A brief history of climate science: from Fourier to Callendar

Ed Hawkins

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#greenhouse50

1820s & 1830s: Two puzzles

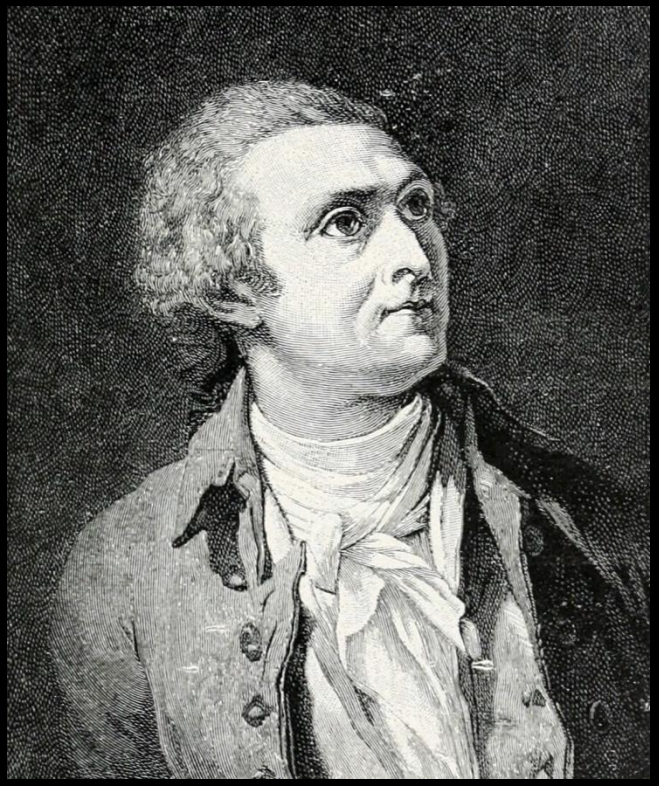
Joseph Fourier
(1768-1830)

Louis Agassiz
(1807-1873)

First to realise that solar energy alone not enough to maintain Earth's temperature above freezing

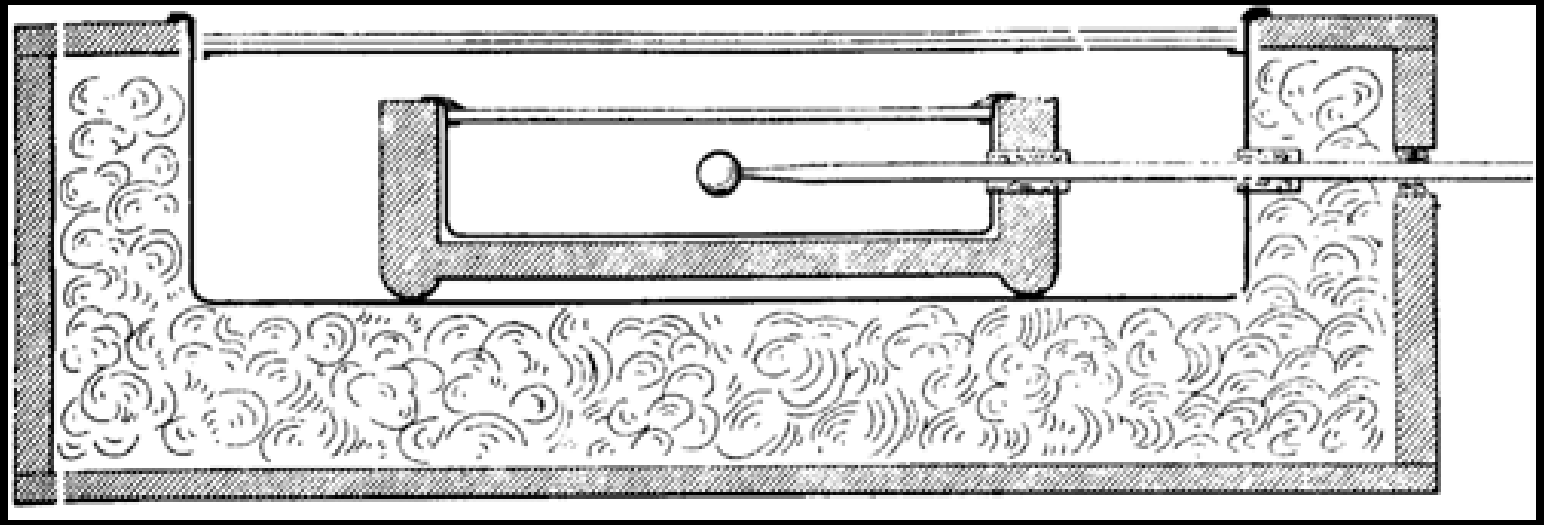
Fourier, 1824

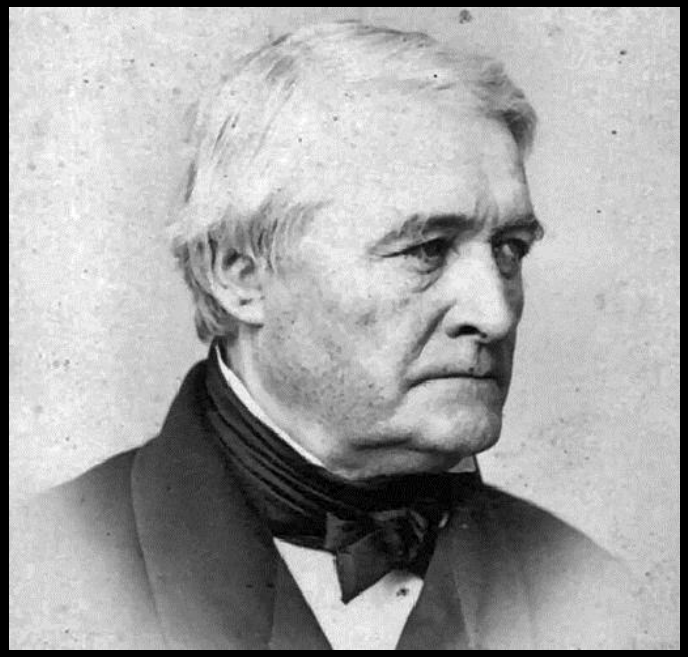
there exists a physical cause always present which modifies the temperature at the surface of the earth, and gives this planet a fundamental heat, which is both independent of the action of the sun and that internal heat preserved in its own center. This fixed temperature, which the earth receives from space,

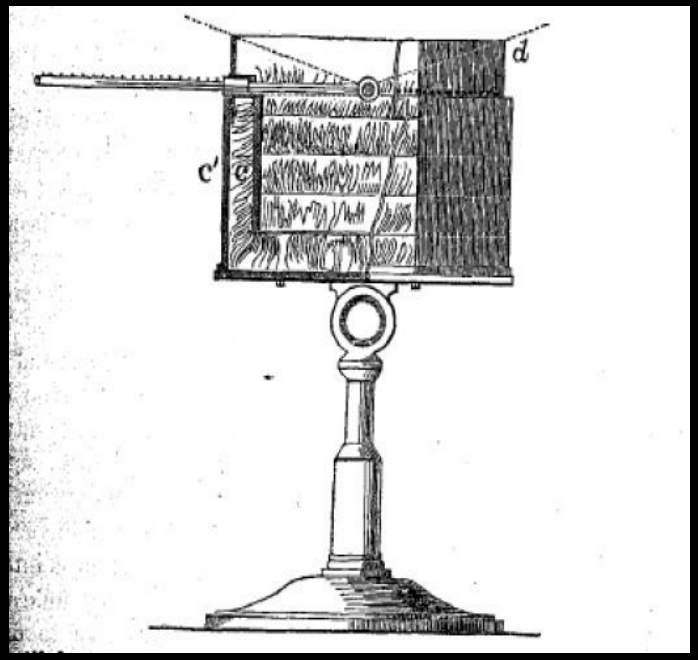


Horace-Bénédict de Saussure (1740-1799)

- The first mountaineer?
- Invented & carried meteorological instruments to top of Alpine peaks
- Experimented with first ‘solar oven’

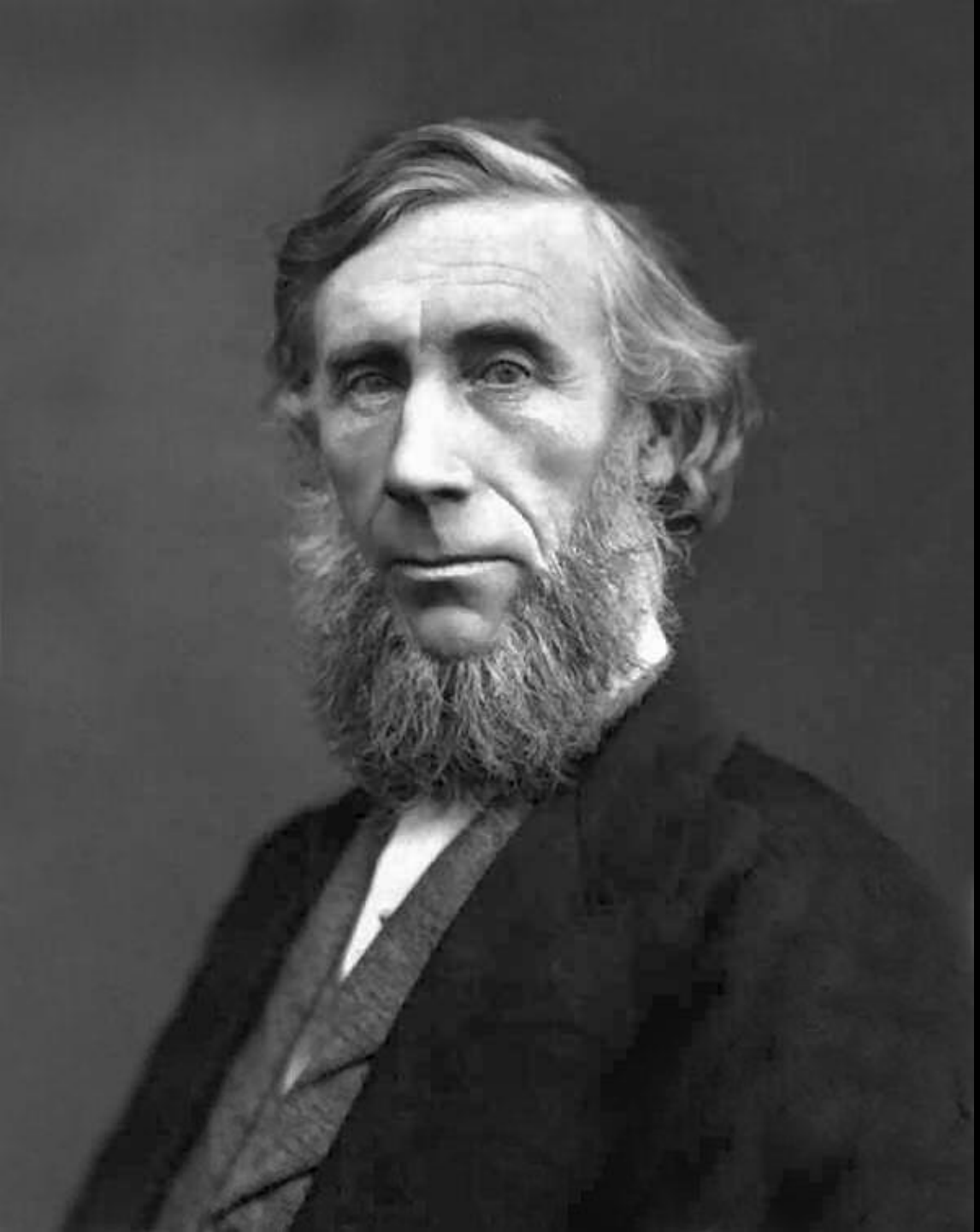




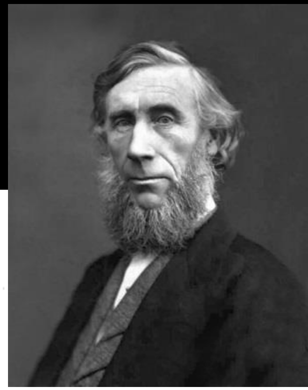


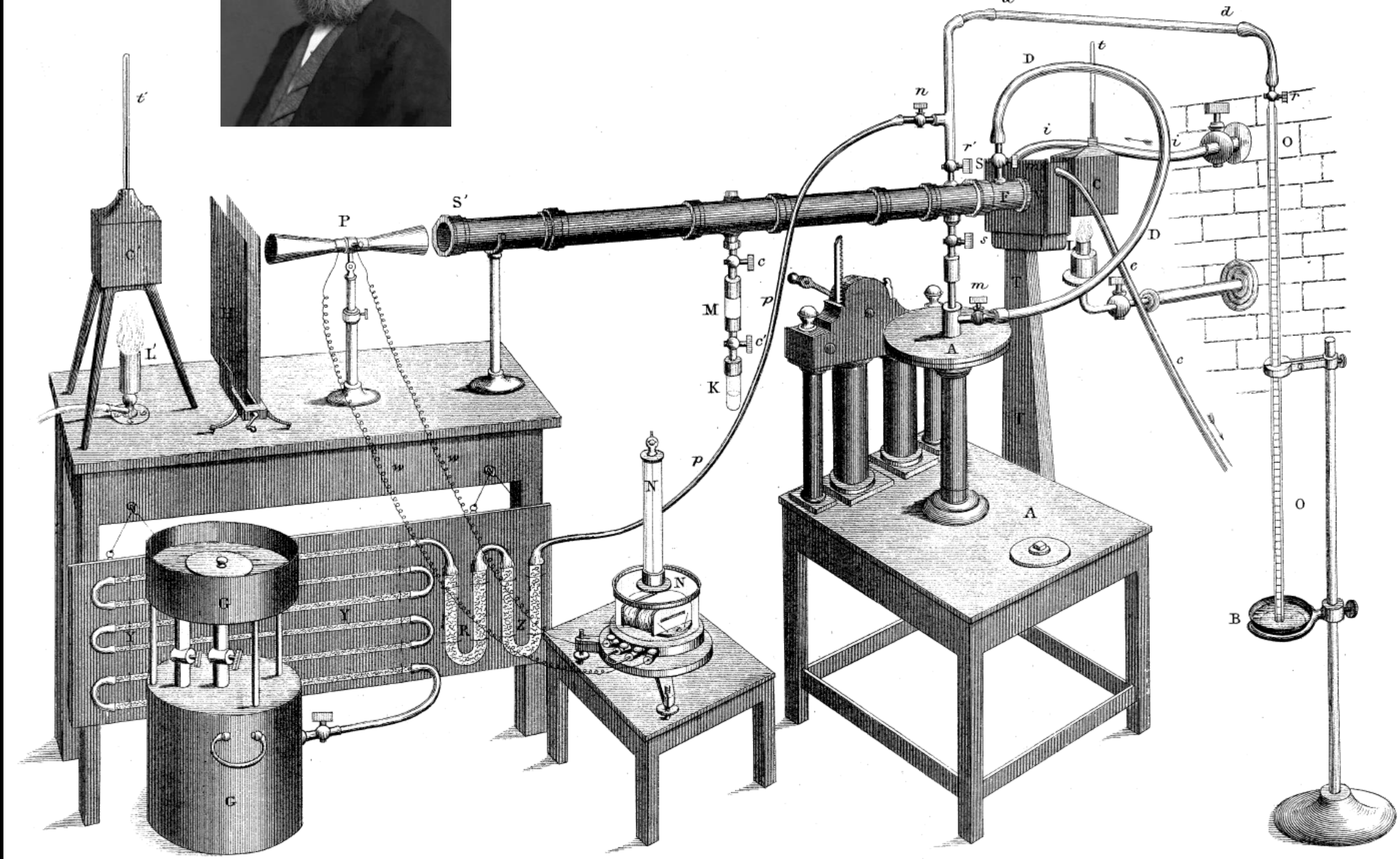
Claude Pouillet (1791-1868)

- 1838: first estimate of solar constant (1228 Wm^{-2})
- Invented the pyrheliometer
- Discovered downwelling infrared radiation at night
- Suggested that outer space was too cold to provide the necessary heat to warm the Earth



John Tyndall (1820-1893)





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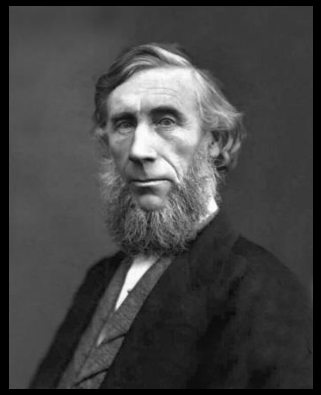


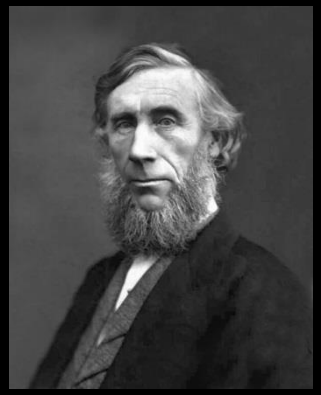
JOURNAL OF SCIENCE.

[FOURTH SERIES.]

SEPTEMBER 1861.

XXIII. *On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical Connexion of Radiation, Absorption, and Conduction.—The Bakerian Lecture.* By JOHN TYNDALL *Esq., F.R.S. &c.**

Air	. . . .	A fraction of a degree
Oxygen	. . .	„ „
Nitrogen	. .	„ „
Hydrogen	. .	„ „
Carbonic oxide	. . .	18°
Carbonic acid	. . . .	25°
Nitrous oxide	. . . .	44°
Olefiant gas	. . . .	61°



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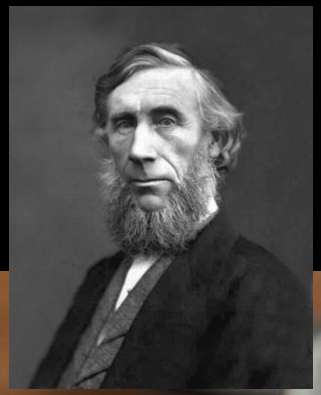
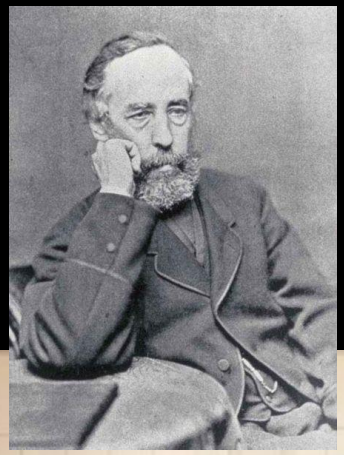
an almost inappreciable admixture of any of the hydrocarbon vapours would produce great effects on the terrestrial rays and produce corresponding changes of climate.

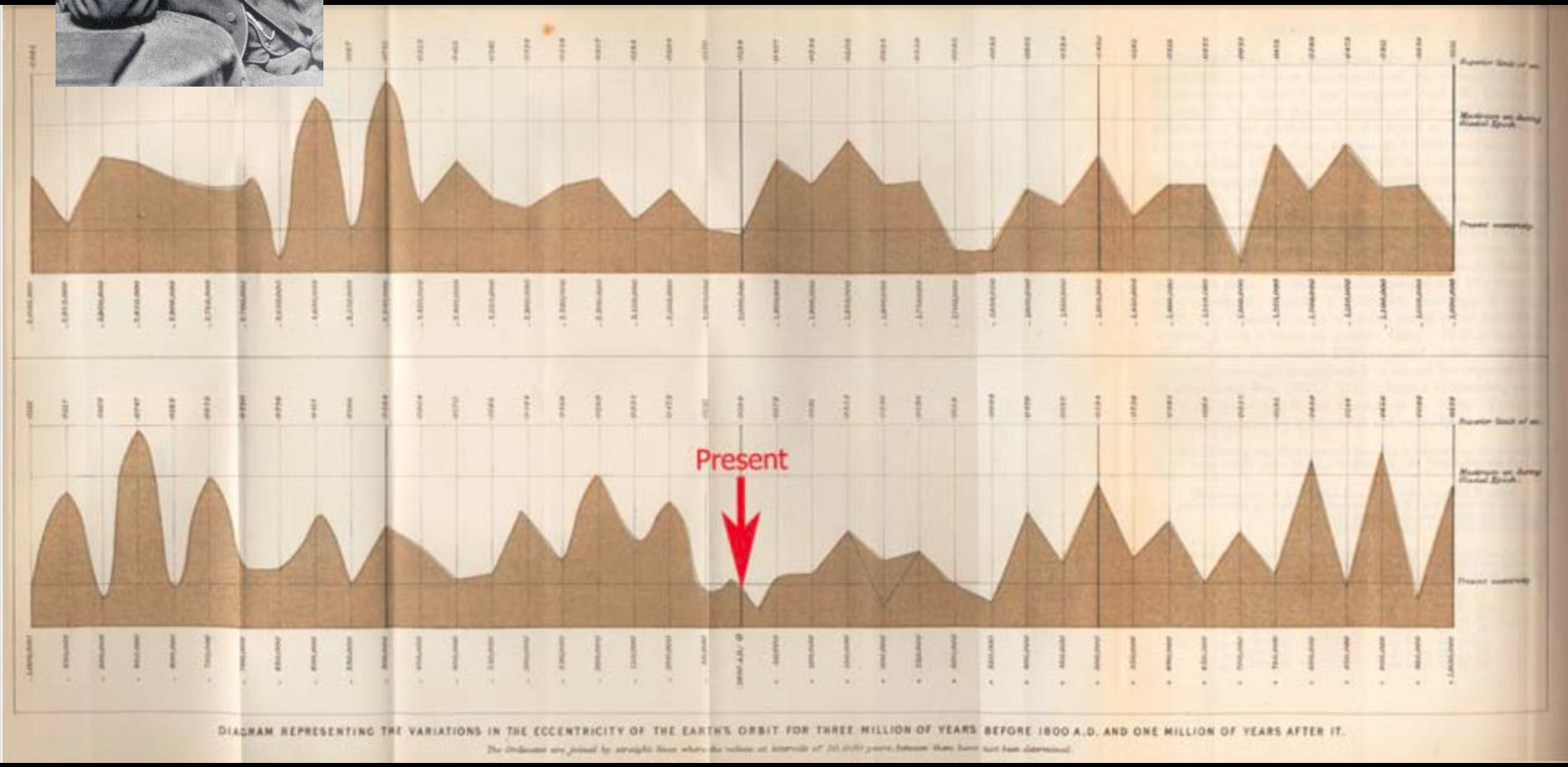


Tyndall's original equipment

Photo: Royal Institution



Eccentricity of the Earth's orbit



James Croll, 1875

Svante Arrhenius (1859-1927)

Swedish Nobel prize-winning chemist

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

- First estimate of effect of changing levels of CO_2 in atmosphere
- Estimated climate sensitivity of about 5°C for doubling of CO_2
- First time that human contribution discussed

Arrhenius, 1896

TABLE VII.—*Variation of Temperature caused by a given Variation of Carbonic Acid.*

Latitude.	Carbonic Acid = 0·67.					Carbonic Acid = 1·5.					Carbonic Acid = 2·0.					Carbonic Acid = 2·5.					Carbonic Acid = 3·0.				
	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.
70																									
60	−2·9	−3·0	−3·4	−3·1	−3·1	3·3	3·4	3·8	3·6	3·52	6·0	6·1	6·0	6·1	6·05	7·9	8·0	7·9	8·0	7·95	9·1	9·3	9·4	9·4	9·3
50	−3·0	−3·2	−3·4	−3·3	−3·22	3·4	3·7	3·6	3·8	3·62	6·1	6·1	5·8	6·1	6·02	8·0	8·0	7·6	7·9	7·87	9·3	9·5	8·9	9·5	9·3
40	−3·2	−3·3	−3·3	−3·4	−3·3	3·7	3·8	3·4	3·7	3·65	6·1	6·1	5·5	6·0	5·92	8·0	7·9	7·0	7·9	7·7	9·5	9·4	8·6	9·2	9·17
30	−3·4	−3·4	−3·2	−3·3	−3·32	3·7	3·6	3·3	3·5	3·52	6·0	5·8	5·4	5·6	5·7	7·9	7·6	6·9	7·3	7·42	9·3	9·0	8·2	8·8	8·82
20	−3·3	−3·2	−3·1	−3·1	−3·17	3·5	3·3	3·2	3·5	3·47	5·6	5·4	5·0	5·2	5·3	7·2	7·0	6·6	6·7	6·87	8·7	8·3	7·5	7·9	8·1
10	−3·1	−3·1	−3·0	−3·1	−3·07	3·5	3·2	3·1	3·2	3·25	5·2	5·0	4·9	5·0	5·02	6·7	6·6	6·3	6·6	6·52	7·9	7·5	7·2	7·5	7·52
0	−3·1	−3·0	−3·0	−3·0	−3·02	3·2	3·2	3·1	3·1	3·15	5·0	5·0	4·9	4·9	4·95	6·6	6·4	6·3	6·4	6·42	7·4	7·3	7·2	7·3	7·3
−10	−3·0	−3·0	−3·1	−3·0	−3·02	3·1	3·1	3·2	3·2	3·15	4·9	4·9	5·0	5·0	4·95	6·4	6·4	6·6	6·6	6·5	7·3	7·3	7·4	7·4	7·35
−20	−3·1	−3·1	−3·2	−3·1	−3·12	3·2	3·2	3·2	3·2	3·2	5·0	5·0	5·2	5·1	5·07	6·6	6·6	6·7	6·7	6·65	7·4	7·5	8·0	7·6	7·62
−30	−3·1	−3·2	−3·3	−3·2	−3·2	3·2	3·2	3·4	3·3	3·27	5·2	5·3	5·5	5·4	5·35	6·7	6·8	7·0	7·0	6·87	7·9	8·1	8·6	8·3	8·22
−40	−3·3	−3·3	−3·4	−3·4	−3·35	3·4	3·5	3·7	3·5	3·52	5·5	5·6	5·8	5·6	5·62	7·0	7·2	7·7	7·4	7·32	8·6	8·7	9·1	8·8	8·8
−50	−3·4	−3·4	−3·3	−3·4	−3·37	3·6	3·7	3·8	3·7	3·7	5·8	6·0	6·0	6·0	5·95	7·7	7·9	7·9	7·9	7·85	9·1	9·2	9·4	9·3	9·25
−60	−3·2	−3·3	—	—	—	3·8	3·7	—	—	—	6·0	6·1	—	—	—	7·9	8·0	—	—	—	9·4	9·5	—	—	—

Thomas Chamberlin (1843-1928)

- The first ‘Earth System’ scientist
- Resolved competing theories of ice ages
- Series of papers in 1897-1899 suggested that ice ages could be described by orbital changes & feedbacks, such as from CO_2

Nils Ekholm (1848-1923)

- Improved understanding of how radiation propagates through atmosphere
- Described how the height at which the radiation is emitted to reach space is crucial

NOVEMBER, 1922. MONTHLY WEATHER REVIEW.

THE CHANGING ARCTIC.

By GEORGE NICOLAS IFFT.

[Under date of October 10, 1922, the American consul at Bergen, Norway, submitted the following report to the State Department, Washington, D. C.]

The Arctic seems to be warming up. Reports from fishermen, seal hunters, and explorers who sail the seas about Spitzbergen and the eastern Arctic, all point to a radical change in climatic conditions, and hitherto unheard-of high temperatures in that part of the earth's surface.

"The Arctic seems to be warming up." – first suggestion of changes occurring.

MONTHLY WEATHER REVIEW

Editor, W. J. HUMPHREYS

VOL. 61, No. 9
W.B. No. 1112

SEPTEMBER 1933

CLOSED NOVEMBER 3, 1933
ISSUED DECEMBER 27, 1933

IS OUR CLIMATE CHANGING? A STUDY OF LONG-TIME TEMPERATURE TRENDS

By J. B. KINCER

[Weather Bureau, Washington, D.C., Sept. 29, 1933]

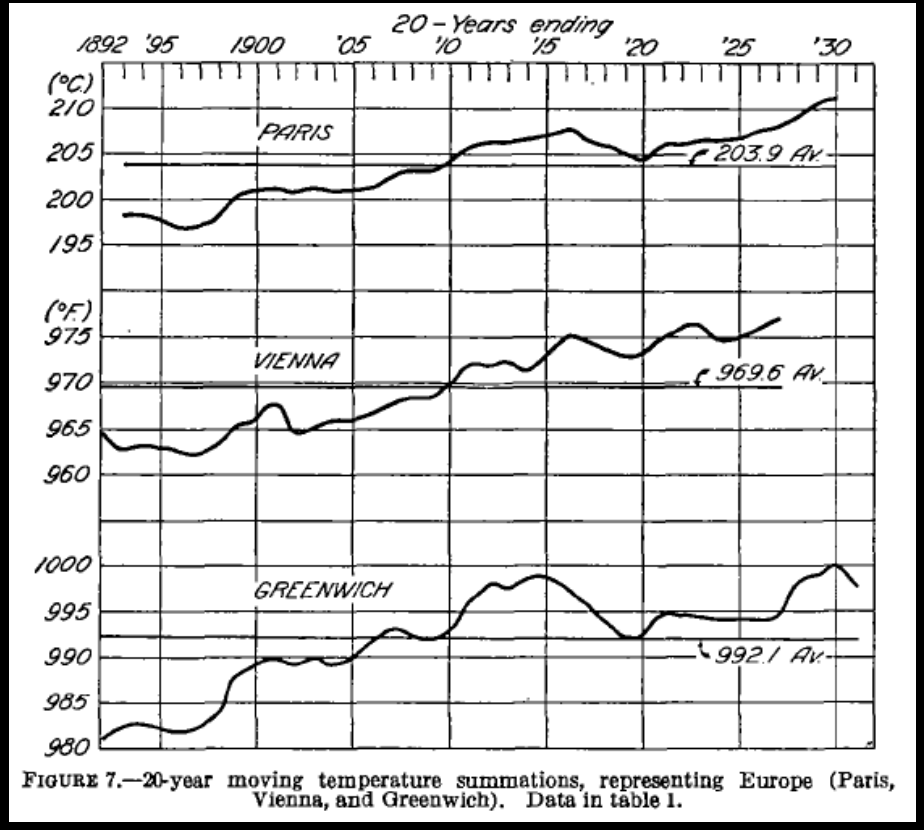


FIGURE 7.—20-year moving temperature summations, representing Europe (Paris, Vienna, and Greenwich). Data in table 1.

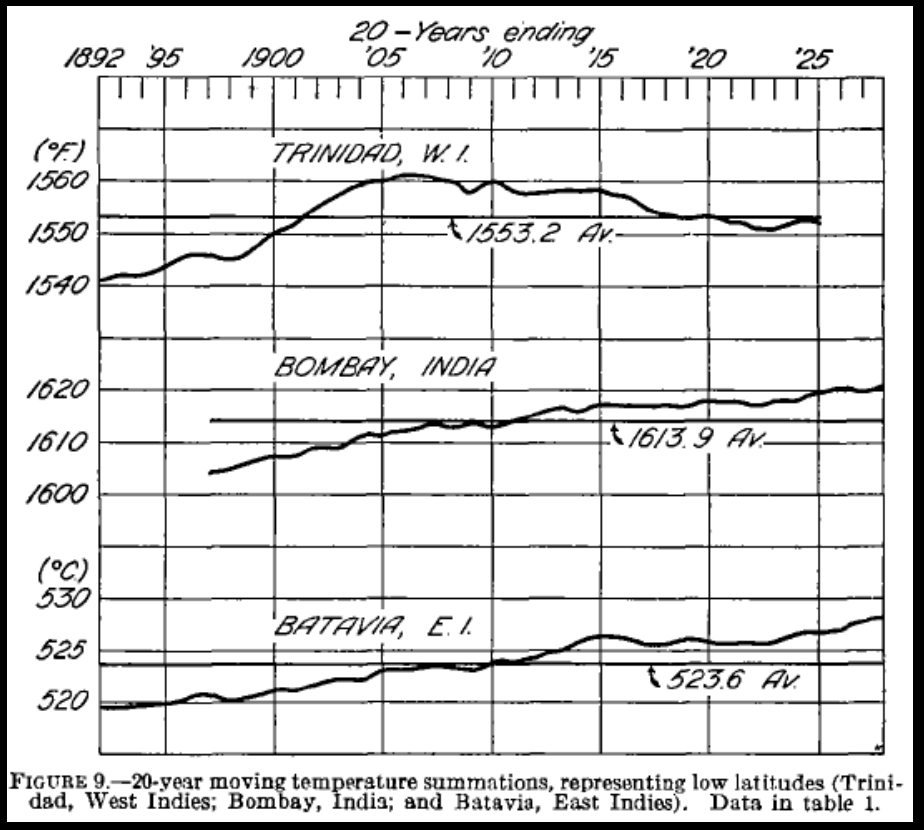
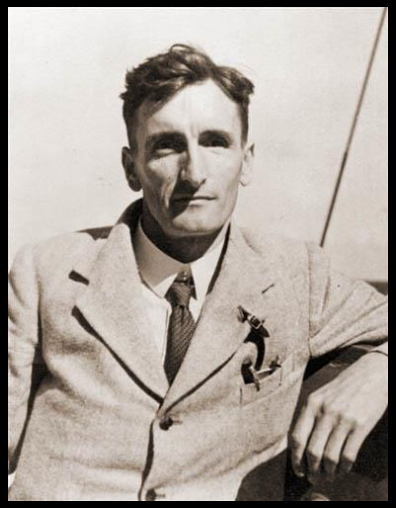


FIGURE 9.—20-year moving temperature summations, representing low latitudes (Trinidad, West Indies; Bombay, India; and Batavia, East Indies). Data in table 1.

Guy Callendar (1898-1964)



THE ARTIFICIAL PRODUCTION OF CARBON DIOXIDE AND ITS INFLUENCE ON TEMPERATURE

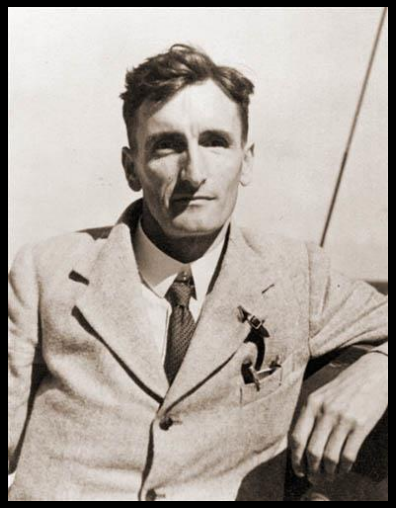
By G. S. CALLENDAR

(Steam technologist to the British Electrical and Allied Industries Research Association.)

(Communicated by Dr. G. M. B. Dobson, F.R.S.)

[Manuscript received May 19, 1937—read February 16, 1938.]

- Collated observations of atmospheric CO_2 concentrations which showed a recent increase
- Suggested that ocean not able to absorb all human-emitted CO_2
- First estimate of 'airborne fraction' of CO_2 (0.75)
- Estimated expected temperature rise from observed CO_2 increase (0.03K/decade)



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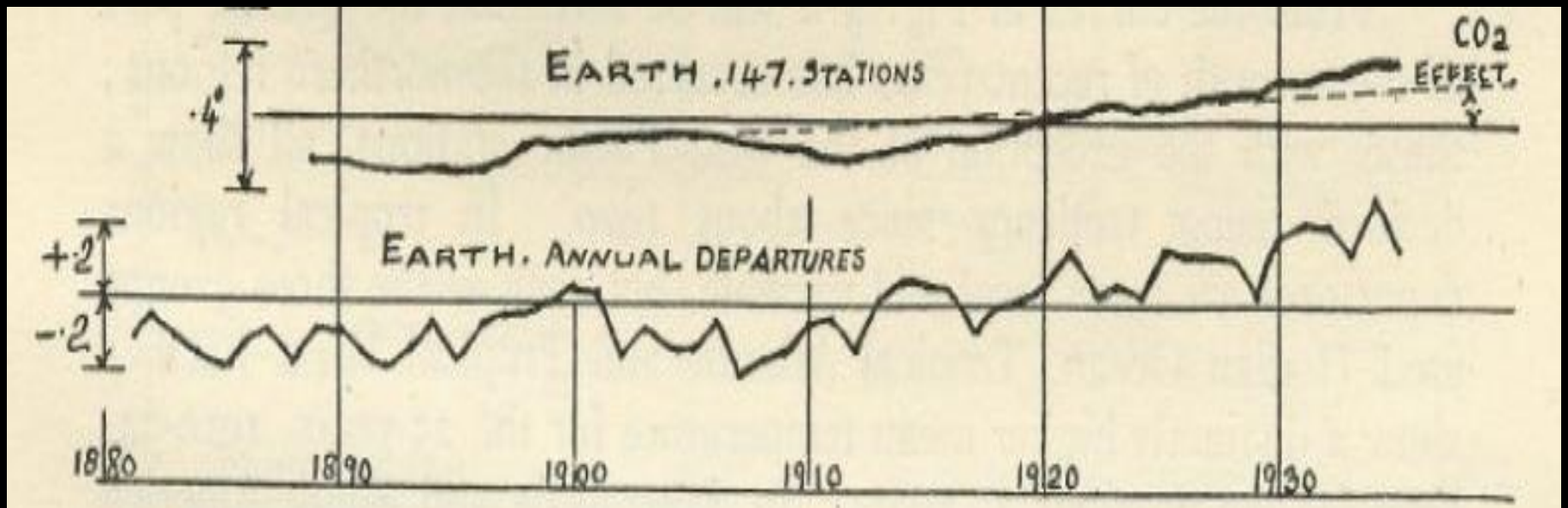
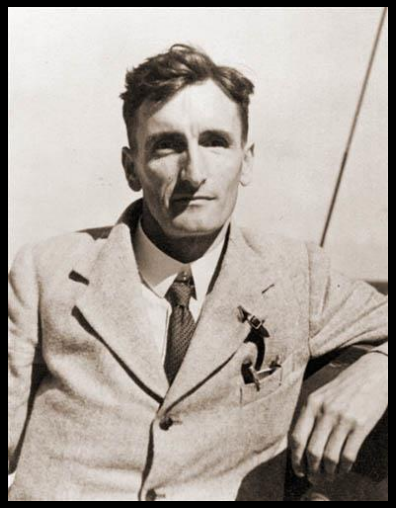


FIG. 4.—Temperature variations of the zones and of the earth. Ten-year moving departures from the mean, 1901-1930, °C.



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[Manuscript received May 19, 1937—read February 16, 1938.]

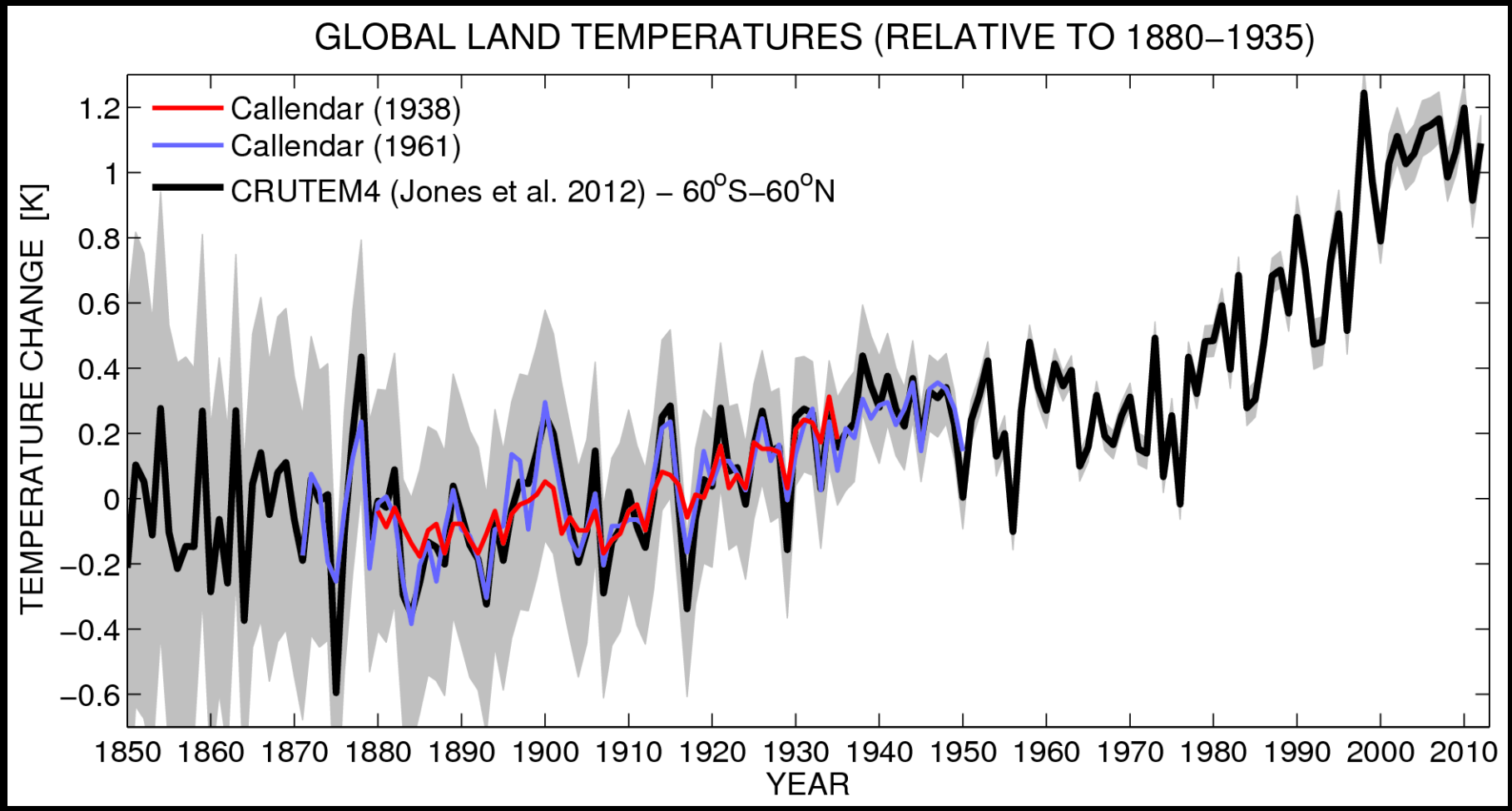
- Suggested ‘urban heat island’ effects negligible
- Calculations done without a computer, in spare time
- Quotes:

  “combustion of fossil fuel […] likely to prove beneficial in several ways, besides the provision of heat & power.”

  “small increases of mean temperature would be important at the northern margin of cultivation”

  “return of the deadly glaciers should be delayed indefinitely”

How good were Callendar's temperature estimates?



Hawkins & Jones, 2013, QJRMS

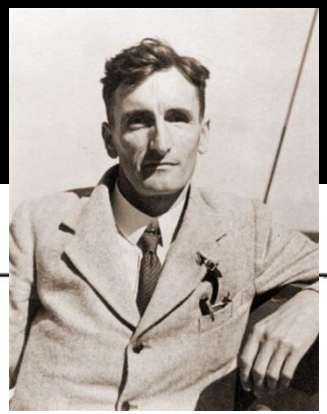
Science Museum, London

Gilbert Plass

- Performed the first radiative transfer computer modelling in 1956
- Demonstrated that atmosphere was not 'saturated' with CO_2 as many believed

Roger Revelle & Hans Suess

- Demonstrated in 1957 that the oceans could not absorb all excess CO_2 from human emissions



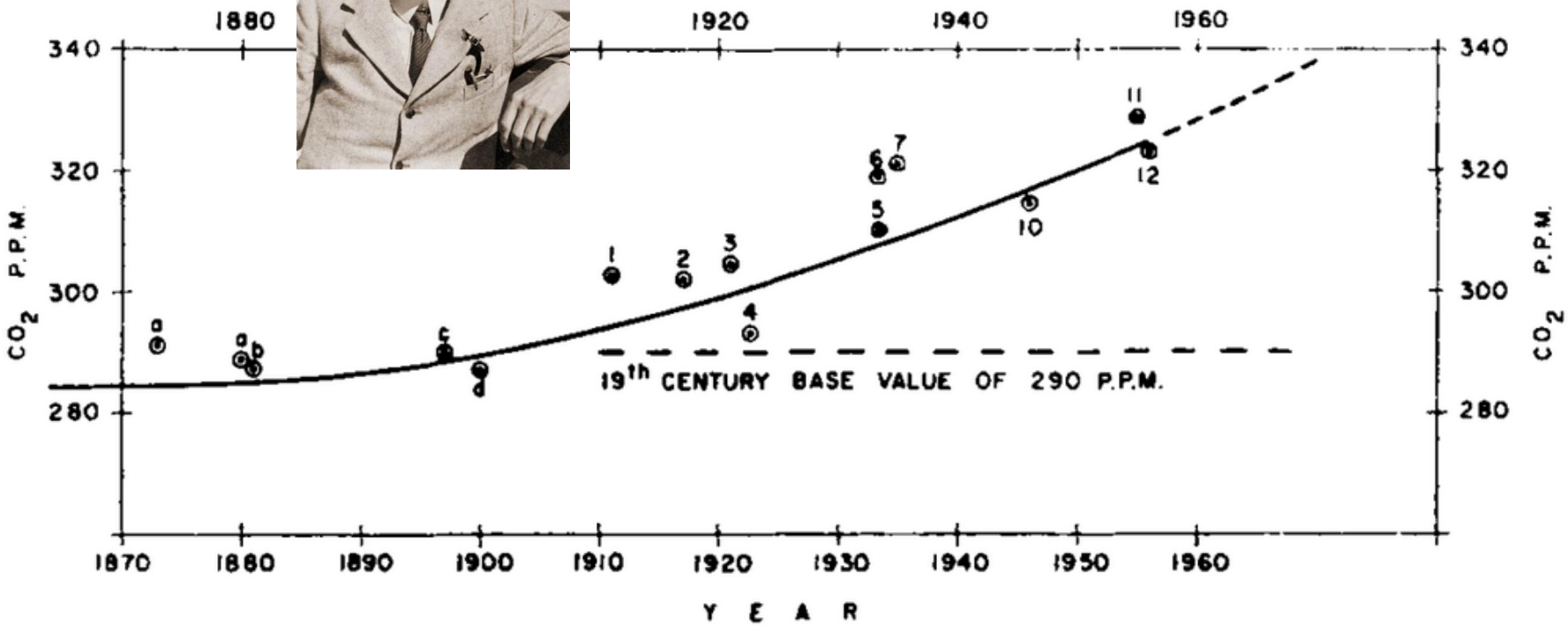
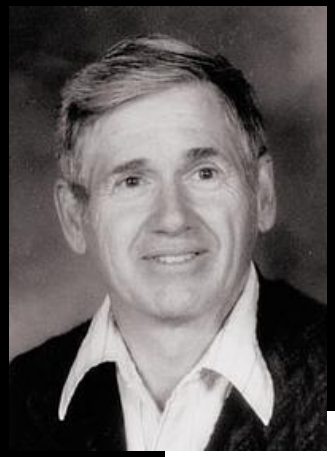


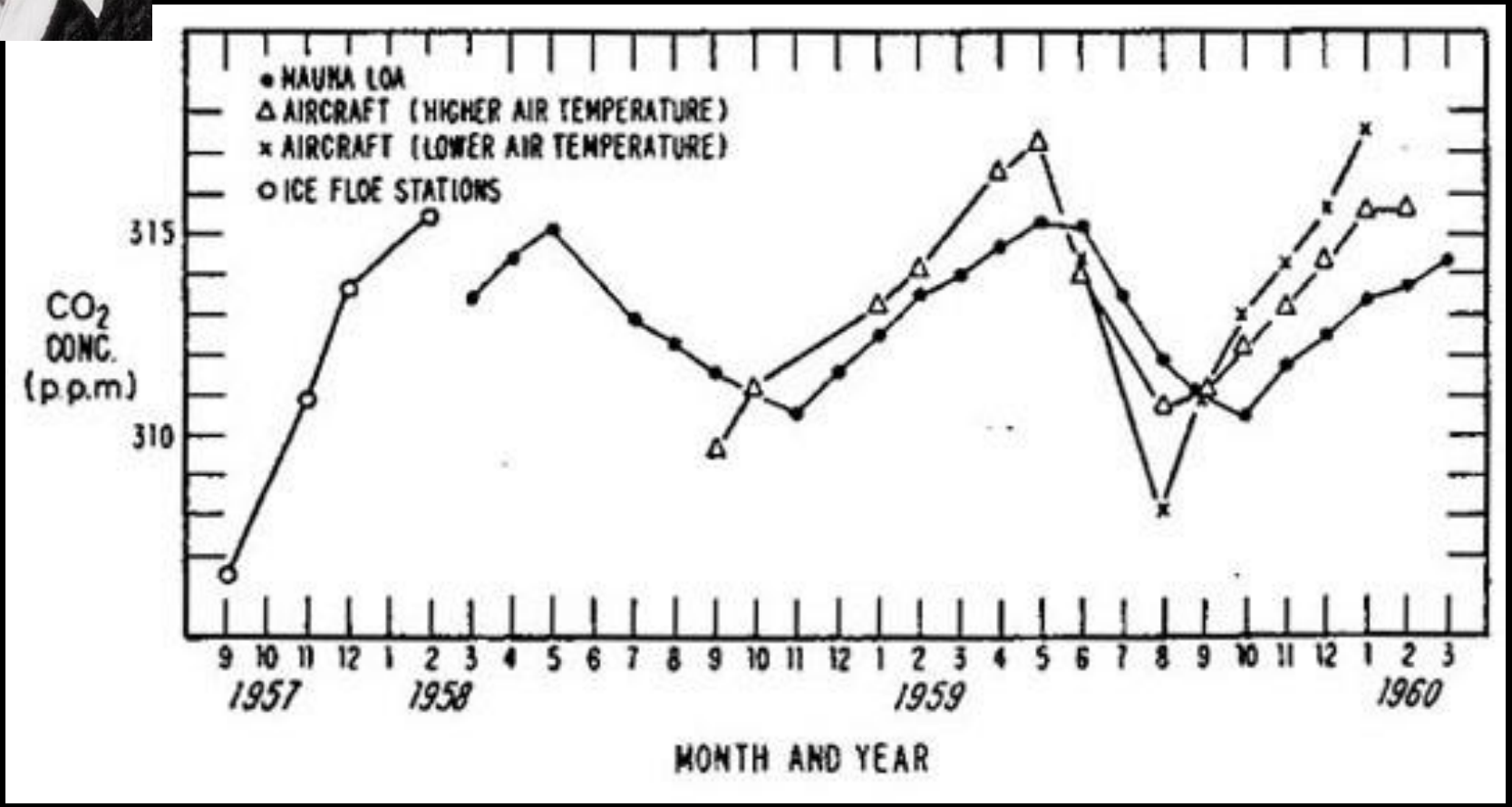
Fig. 1. Amount of CO_2 in the free air of the N. Atlantic region. 1870—1956. Full curve, amount from fossil fuel (See Appx. Table B. for numbered obs. points, and text Table 1 for the 19th century obs. points.)

Callendar, 1958

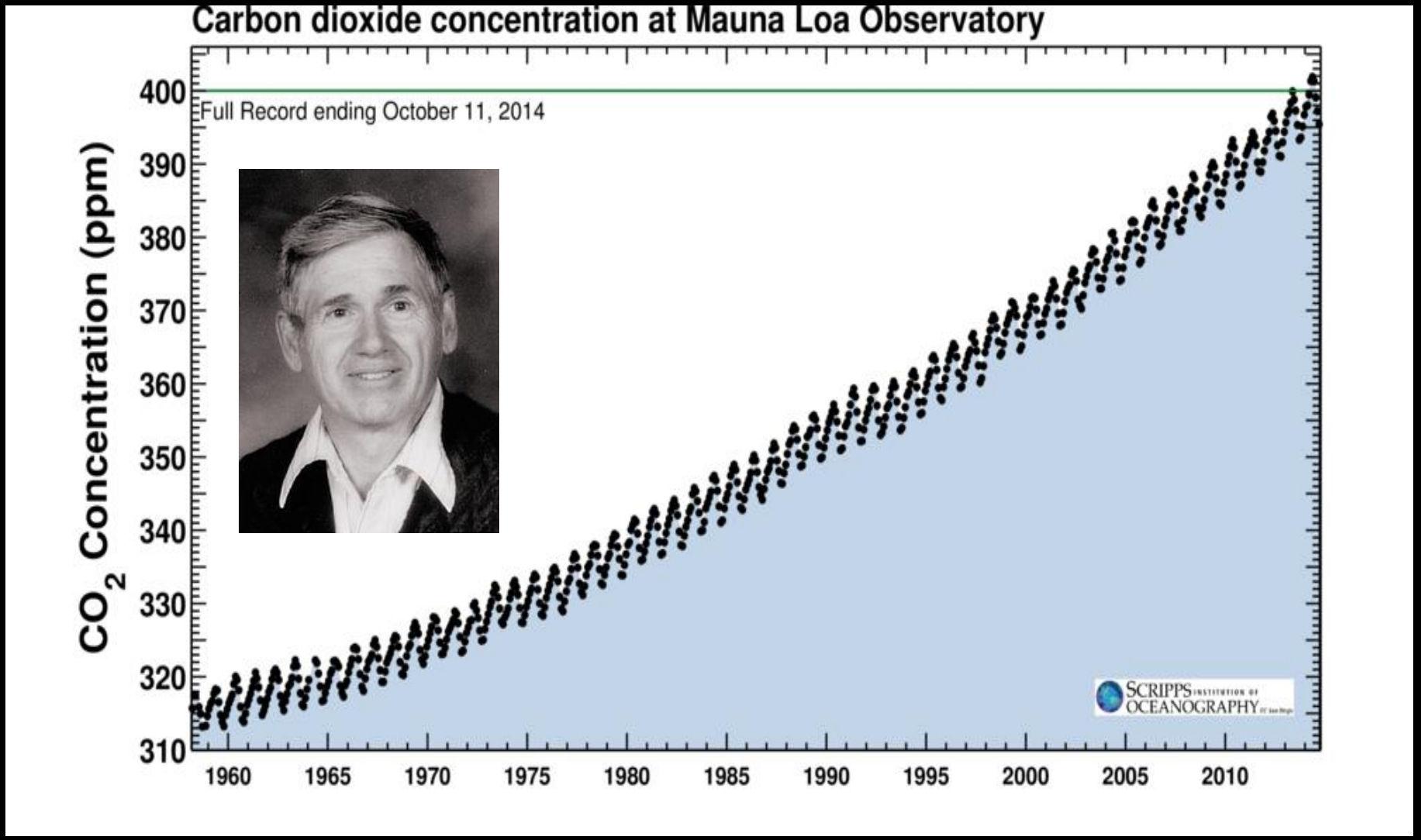


Charles Keeling

- Built & maintained long-term CO_2 observations in Hawaii



Keeling, 1960



Keeling curve

Summary:

- Understanding the climate is an interesting scientific problem and has been studied for nearly 200 years
- Early efforts focussed on understanding ice ages, not the human influence
- Communicating this long history may help when discussing climate change with the public
- Can even find @GuyCallendar & @ProfTyndall on twitter!