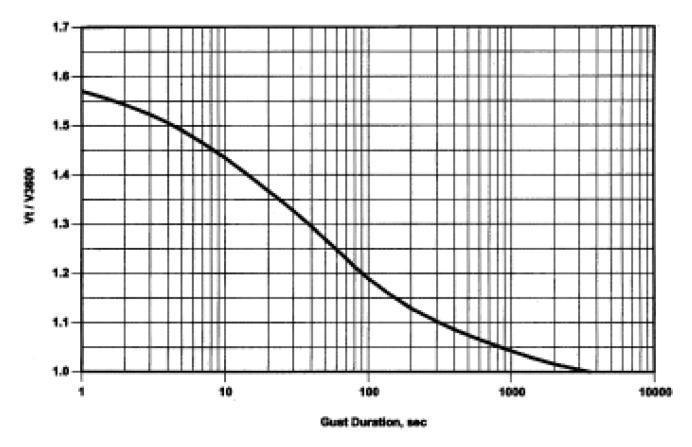
RESEARCH PROCESS



BL KINEMATIC VARIABLES

- Gust Factor
 - Also used to convert between different averaging times → "Durst Curve"





THE RESEARCH PROCESS

- Develop research question (s)
 - "Science Leads."
 - For instance, "Why do some thunderstorms produce tornadoes, while others do not?
- Narrow down your questions and develop TESTABLE hypotheses
 - Example: "Thunderstorms need strong low level winds to produce a tornado."
- Determine what data you need and how you will collect it
 - The data will dictate what tools you need. Our focus is on wind, so what tools allow us to collect wind data?



THE RESEARCH PROCESS

- You know what tools you need and what kind of data you will collect, but how will you collect it?
 - Field Projects
 - Example: Project SCOUT
- Data collection must be carefully designed and must take into account personnel and equipment safety.
- Important:
 - Instrument characteristics
 - Data
 - Biases



THE RESEARCH PROCESS

- Data collection is over...now what?
- DATA PROCESSING
- The ultimate goal of research is to share your answers with the scientific community
 - Publications
 - Conference Presentations
 - Lectures

1438

MONTHLY WEATHER REVIEW

VOLUME 109

Five Scales of Airflow Associated with a Series of Downbursts on 16 July 1980

T. THEODORE FUJITA AND ROGER M. WAKIMOTO

The University of Chicago, Chicago, IL 60637

(Manuscript received 5 September 1980, in final form 17 March 1981)

ABSTRACT

A series of destructive windstorms on 16 July 1980 in a 50 km (30 mi) wide zone from Chicago to Detroit was surveyed both from the air and the ground. In spite of the initial suspicion of 10-20 tornadoes in the area, the nature of the windstorms was confirmed to be downbursts and microbursts characterized by multiple scales of airflows with their horizontal dimensions extending tens of meters to hundreds of kilometers.

An attempt was made to estimate the wind speed based on three types of airborne objects: a 180 kg (390 lb) chimney, a 1000 kg (one ton) corn storage bin, and lumber from damaged roofs found inside downburst areas, obtaining the maximum wind speed of 65 ± 10 m s⁻¹ (140 ± 25 mph). A total of \$500 million damage reported was caused by thunderstorm-induced non-tornadic storms which affected very large areas:

SMS/GOES pictures showed that the parent cloud was oval-shaped with its lifetime in excess of 12 h. The overshooting areas enclosed by the -66°C isotherms shrunk rapidly at the onset of the Chicago-aration downbursts, indicating that the downbursts began when overshooting activities subsided. This variation of the overshooting features, however, does not necessarily imply a direct physical link between the collapsing top and the downbursts at the surface. This paper presents cloud-top features and wind effects on the ground with no attempt to relate them on the basis of conceptual models currently available.

ORIGINAL RESEARCH article

Front. Built Environ., 15 October 2019 | https://doi.org/10.3389/fbuil.2019.00119



Exploring the Feasibility of Using Commercially Available Vertically Pointing Wind Profiling Lidars to Acquire Thunderstorm Wind Profiles

William Scott Gunter*

1. Introduction

Suckstorff (1938) postulated that precipitation cooling within thunderstorms causes an outflow of cold air which results in strong surface winds. As air traffic increased in the late 1930's, squall-line related accidents occurred in various parts of the world, resulting in the operation of fact-finding pro-

world, resulting in the operation of fact-finding projects of thunderstorms and squall-line circulations.

Results of the Japanese Thunderstorm Observa-

one related the localized wind with the foot of a strong downdraft which could spread out violently and result in uprooted trees and damaged houses.

There are numerous reports of uprooted trees in NOAA's Storm Data in which types of damaging winds are classified as tornado or straight-line winds. Straight-line winds are assumed to be those which rush out of thunderstorms behind advancing gust fronts which are tens of kilometers in length.

EARTH'S CLIMATE HISTORY (AND PRESENT)



EARTH'S CLIMATE HISTORY

 Based on dating of Uranium isotopes, Earth has been around for about 4.6 billion years.

- Most of the paleo-climatological methods (proxies) only give us information from ~ the last million years.
 - Dendroclimatology / Dendrochronology
 - Ice Cores



GOOD QUOTE

 Data from before the instrument record are called proxy data.

 Proxy Data – " …long-lived geological, chemical, or biological systems that have the climate imprinted on them" -- Dessler (2016)

 Goal: Reconstruct past climates and analyze the results

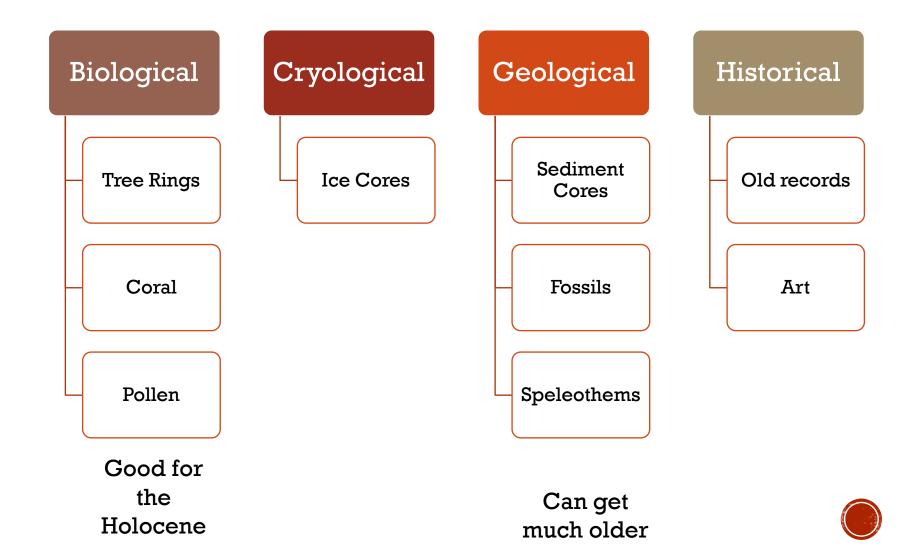


PALEOCLIMATOLOGY

- Proxy Data:
 - Accuracy declines with increasing time before present.
 - Declining Resolution
 - Fragmented records
 - Correlating proxy variables to physical quantities.
 - Lack of benchmarks



PALEO-CLIMATOLOGY



Resolution in Record (years) 1,000,000 10,000 10,000 100 10 Sedimentary rocks -Fossils Marine sediments – Isotopes Glacial features Terrestrial scouring -Isotopes Polar ice -Lakes and bogs -Pollen Tree Rings Wood record -Historical data -**Documents** Thermometers, Instrumental record -Rain gauges 100,000,000,000,000,000,000,000,000 10,000 1000 100 0,

Length in Record (years ago)

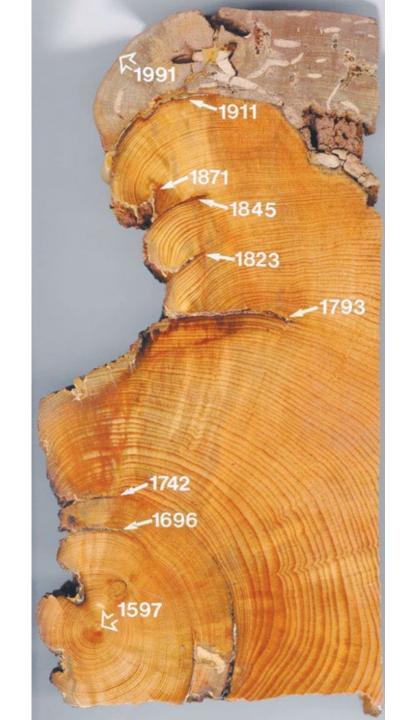
DENDRO-

 -chronology: the use of tree rings for dating.

 -climatology: the use of tree rings as a proxy indicator of climate.

 Both based on analyzing the thickness and density of annual growth rings of certain tree species.







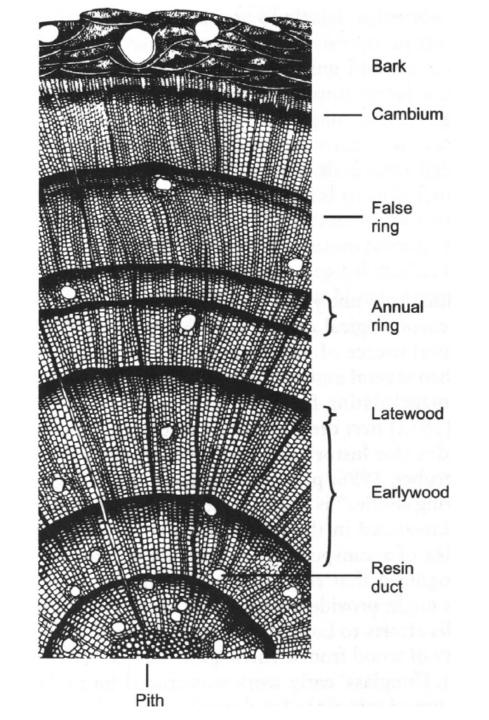
TREE RINGS: LIGHT AND DARK

- Color based on cell type:
 - Spring growth cells are lighter in color
 - Late growth cells are smaller, thick-walled, and more dense

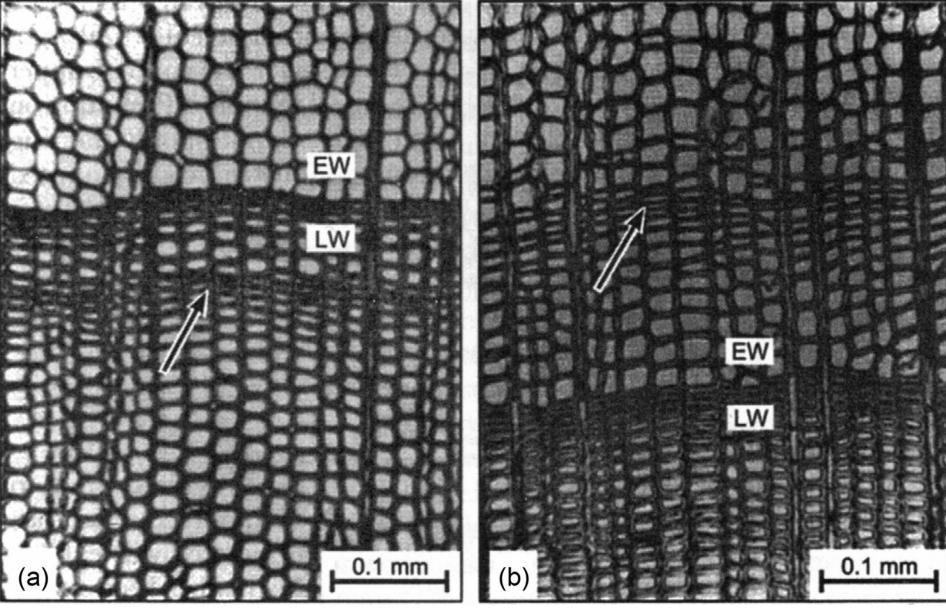
 Abrupt changes in cell type mark the boundary between annual growth rings.

 Can get "false rings" when conditions get rough before end of growing season.











TREE RINGS

- The width of the rings is controlled by multiple factors:
 - Age of the tree
 - Tree species
 - Food storage / soil quality
 - Climate factors
 - Sunshine Temperature
 - Precipitation Humidity
 - Wind speed
- Account for non-climate signals through the treegrowth index: ratio of width to expected width based on age

ISOLATING A CLIMATE SIGNAL: SITE CONSIDERATIONS

- Need a location where trees are under some stress:
 - Temp stress: trees @ altitudinal or latitudinal tree line
 - Precipitation stress: trees in semi-arid regions
- Example: Proximity to the water table can reduce the climate signal.







ISOLATING A CLIMATE SIGNAL: SITE CONSIDERATIONS

- Need a location where trees are under some stress:
 - Temp stress: trees @ altitudinal or latitudinal tree line
 - Precipitation stress: trees in semi-arid regions
- Example: Proximity to the water table can reduce the climate signal.

- Location with a proper sample size:
 - 2 to 3 cores from each tree
 - ~20 trees from each site.



ISOLATING A CLIMATE SIGNAL: SITE CONSIDERATIONS

- Primary Tree species used are:
 - Ponderosa Pine
 - Douglas Fir
 - Bristlecone Pine

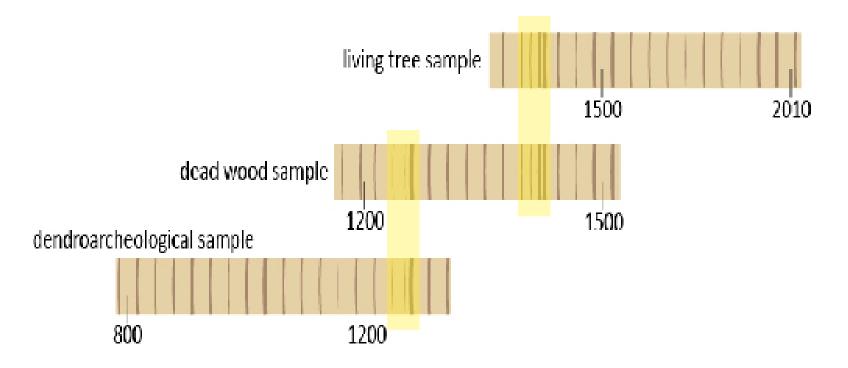
 Oldest living individual tree is ~ 5,000 years old.





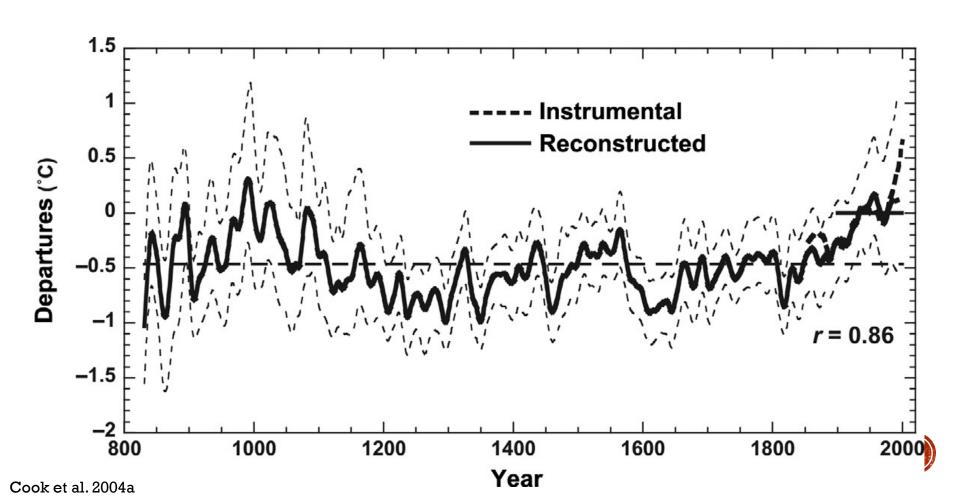
TREE CORE RECORDS

- Records are typically limited to 500-700 years.
- Can use "cross dating" to extend the record back ~ 10,000 years.



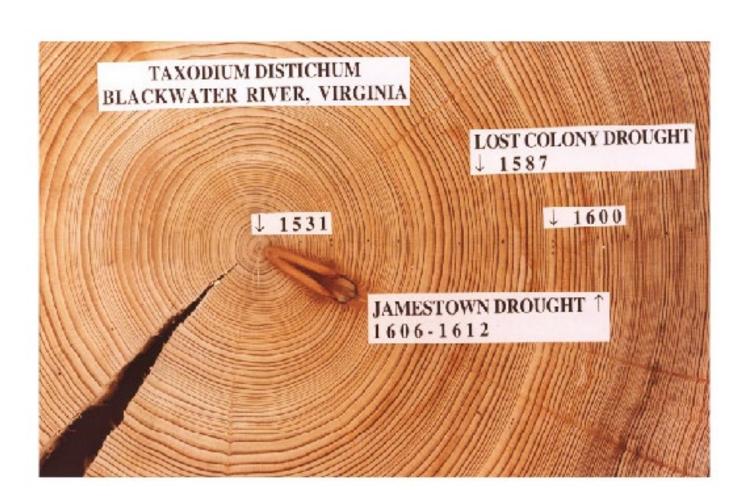
WHAT DO WE GET?

- Reconstructions can yield
 - Temperature time histories



WHAT DO WE GET?

Drought information:

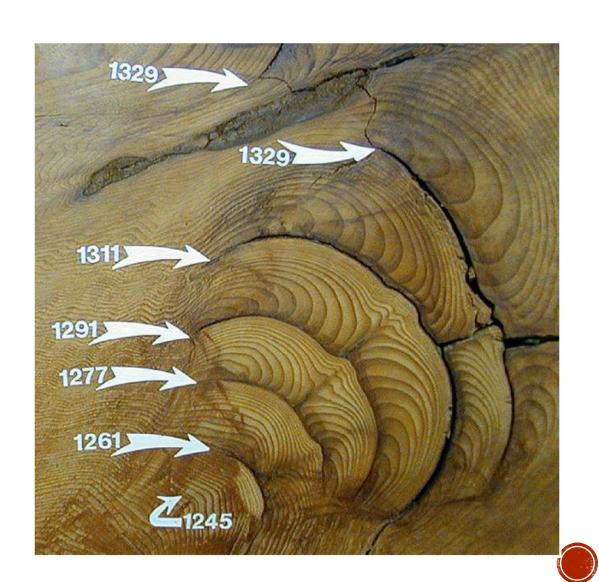




WHAT DO WE GET?

Wildfire information.

 Which we can relate to other atmospheric variables.



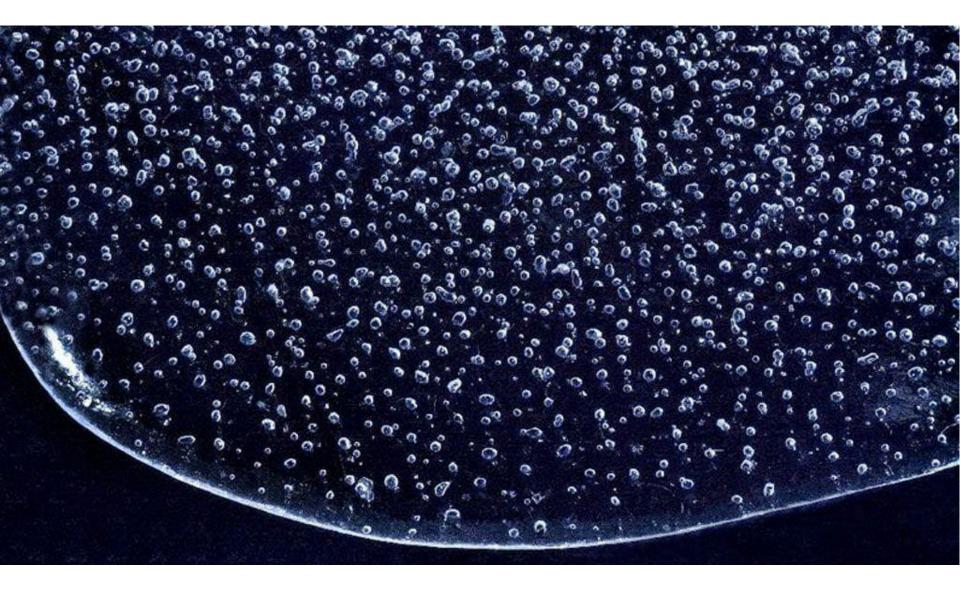
ICE CORE BASICS

- Starts as snowfall.
- Snow accumulates ... slowly.
 - Interior regions of Antarctica receive only about 2 inches of snow a year.
- Weight of accumulated snow causes underlying crystals to settle, deform, and recrystallize, which removes the air spaces between the crystals.
 - Taking air out → increase in density
 - "Densification"



Sintering process Density (g cm⁻³) Surface Air in contact - 0.55 15 with atmosphere Depth (m) Bubbles closed off 50-120 - 0.83 Air isolated







WHAT CAN WE GET FROM ICE CORES?

TABLE 5.1 Principal Sources of Paleoclimatic Information from Ice Cores

Parameter	Analysis
Temperature	
Summer	Melt layers
Annual	δD , $\delta^{18}O$ (ice), Ar, N_2 (diffusion)
Source region temperature/humidity	Deuterium excess (d)
Accumulation (net)	Seasonal signals
Volcanic activity	Conductivity, non-sea salt (nss.) SO_4^{2-} , glaciochemistry
Tropospheric turbidity	ECM, microparticle content, trace elements
Wind speed	Particle size, concentration
Atmospheric composition	Trace gases (CO ₂ , CH ₄ , and N ₂ O)
Sea ice extent	Glaciochemistry (Br-, I-, and Na+)
Atmospheric circulation	Glaciochemistry (major ions)
Solar activity and geomagnetic field changes	¹⁰ Be
Forest fire history	Levoglucosan and other biomarkers

GEOLOGIC TIME SCALE

INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

www.stratigraphy.org

International Commission on Stratigraphy





Note							
Ploistocene Meshippian No.00117 N.126 N.781 N.80 N.781 N.80 N.801	€one.	Erathen	System	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Pleistocene			nary	Holocene M	Northarippian	N.	0.0082
Messinian 7,246			uater	Pleistocene		4	0.781
Messinian 7,246			Ø	Pliocene	Piacenzian	4	
Note			ne		Messinian	1	
Campanian 15.97 20.44 23.03 27.82 Rupelian 33.9 27.82 Rupelian 37.8 41.2 20.44 23.03 27.82 Rupelian 37.8 41.2 20.44 23.03 27.82 20.44 23.03 27.82 20.44 23.03 27.82 20.44 23.03 27.82 20.44 23.03 27.82 20.44 23.03 27.82 20.44 23.03 27.82 20.41 20.4			eode	Miocene	Serravallian		
Oligocene Rupelian 33.9 Priabonian 37.8 Bartonian 41.2 Lutetian 47.8 Ypresian 56.0 59.2 Selandian 59.2 Selandian 66.0 Maastrichtian 72.1 ±0.2 Campanian 66.0 Maastrichtian 72.1 ±0.2 Campanian 83.6 ±0.2 80.3 ±0.5 Coniacian 93.9 Cenomanian 100.5 Albian ~ 113.0 Aptian ~ 125.0 Barremian Valanginian Berriasian 83.8		ozoic	Ž				
Priabonian 37.8		Cen					23.03
Bartonian		Mesozoic	aleogene	Oligocene			
Paleocene	ပ				Bartonian		
Paleocene	rozoi						47.8
Danian 66.0	hane		_			N N	59.2
Upper Santonian 83.6 ±0.2 86.3 ±0.5 89.8 ±0.3 Turonian 93.9 Cenomanian 100.5 Albian ~ 113.0 Aptian ~ 125.0 Barremian Hauterivian Valanginian Berriasian Berriasian 13.8	ш			T GIOGOGIIO	Danian	4	
Upper Santonian Coniacian Turonian 93.9 Cenomanian 100.5 Albian Aptian Lower Barremian Hauterivian Valanginian Berriasian 83.6 ±0.2 86.3 ±0.5 89.8 ±0.3 93.9 100.5 - 113.0 - 125.0 - 129.4 - 132.9 - 139.8			Cretaceous			1	72.1 ±0.2
Turonian 93.9 Cenomanian 100.5 Albian 113.0 Aptian				Upper	Santonian	3	
Albian Aptian Aptian Aptian Alaurerivian Valanginian Berriasian 100.5 Albian ~ 113.0 Aptian ~ 125.0 Authority an Valanginian — 139.8						4	
Aptian ~ 125.0 Barremian ~ 129.4 Hauterivian Valanginian — 139.8 Berriasian ~ 139.8						4	
Lower Barremian ~ 125.0 Hauterivian ~ 132.9 Valanginian ~ 139.8 Berriasian				Lower -		4	~ 113.0
Lower Hauterivian ~ 129.4 ~ 132.9 Valanginian ~ 139.8							
~ 139.8 Berriasian					Hauterivian		

IUGS

	non	m/E	00			•					
\$00°	Eran Chem	System/E	Se	ries / Epoch	Stage / Age	GSSF	numerical age (Ma) ~ 145.0				
					Tithonian		152.1 ±0.9				
				Upper	Kimmeridgian		157.3 ±1.0				
					Oxfordian		163.5 ±1.0				
		Si.			Callovian Bathonian	4	166.1 ±1.2				
		ass		Middle	Bajocian	4	168.3 ±1.3 170.3 ±1.4				
		ğ			Aalenian	3	174.1 ±1.0				
					Toarcian	4	182.7 ±0.7				
	lesozoic			Lower		4	190.8 ±1.0				
	SOZ					5					
	Ne				Hettangian	3	199.3 ±0.3 201.3 ±0.2				
	_				Rhaetian		~ 208.5				
					Norian		200.0				
		Sic			Norian		~ 227				
		ass			Carnian	~					
		ī		CERTIFICATION OF THE PARTY OF T	Ladinian	5	~ 237				
Ö				Middle	Anisian	-	~ 242				
20				Lower	Olenekian	0	247.2 251.2				
ne					Induan Changhsingiar	13	251.902 ±0.024 254.14 ±0.07				
Phanerozoic			L	opingian	Wuchiapingian	1	259.1 ±0.5				
щ					Capitanian	4	265.1 ±0.4				
		Ę	Guadalupian		Wordian	3	268.8 ±0.5				
		mis			Roadian	3	272.95 ±0.11				
			Permian			Kungurian		283.5 ±0.6			
		_	C	isuralian	Artinskian		290.1 ±0.26				
	Paleozoic		-		Sakmarian	<	290.1 ±0.20 293.52 ±0.17				
					Asselian	4	298.9 ±0.15				
	e		ian	Upper	Gzhelian		303.7 ±0.1				
	Pa		van	орро.	Kasimovian		307.0 ±0.1				
		sn	nsyl	Middle	Moscovian		315.2 ±0.2				
		onifero	Pennsy	Lower	Bashkirian	4	323.2 ±0.4				
			nil	Jui	inc	Juit	Jui	an	Upper	Serpukhovian	
		arbo	Carbo Mississippia	Middle	Visean	721	330.9 ±0.2				
		0		Lower	Tournaisian	3	346.7 ±0.4				
				201101	Todificiolari	1	358.9 ±0.4				

us.	Eran en	System / E	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)		
~	~	٠,	Comoo / Epoon	Olago 171go	0	358.9 ± 0.4		
			Upper	Famennian	4	372.2 ±1.6		
		Devonian	***************************************	Frasnian	4	382.7 ±1.6		
			Middle	Givetian	3			
				Eifelian	4	387.7 ±0.8		
		ă				393.3 ±1.2		
				Emsian	4			
			Lower	Pragian	3	407.6 ±2.6 410.8 ±2.8		
				Lochkovian		410.0 12.0		
			Pridoli		3	419.2 ±3.2		
		_	Pridoli	Ludfordian	3	423.0 ±2.3		
			Ludlow	Gorstian	3	425.6 ±0.9		
		<u>'ā</u>	\\/anlask	Homerian	4	427.4 ±0.5 430.5 ±0.7		
		Ξ	Wenlock	Sheinwoodian	1	433.4 ±0.8		
		S		Telychian	<			
			Llandovery	Aeronian	3	438.5 ±1.1 440.8 ±1.2		
.9	Paleozoic			Rhuddanian	1	440.8 ±1.2 443.8 ±1.5		
ŭ		Ordovician			Hirnantian	3	445.2 ±1.4	
erc			Upper	Katian	<			
Phanerozoic				Sandbian	4	453.0 ±0.7		
₫			Middle Darriwilian	Darriwilian		458.4 ±0.9		
					4	467.3 ±1.1		
				Dapingian	1	470.0 ±1.4		
					Lower	Floian	4	477.7 ±1.4
				Tremadocian	4	485.4 ±1.9		
					Stage 10		~ 489.5	
			Paibia Guzhan Miaolingian Drumi	Jiangshanian	3			
				Paibian	3	~ 494 ~ 497		
		Cambrian		Guzhangian	1	~ 500.5		
				Drumian	5			
				Wuliuan	5	~ 504.5		
			Series 2	Stage 4	-	~ 509		
						~ 514		
				Stage 3		~ 521		
			Terreneuvian	Stage 2		021		
						~ 529		
				Fortunian				
					1	541.0 ±1.0		

		them Eon	Erathem / Era	System / Period	GSSP	numerica age (Ma) 541.0 ±1.0		
				Ediacaran	4	~ 635		
			Neo- proterozoic	Cryogenian		~ 720		
			p. 010.020.0	Tonian				
				Stenian	Y	1000		
		O	Meso- proterozoic	Ectasian	- ⊘	1200		
		Proterozoic	protorozoto	Calymmian	O	1400		
		tero		Statherian	-0	1600		
	E	Prof	Paleo- proterozoic	Orosirian		1800		
	oria			Olosiliali	(A)	2050		
	amk			Rhyacian	Ĭ			
9	Precambrian			Siderian	Ĭ	2300		
	Δ.		Neo- archean		O	2500		
		_	Meso-		O	2800		
		леа	archean		_	3200		
		Archean	Paleo-			3200		
			archean		Ø	3600		
			Eo- archean					
					0	4000		
	4000							
	~ 4600							

Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA), Charts and detailed information on ratified GSSPs are available at the website http://www.stratigraphy.org. The URL to this chart is found below.

Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (-) is provided.

Ratified Subseries/Subepochs are abbreviated as UfL (DpperLate), M (Middle) and LFE (Lower/Early). Numerical ages for all systems except Quaternary, upper Paleogene, Cretaceous, Triassic, Permian and Precambrian are taken from 'A Geologic Time Scale 2012 'Recardstein et al. (2012), those for the Quaternary, upper Paleogene, Cretaceous, Triassic, Permian and Precambrian were provided by the relevant ICS subcommissions.

Colouring follows the Commission for the Geological Map of the World (http://www.ccgm.org)

Chart drafted by K.M. Cohen, D.A.T. Harper, P.L. Gibbard, J.-X. Fan (c) International Commission on Stratigraphy, August 2018

To cite: Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fan, J.-X. (2013; updated) The ICS International Chronostratigraphic Chart. Episodes 36: 199-204.

URL: http://www.stratigraphy.org/ICSchart/ChronostratChart2018-08.pdf



EARTH'S CLIMATE HISTORY

- We are currently in the:
 - Phanerozoic Eon
 - The Cenozoic Era
 - Quaternary Period
 - Holocene Epoch
- The previous Epoch, the Pleistocene, was characterized by the Ice Age



EARTH'S CLIMATE HISTORY: THE ICE AGE

 Ice Age: A series (cycle) of glacial and interglacial periods that occurred during a ~1.7 million year period of the Pleistocene



 Climate was extremely variable. A major player on the Norther American Continent was the Laurentide Ice Sheet







ICE AGE

 Each glacial advance erases evidence of the previous advance.

 Thus, our most reliable evidence extends only back to the last glacial maximum (LGM)

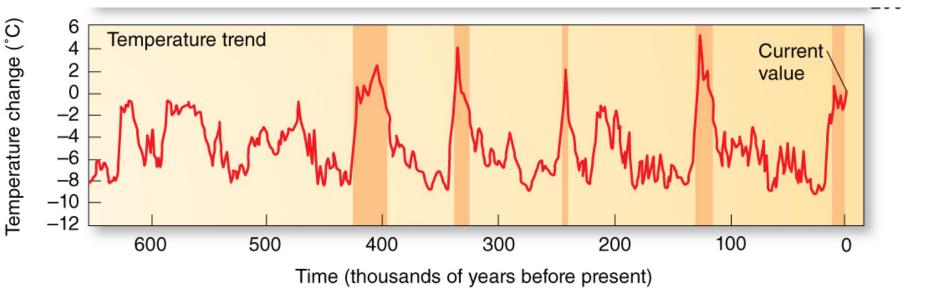
 The LGM began about 27K ya and peaked ~18K ya.

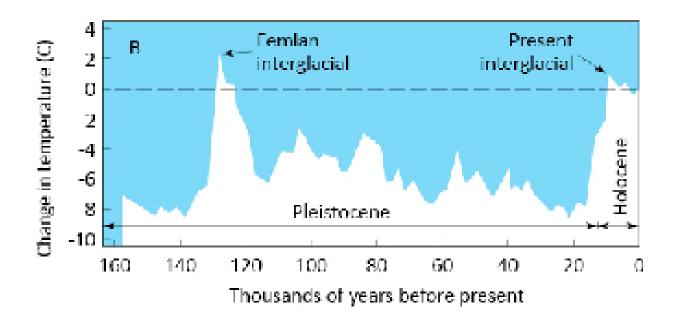


ICE AGE CYCLE

- The end of the LGM was marked by a temp increase to the present interglacial:
- Laurentide Ice Sheet began to melt.
- Melting occurred with only:
 - 5 Deg C temp increase in tropics
 - 6-8 Deg C temp increase in the mid-lats
 - 10 Deg C temp increase at the poles
- One of multiple cycles. Glacial period ~ every 100,000 years separated by ~11,000 year interglacial period.









ICE AGE CYCLES

• Why were these period so repetitive?



• The 100,000 year fluctuation can be attributed to Milankovitch Theory: slight changes in earth's orbit alter the sun-earth geometry.



MILANKOVITCH THEORY

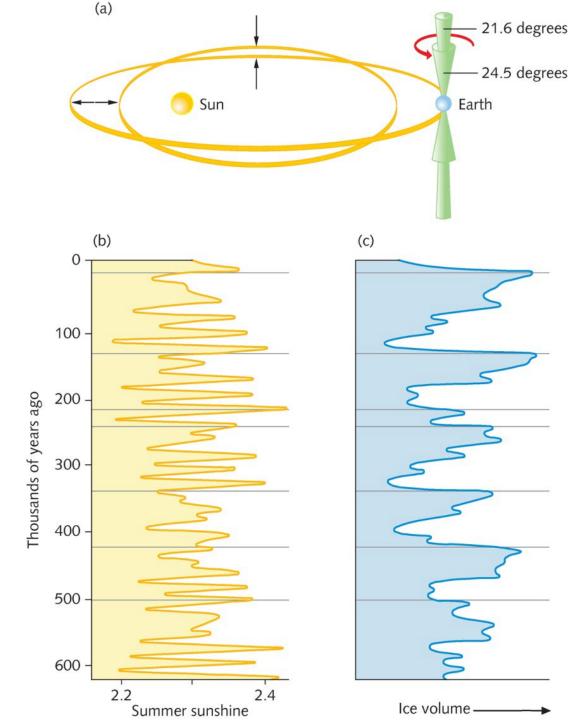
- Three modes:
 - Changes in the eccentricity of Earth's Orbit
 - How close to a perfect circle is Earth's orbit around the sun?
 - 100,000 year cycle
 - Changes in the obliquity of Earth's Orbit
 - Tracks changes in Earth's tilt
 - 41,000 year cycle
 - Precession
 - Which star is Earth's axis pointing to? Polaris right now.
 - 27,000 year cycle.



 Milankovitch modes explain about 60% of the variance in Earth's climate history.

 Effects greatest at high latitudes in summer where insolation can vary by 20%

 These changes (glacial vs interglacial) have been globally synchronous

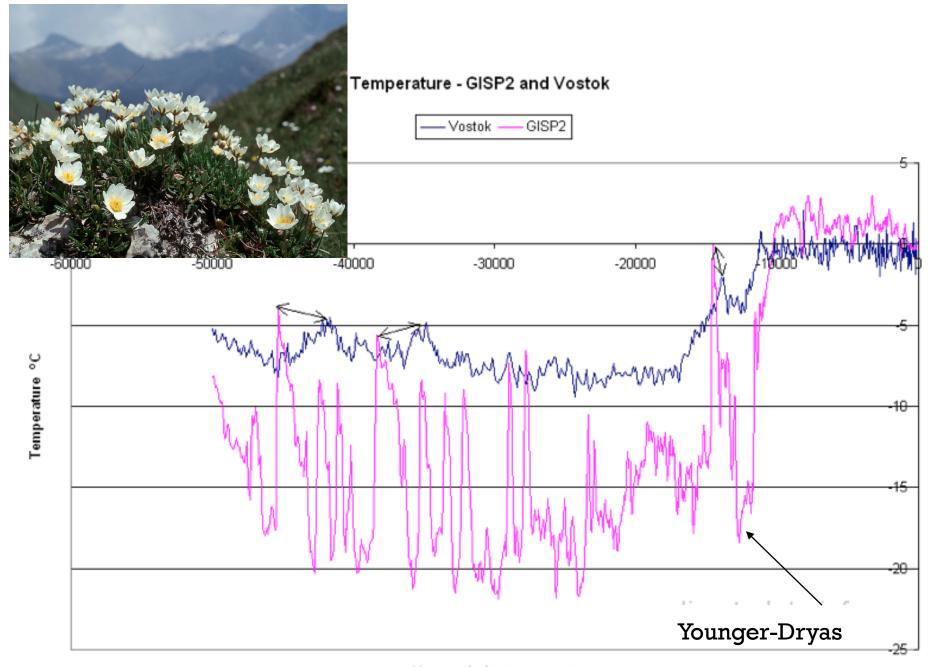


GLOBAL / NON-GLOBAL CHANGES

Despite glacial / interglacial periods being globally synchronous, ice core data show:

- Southern Hemisphere climate been more stable
- Time delays in most recent glacial cycle
- Abrupt changes on the scale of 2-3K years and 7-12 K years.





Years relative to present

YOUNGER-DRYAS

Regional short-term climate fluctuation.

Abrupt cooling

 Palynology data revealed the pollen of the Dryas Octopetala much further south than normal.

• Time scale too short to be Milankovitch...so what caused it?



YOUNGER DRYAS

 Related to the melting of the Laurentide Ice Sheet and the AMOC.



- When the AMOC resumed its normal pattern, warming continued
 - \blacksquare The arctic warmed by 7 $^{\circ}\text{C}$ over the course of 50 years .



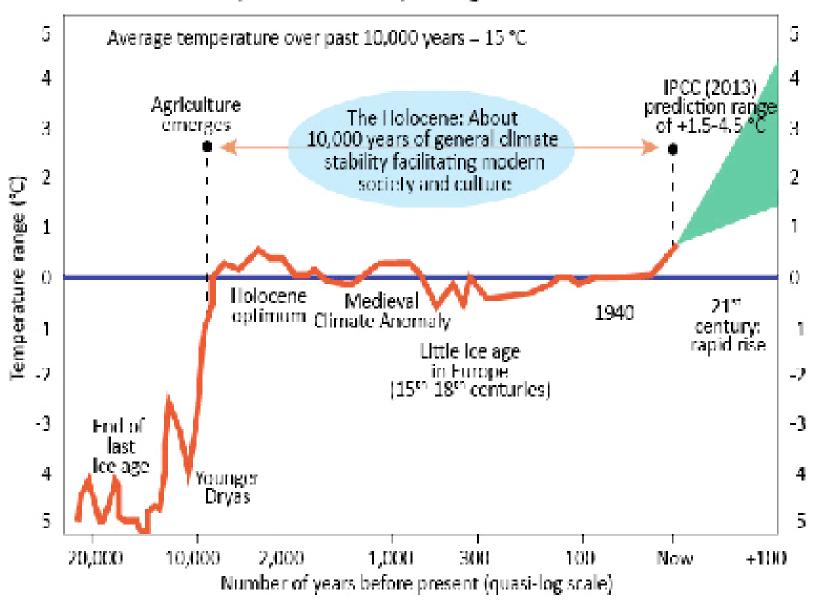
THE HOLOCENE

 At the conclusion of the Younger-Dryas Period, Earth entered into the present interglacial period: The Holocene Epoch (~10,500 YBP)

- Characterized by:
 - Relatively stable climate (compared to the last Epoch)
 - Development of Agrarian Societies
 - Modern Civilization



Temperature stability during the Holocene

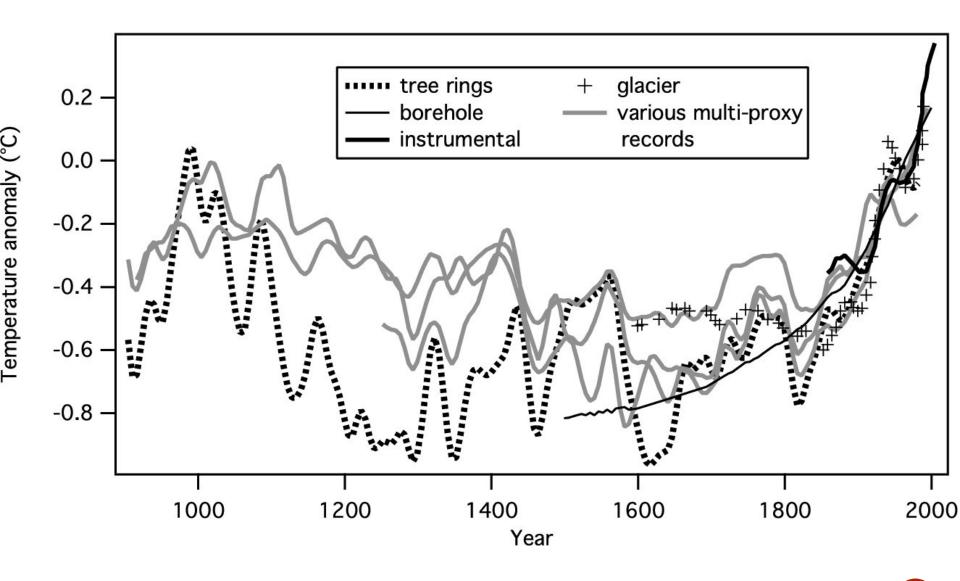




THE HOLOCENE

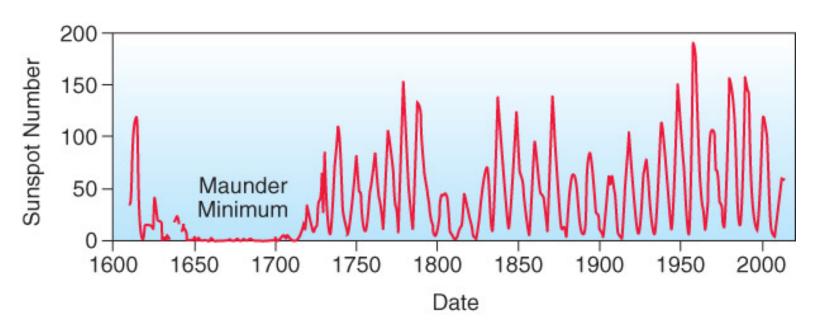
- There have also been several small scale climate fluctuations with in the Holocene (specifically over the last 1000 years):
 - Medieval Climate Anomaly (MCA)
 - Mild Winters; Growing Wine in England
 - Isolated to N.H. based on data
 - Vikings get adventurous...
 - Little Ice Age (LIA)
 - Multi-century cool period
 - Global temp ~0.5 cooler.
 - Vikings give up; Food shortage; Societal Unrest.





LITTLE ICE AGE

- What caused it?
 - Not Entirely sure
 - Sunspots?





ANTHROPOCENE?

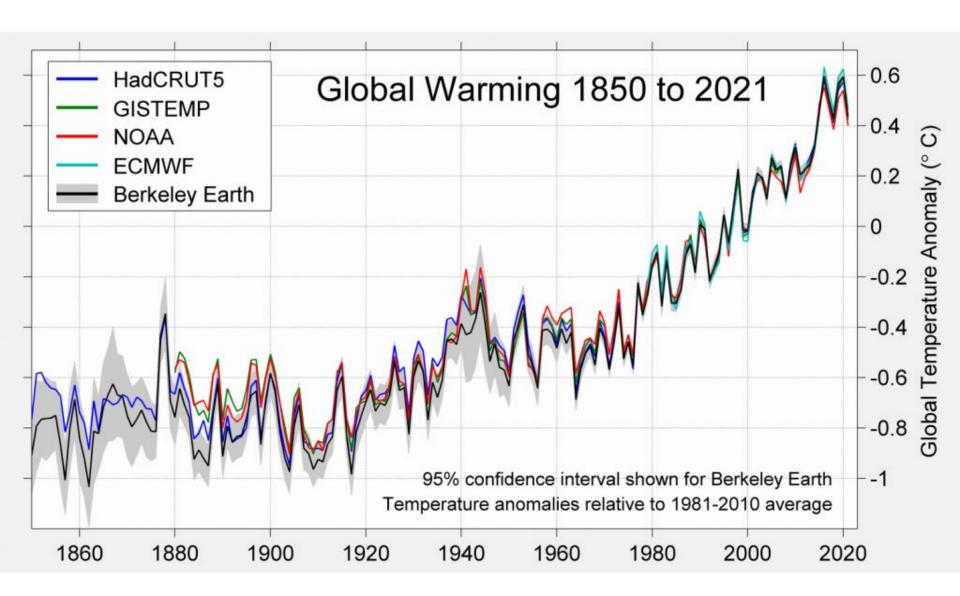
Check out this article:

https://www.smithsonianmag.com/sciencenature/what-is-the-anthropocene-and-are-we-in-it-164801414/

• Watch this clip:

http://www.smithsonianmag.com/videos/category/science/what-is-the-anthropocene/?jwsource=cl

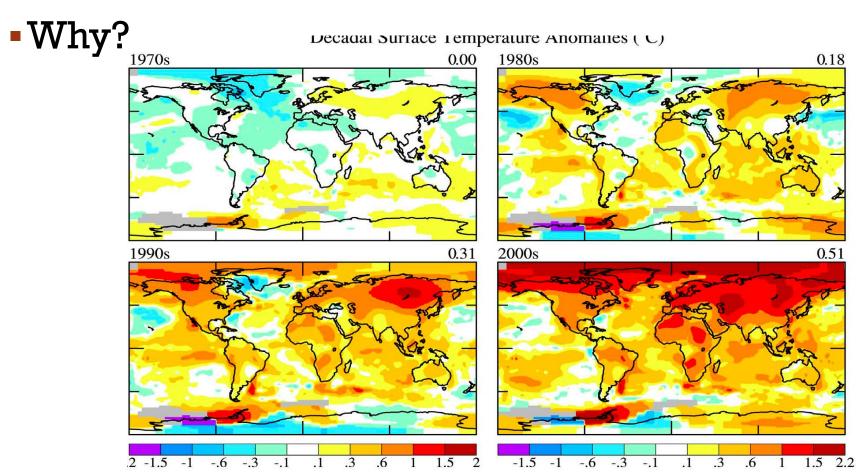






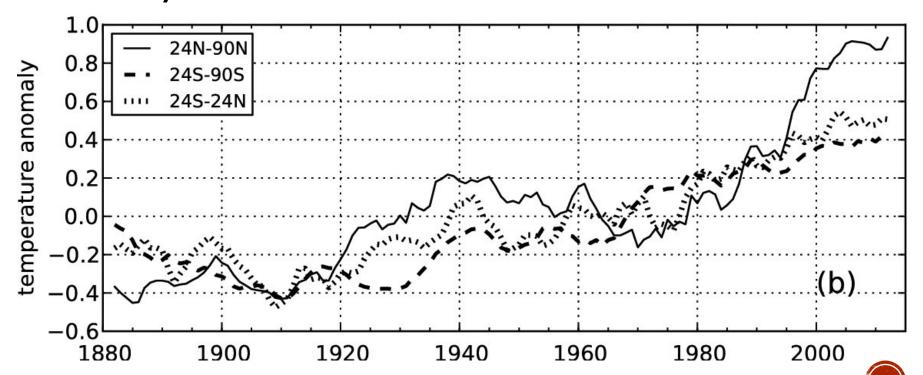
GLOBAL TEMPERATURE RECORD

 Additionally, land areas have warmed more than ocean



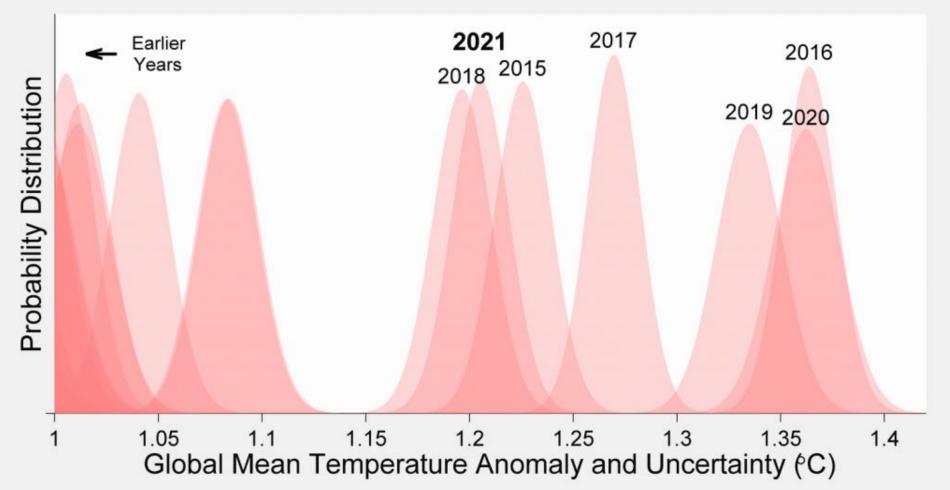
GLOBAL TEMPERATURE RECORD

- NH warmed more than Southern Hemisphere
 - Why?



RECENT DATA

Rank 1 = Warmest Period of Record: 1880–2021	Year	Anomaly °C	Anomaly °F
1	2016	0.99	1.78
2	2020	0.98	1.76
3	2019	0.95	1.71
4	2015	0.93	1.67
5	2017	0.91	1.64
6	2021	0.84	1.51
7	2018	0.82	1.48
8	2014	0.74	1.33
9	2010	0.72	1.30
10 (tied)	2013	0.67	1.21
10 (tied)	2005	0.67	1.21



Based on Berkeley Earth's estimates of the global annual average temperature increase relative to 1850-1900.

