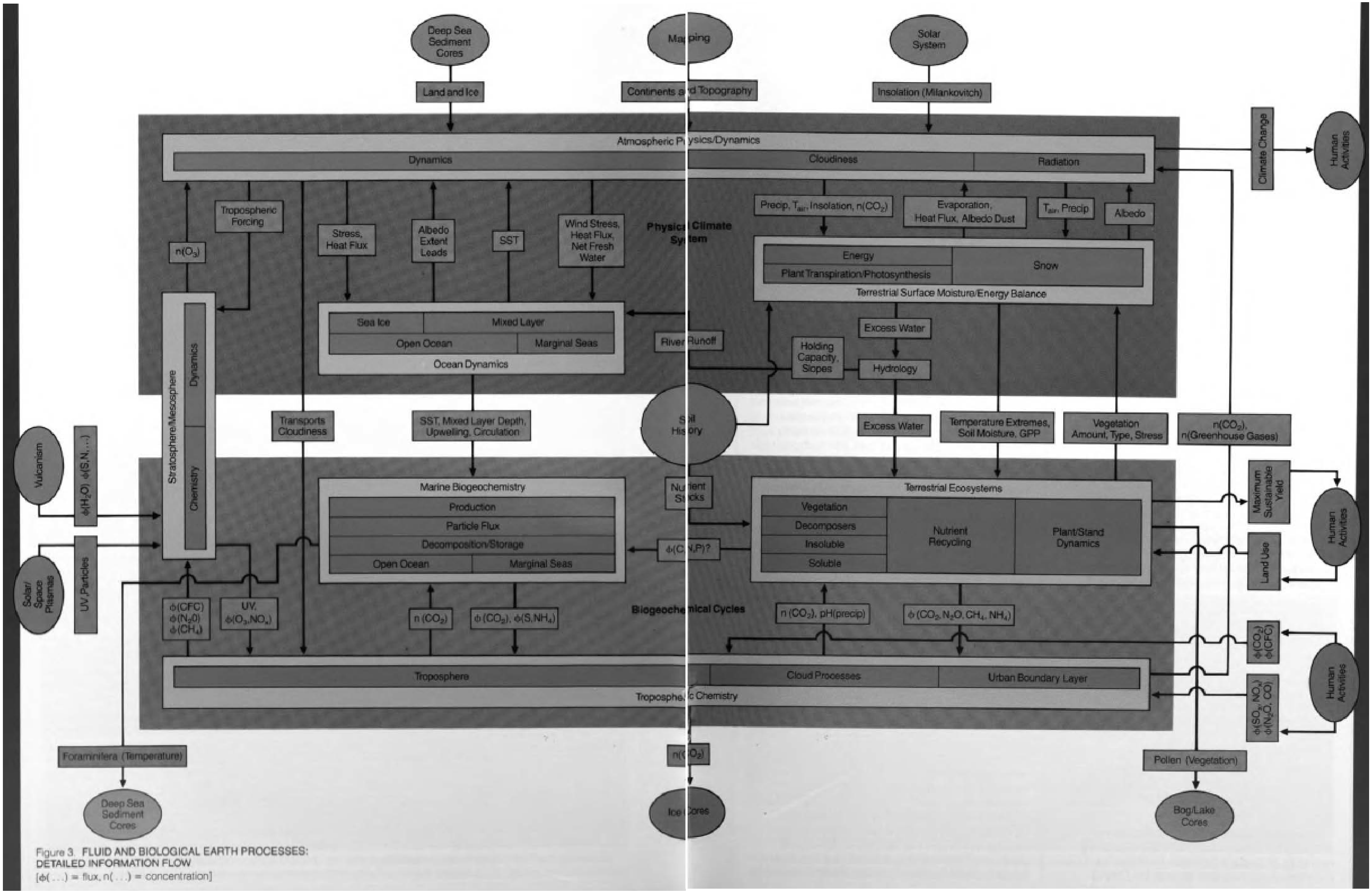


Figure 3. FLUID AND BIOLOGICAL EARTH PROCESSES: DETAILED INFORMATION FLOW
[φ(...) = flux, n(...) = concentration]

https://nap.nationalacademies.org/download/19210

Earth System Science: Overview: A Program for Global Change (1986)

NASA SPACE RESEARCH MISSIONS PROBE GLOBAL EARTH PROCESSES. Joint U.S./France TOPEX/POSEIDON satellite will measure sea-surface topography to provide data for models of ocean circulation *(artist's conception)*.

◆ Ocean Topography Experiment (TOPEX/POSEIDON). This joint US/France mission, proposed as a 1987 NASA new start, will use radar altimetry to measure the surface topography of the oceans over a period of several years. When combined with appropriate *in situ* measurements, these observations will permit a determination of the three-dimensional structure of the world's ocean currents. The prime sensor will be a modification of the highly successful 1978 Seasat altimeter providing direct measurement of ocean topography through two-frequency operation. Highly accurate orbital characteristics are to be provided by receivers of the Global Positioning System; laser-tracking retroreflectors will be carried as well. Two experimental French instruments are part of the payload, and launch will be provided by Ariane.

https://nap.nationalacademies.org/download/19210

Chapter 1: Climate and Ecosystems

Imagine a drying trend. The increasingly taller drought-tolerant trees begin to shadow the water-loving species and reduce the light available to them for growth. Even in wet years, the drought-tolerant trees now have an advantage, and the entire community of organisms (including the animals that feed on the trees, and the predators that eat those herbivores) begins to change.

Although climate initiated the change, the interactions among the forest's organisms now take hold and control some of the change. Did a water-loving tree die of drought, or did it perish from inadequate light for growth owing to shade from a taller drought-tolerant tree? Was this tree death a climate effect or an effect of plant community processes? Of course, it was both, and in this simplified tale we can begin to see the complexity of climate–ecosystem interactions. As the forest canopy grows and covers more of the landscape, it makes the land surface darker, so it absorbs more sunlight, warming the surface more, and actually begins to change the local climate. Climate affects the metabolism and behavior of individual organisms, but these biological changes affect an organism's interactions with other organisms, and both the physics and the ecology of the system.

https://press.princeton.edu/books/paperback/9780691151960/climate-and-ecosystems

Uptake of Atmospheric CO_2 by Trees (Land Sink)

Land sink: relatively short lived reservoir

- In this model, future water stress due to climate change eventually limits plant growth
- Feedbacks between climate change & plants could lead to almost 100 ppm additional CO_2 by end of century

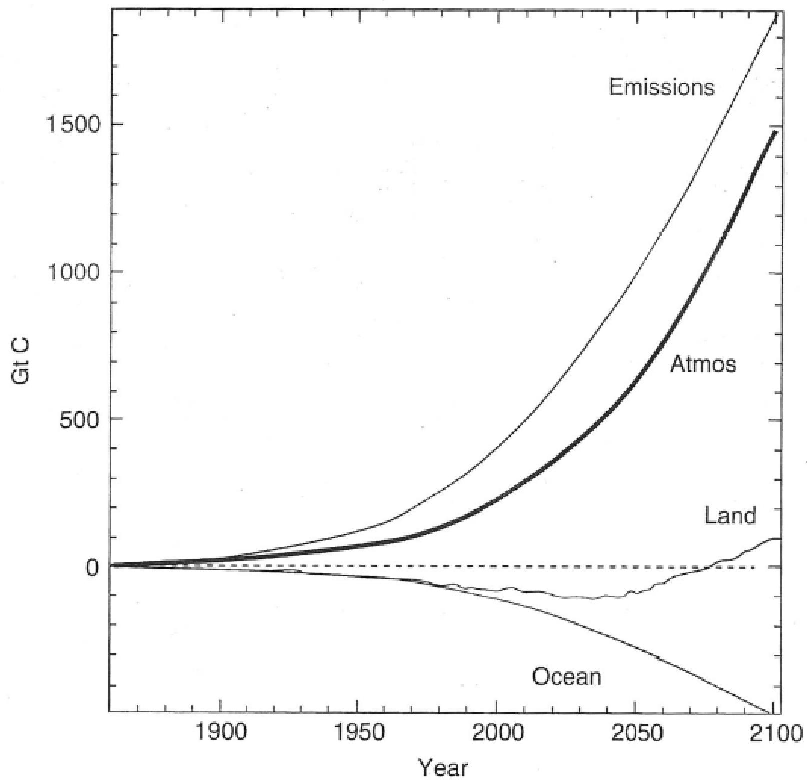
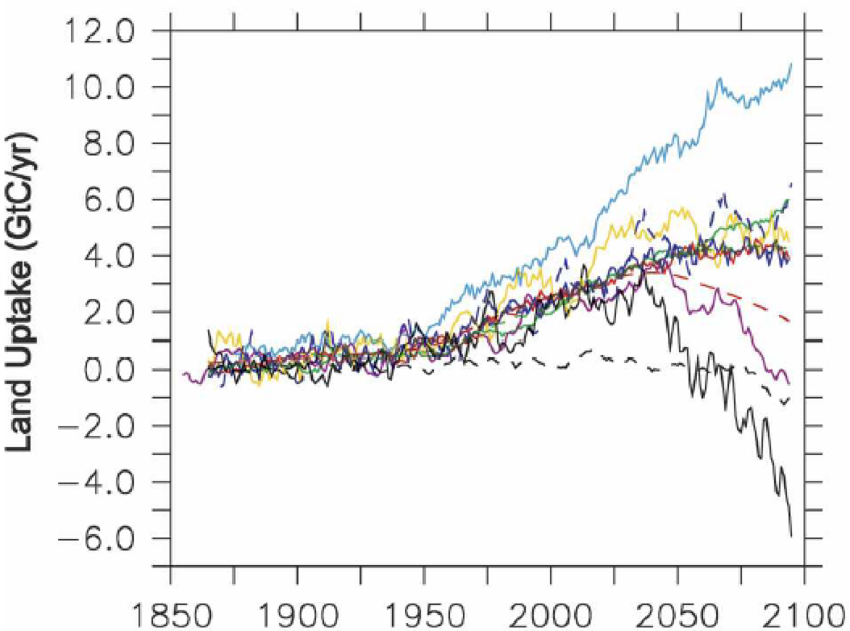


Figure 3.5 Illustrating the possible effects of climate feedbacks on the carbon cycle. Results are shown of the changing budgets of carbon

Figure 3.5, Houghton 3[d] Edition

- Future fate of land sink highly uncertain according to **11** coupled climate-carbon cycle models examined by Friedlingstein et al. (2006)



Uptake of Atmospheric CO_2 by Trees (Land Sink)

Land sink

As CO_2 ↑, photosynthesis (all things being equal) will increase.

Known as the **"CO_2 fertilizer" effect**

Difficult to quantify empirically in a greenhouse setting because ?

The results of this study suggest that competition for light was the major factor influencing community composition, and that CO_2 influenced competitive outcome largely through its effects on canopy architecture. Early in the experiment competition for nutrients was intense.

Fakhri A. Bazzaz, 1990: https://www.jstor.org/stable/pdf/2097022.pdf

Many Free-Air Carbon dioxide Enrichment (FACE) experiments have been developed, throughout the world including a new experiment in Brazil, to attempt to understand how the terrestrial biosphere will respond to rising levels of atmospheric CO_2

http://aspenface.mtu.edu

https://www.nature.com/news/polopoly_fs/1.12855!/menu/main/topColumns/topLeftColumn/pdf/496405a.pdf?origin=ppub

https://www.nature.com/scitable/knowledge/library/effects-of-rising-atmospheric-concentrations-of-carbon-13254108

Drought and Canopy Height

LETTER

Forest drought resistance distinguished by canopy height

Peipei Xu[1,2,3], Tao Zhou[1,2,6], Chuixiang Yi[3,4,6], Wei Fang[3], George Hendrey[3,4] and Xiang Zhao[5]

Abstract

How are the survival and growth of trees under severe drought affected by their size? While some studies have shown that large trees are more vulnerable to drought than smaller trees, others found that small trees are the more vulnerable. We explored the potential relationships between canopy height and forest responses to drought indicated by tree mortality, tree ring width index (RWI), and normalized difference vegetation index (NDVI) in the southwestern United States (SWUS) in 2002. In that year many trees had zero tree ring growth due to mortality and dieback, presumably related to drought-stress. With RWI data from a tree ring data base and climate data co-located with the field measurements, we found size-dependent linear correlations between these forest responses and canopy height in SWUS under severe drought condition. During that drought period, both trunk growth (RWI) and leaf growth (NDVI) were positively correlated with canopy height of the smaller trees (less than 18 m) and negatively correlated with canopy height of greater than 18 m. Tree mortality was negatively correlated with canopy height up to 15 m. Both local-scale and regional-scale data are consistent in showing that forests with medium canopy height (around 18 meters) showed the greatest resistance to severe drought. We suggest that negative impacts of severe drought on forests could be modified with active management of canopy structure.

Xu *et al*., *Environ. Res. Lett.*, 2018: https://iopscience.iop.org/article/10.1088/1748-9326/aacadd

Drought and Canopy Height

RWI: tree ring width index

NDVI: normalized difference vegetation index

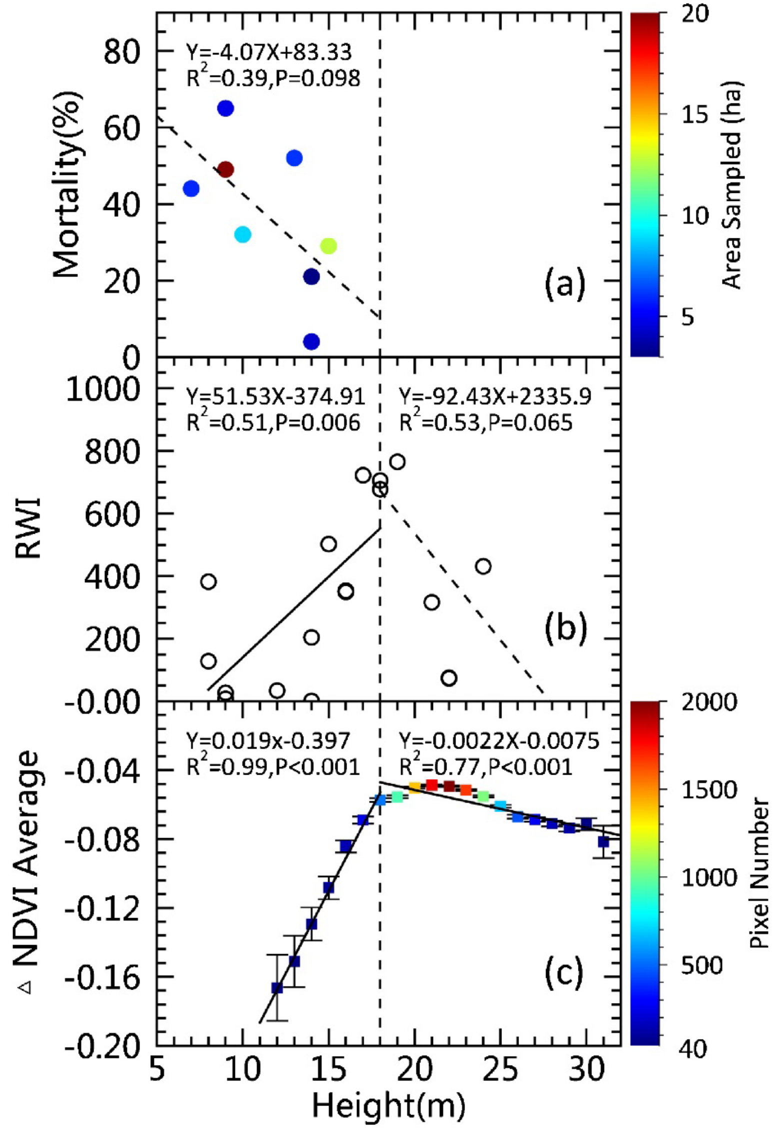


Figure 2. The relationship between forest growth variables and canopy height under severe drought.

(for two dominant conifer species, PIED and PIPO in Arizona, New Mexico, Colorado, and Utah)

Xu *et al.*, *Environ. Res. Lett.*, 2018: https://iopscience.iop.org/article/10.1088/1748-9326/aacadd

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1. Introduction

End of Intro:

In this study, we attempted to reveal the relationship between the growth of forests in the Southwest and canopy height under severe drought condition. By integrating field measurement data, remote sensing data and climate data, we analyzed the drought responses in different forests with various canopy heights. The objective of this study was answer this question: when a drought reaches the tipping point that may lead to zero tree ring growth, what is the role of canopy height in forest resistance to drought?

SPEI: standardized precipitation evapotranspiration index

SWUS: Southwest US

4. Conclusion

In this study, we analyzed the characteristics of severe drought responses in forests with different canopy heights based on multi-resource data. Our results demonstrated that when drought reached the tipping point of SPEI <-1.64, the amount of tree mortality and reductions in stem growth (RWI) and leaf growth (NDVI) of the forests was correlated with canopy height in SWUS. Both short and tall forests were more vulnerable and susceptible to drought than medium-height forest stands. The medium height forests had the greatest drought resistance. Considering the increase in the frequency and duration of severe drought in the context of global climate change, more attention needs to be given to canopy structure in forest management and risk assessments in the future.

Xu *et al.*, *Environ. Res. Lett.*, 2018: https://iopscience.iop.org/article/10.1088/1748-9326/aacadd

THE HUMAN TIMESCALE: THE ANTHROPOCENE

Geological time periods reflect events that are recorded in the rock record, through volcanic or erosional processes and other events that leave global traces evident to geologists. Recently, scientists have discussed terming the present the Anthropocene, because the effects of human use of natural resources, construction of cities and other infrastructure, climate change, and the impact of human-caused mass extinctions on the future fossil record should be evident to far-future researchers. In trying to understand present climate–ecosystem interactions the impacts of humanity are crucial. Human activity can change the way events occur over many different timescales. Harvesting a forest can instantaneously remove most of the wood slowly accumulated over days to centuries. However, that removal resets the forest's clock and will influence its dynamics for—at least—the lifespan of those trees. Human disturbance (forestry, conversion to agriculture) tends to cause rapid change to ecosystems but triggers slow responses as systems recover biomass and species composition over decades.

https://press.princeton.edu/books/paperback/9780691151960/climate-and-ecosystems

History of the term Anthropocene

FEATURES | October 5. 2016.

Anthropocene: The journey to a new geological epoch

Over the last century, humans have littered the oceans with plastic, pumped CO2 into the air and raked fertilisers across the land. The impact of our species is so severe and so enduring that the current geological time period could soon be declared the "Anthropocene".

Antonio Stoppani is often cited as the first person to suggest that the current geological epoch should be defined by the influence of humans. Formerly a Catholic priest, the Italian professor had turned to geology after he was expelled from the seminary where he taught grammar for his political fervour.

Stoppani saw the footprints of humanity everywhere: it had carved the paths of rivers, mined the Alps, dammed the ocean and built cities. "The Anthropozoic era has begun: geologists cannot predict its end at all," he wrote in his 1873 work *Corso di Geologia*. And while the so-called Anthropozoic era might have only lasted a "handful of centuries" so far, he predicted that our species' influence would continue long into the future.

His ideas may have been influenced by American conservationist George Perkins Marsh, who was ambassador to Italy at the time, although Marsh himself acknowledges that Stoppani went further than he ever did.

Throughout the 19th and 20th centuries, more geologists played with the idea of introducing humanity into the sequence of geological time periods.

https://www.carbonbrief.org/anthropocene-journey-to-new-geological-epoch/

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'A dangerous shift'

In 2000, Nobel-prize winning chemist Paul Crutzen and Great Lakes specialist Eugene F. Stoermer made reference to some of these scientists in a newsletter for the now defunct International Geosphere-Biosphere Programme. In this short article, they wrote:

> "Considering these and many other major and still growing impacts of human activities on Earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasise the central role of mankind in geology and ecology by proposing to use the term 'anthropocene' for the current geological epoch. The impacts of current human activities will continue over long periods."

It was this that revived the idea of the Anthropocene as a possible new geological time period and re-entered it into the scientific vernacular. Crutzen followed up the idea two years later with a paper in the journal Nature.

https://www.carbonbrief.org/anthropocene-journey-to-new-geological-epoch/

Crutzen, Nature, 2000

NATURE | VOL 415 | 3 JANUARY 2002 | www.nature.com

concepts

Geology of mankind

Paul J. Crutzen

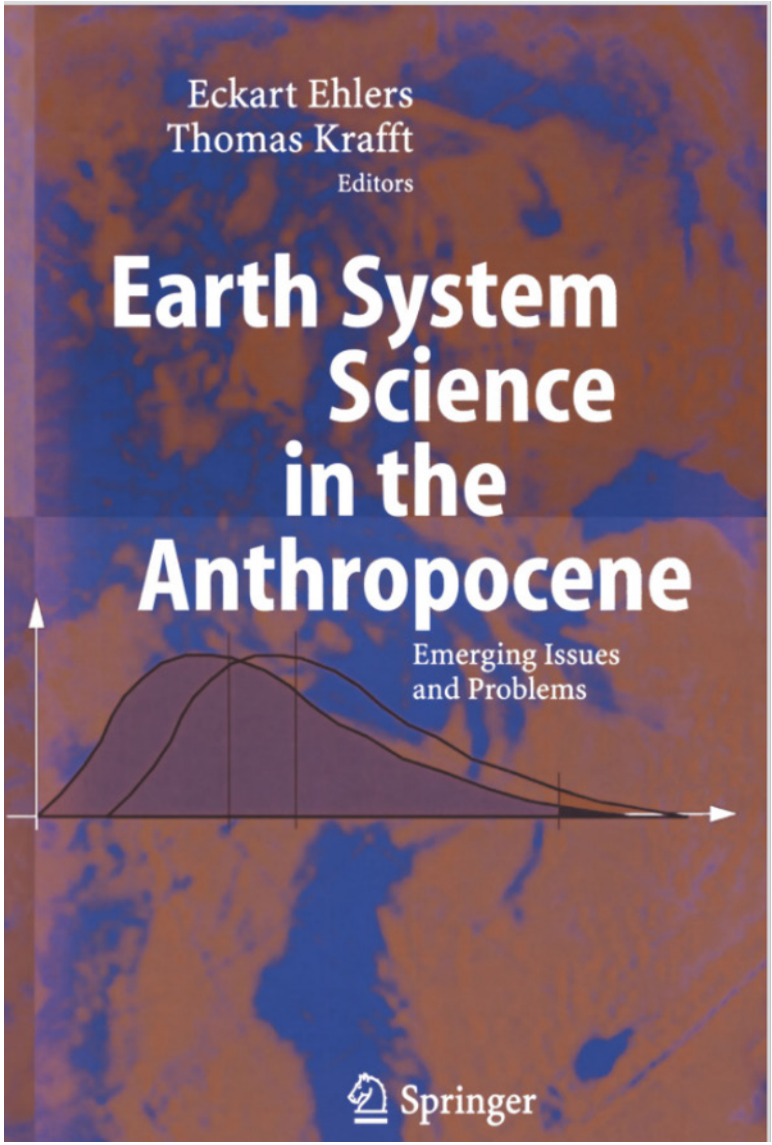
About 30–50% of the planet's land surface is exploited by humans. Tropical rainforests disappear at a fast pace, releasing carbon dioxide and strongly increasing species extinction. Dam building and river diversion have become commonplace. More than half of all accessible fresh water is used by mankind. Fisheries remove more than 25% of the primary production in upwelling ocean regions and 35% in the temperate continental shelf. Energy use has grown 16-fold during the twentieth century, causing 160 million tonnes of atmospheric sulphur dioxide emissions per year, more than twice the sum of its natural emissions. More nitrogen fertilizer is applied in agriculture than is fixed naturally in all terrestrial ecosystems; nitric oxide production by the burning of fossil fuel and biomass also overrides natural emissions. Fossil-fuel burning and agriculture have caused substantial increases in the concentrations of 'greenhouse' gases — carbon dioxide by 30% and methane by more than 100% — reaching their highest levels over the past 400 millennia, with more to follow.

The Anthropocene

The Anthropocene could be said to have started in the late eighteenth century, when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and methane.

https://www.nature.com/articles/415023a

2006: Compendium of 18 papers



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https://link.springer.com/content/pdf/10.1007/b137853.pdf

Crutzen's 2006 Update:

1.2 The "Anthropocene"

Paul J. Crutzen
Max-Planck-Institute for Chemistry, Joh.-Joachim-Becher-Weg 27, 55128 Mainz

Abstract. Human activities are exerting increasing impacts on the environment on all scales, in many ways outcompeting natural processes. This includes the manufacturing of hazardous chemical compounds which are not produced by nature, such as for instance the chlorofluorocarbon gases which are responsible for the "ozone hole". Because human activities have also grown to become significant geological forces, for instance through land use changes, deforestation and fossil fuel burning, it is justified to assign the term "anthropocene" to the current geological epoch. This epoch may be defined to have started about two centuries ago, coinciding with James Watt's design of the steam engine in 1784.

Table 1.2.1 A partial record of the growths and impacts of human activities during the 20th century

Item	Increase Factor, 1890s-1990s
World population	4
Total world urban population	13
World economy	14
Industrial output	40
Energy use	16
Coal production	7
Carbon dioxide emissions	17
Sulphur dioxide emissions	13
Lead emissions	≈ 8
Water use	9
Marine fish catch	35
Cattle population	4
Pig population	9
Irrigated area	5
Cropland	2
Forest area	20% decrease
Blue whale population (Southern Ocean)	99.75 % decrease
Fin whale population	97 % decrease
Bird and mammal species	1 % decrease

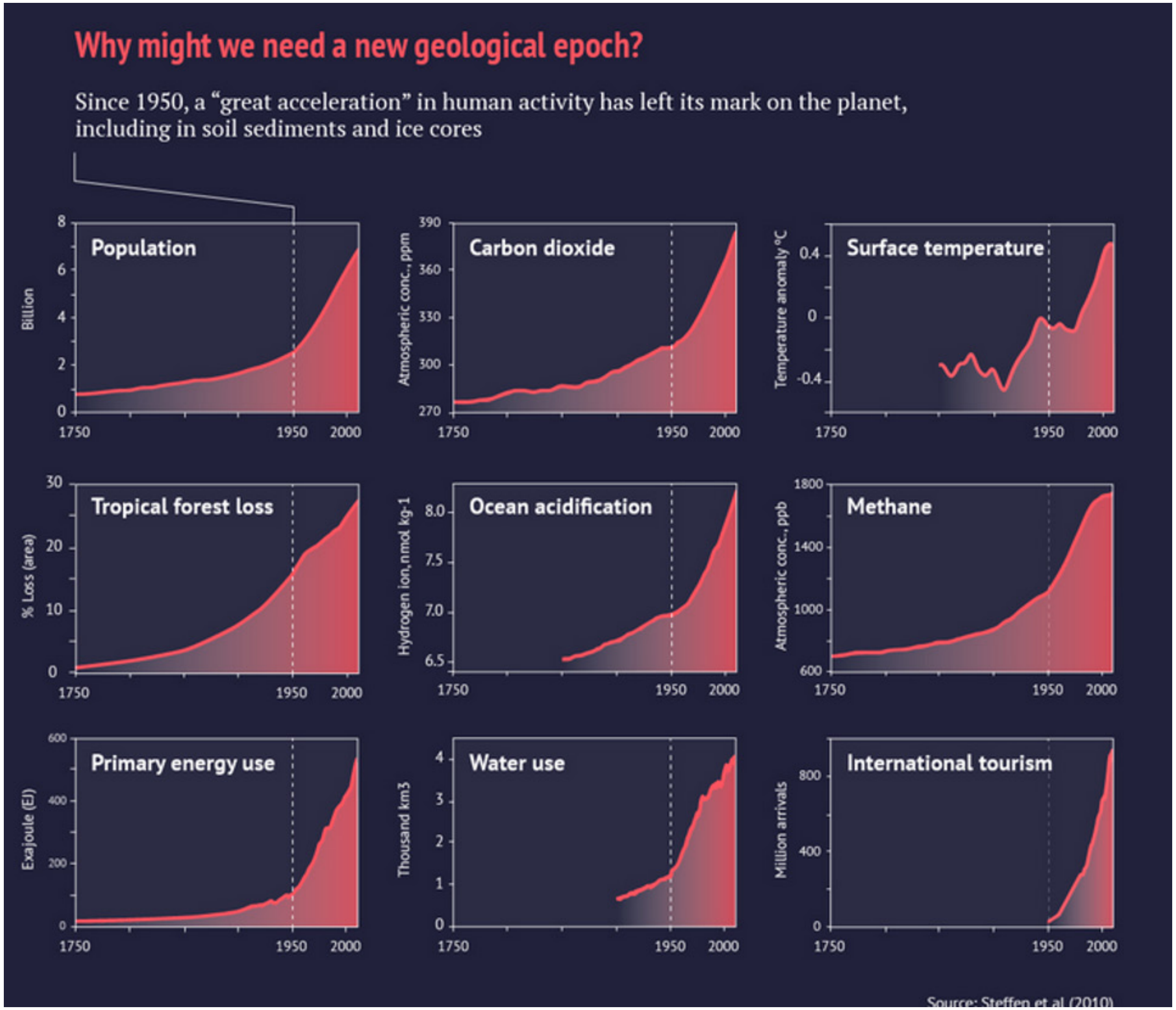
J. R. Mc Neill, Something New Under the Sun, Norton, 2000

https://link.springer.com/content/pdf/10.1007/b137853.pdf

Start of the Anthropocene?

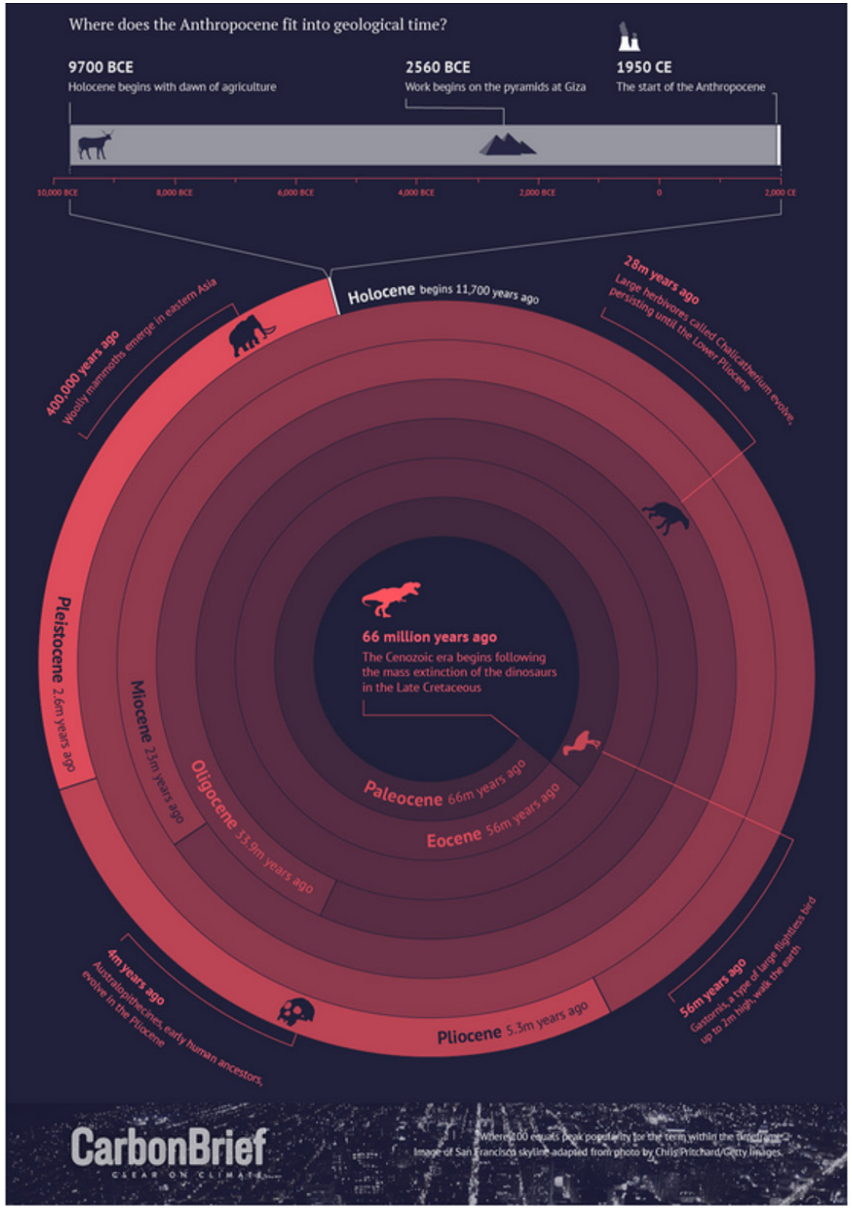
FEATURES | October 5. 2016.

Anthropocene: The journey to a new geological epoch



https://www.carbonbrief.org/anthropocene-journey-to-new-geological-epoch/

Start of the Anthropocene?



https://www.carbonbrief.org/anthropocene-journey-to-new-geological-epoch/

The living world, in turn, also shapes the physical and chemical Earth System. The composition of the atmosphere reflects the chemistry of life and is far from the chemical equilibrium that would obtain without the oxygen released by plant and microbial photosynthesis, the nitrogen converted by microorganisms into the forms that help warm our planet, and the water mined by trees from soils and released back into the atmosphere to cool the planet's surface.

At other Maya sites from the pre-Classic era, where the Maya went overboard in lavish use of thick plaster on buildings, plaster production may have been a major cause of deforestation. Besides causing sediment accumulation in the valleys and depriving valley inhabitants of wood supplies, that deforestation may have begun to cause a "man-made drought" in the valley bottom, because forests play a major role in water cycling, such that massive deforestation tends to result in lowered rainfall.

First quoted text block from David Schimel: https://press.princeton.edu/books/paperback/9780691151960/climate-and-ecosystems

Second quoted text block from Jared Diamond: https://www.amazon.com/Collapse-Societies-Succeed-Revised-Edition/dp/0143117009

Steffan et al., Nature, 2020

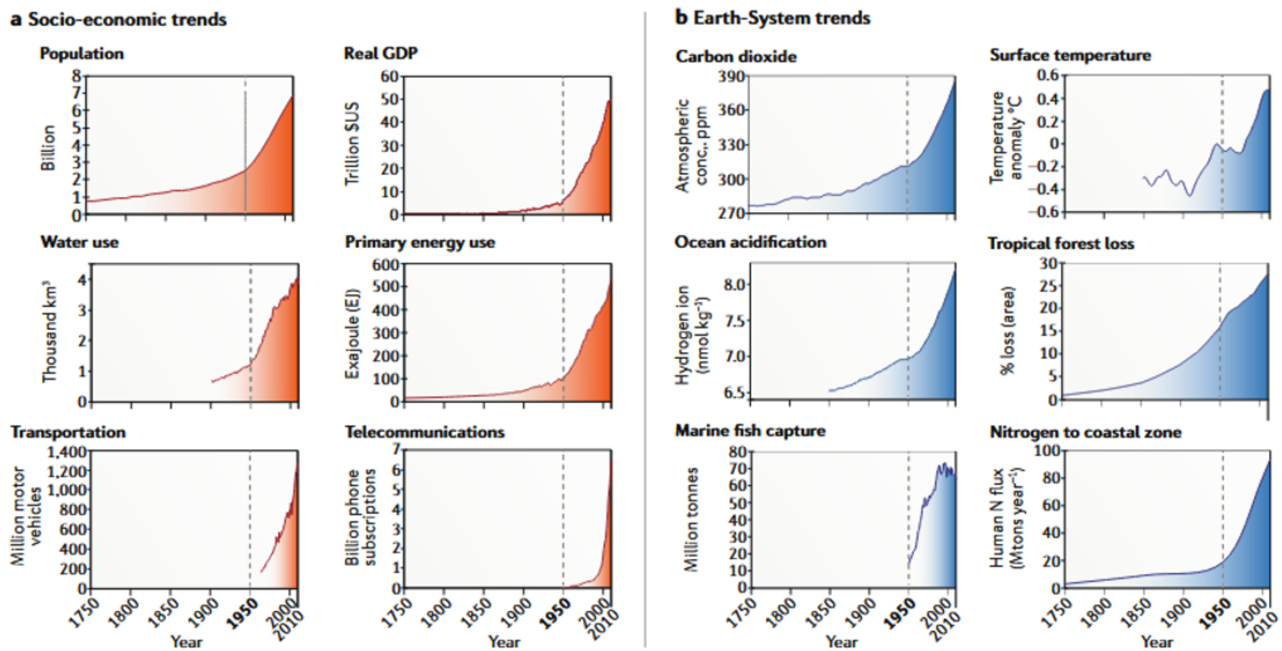
Box 2 | The Anthropocene

The term 'Anthropocene' was originally introduced by E. F. Stoermer in the early 1980s but in the context of freshwater limnology research. It was not until 2000, when the phrase was independently re-introduced by P. J. Crutzen[132,133], that it spread rapidly throughout the natural and social science communities and the humanities. The Anthropocene as proposed in 2000 had two meanings. In a geological context, Crutzen proposed the Anthropocene as a new epoch to follow the Holocene in the geological time scale[133]. In an Earth-System context, the Anthropocene was proposed as a very rapid trajectory away from the 11,700-year, relatively stable conditions of the Holocene[55]. The two definitions, although not identical, have much in common[134].

The primary evidence for the Anthropocene were the Great Acceleration graphs, which arose from the International Geosphere-Biosphere Programme (IGBP) synthesis project and highlight trends in socio-economic and Earth-System metrics[55,109,135]. They demonstrated that the rapid exit of the Earth System from the Holocene was directly related to the explosive growth of the human enterprise from the mid-20th century onwards. Although new to the Earth System Science community, the Great Acceleration had already been extensively explored by the historian J. R. McNeill[136].

In response to Crutzen's (2002) proposal that the Anthropocene be formally included in the geological time scale[133], the Anthropocene Working Group was established in 2009 by the Subcommission on Quaternary Stratigraphy (SQS). In 2019, following a decade of research, publications, discussion and robust debate, the working group formally recommended that the Anthropocene be treated as a formal chronostratigraphic unit defined by a Global Boundary Stratotype Section and Point (GSSP), and the primary guide for the base starting date of the Anthropocene should be a stratigraphic signal around the mid-20th century[137,138].

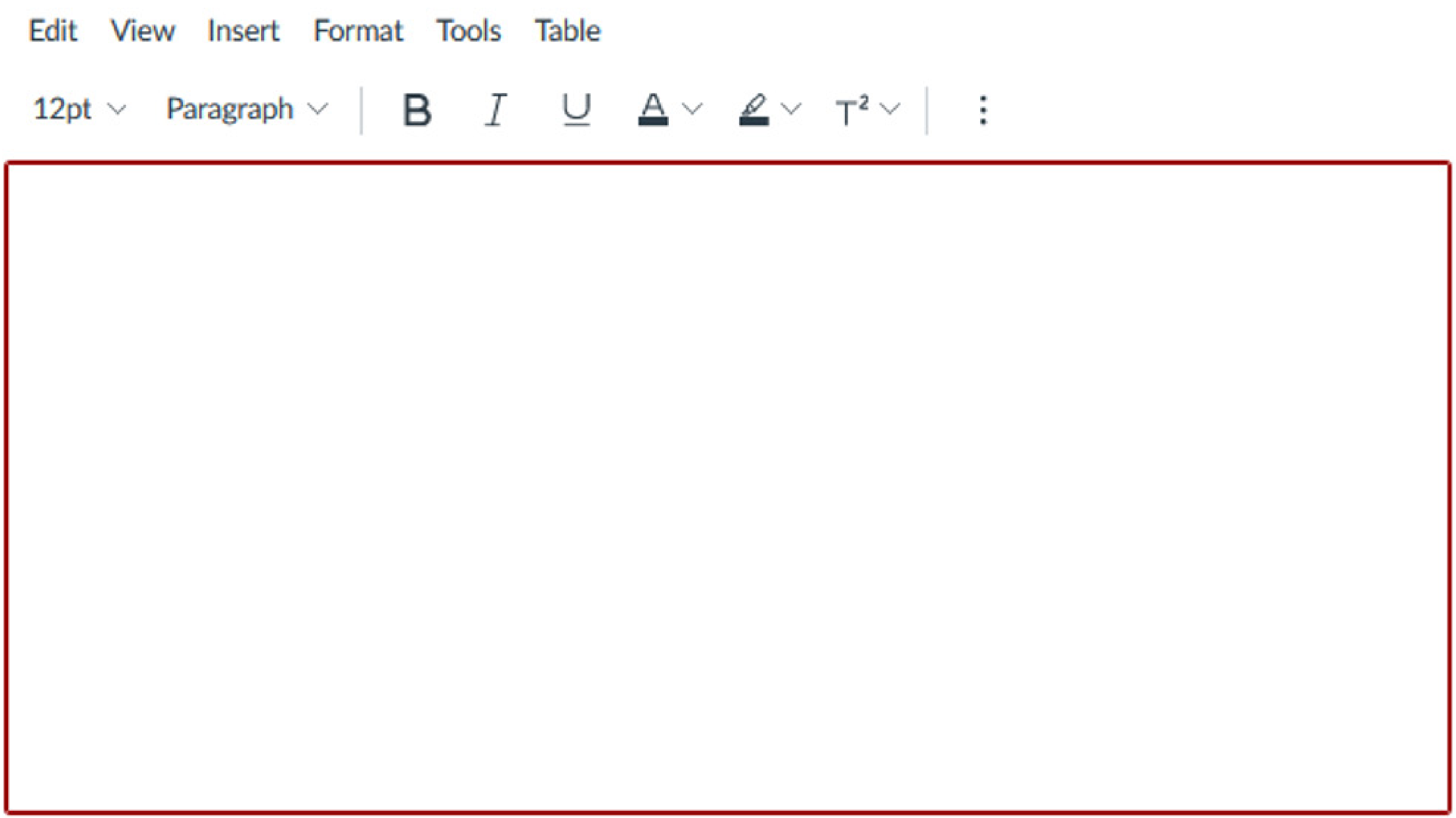
In the social sciences and humanities, the Anthropocene is viewed as a novel, holistic framing that captures complex human dynamics and their interactions with natural systems[139]. It has generated considerable discussion around the importance of the unequal responsibilities of different countries and people for the Anthropocene[106,140] and highlights not only humanity's geological-scale impacts but its challenge to achieve global sustainability[141].



http://macroecointern.dk/pdf-reprints/Steffen_Nature_2020.pdf

Chapter 2: Climate and Ecosystems

In Chapter 2 of Climate and Ecosystems, David Schimel writes "although relative temperature changes are important, absolute temperatures also matter". Explain the importance of absolute temperature changes, for biology. Here, for full credit, I am looking for a well written paragraph that touches upon concepts explained both above and below the appearance of the quoted phrase.



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Temperature Threshold In Biology

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

Phil. Trans. R. Soc. B (2005) **360**, 2021–2035
doi:10.1098/rstb.2005.1752
Published online 24 October 2005

Crop responses to climatic variation

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The yield and quality of food crops is central to the well being of humans and is directly affected by climate and weather. Initial studies of climate change on crops focussed on effects of increased carbon dioxide (CO_2) level and/or global mean temperature and/or rainfall and nutrition on crop production. However, crops can respond nonlinearly to changes in their growing conditions, exhibit threshold responses and are subject to combinations of stress factors that affect their growth, development and yield. Thus, climate variability and changes in the frequency of extreme events are important for yield, its stability and quality. In this context, threshold temperatures for crop processes are found not to differ greatly for different crops and are important to define for the major food crops, to assist climate modellers predict the occurrence of crop critical temperatures and their temporal resolution.

This paper demonstrates the impacts of climate variability for crop production in a number of crops. Increasing temperature and precipitation variability increases the risks to yield, as shown via computer simulation and experimental studies. The issue of food quality has not been given sufficient importance when assessing the impact of climate change for food and this is addressed. Using simulation models of wheat, the concentration of grain protein is shown to respond to changes in the mean and variability of temperature and precipitation events. The paper concludes with discussion of adaptation possibilities for crops in response to drought and argues that characters that enable better exploration of the soil and slower leaf canopy expansion could lead to crop higher transpiration efficiency.

https://royalsocietypublishing.org/doi/abs/10.1098/rstb.2005.1752

Temperature Threshold In Biology

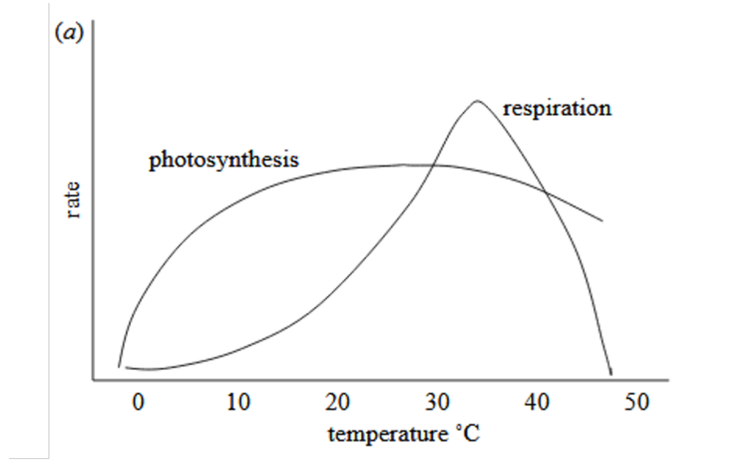
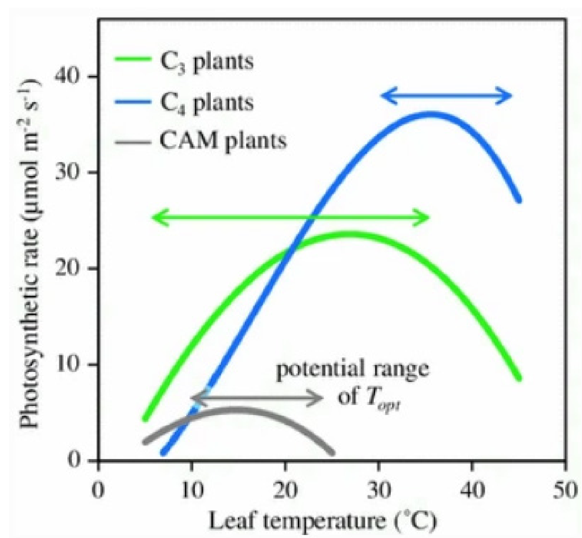


Figure 2. Changes in the rate of C_3 photosynthesis and temperature.



Typical temperature responses of photosynthesis in C_3, C_4, and CAM plants. Temperature responses of photosynthesis are pooled from published data for 86 C_3 plants, 31 C_4 plants, and 27 CAM plants. The potential range of optimum temperature for photosynthesis is indicated in C_3, C_4, and CAM plants, respectively.

Top figure: https://royalsocietypublishing.org/doi/abs/10.1098/rstb.2005.1752
Bottom figure: https://link.springer.com/article/10.1007/s11120-013-9874-6

Temperature Threshold In Atmospheric Chemistry

CHAPTER

3.3

Stratospheric Ozone Depletion and Recovery

David M. Wilmouth[1], *Ross J. Salawitch*[2], *Timothy P. Canty*[2]

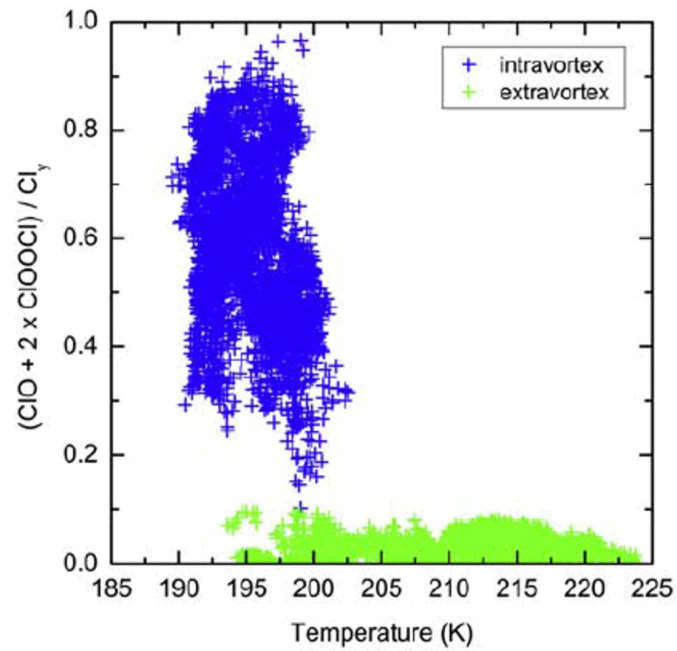


FIGURE 3.3.12 Atmospheric measurements of inorganic chlorine activation as a function of temperature. Data were acquired in situ in the lower stratosphere onboard the NASA ER-2 aircraft as part of the SOLVE mission January-March 2000. Measurements acquired inside the Arctic polar vortex are in blue (dark gray in print versions) and outside the polar vortex are in green (gray in print versions). Activated chlorine is dramatically higher at the colder temperatures inside the polar vortex. *Figure adapted from Wilmouth DM, Stimpfle RM, Anderson JG, Elkins JW, Hurst DF, Salawitch RJ, et al. Evolution of inorganic chlorine partitioning in the Arctic polar vortex.* J Geophys Res *2006;***111***:D16308.*

https://www.elsevier.com/books/green-chemistry/torok/978-0-12-809270-5

Chapter 2: Climate and Ecosystems

In Chapter 2 of Climate and Ecosystems, David Schimel writes "We know that the El Niño cycle has strong reverberations in the biosphere", followed by four examples.

Pick one of the four examples, then based on brief, independent web research, write a paragraph explaining what you have learned regarding how El Niño affects your chosen example. Please place a URL into your reply, and be prepared to speak in class on Thurs regarding what you have learned about the relation between El Niño and the chosen example.

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https://press.princeton.edu/books/paperback/9780691151960/climate-and-ecosystems

Who Dat?