Avoid the Unmanageable, Manage the Unavoidable

Eight Interdisciplinary Lectures on Climate Change

Charles F. Kennel

Monday Evenings, 5:30-7 pm, Martin Johnson House

Scripps Institution of Oceanography, University of California San Diego

October 13, 2014: Origins of Modern Climate Research

Historical pioneers; the greenhouse effect; the increase of atmospheric CO2 concentrations; earth system science, climate models, space observations; earth's radiation balance and carbon cycle; hard truths about climate change; ethical dilemmas; governance

Avoid The Unmanageable, Manage the Unavoidable

Eight Interdisciplinary Lectures on Climate Change by Charles F. Kennel
Monday Evenings, 5:30-7 pm, Martin Johnson House, except for Nov 3, Sumner Hall
Scripps Institution of Oceanography, University of California San Diego

Oct 13: Origins of Modern Climate Research

Historical pioneers; the greenhouse effect; the increase of atmospheric CO2 concentrations; earth system science, climate models, space observations; earth's radiation balance and carbon cycle; hard truths about climate change; ethical dilemmas; governance

Oct 20: Paleoclimatology

Earth's climate in the past 65 million years; orbital forcing and ice ages; instability of ice age climates; abrupt events; volcanoes, ice, and ocean circulation; our benign interglacial; medieval warm period and little ice age; the Anthropocene

Oct 27: Arctic Climate Change and the Present Hiatus in Warming

Why the global temperature has been constant during the past sixteen years, yet Arctic warming has accelerated and extreme events have increased; world-wide impact of sea ice retreat; ecological, economic, and diplomatic aspects of Arctic climate change

Nov 3: How Climate Change could affect us in the next 50-100 years

Inferring from today's changes and climate models what tomorrow's world might look like; Regional weather patterns, water availability, floods, drought, wildfires; Impacts on agriculture, ecology, human disease, regional technical systems

Nov 10: How we can slow the pace of climate change; why we still will have much to adapt to

The failure of the climate negotiations; the inertia of the of the global energy system; slowing climate change by working with short-lived climate pollutants; why we probably cannot avoid 2 degC warming at mid-century; the case for adaptation

Nov 17: Adaptation Risks: Sea Level Rise, Coastal Cities, and Island Nations

Factors affecting rates of global and local sea level rise; How advanced regions are preparing-Venice, the Netherlands, Sacramento Bay-Delta; Vulnerable cities, agricultural river deltas, low-lying island nations

Nov 24: California Prepares to Adapt

The El Nino, atmospheric rivers, floods and droughts, water resources and management; how California learned from air pollution; California's regional assessments; Impacts on regional natural systems, regional technical systems, and populations

Dec 1: Global Adaptive Management of Climate Change

The essential role of assessment in the adaptive management of complex systems; the regional specificity of climate change impacts; the critical role of local communities; the complexity of knowledge assembly for regional and local decision-support; the need to encourage timely decisions; and the capacity problem; how "Knowledge Action Networks" comprising international experts and local decision-makers could inform and motivate good decisions

A Timeline of Atmospheric Science

Crutzen, P. J., & V. Ramanathan, The Ascent of Atmospheric Sciences, in "Pathways of Discovery", *Science, 290*, 13 October, 2000.

340 — Aristotle's Meteorologica is published.Its theories remain unchallenged for nearly 2000 years

http://classics.mit.edu/Aristotle/meteorology.html

0

1590s — Galileo invents the thermoscope, a precursor of thermometers

1643 — Torricelli performs experiments on atmospheric Pressure using a mercury barometer

1686 — Halley shows that low latitudes receive more solar radiation than higher ones and proposes that this gradient provides forcing for the atmosphere's general circulation.

1714 — Fahrenheit develops the thermometer and a temperature scale

1750 — J.Black identifies CO_2 in atmospheric air

1752 — B.Franklin found out that lightining is an electrical discharge by using kites.

1770s — Rutherford identifies N_2 in air. Scheele and Priestley independently discover O_2

1781 — H.Cavendish measures the composition of air to be 79.16% nitrogen and 20.84% oxygen.

Fahrenheit's first thermometers contained a column of alcohol which expanded and contracted directly. Fahrenheit substituted mercury for alcohol because its rate of expansion, although less than that of alcohol, is more constant. Furthermore, mercury could be used over a much wider temperature range than alcohol.

(Crutzen and Ramanathan,2000)

Instrumental Weather Data

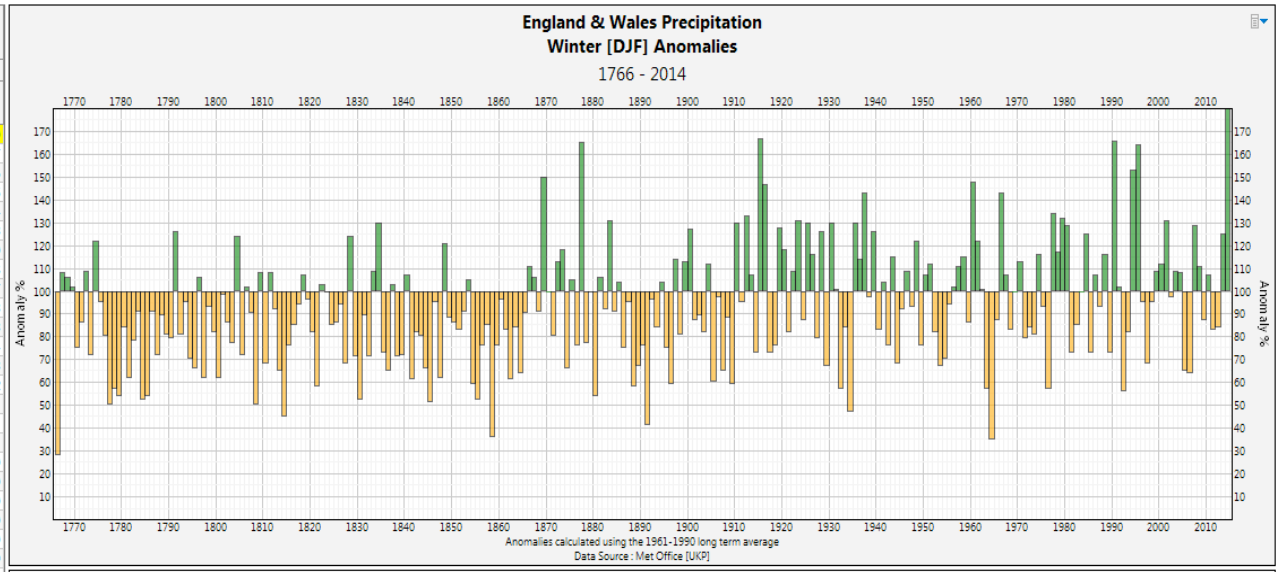
Temperature Record for Central England from 1659

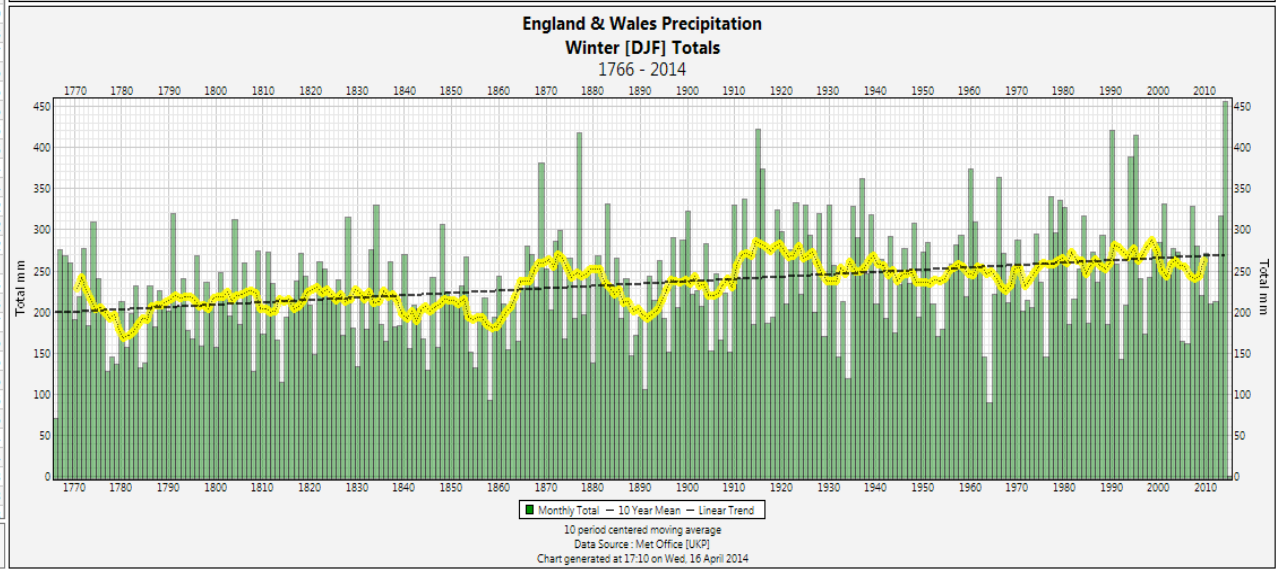
England & Wales Precipitation from 1766

England & Wales Precipitation
Winter [DJF]
1766-2014

#	Year	Rainfall		
		Total		Anom
		mm	in	%
1	2013/14	456.1	17.96	180
2	1914/15	423.0	16.65	167
3	1989/90	420.9	16.57	166
4	1876/77	418.3	16.47	165
5	1994/95	415.6	16.36	164
6	1993/94	388.3	15.29	153
7	1868/69	380.6	14.98	150
8	1959/60	374.3	14.74	148
9	1915/16	373.5	14.71	147
10	1965/66	363.0	14.29	143
11	1936/37	362.0	14.25	143
12	1976/77	340.0	13.39	134
13	1911/12	337.7	13.29	133
14	1978/79	335.2	13.20	132
15	1922/23	332.6	13.09	131
16	2000/01	331.9	13.07	131
17	1882/83	331.7	13.06	131
18	1833/34	330.6	13.02	130
19	1924/25	330.4	13.01	130
20	1929/30	330.2	13.00	130
21	1909/10	329.4	12.97	130
22	1934/35	328.3	12.93	130
23	2006/07	327.8	12.90	129
24	1979/80	326.5	12.85	129
25	1918/19	323.9	12.75	128
26	1899/00	322.9	12.71	127
27	1927/28	320.1	12.60	126
28	1790/91	319.6	12.58	126
29	1938/39	318.9	12.55	126
30	1983/84	317.5	12.50	125
31	2012/13	316.5	12.46	125
32	1827/28	314.8	12.39	124
33	1803/04	313.0	12.32	124
34	1960/61	309.9	12.20	122
35	1773/74	309.2	12.17	122
36	1947/48	308.4	12.14	122
37	1847/48	306.7	12.07	121
38	1872/73	298.7	11.76	118
39	1919/20	298.0	11.73	118
40	1977/78	296.7	11.68	117
41	1973/74	295.0	11.61	116
42	1987/88	293.4	11.55	116
43	1925/26	293.2	11.54	116
44	1957/58	292.7	11.52	115
45	1942/43	292.2	11.50	115
46	1935/36	290.0	11.42	114
47	1896/97	289.8	11.41	114
48	1969/70	287.6	11.32	113
49	1898/99	286.9	11.29	113
50	1871/72	286.7	11.29	113

x=1766 y=199.2
x1=2014 y1=269.4
m=+35.3





United Kingdom Meteorological Office

The First Weather Forecasts

Vice-Admiral Robert Fitzroy RN, 1805-1865

Captain of HMS *Beagle,* 1831-1836; Founder of the UK Met Office, 1854

BRITISH

ELECTRIC TELEGRAPH

COMPANY,

CENTRAL OFFICES, ROYAL EXCHANGE,

LONDON.

THE WEATHER.

METEOROLOGICAL REPORTS.

Wednesday, July 31, 8 to 9 a.m.	B.	E.	M.	D.	F.	C.	I.	S.
Nairn..	29·54	57	56	W.S.W.	6	9	o.	3
Aberdeen	29·60	59	54	S.S.W.	5	1	b.	3
Leith	29·70	61	55	W.	3	5	c.	2
Berwick	29·69	59	55	W.S.W.	4	4	c.	2
Ardrossan	29·73	57	55	W.	5	4	c.	5
Portrush	29·72	57	54	S.W.	2	2	b.	2
Shields	29·80	59	54	W.S.W.	4	5	o.	3
Galway	29·83	65	62	W.	5	4	c.	4
Scarborough ..	29·86	59	56	W.	3	6	c.	2
Liverpool	29·91	61	56	S.W.	2	8	c.	2
Valentia	29·87	62	60	S.W.	2	5	o.	3
Queenstown ..	29·88	61	59	W.	3	5	c.	2
Yarmouth.. ..	30·05	61	59	W.	5	2	c.	3
London	30·02	62	56	S.W.	3	2	b.	—
Dover..	30·04	70	64	S.W.	3	7	o.	2
Portsmouth ..	30·01	61	59	W.	3	6	o.	2
Portland	30·03	63	59	S.W.	3	2	c.	3
Plymouth.. ..	30·00	62	59	W.	5	1	b.	4
Penzance	30·04	61	60	S.W.	2	6	c.	3
Copenhagen ..	29·94	64	—	W.S.W.	2	6	c.	3
Helder	29·99	63	—	W.S.W.	6	5	c.	3
Brest	30·09	60	—	S.W.	2	6	c.	5
Bayonne	30·13	68	—	—	—	9	m.	5
Lisbon	30·18	70	—	N.N.W.	4	3	b.	2

General weather probable during next two days in the—

North—Moderate westerly wind ; fine.

West—Moderate south-westerly ; fine.

South—Fresh westerly ; fine.

Explanation.

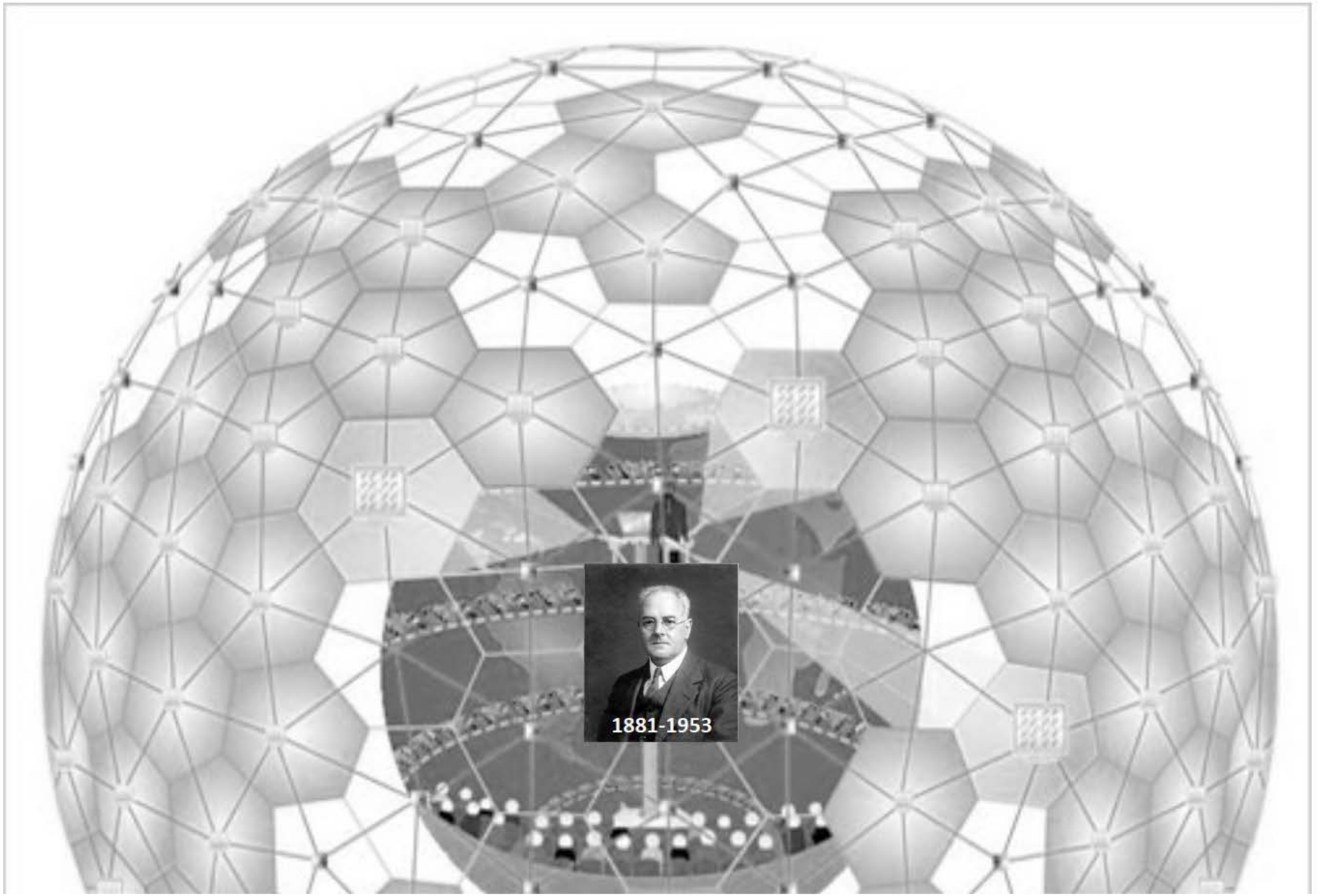
B. Barometer, corrected and reduced to 32° at mean sea level ; each 10 feet of vertical rise causing about one-hundredth of an inch diminution, and each 10° above 32° causing nearly three-hundredths increase. E. Exposed thermometer in shade. M. Moistened bulb (for evaporation and dew-point). D. Direction of wind (true— two points [illegible] estimated). C. Cloud (1 to 9). I. Initials :—b., blue sky ; c., clouds (detached) ; f., fog ; h., hail ; l., lightning ; m., misty (hazy) ; o., overcast (dull) ; r., rain ; s., snow ; t., thunder. S. Sea disturbance (1 to 9).

The Times, August 1, 1861

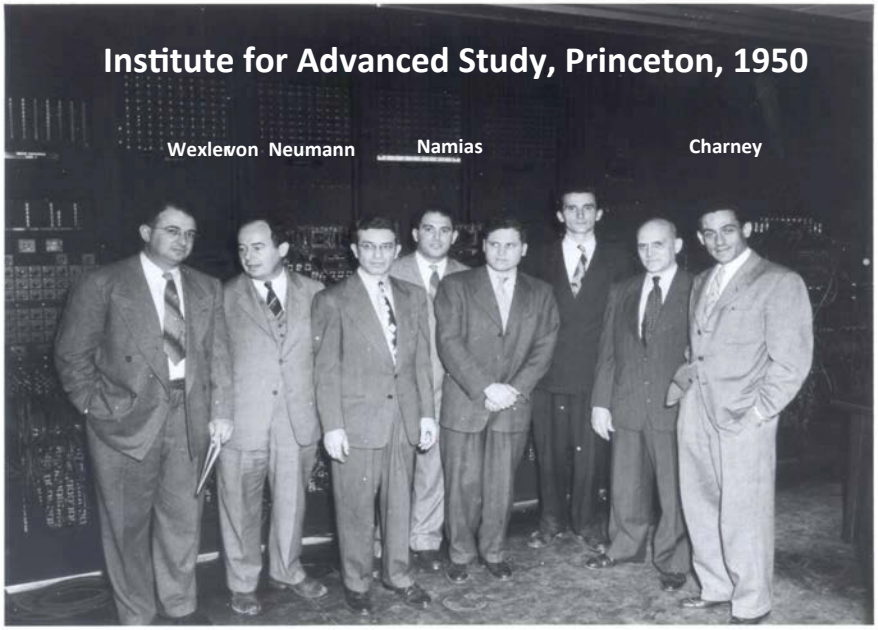
Fitzroy's technology-driven empiricism did not satisfy the savants of the Royal Society who, with some justification, complained there was no theoretical basis for the weather forecast. But, no-one then could solve the Navier-Stokes equations, either. In fact, today's forecasting blends theory-based computations and empirical data.

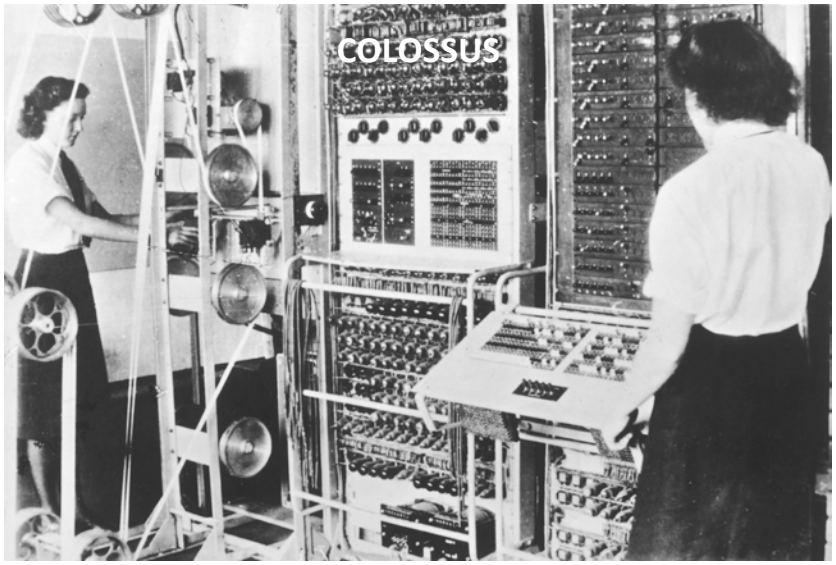
Lewis Fry Richardson's Forecast Factory, 1922

Numerical algorithm needed 64,000 human "computers"

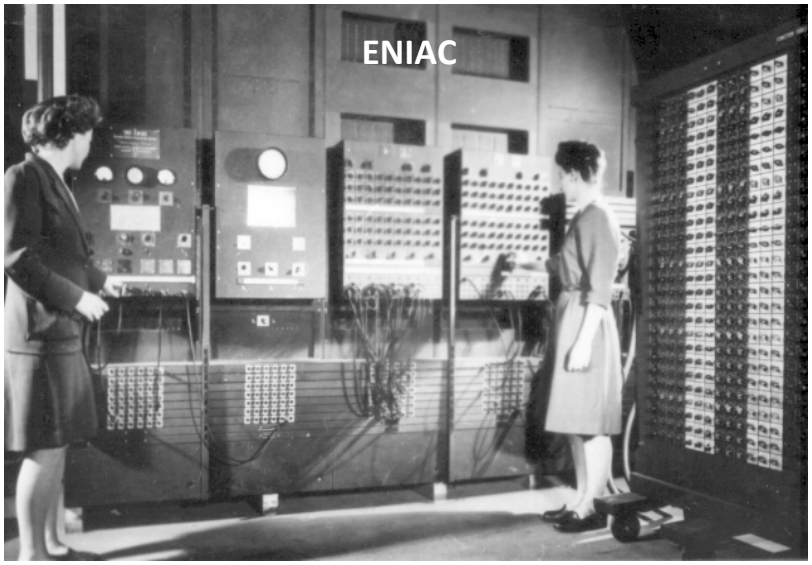


The First Electronic Weather Calculations





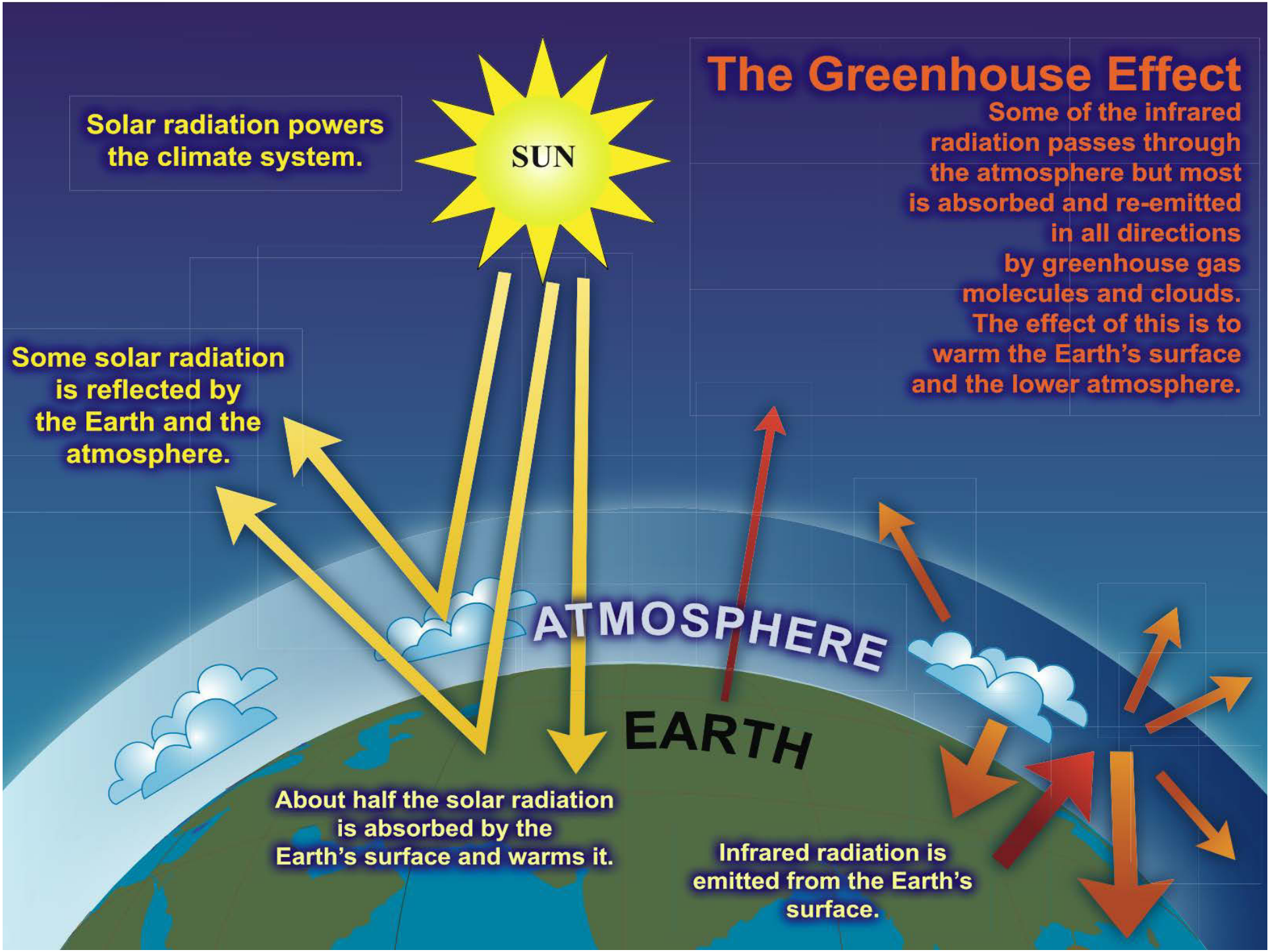
Bletchley Park, 1943



Los Alamos/U. Pennsylvania, 1946

If the earth were a perfect black body with no atmosphere….

it would absorb solar energy until it glows in the infrared. The surface temperature at which solar radiation in balances infrared radiation out is -18 degC. The observed temperature is + 14 degC.


The Greenhouse Effect
Solar radiation powers the climate system.
SUN
Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.
Some solar radiation is reflected by the Earth and the atmosphere.
ATMOSPHERE
EARTH
About half the solar radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

Pathways of Discovery

Herschel (1800): Discovery of infrared heat radiation
Fourier (1825-27): Greenhouse effect keeps the earth warmer than expected from visible solar radiation energy flux alone
Tyndall (1850s): Atmospheric H_2O, CO_2 selectively absorb infrared radiation
Arrhenius (1896): Fossil fuel CO_2 should cause global warming
Callendar (1938): Global land temperatures had increased in previous 50 years
Revelle and Suess (1957): Oceans cannot absorb all the increase in CO_2 concentration
Keeling (1957-2005): Atmospheric CO_2 is increasing at rate consistent with fossil fuel sources

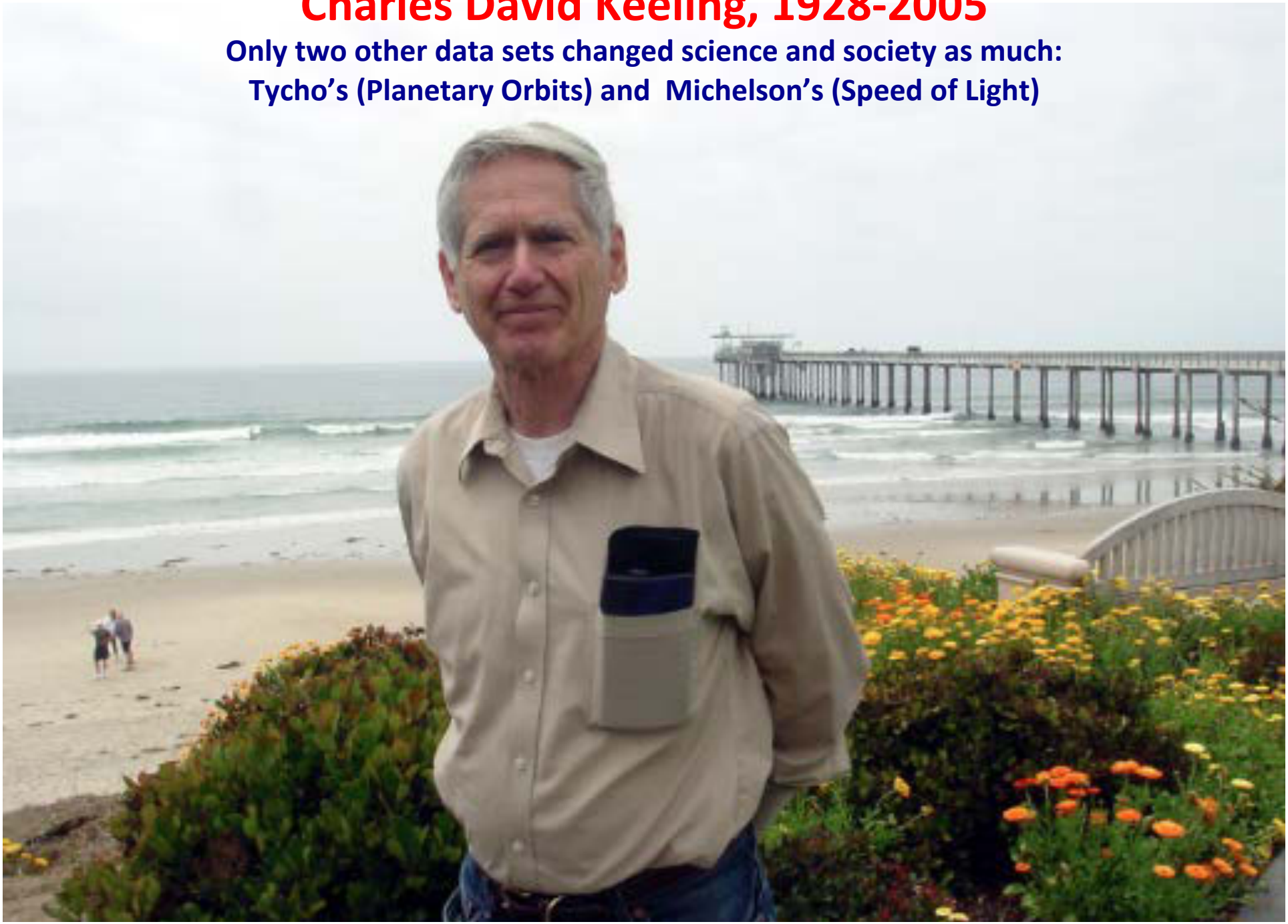
"A Great One-Time Geophysical Experiment"

Could not have happened in the past nor be reproduced in the future

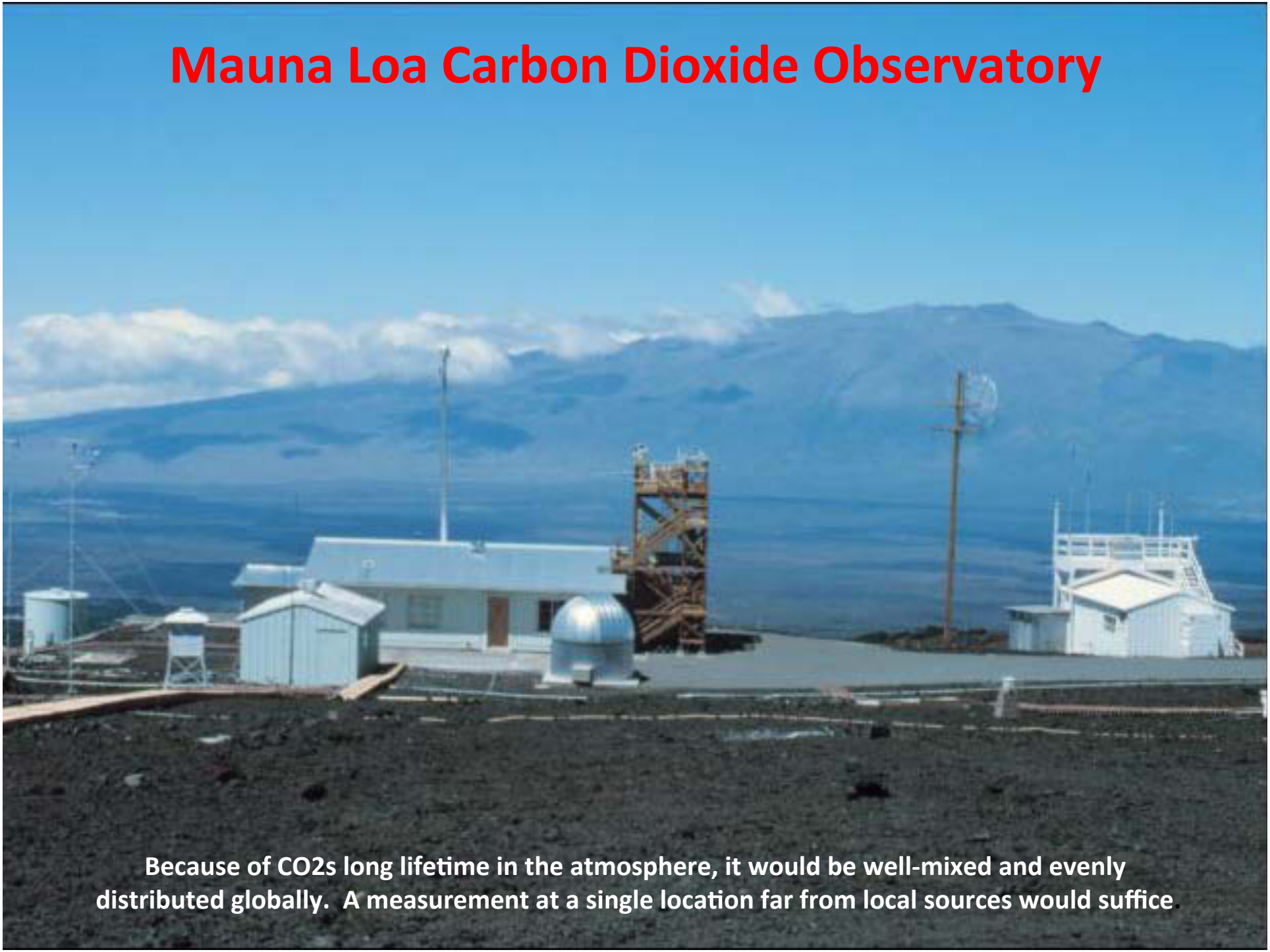
In those pre-Anthropocene days, people thought that the vast oceans would easily absorb the atmospheric carbon dioxide produced by human industrial activity. In a landmark paper, Revelle and Hans Suess (1957) ascertained the rate of CO2 exchange between the atmosphere and sea water. They estimated the CO2 lifetime to be 20 years. A fair fraction of the CO2 humans are producing would therefore accumulate in the atmosphere. The next question was, is it increasing? This needed to be measured, not calculated, and Revelle brought Dave Keeling to Scripps from CalTech.

Charles David Keeling, 1928-2005

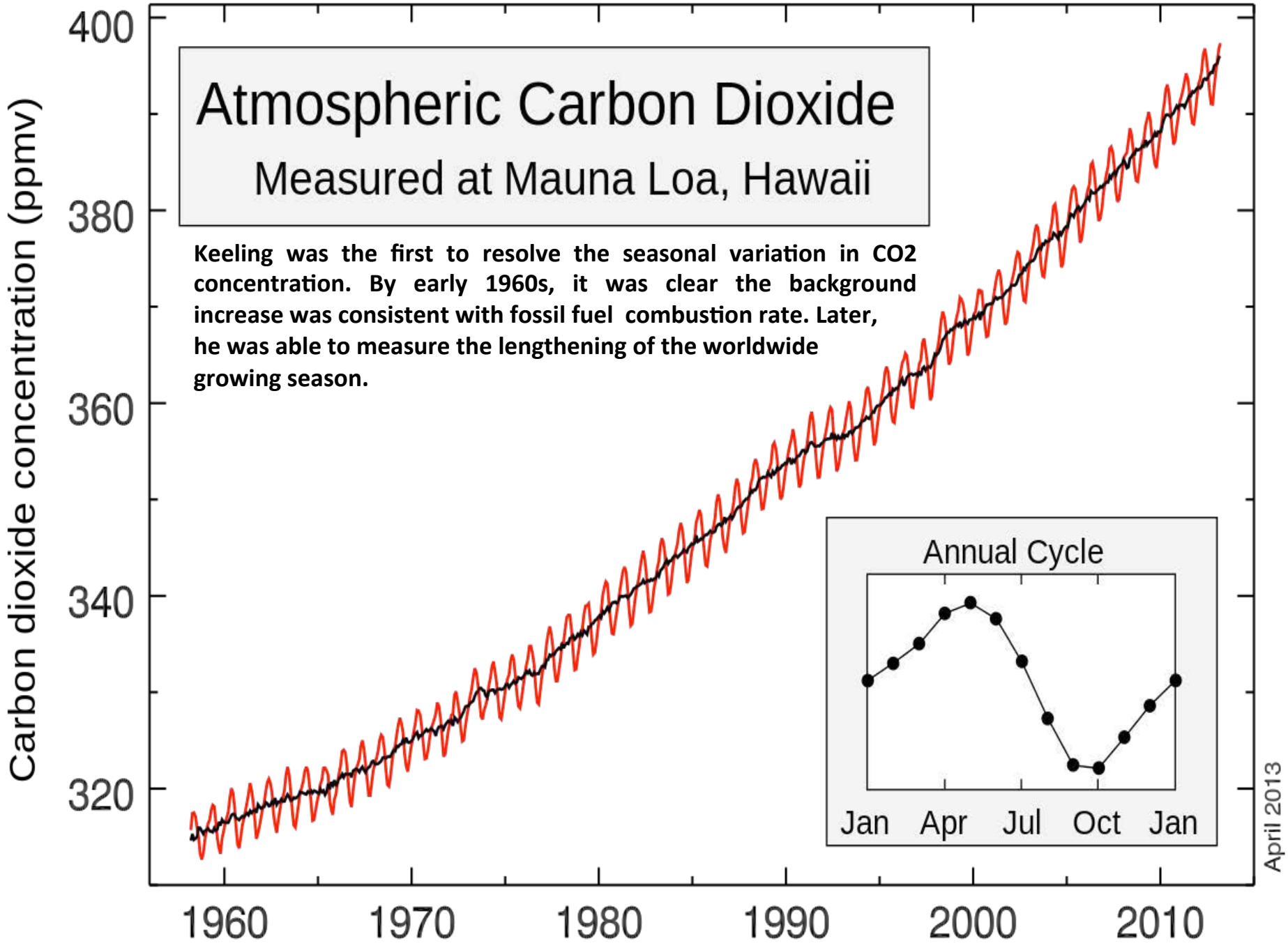
Only two other data sets changed science and society as much:
Tycho's (Planetary Orbits) and Michelson's (Speed of Light)



Mauna Loa Carbon Dioxide Observatory



Because of CO2s long lifetime in the atmosphere, it would be well-mixed and evenly distributed globally. A measurement at a single location far from local sources would suffice.


Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii
Keeling was the first to resolve the seasonal variation in CO2 concentration. By early 1960s, it was clear the background increase was consistent with fossil fuel combustion rate. Later, he was able to measure the lengthening of the worldwide growing season.
Carbon dioxide concentration (ppmv)
400
380
360
340
320
1960
1970
1980
1990
2000
2010
Annual Cycle
Jan
Apr
Jul
Oct
Jan
April 2013

Carbon Dioxide and Climate: A Scientific Assessment

Report of an Ad Hoc Study Group on Carbon Dioxide and Climate
Woods Hole, Massachusetts
July 23–27, 1979
to the
Climate Research Board
Assembly of Mathematical and Physical Sciences
National Research Council

Jule Charney

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1979

Things that are still true:

"The primary effect of increased atmospheric CO2 on climate… is to cause more absorption of thermal radiation from the earth's surface and thus to increase the air temperature….

When…the CO2 content of the atmosphere is doubled and … equilibrium is achieved,… modeling efforts predict a global surface warming of between 2°C and 3.5°C,with greater increases at high latitudes…

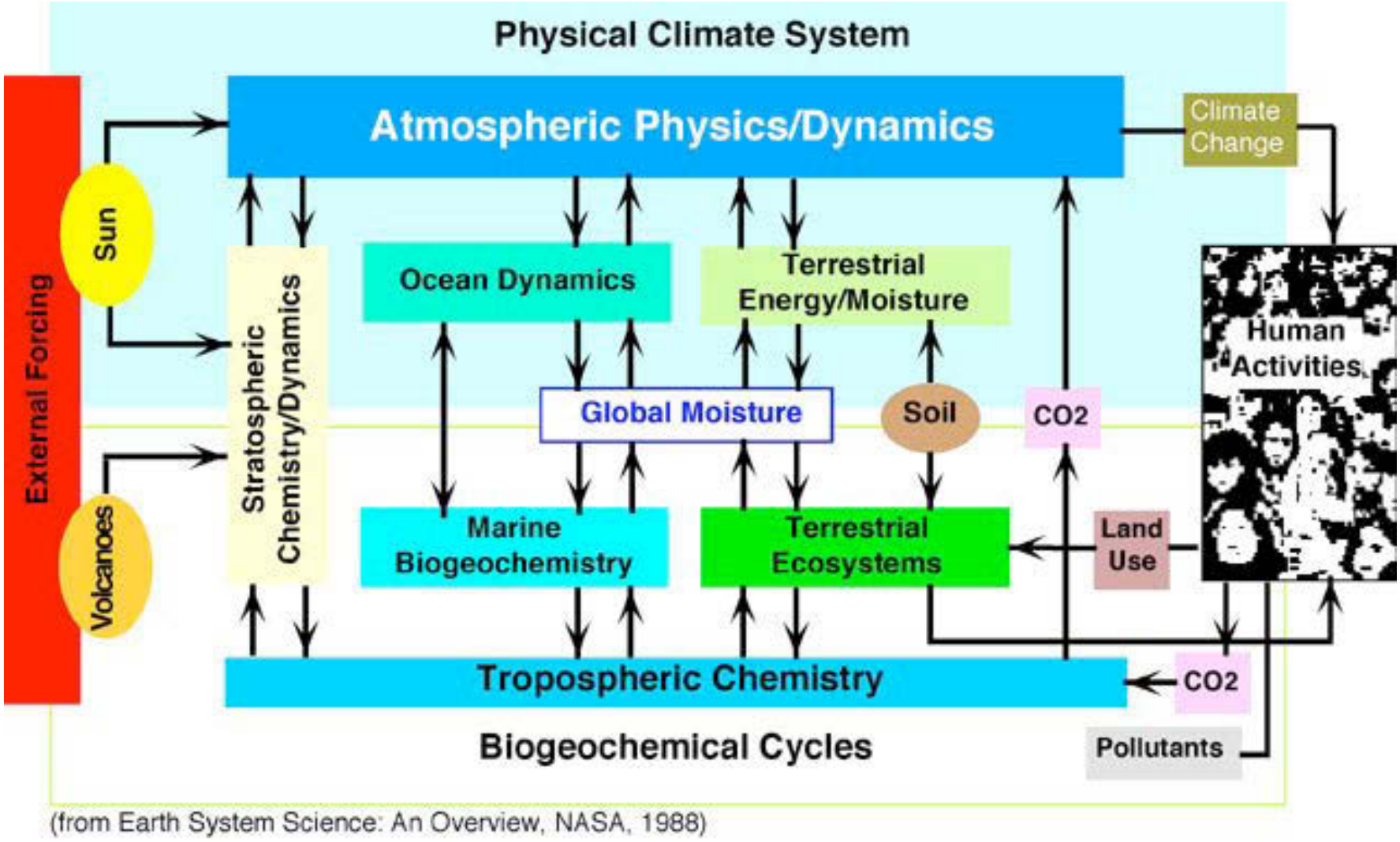
….the warming will eventually occur, and the associated regional climatic changes (will be) so important (that) socioeconomic consequences may… be significant"

Reorganization of the Earth Sciences

Earth System Science
Planetary Subsystems
Observing Systems
Cyber-Infrastructure

Earth System Science

Interdisciplinary Science for the Anthropocene

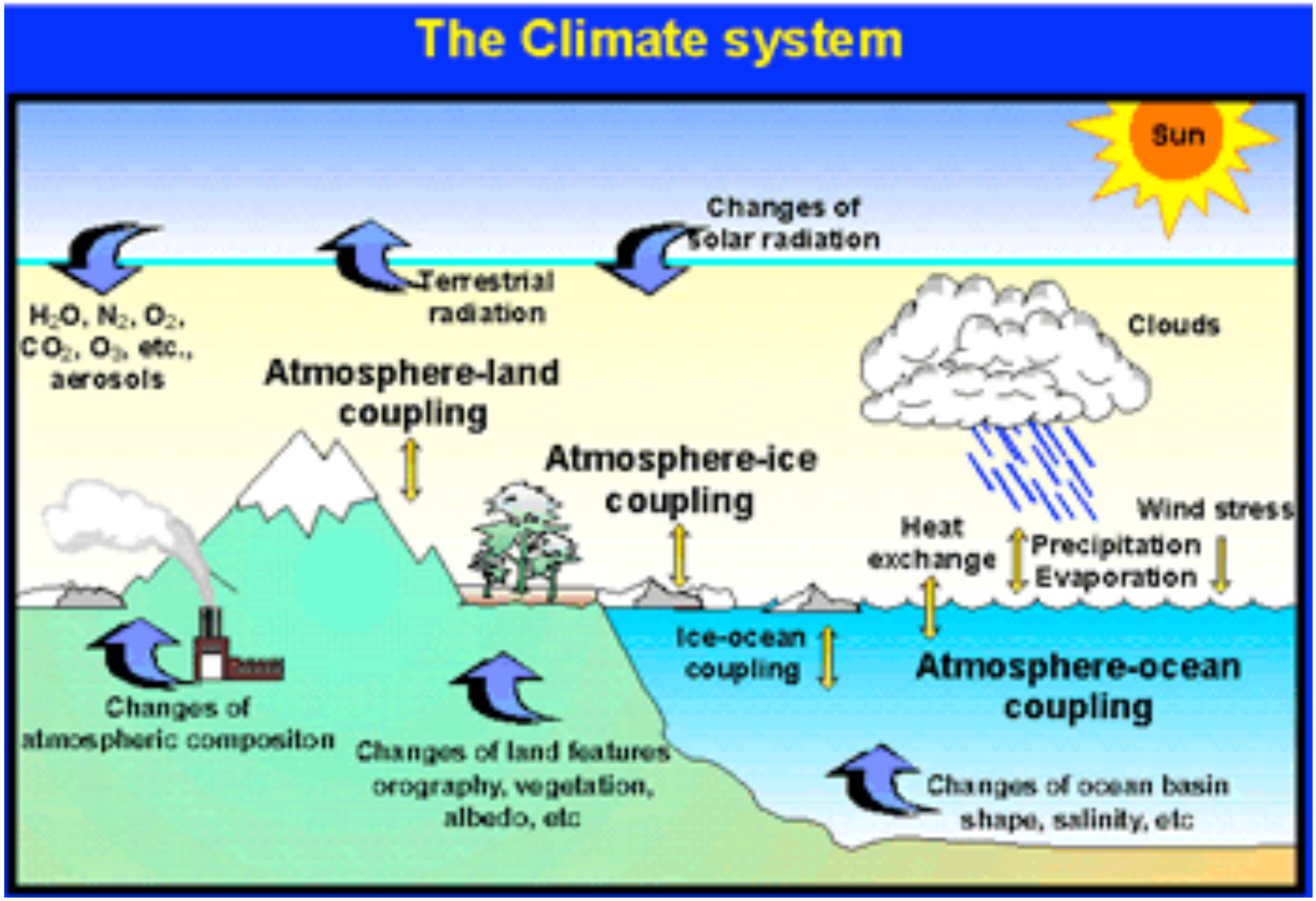


(from Earth System Science: An Overview, NASA, 1988)

Centuries, not Eons

Francis Bretherton, 1982 ff.

Interacting Planetary Subsystems



Source: Commonwealth Scientific and Industrial Research Organisation (CSIRO), Modelling Climate: CSIRO Atmospheric Research Greenhouse Information Paper. Australia 1996. http://www.dar.csiro.au/publications/info98_4.htm

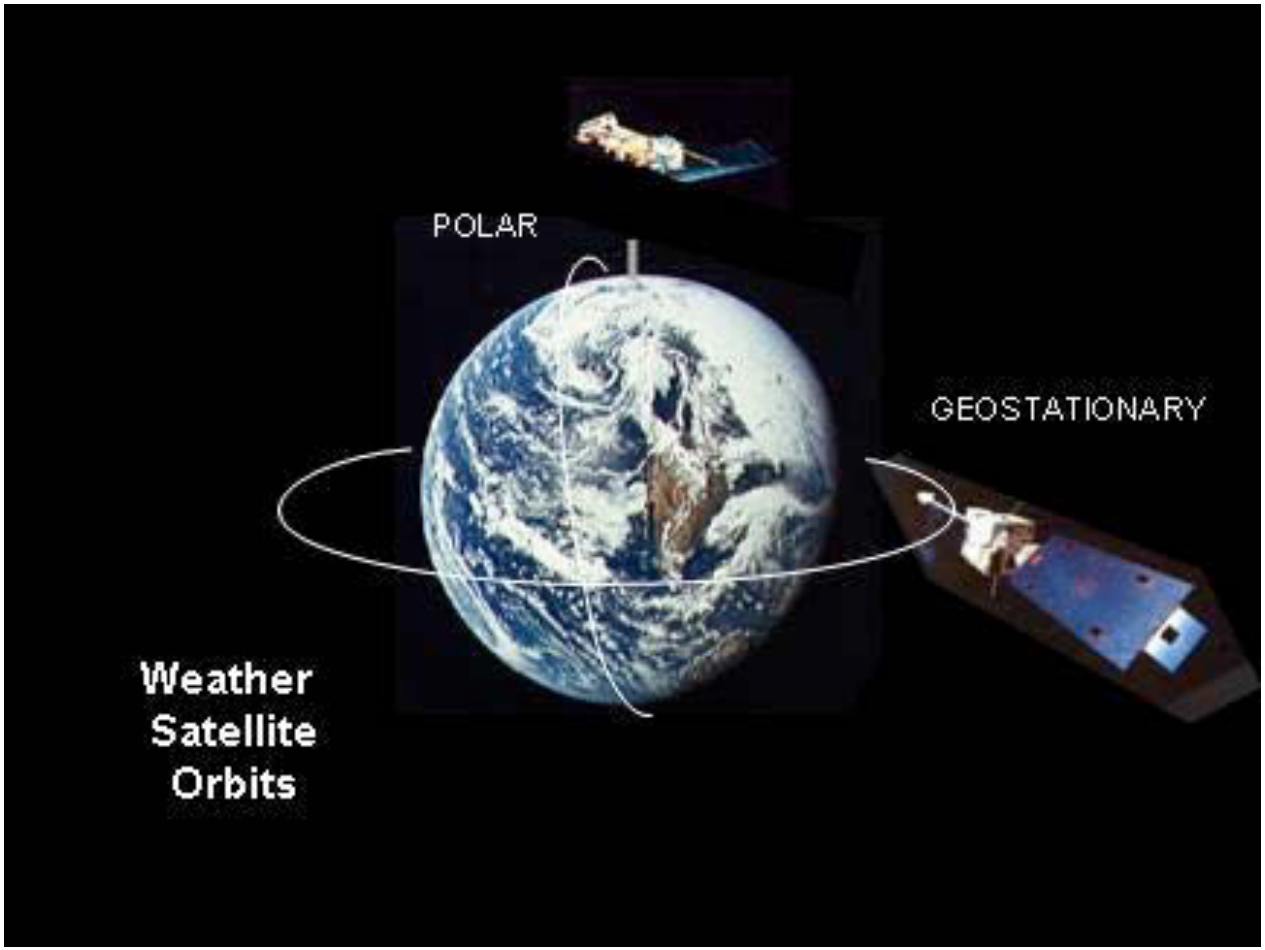
Weather Satellites

Nimbus-1 (1964) first weather satellite

Global observations extended forecasts out to 7 days

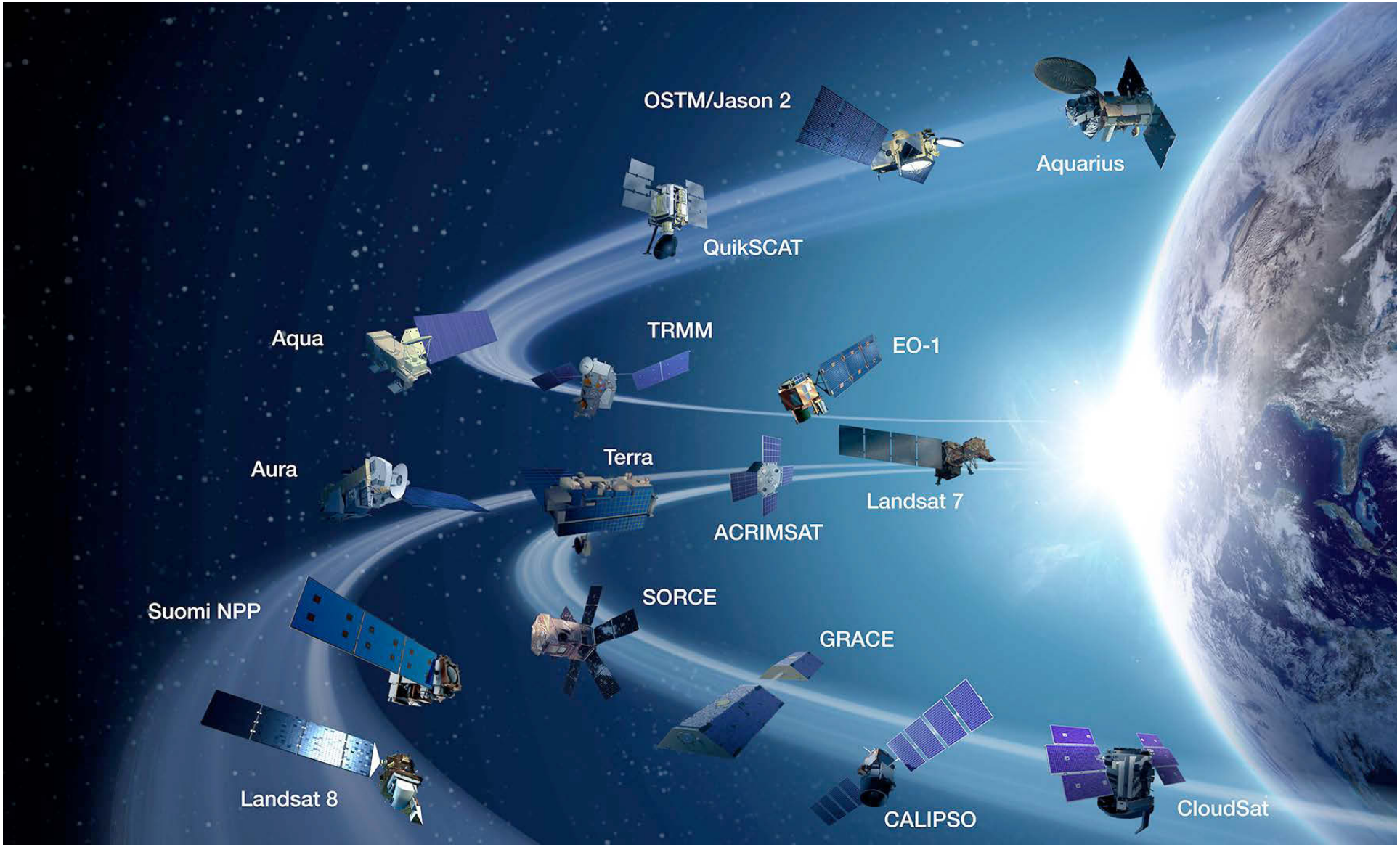
Enabled storm track projections

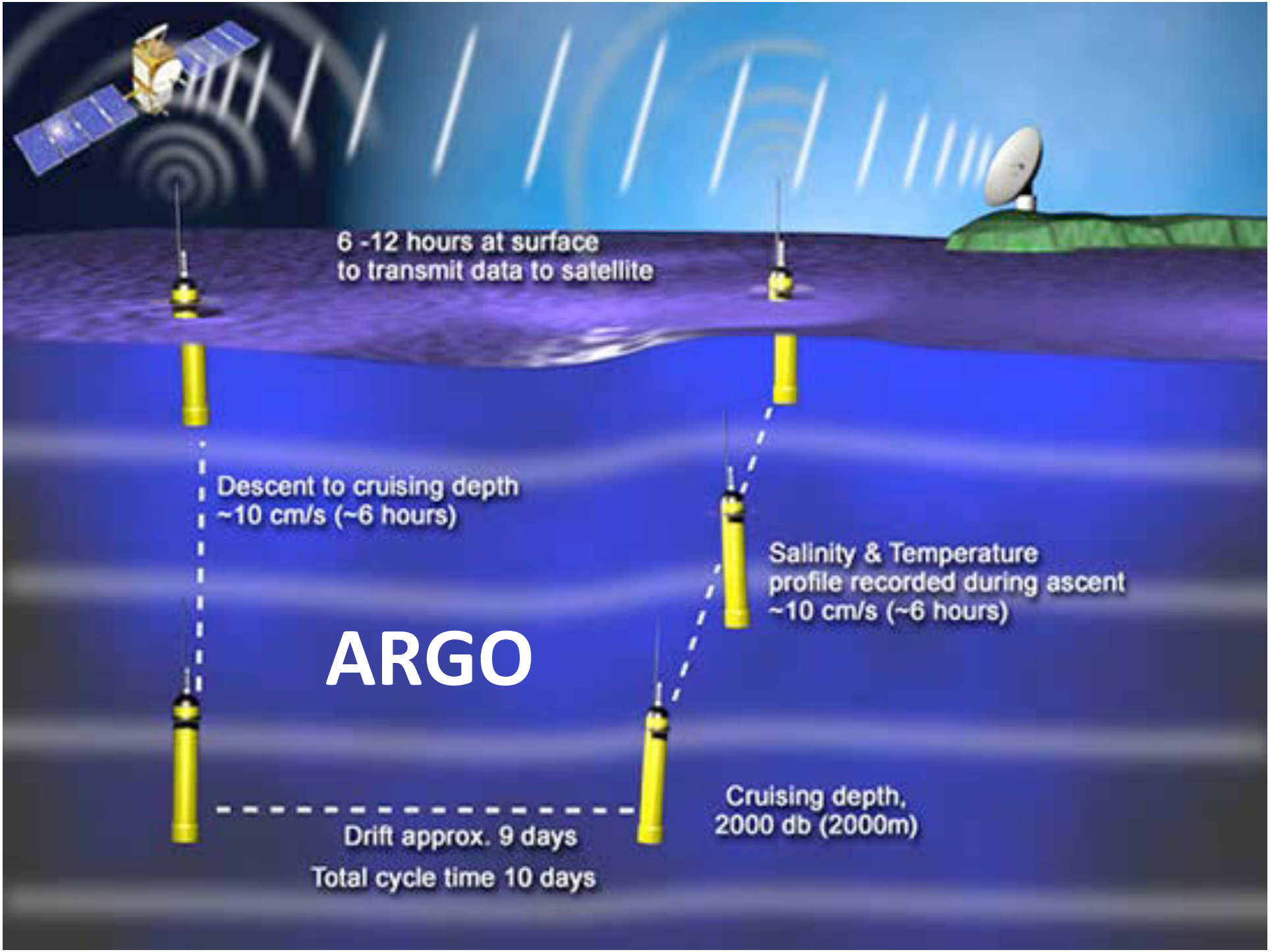
Dramatically improved empirical data needed for climate purposes



Earth Observing System, 1990-

Multi-Disciplinary Observations for Earth System Science

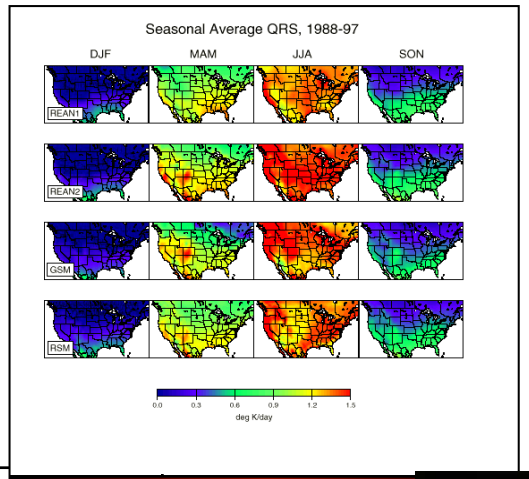



6 -12 hours at surface
to transmit data to satellite
Descent to cruising depth
~10 cm/s (~6 hours)
Salinity & Temperature
profile recorded during ascent
~10 cm/s (~6 hours)
ARGO
Cruising depth,
2000 db (2000m)
Drift approx. 9 days
Total cycle time 10 days

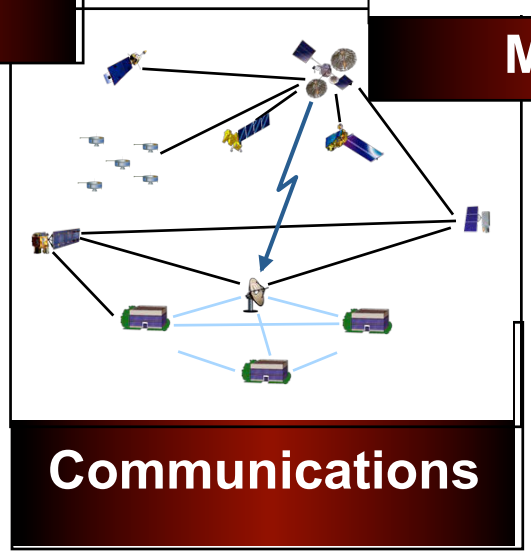
Cyber-Infrastructure

The Earth Observing System's Data and Information System (EOSDIS) pioneered collection, integration, analysis, and distribution of "big data"; modeling used the data to create understanding and make projections

Computing



Modeling



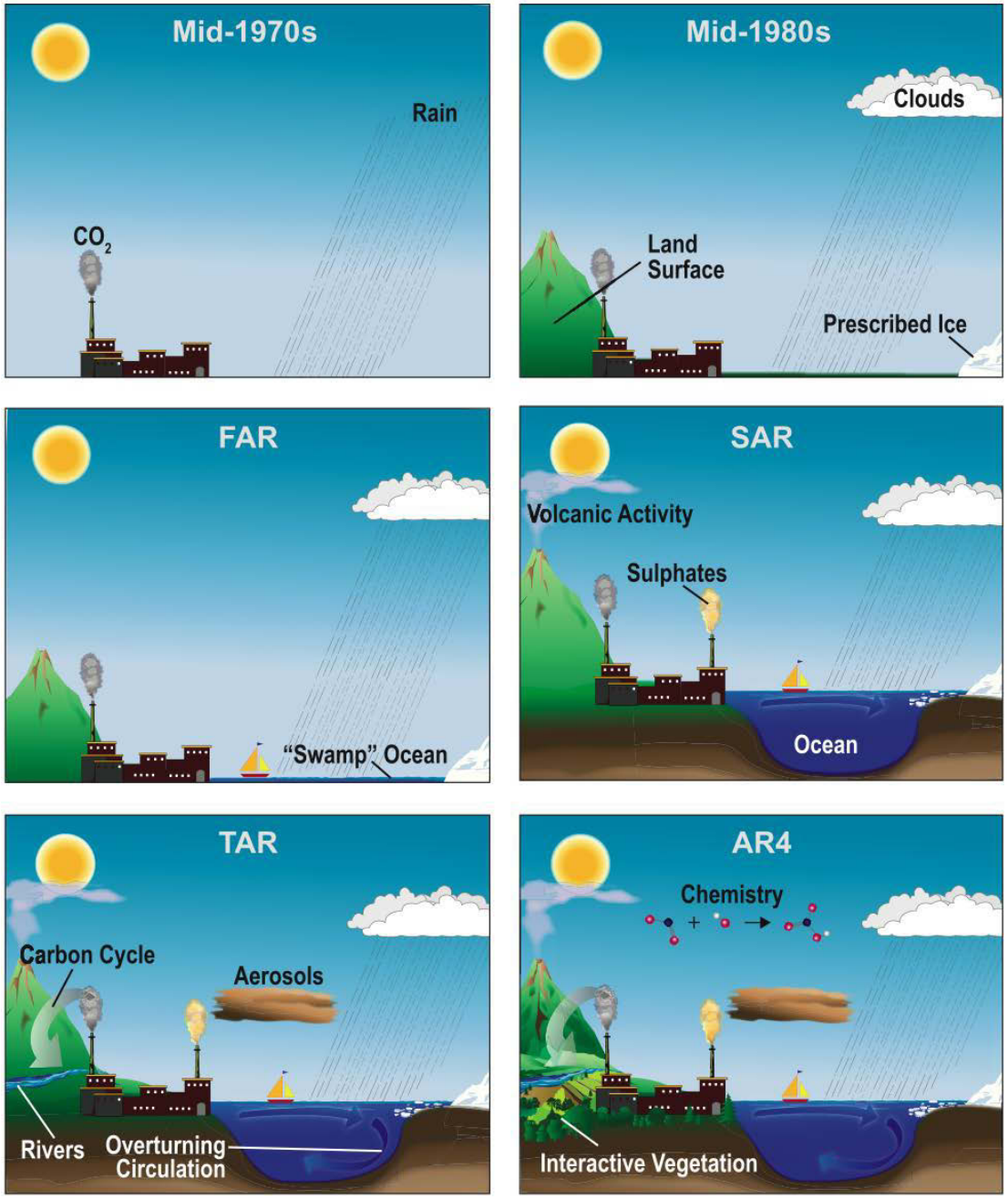
Communications

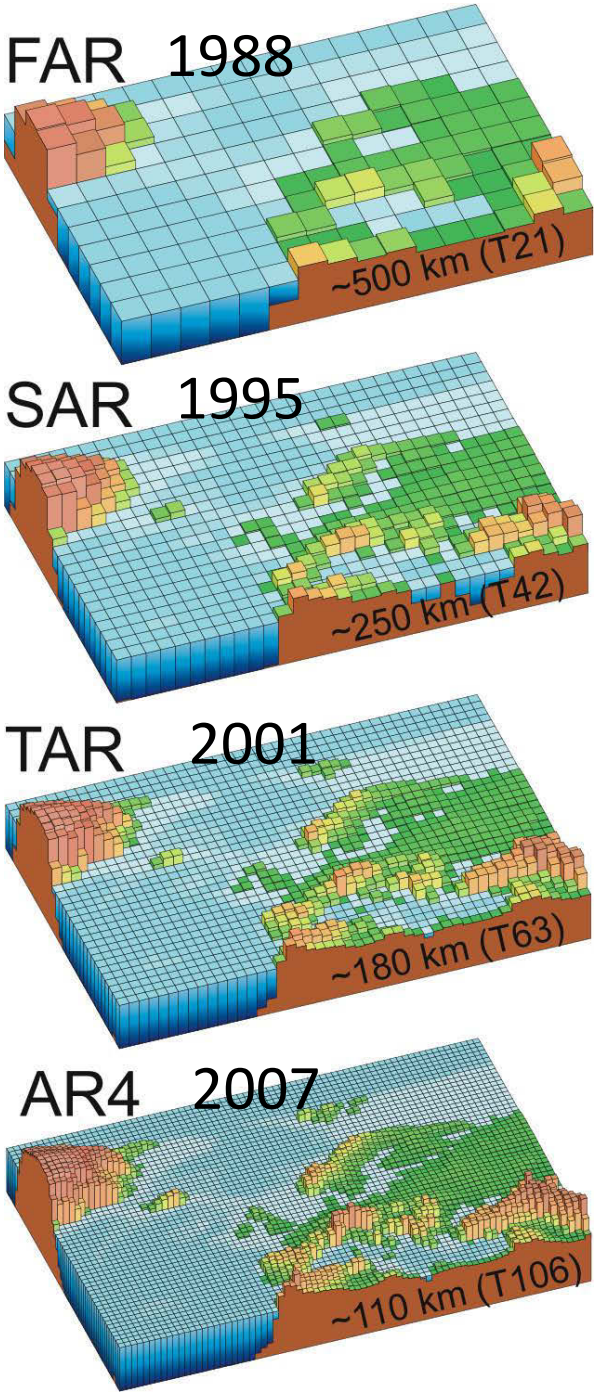
Visualization

Atmosphere-Ocean General Circulation Models

Richardson's dream realized

The World in Global Climate Models





Key Achievements

Earth's Radiation Balance

Global Carbon Cycle

Circulation of Oceans and Atmosphere

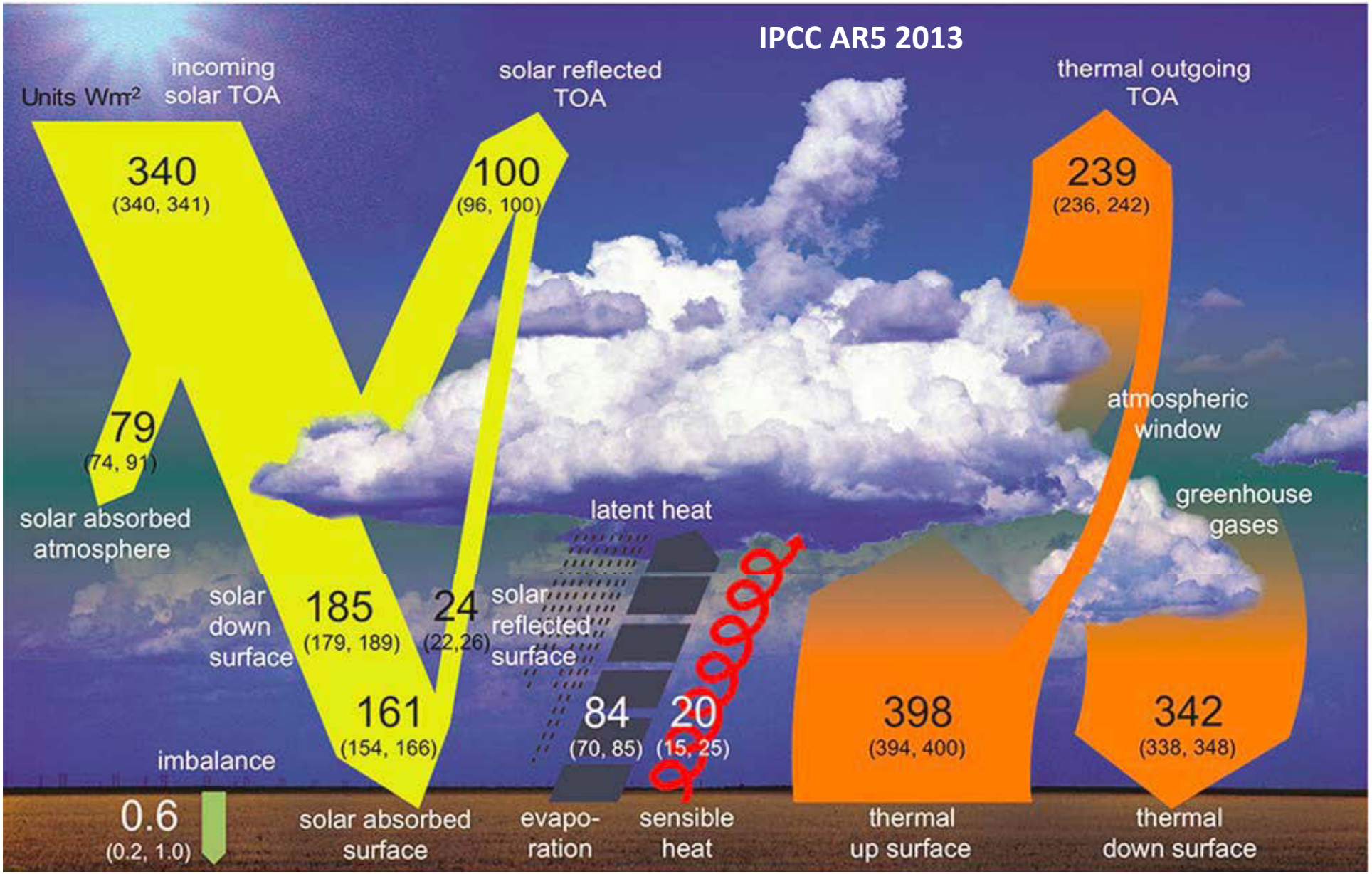
Role of Cryosphere

Greenhouse Gas Emission Inventory

Global Temperature Increase

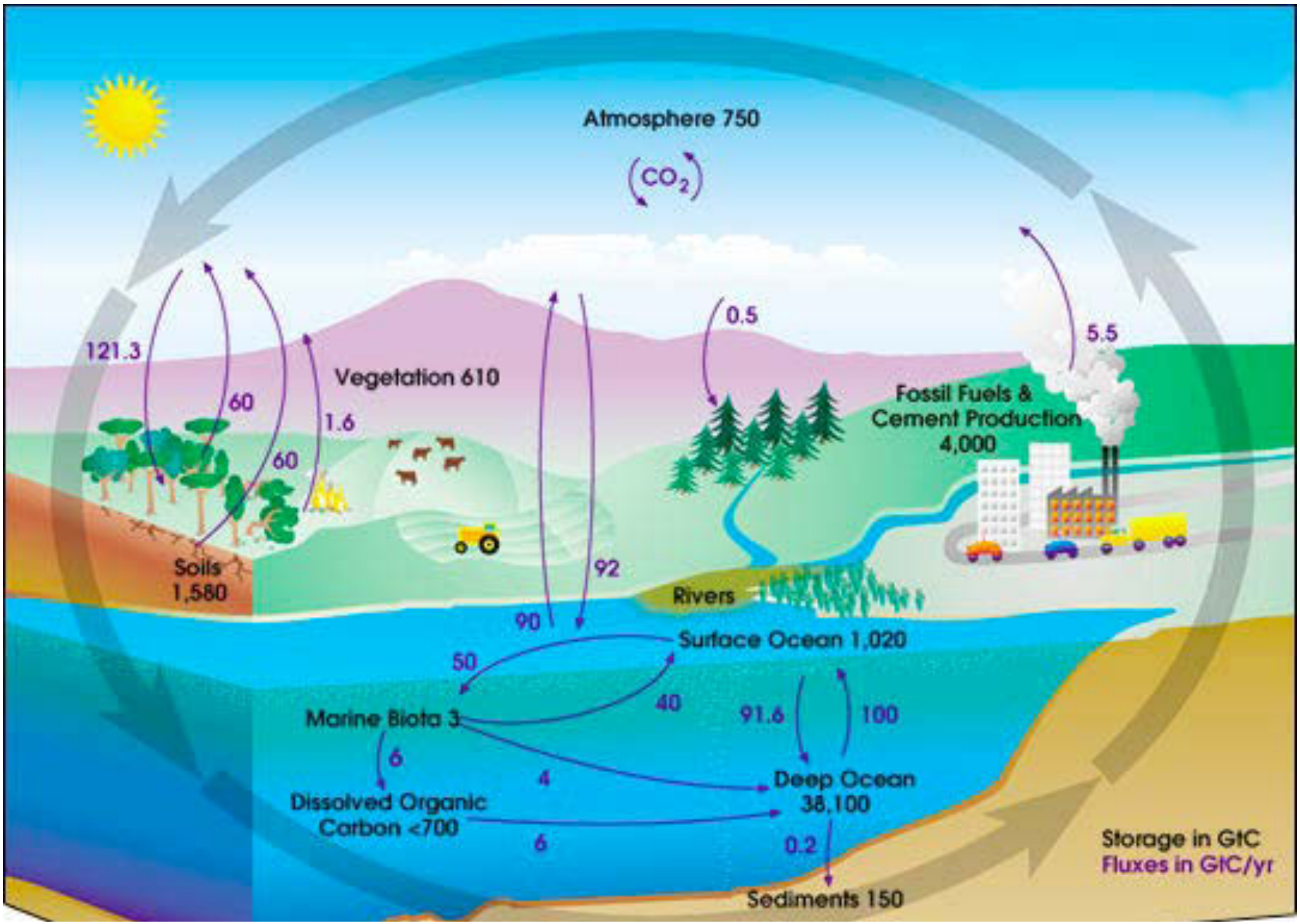
Follow the Energy

Contemporary Radiation Balance



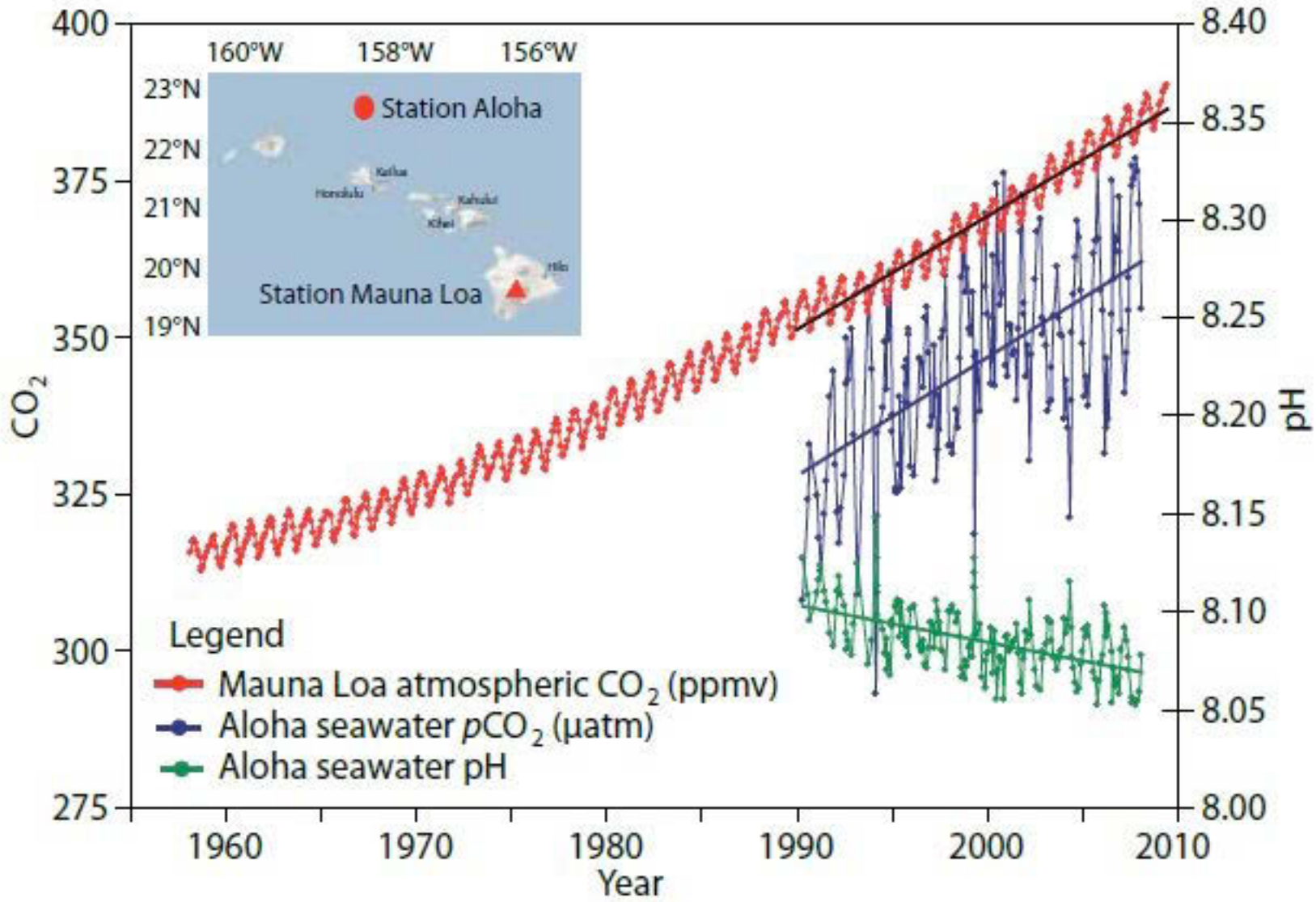
Follow Carbon Dioxide

Terrestrial and Oceanic Inventories and rates of exchange with the atmosphere



Oceans Absorb ~ 25% of Anthropogenic CO2

Resulting acidification has profound implications for shelled marine life

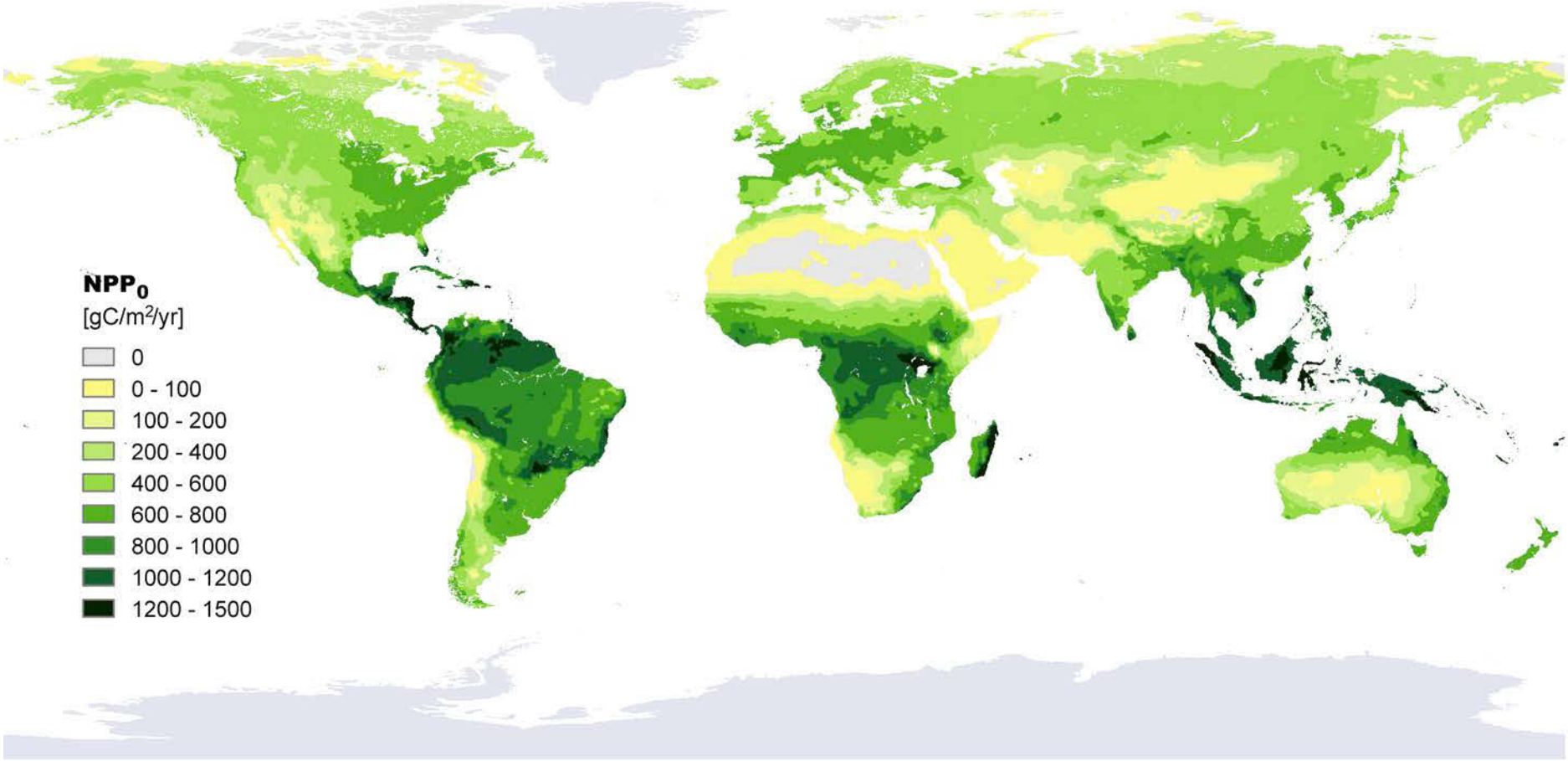


Scott C. Doney *et al,* Ocean Acidification-a critical emerging problem for the ocean sciences, *Oceanography, 22,* no 4, 2009

Terrestrial Biosphere Absorbs ~ 25% of Anthropogenic CO2

Net Primary Productivity

Rate of Carbon Take-up by Photosynthetic Growth of Vegetation on Land

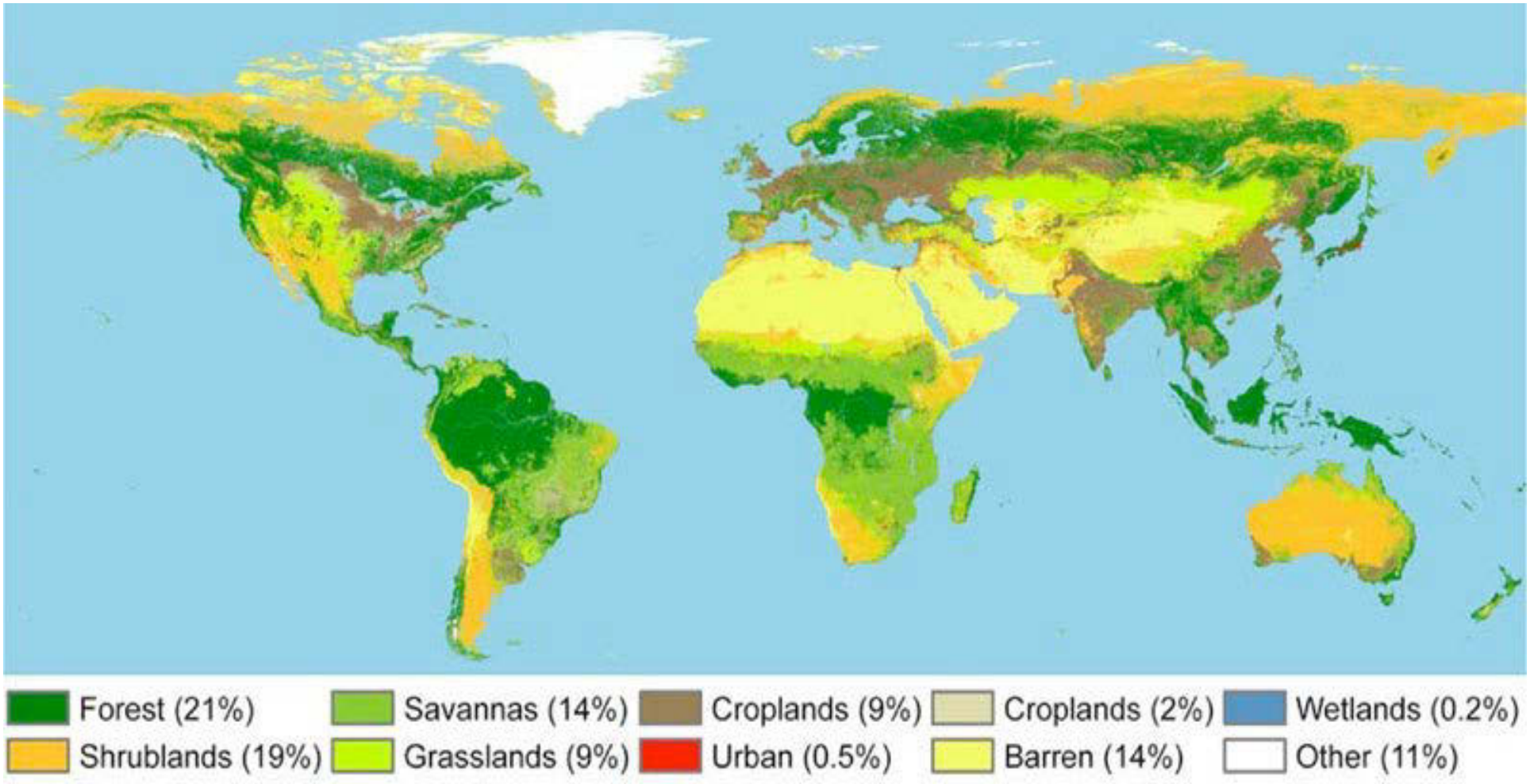


Plant growth in northern hemisphere spring and summer draws down CO2, accounting for Keeling's seasonal cycle. The global growing season has lengthened by several weeks since Keeling started taking data. The Northern Hemisphere has been "greening"

Land Cover Change

Essential for understanding ecology's role in climate change

Human land use has played a role in climate since the agricultural revolution

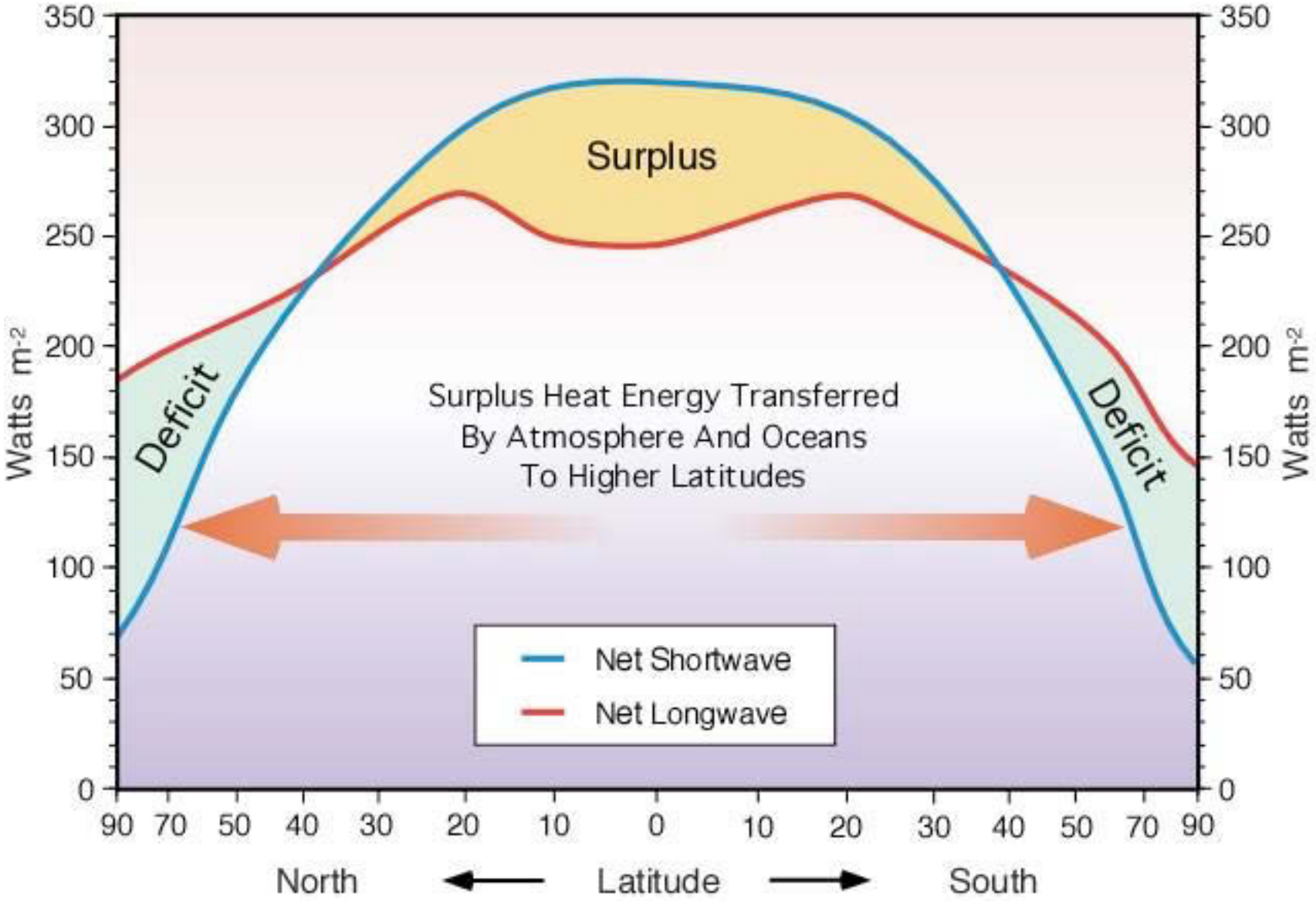


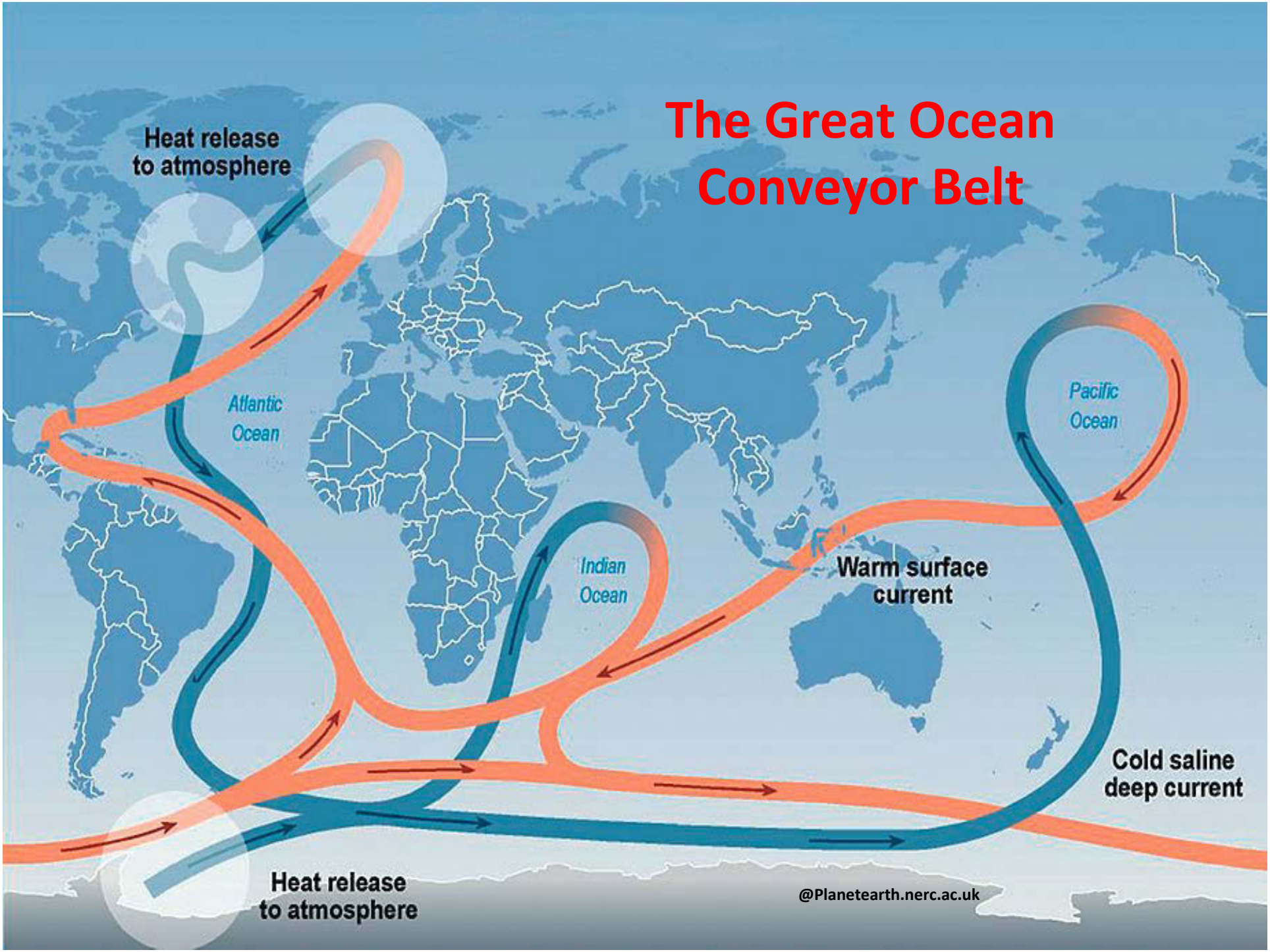
Source: University of Texas


Deforestation
10-15% of Greenhouse Warming
Image: Los Angeles Times

Halley Quantified

Net radiative warming drives equator-to-pole circulation of both atmosphere and ocean

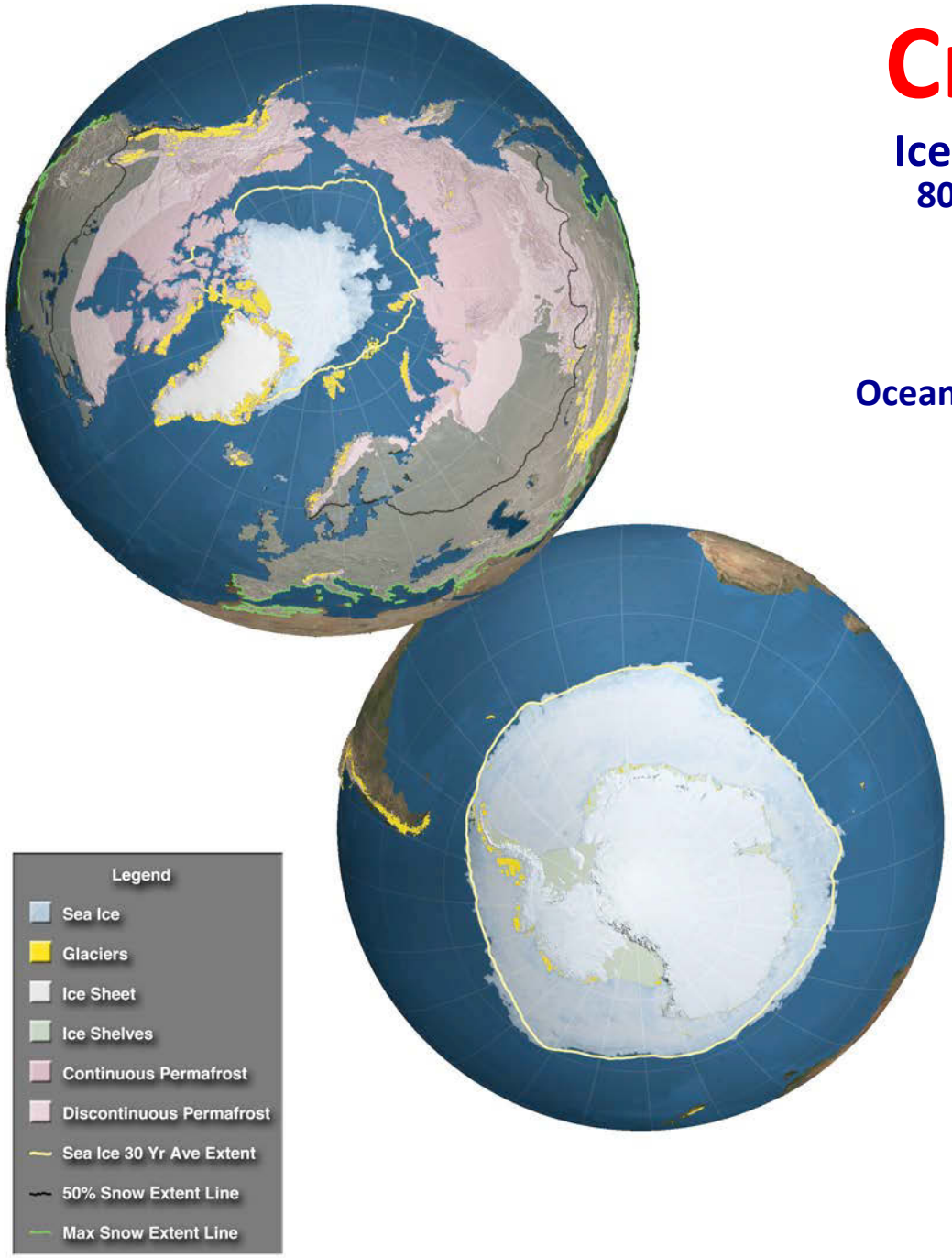



The Great Ocean Conveyor Belt
Heat release to atmosphere
Atlantic Ocean
Pacific Ocean
Indian Ocean
Warm surface current
Cold saline deep current
Heat release to atmosphere
@Planetearth.nerc.ac.uk

Cryosphere

Ice, Snow, & Permafrost

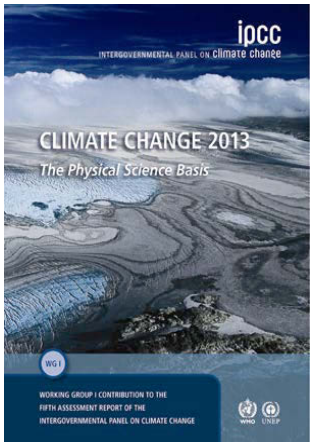
80 % of world's fresh water

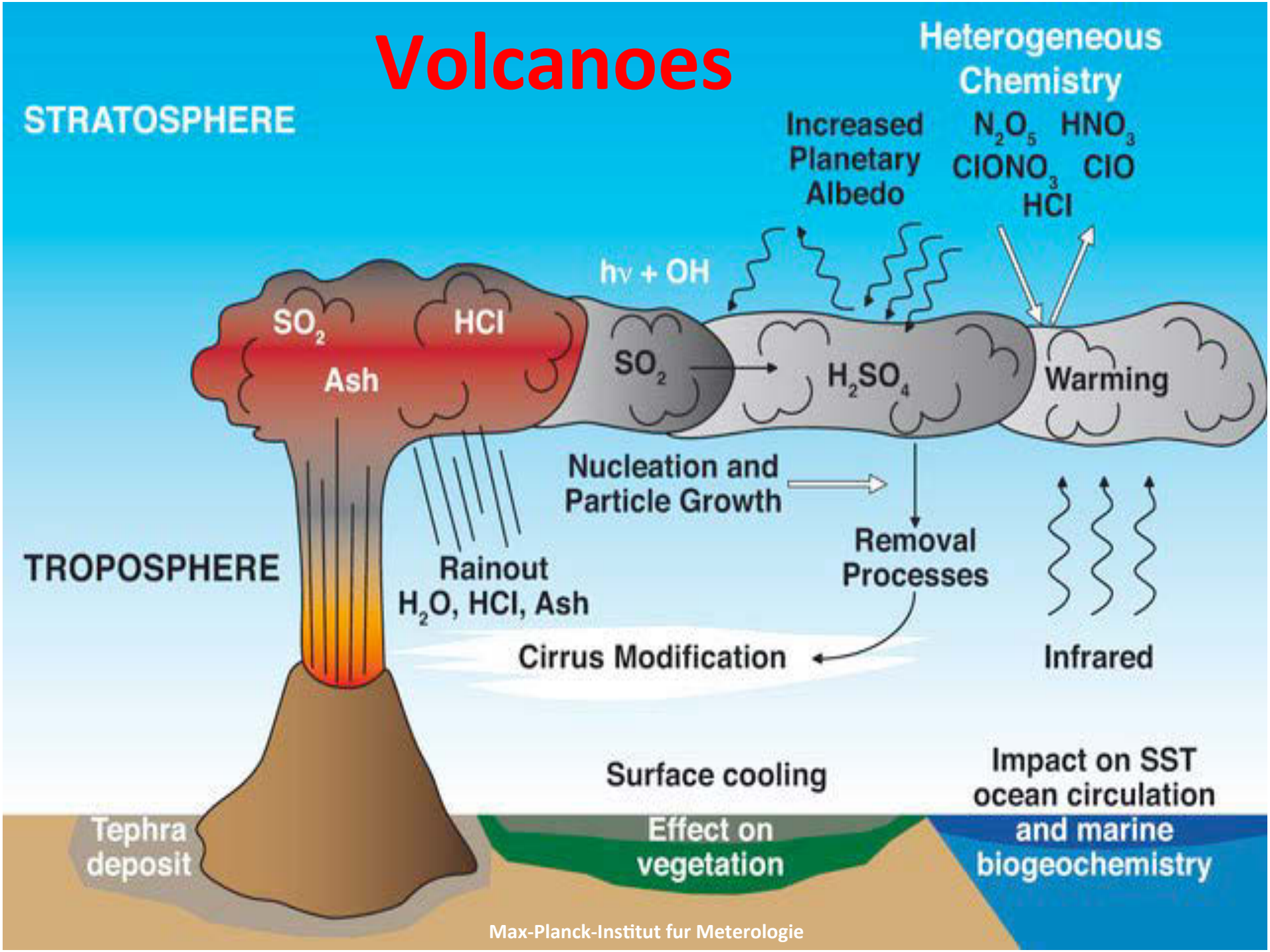


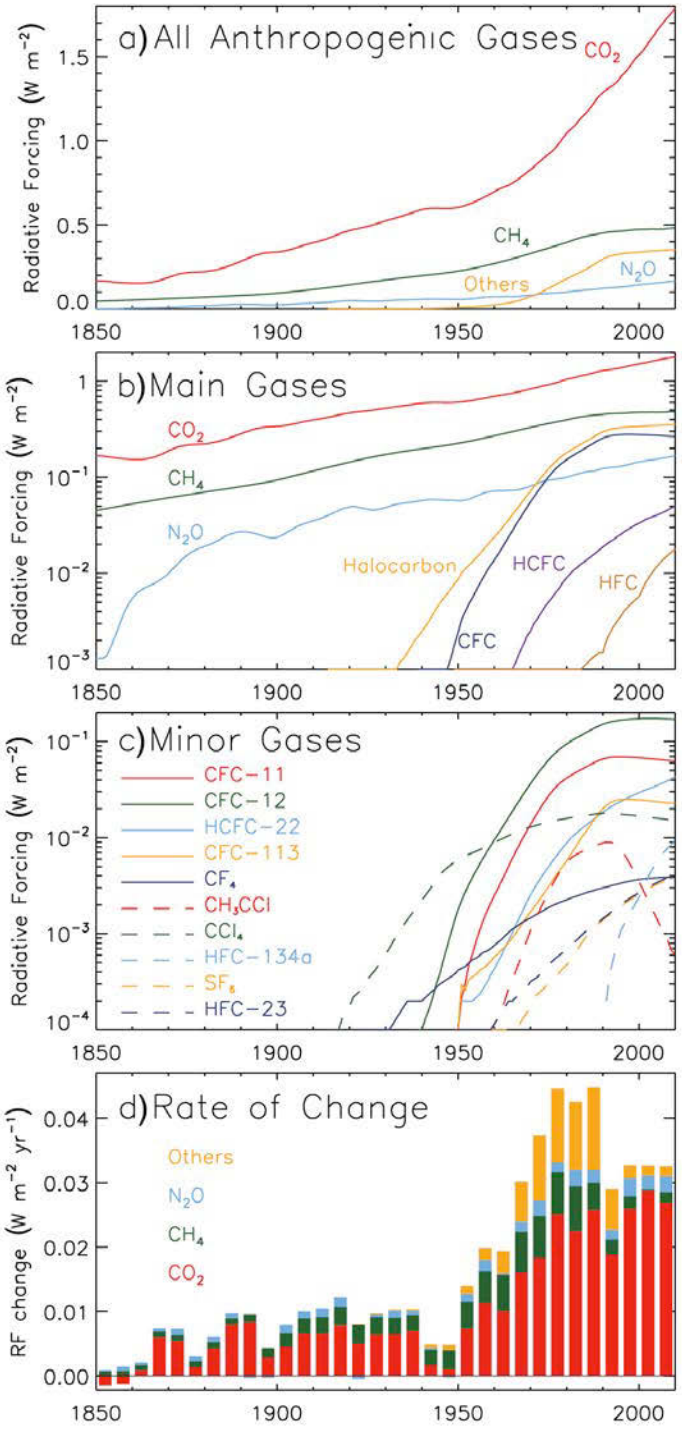
Thermal balance

Ocean and Atmosphere Circulation

Sea level rise

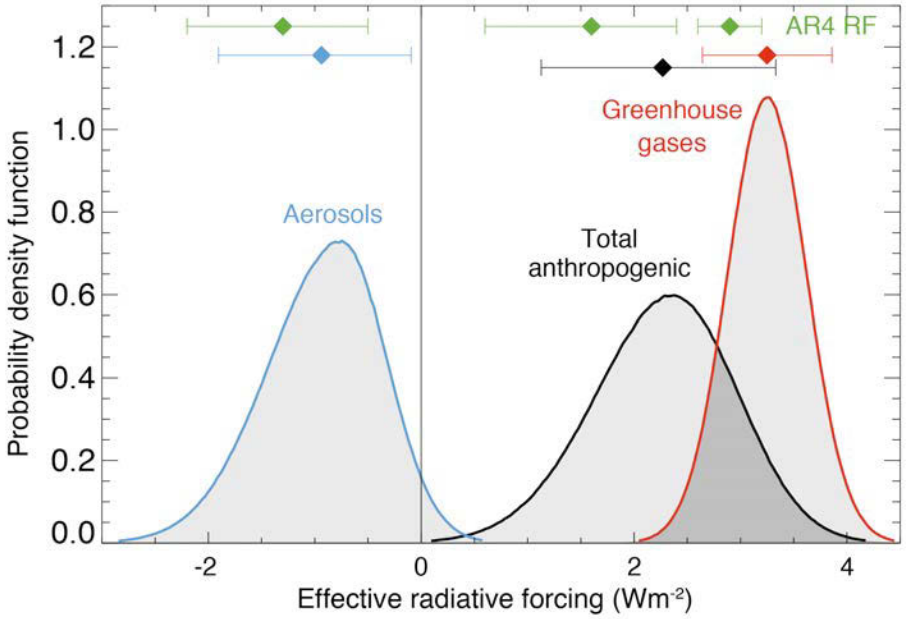



Volcanoes
STRATOSPHERE
Heterogeneous Chemistry
Increased Planetary Albedo
N_2O_5 HNO_3
$ClONO_2$ ClO
HCl
hν + OH
SO_2
HCl
Ash
SO_2
H_2SO_4
Warming
Nucleation and Particle Growth
Removal Processes
TROPOSPHERE
Rainout
H_2O, HCl, Ash
Cirrus Modification
Infrared
Surface cooling
Impact on SST ocean circulation and marine biogeochemistry
Tephra deposit
Effect on vegetation
Max-Planck-Institut fur Meterologie



Human Drivers of Climate Change

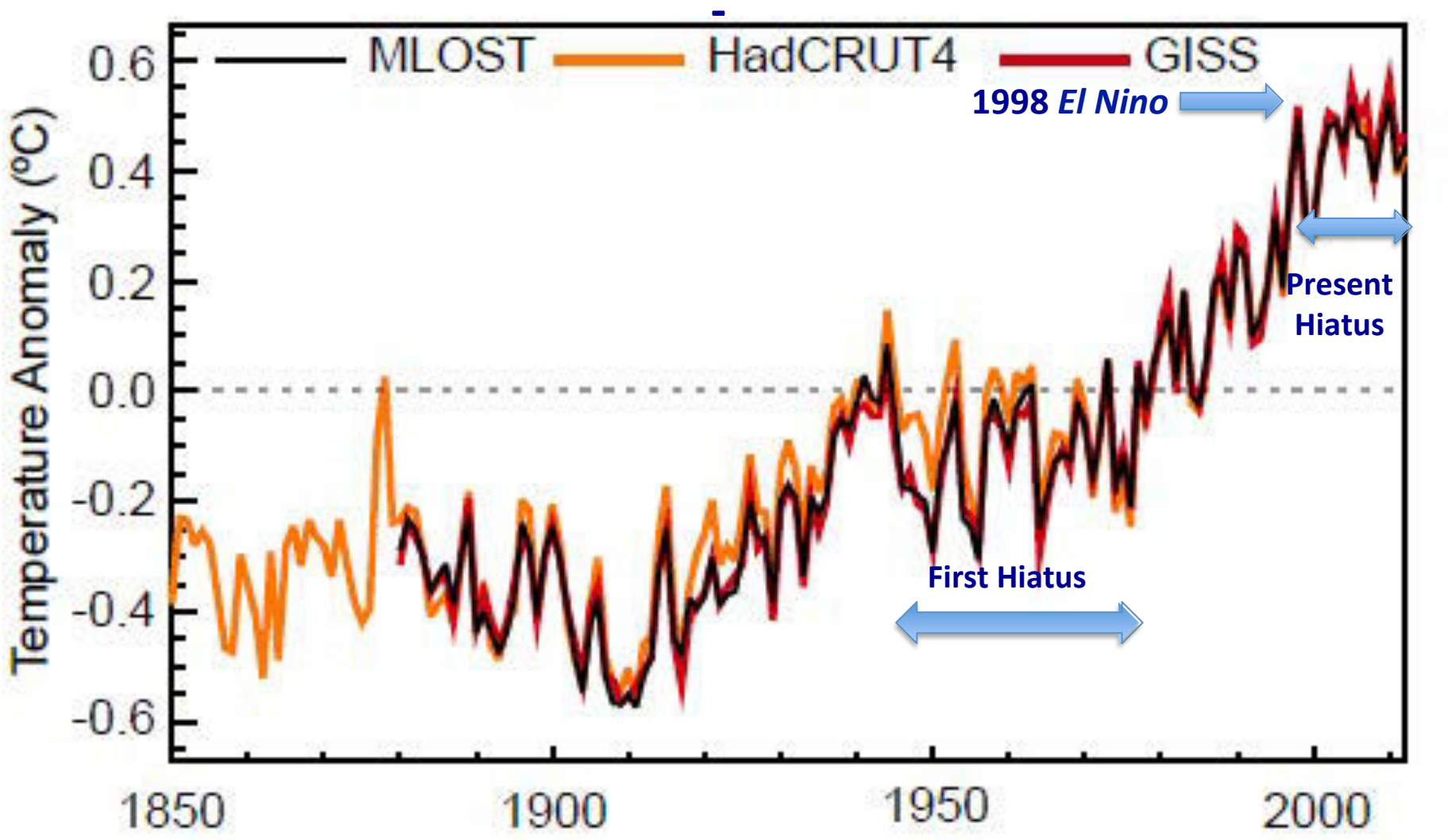
Both warming and cooling; net increase since 1750 from all sources has been 2.3 W/m2



IPCC AR5, Working Group I, 2013
Figures 8.6 and 8.16

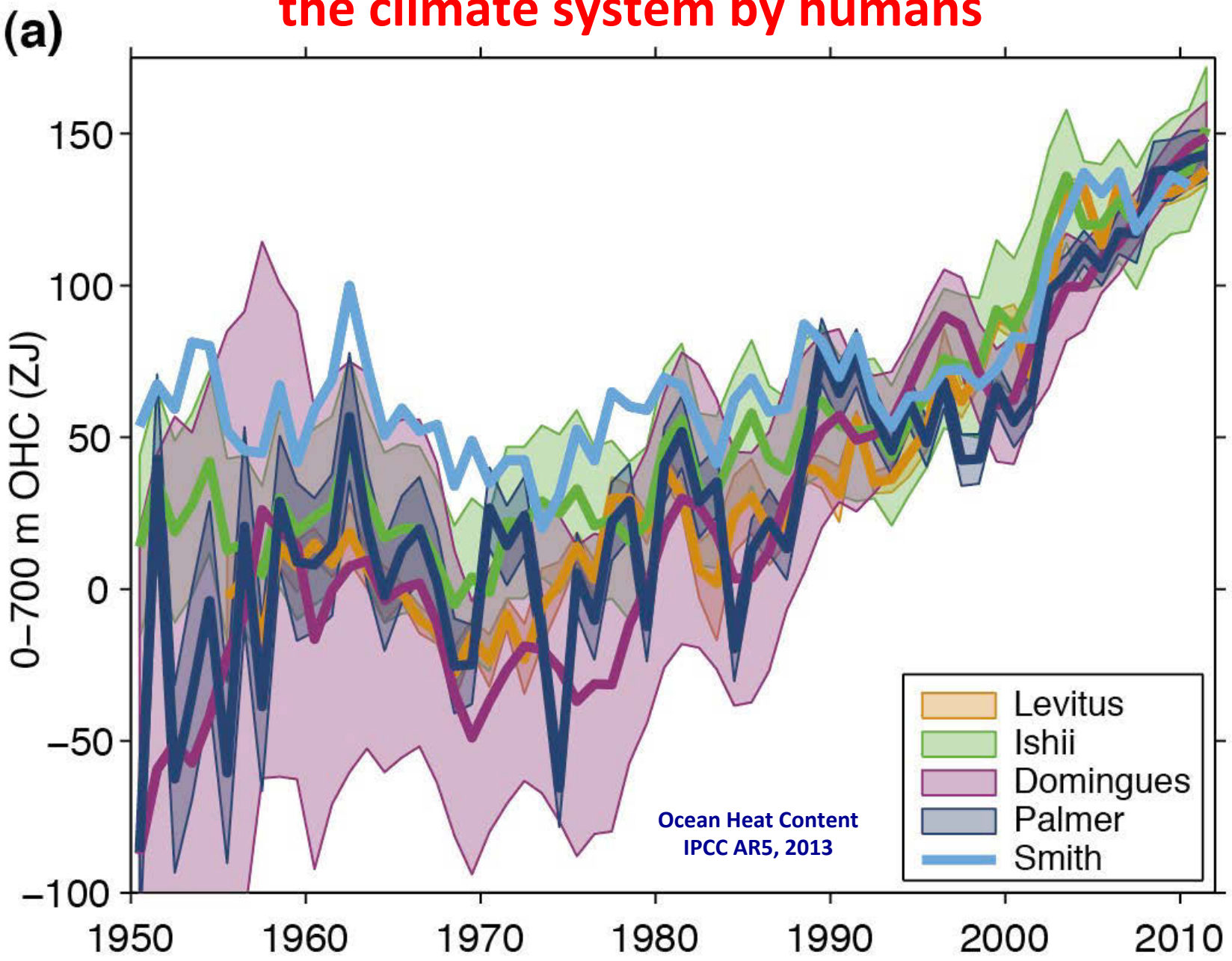
Industrial Period, 1850-2012

Global Average Annual Land + Sea Surface Temperature



"It is certain that Global Mean Surface Temperature has increased since the late 19th century. Each of the past three decades has been significantly warmer than all the previous decades in the instrumental record, and the first decade of the 21st century has been the warmest". IPCC AR5, Chapter 2, 2013

Oceans absorb 93% of the energy added to the climate system by humans

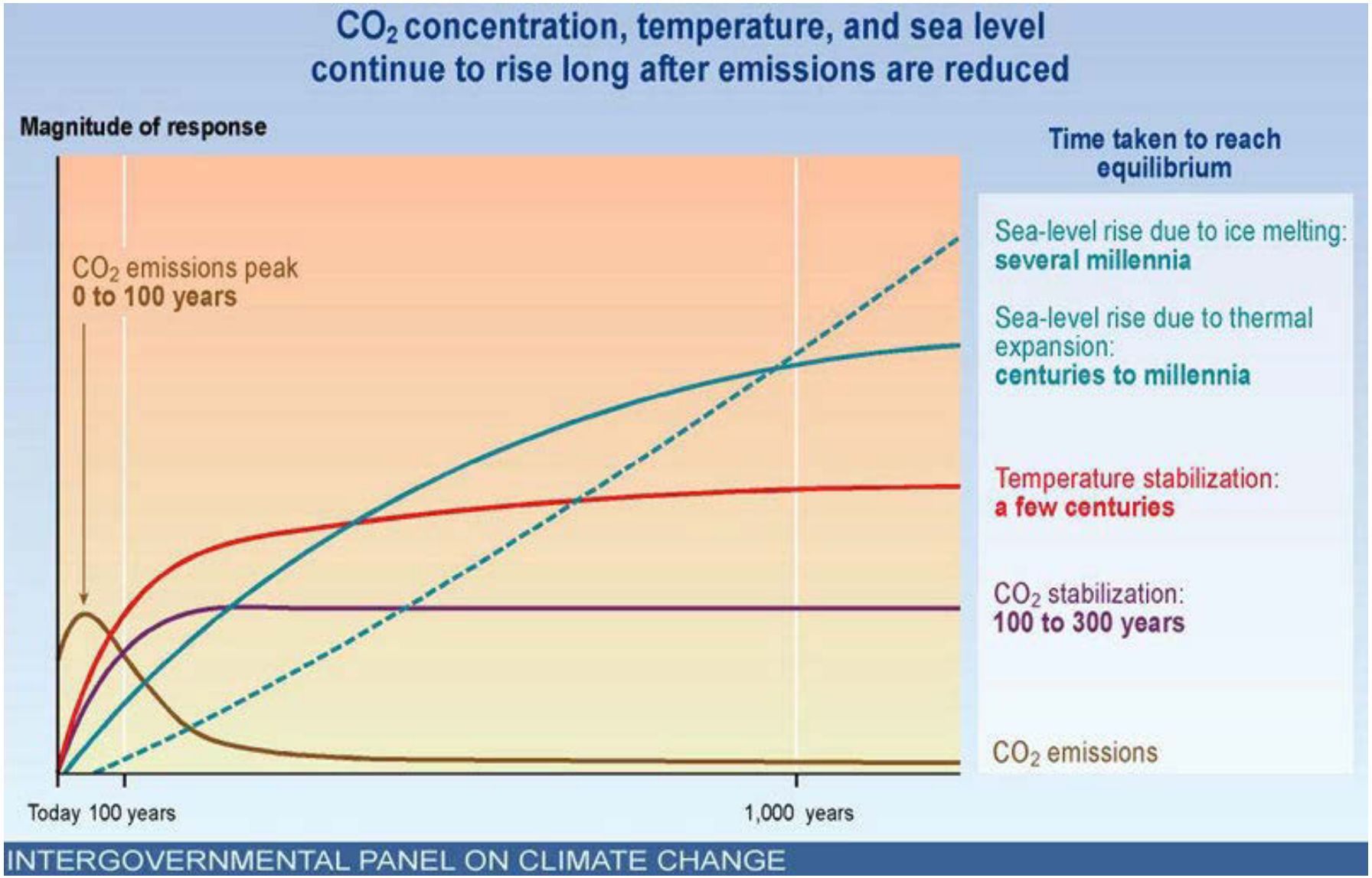


Hard Truths

CO2's Atmospheric Lifetime is 100 Years

Ocean Heat Storage Time is 1000 Years

Implications of Oceanic and Carbon Cycle Inertia

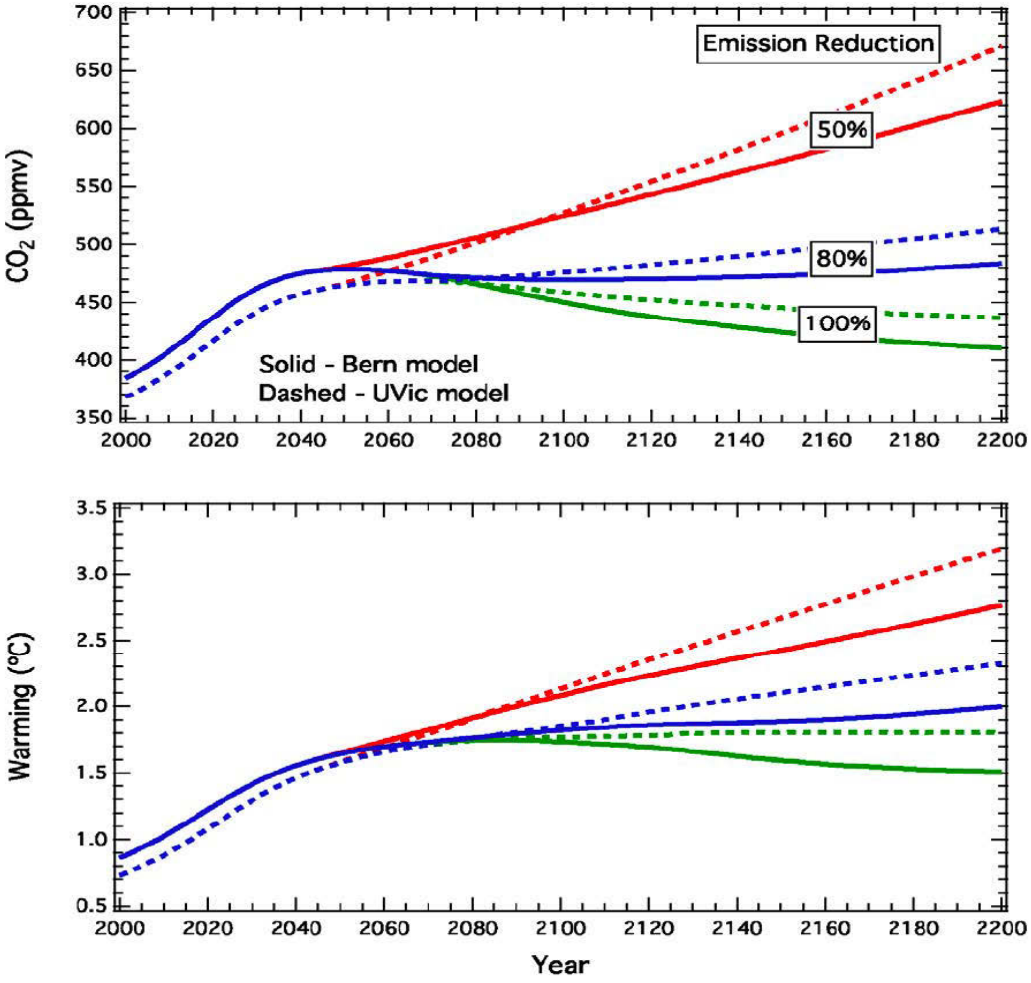


We cannot avoid significant climate change because of what we have already done, much less what we are about to do

The oceans, right now our friend, are storing up problems

The oceans are helping us by taking up 25% of the CO2 and 93% of the energy added to the climate system by humans. If and when we reduce CO2 emissions, dissolved CO2 and embedded ocean heat will be released to the atmosphere until the entire ocean has equilibrated with the atmosphere. This will take about 1000 years. Climate change will be a problem for at least that long.

CO2 Stabilization



Deep emissions reductions (>80%) would be required for long-term stabilization of carbon dioxide at *any* chosen target (450, 550, 650 ppm….).

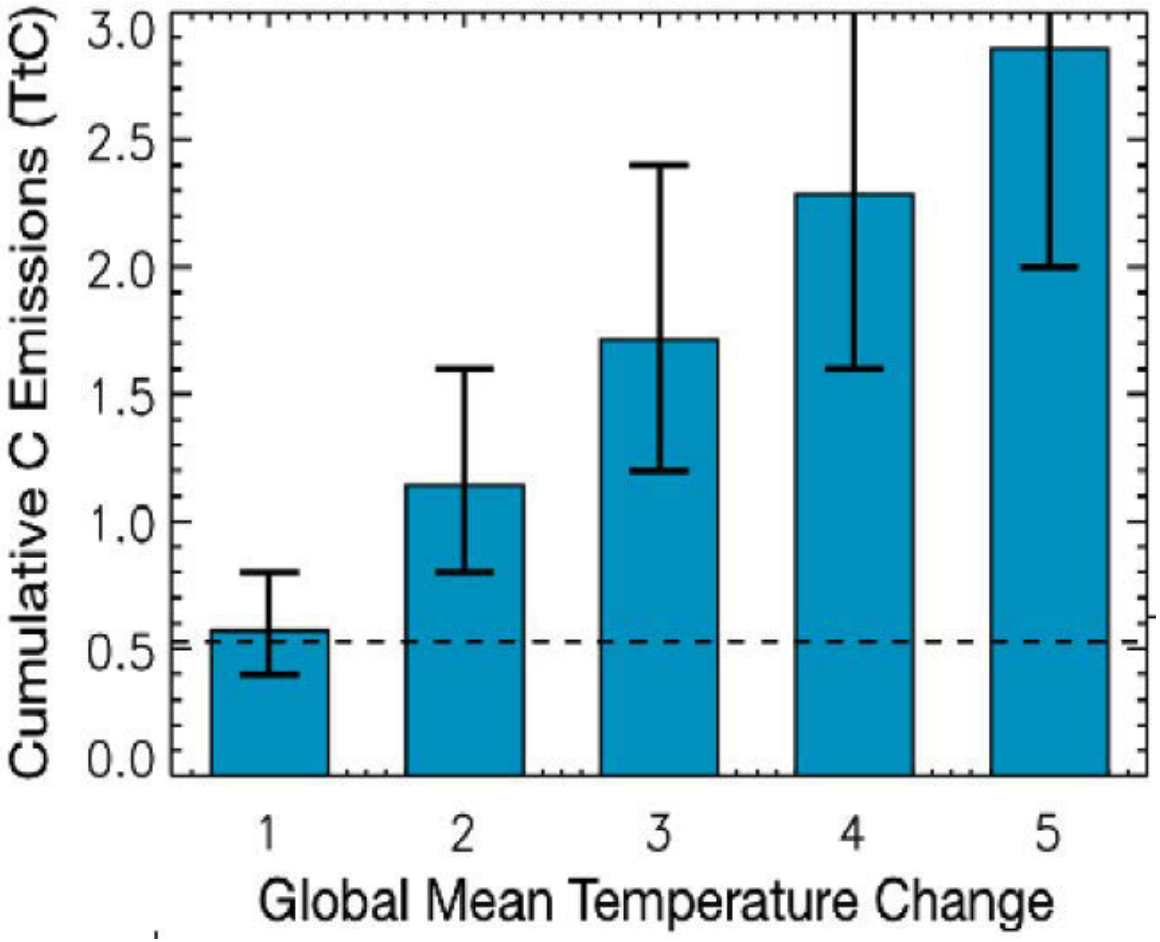
AND

Emission reductions near 100% would be required for manmade CO_2 to decline from *any* peak it reaches.

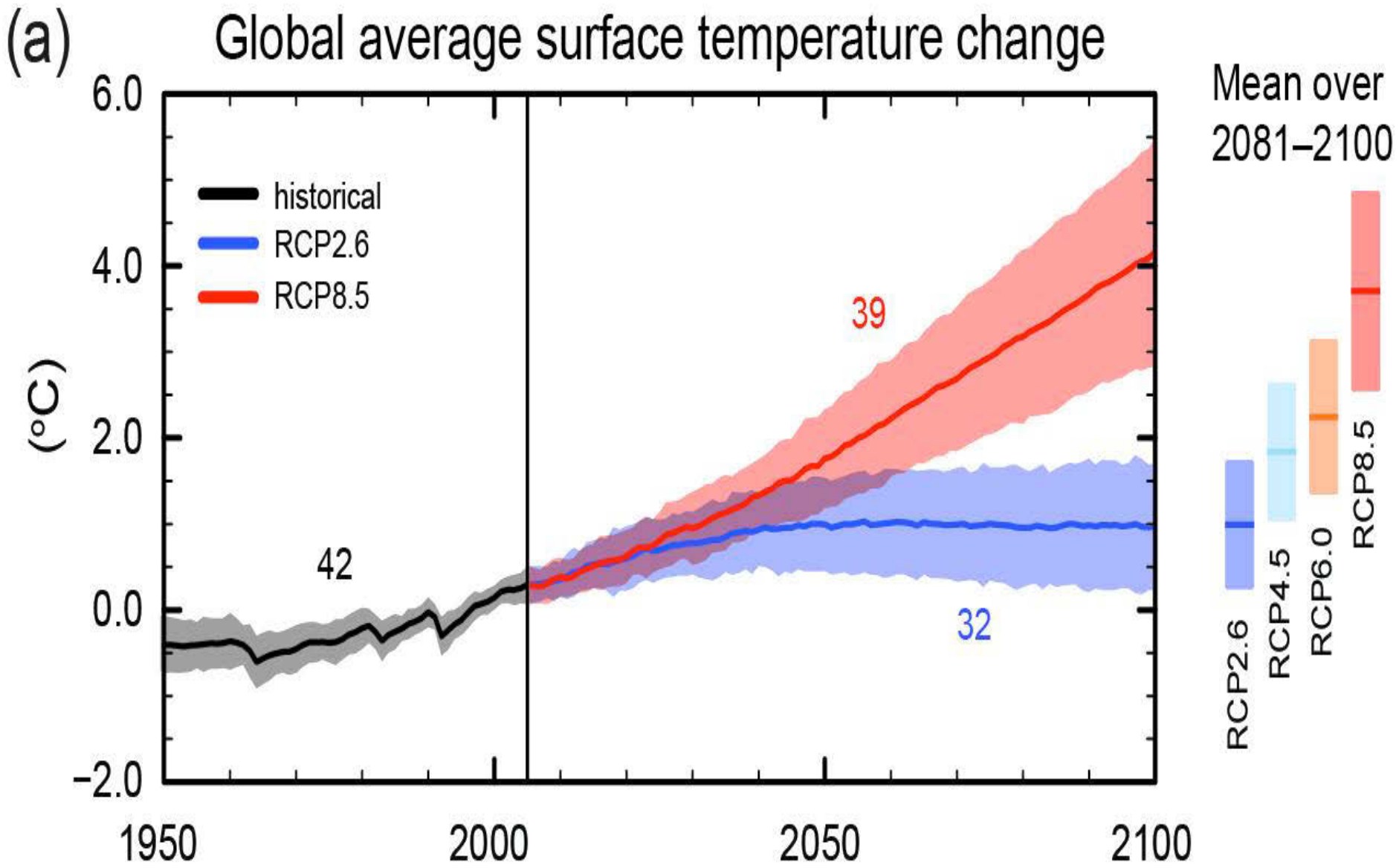
Illustrative calculations showing CO2 concentrations and related warming in two models for a test case in which emissions first increase, followed by a decrease in emission rate of 3% per year to a value 50%, 80%, or 100% below the peak. The test case with 100% emission reduction has 1 trillion tonnes of total emission.

Long-Term Global Temperature Increase is Almost Linearly Related to Cumulative Carbon Emission

Best estimates and likely range of cumulative carbon emissions that would result in global warming of 1, 2, 3, 4, or 5°C.



It does not matter when the emissions occur. Given a maximum tolerable temperature increase, ongoing emissions draw down a finite "carbon account"



Climate change for the next 25-30 years is mostly built in. IPCC AR5 models suggest that the pace of climate change could double.

The Grand Ethical Dilemma

The global distribution and long lifetime of carbon dioxide give rise to major intergenerational ethical issues

Things humans are doing today will change the climate and conditions for all life in unknown ways for thousands of years.

The CO2 emissions each of us causes today do not affect us directly but change the climate for every human on earth in the next generation

Present generations pass on climate risk to future generations as well as assets such as knowledge and infrastructure. The intergenerational challenge is to strike a balance between incurring future climate debt and present investment for that future

The Grand Political Dilemma

The global distribution and long lifetime of carbon dioxide shape the configuration of political issues in climate change

Everyone causes climate change and everyone is affected by it. The climate negotiations therefore seek inclusive global consensus, but this may be impossible to achieve

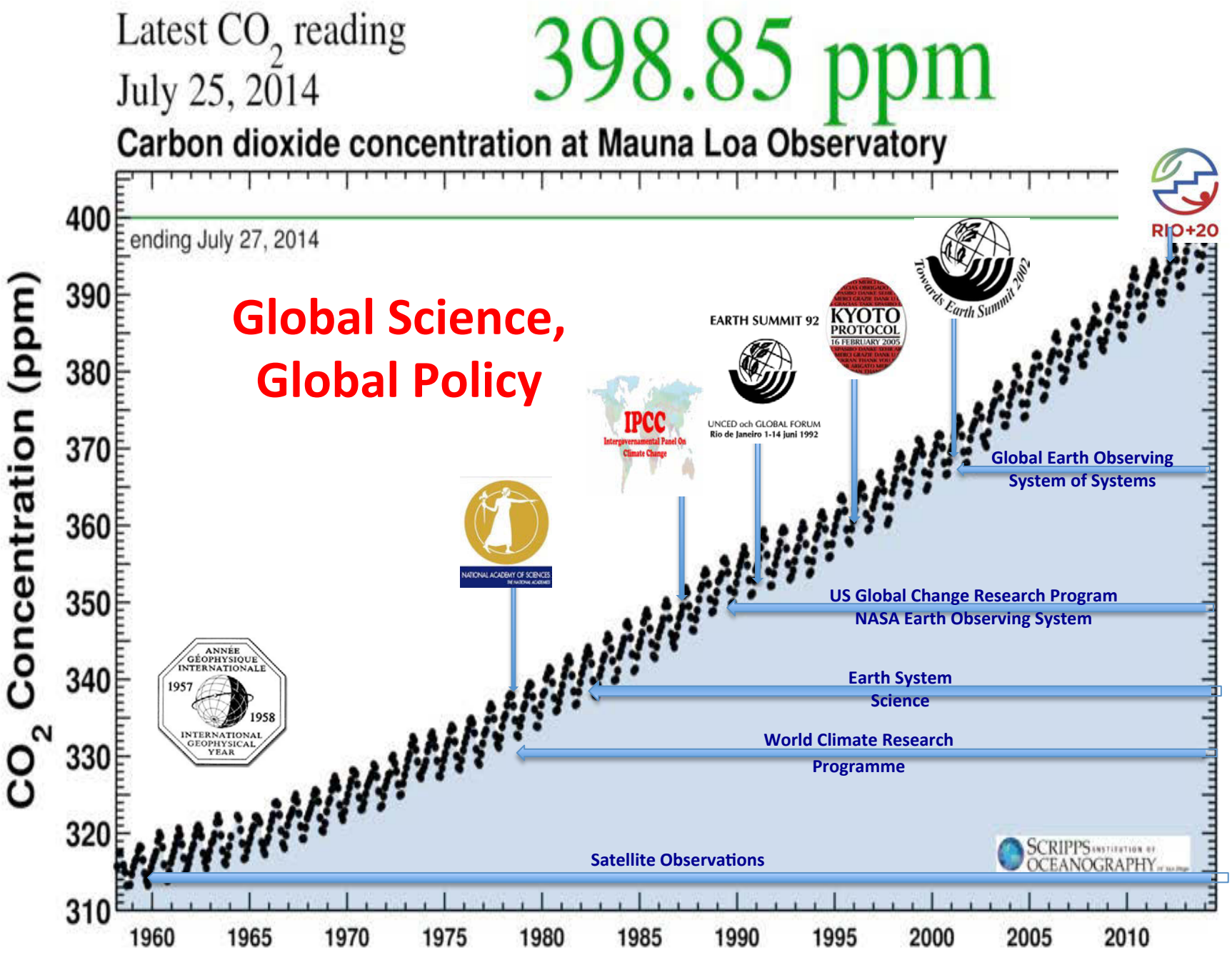
Actions to reduce CO2 emissions affect the climate decades later. Those who make the effort do not reap the benefits in their lifetimes.

The free-rider problem: those who did *not* make the effort will reap benefit from the actions of those who did

CO2 emissions are a fundamental byproduct of the contemporary industrial system, which is bringing prosperity and social advancement around the world. The centrality of fossil fuels in today's global economy is pitting those who value the free market system and present prosperity against those who believe that dealing with climate change is an absolute moral imperative.

Climate change is similar to slavery and colonialism. All three are global issues in which economic benefits for some contest with moral views of others. Colonialism and slavery took a century to solve, not without great conflict

Climate Governance


Latest CO_2 reading
July 25, 2014
398.85 ppm
Carbon dioxide concentration at Mauna Loa Observatory
ending July 27, 2014
CO_2 Concentration (ppm)
400
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Global Science,
Global Policy
RIO+20
Towards Earth Summit 2002
EARTH SUMMIT 92
KYOTO PROTOCOL
16 FEBRUARY 2005
UNCED och GLOBAL FORUM
Rio de Janeiro 1-14 juni 1992
IPCC
Intergovernmental Panel On Climate Change
NATIONAL ACADEMY OF SCIENCES
ANNÉE GÉOPHYSIQUE INTERNATIONALE
1957
1958
INTERNATIONAL GEOPHYSICAL YEAR
Global Earth Observing System of Systems
US Global Change Research Program
NASA Earth Observing System
Earth System Science
World Climate Research Programme
Satellite Observations
SCRIPPS INSTITUTION OF OCEANOGRAPHY

United Nations Framework Convention on Climate Change

Adopted by UN, New York, 9 May 1992; Signed by US, 12 June, 1992; Ratified by Senate, Oct 15, 1992
Entered into force, 21 March, 1994; now, 196 parties to the Convention

The long-term objective of the Convention and its related legal instruments is "to achieve […] the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"

UNFCCC Conference of Parties Meetings

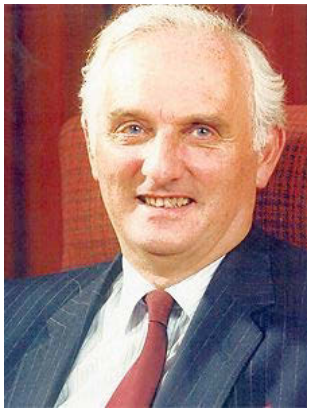
Previously held Conference of Parties (COP)			
	COP 1	1995	The Berlin Mandate
	COP 2	1996	Geneva, Switzerland
	COP 3	1997	Kyoto, Japan
	COP 4	1998	Buenos Aires, Argentina
	COP 5	1998	Bonn, Germany
	COP 6	2000	The Hague, Netherlands
	COP 7	2001	Marrakech, Morocco
	COP 8	2002	New Delhi, India
	COP 9	2003	Milan, Italy
	COP 10	2004	Buenos Aires, Argentina
	COP 11	2005	Montreal, Canada
	COP 12	2006	Nairobi, Kenya
	COP 13	2007	Bali, Indonesia
	COP 14	2008	Poznań, Poland
	COP 15	2009	Copenhagen, Denmark
	COP 16	2010	Cancún, Mexico
	COP 17	2011	Durban, South Africa
	COP 18	**2012**	**Qatar**

Kyoto, 1997

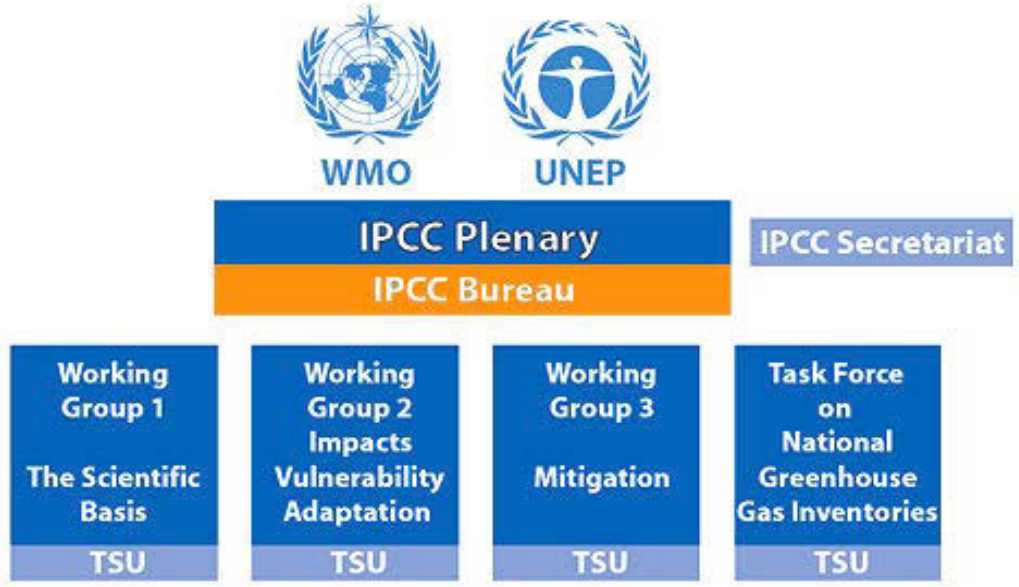
Lima, 2014

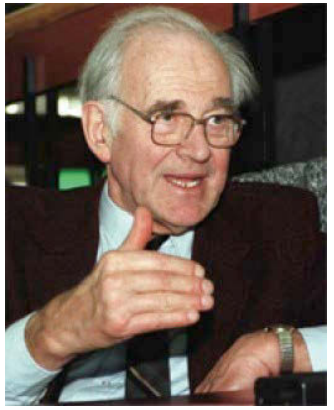
The Intergovernmental Panel on Climate Change

The most rigorous reviews of a state of scientific knowledge ever attempted.



John Houghton



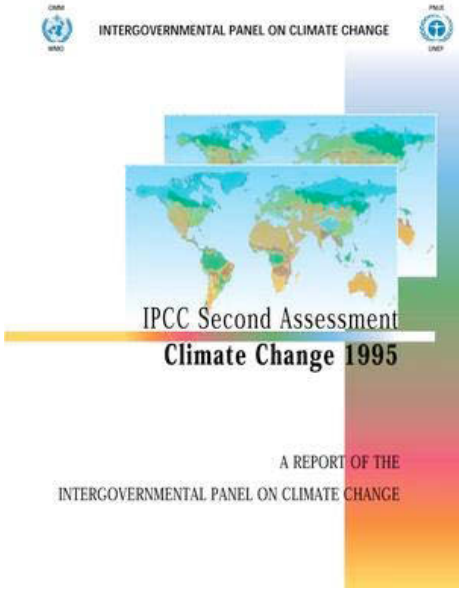


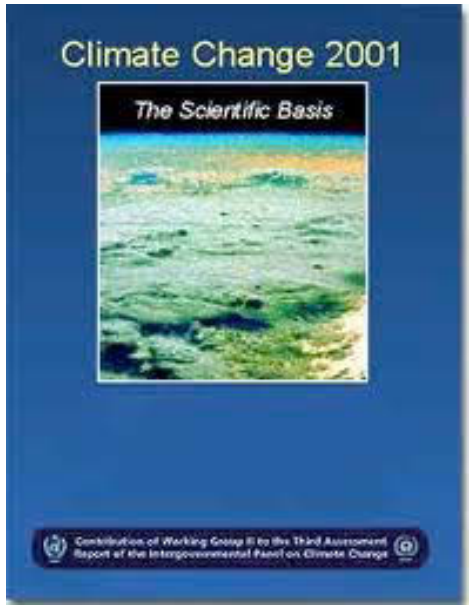
Bert Bolin

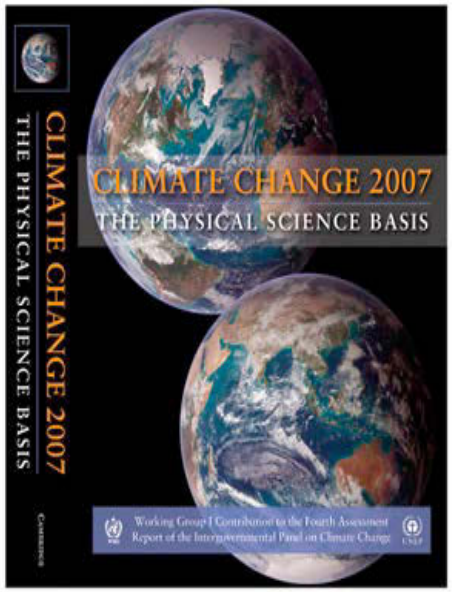
The IPCC was established by WMO and UNEP in 1988 to "assess on a comprehensive objective, open, and transparent basis the latest scientific, technical and socio-economic literature produced worldwide relevant to the understanding of the risk of human-induced climate change, its observed and projected impacts and options for adaptation and mitigation. IPCC reports should be neutral with respect to policy, although they need to deal objectively with policy relevant scientific, technical and socio-economic factors. They should be of high scientific and technical standards, and aim to reflect a range of views, expertise and wide geographical coverage"

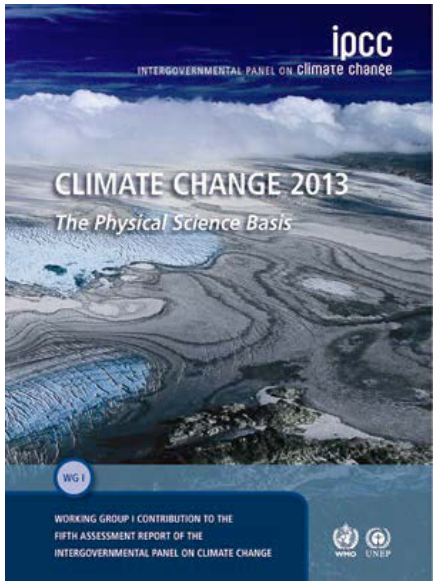
IPCC Assessments

The IPCC's policy influence grew as succeeding reports communicated a consistently evolving understanding of climate change. At the same time, the return to the same themes created a "standard narrative" that shapes the public dialog









The IPCC devised transparent processes intended to promote trust. Its summarized only the peer-reviewed literature. Review panels were chosen with attention to balance among countries, points of view, and economic and institutional interests. Successive panels recruited a majority of new participants to avoid an institutionalized IPCC point of view. Its most important innovation was to separate assessment of science from discussion of policy. After the scientific assessment is complete, the IPCC engages in a separate process to develop summaries for policy makers. Together, scientists and policy-makers compose, line-by-line, the statements pertinent to policy, with explicit attention to the uniform characterization of uncertainty.

Where Attention Goes, Energy Flows

IPCC assessments energized the global public debate about climate. Not a day passes without media discussion of climate change. This is the most important outcome, since public awareness of the risks of climate change encourages governments to pay attention and motivates public and private initiatives. They have been unsuccessful in promoting concrete actions by governments.

Kennel, C.F., Speaking Scientific Truth to Power, *Cambridge Anthropology,* 2013

The Standard Narrative

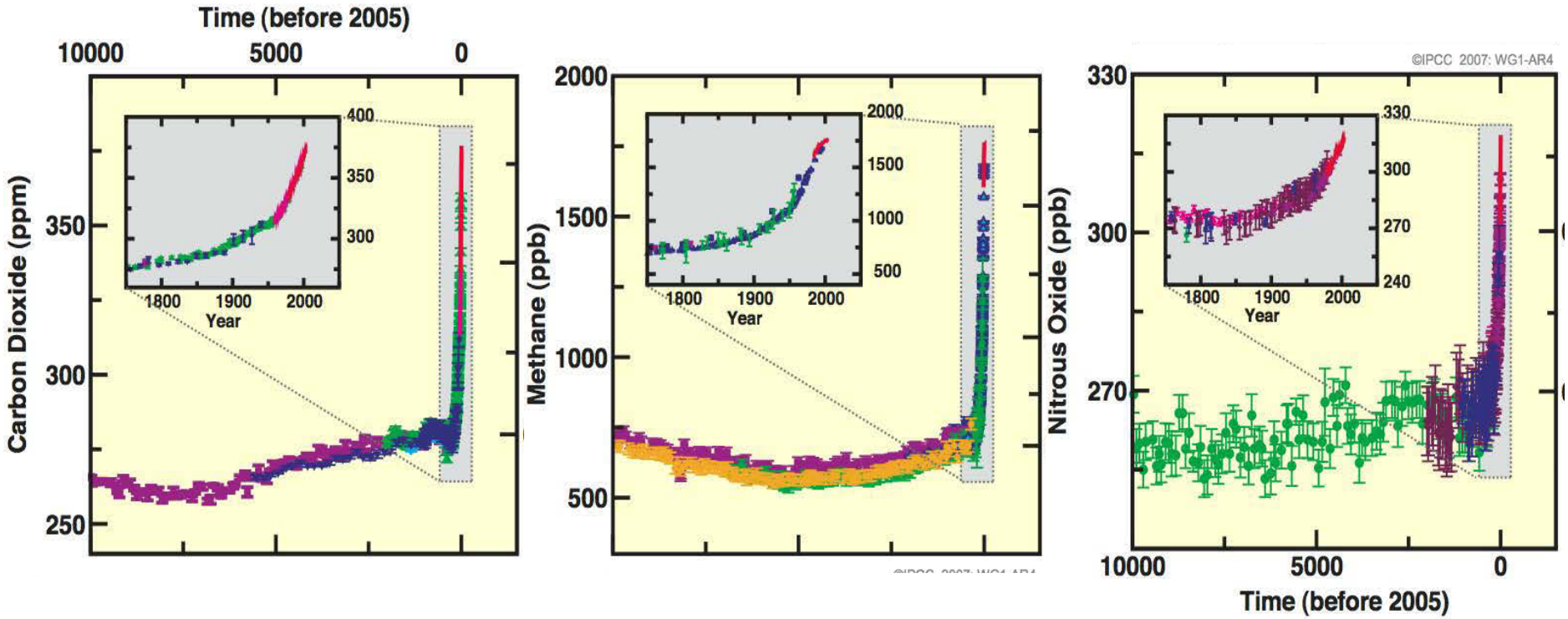
Narrow Focus: CO2 emissions, global temperature

Obscures as it clarifies: the realities and our options are much more nuanced

Moses receiving the tablets of the law, João Zeferino da Costa, 1868

CO2 is not the only driver of Climate Change

Why shouldn't we work with them, too?



Carbon Dioxide

Methane

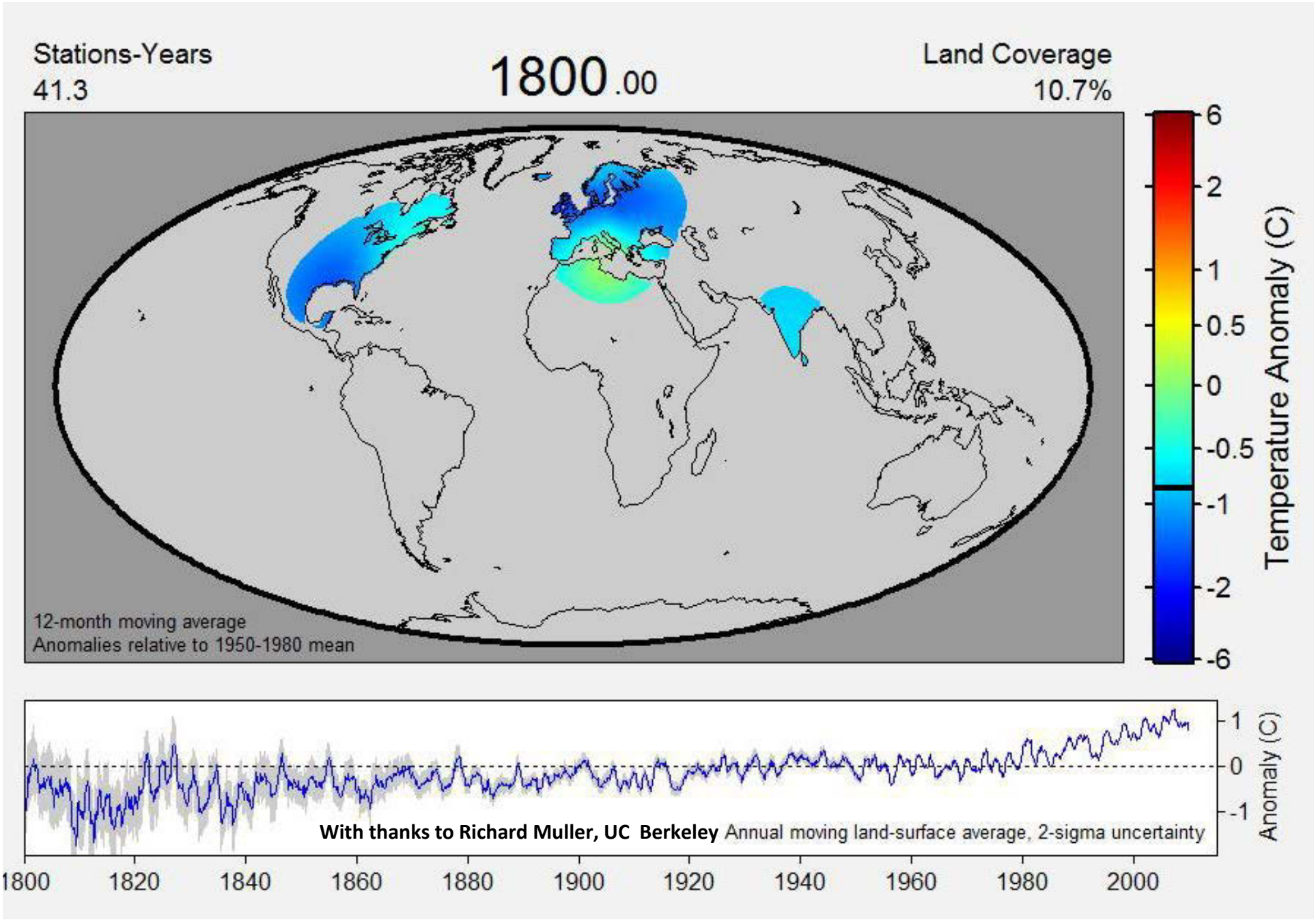
Nitrous Oxide

Changes in greenhouse gas compositions since the end of the last Ice Age
IPCC AR4, 2007

Global Temperature

Designed to simplify, the concept obscures to clarify.

We use a vast modeling infrastructure to compute a number that only a physicist could love, one that conveys a misleading impression that the world warms up uniformly. It is an imperfect index of the rate humans are adding energy to the climate system, which will distribute it in complex ways.


Stations-Years
41.3
1800.00
Land Coverage
10.7%
6
2
1
0.5
0
-0.5
-1
-2
-6
Temperature Anomaly (C)
12-month moving average
Anomalies relative to 1950-1980 mean
1
0
-1
Anomaly (C)
With thanks to Richard Muller, UC Berkeley Annual moving land-surface average, 2-sigma uncertainty
1800
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000

"That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every 'superstar,' every 'supreme leader,' every saint and sinner in the history of our species lived there - on a mote of dust suspended in a sunbeam."

- Carl Sagan, from a lecture delivered at Cornell University: 10/13/94