Advances in Climate Science through the pages of the QJ

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Nils Gustaf Ekholm (QJ 1901)

On the variations of the climate of the geological and historical past and their causes

"This paper is presented to the Royal Meteorological Society at its Jubilee on April 3, 1900, as a humble expression of homage and gratitude by the author."

Contents.

Ekholm (QJ 1901)

Conclusion

those revealed by geological science. Thus a future Ice Age might possibly occur. But here we find a remarkable circumstance that has hitherto been unexampled in the history of the earth. This is the influence of Man on climate.

In fact, we have seen that the present burning of pit-coal is so great that in one year it gives back to the atmosphere about $\frac{1}{1000}$ of its present store of carbonic acid. If this continues for some thousand years it will undoubtedly cause a very obvious rise of the mean temperature of the earth. Also Man will no doubt be able to increase the supply of carbonic acid also by digging of deep fountains pouring out carbonic acid. Further, it might perhaps be possible for Man to diminish or regulate the consumption of carbonic acid by protecting the weathering layers of silicates from the influence of the air and by ruling the growth of plants according to his wants and purposes. Thus it seems possible that Man will be able efficaciously to regulate the future climate of the earth and consequently prevent the arrival of a new Ice Age. By such means also the deterioration of the climate of the northern and Arctic regions, depending on the decrease of the obliquity of the ecliptic, may be counteracted. It is too early to judge of how far Man might be capable of thus regulating the future climate. But already the view of such a possibility seems to me so grand that I cannot help thinking that it will afford to Mankind hitherto unforeseen means of evolution.

Guy Stewart Callendar (QJ 1938)

collated T_s measurements

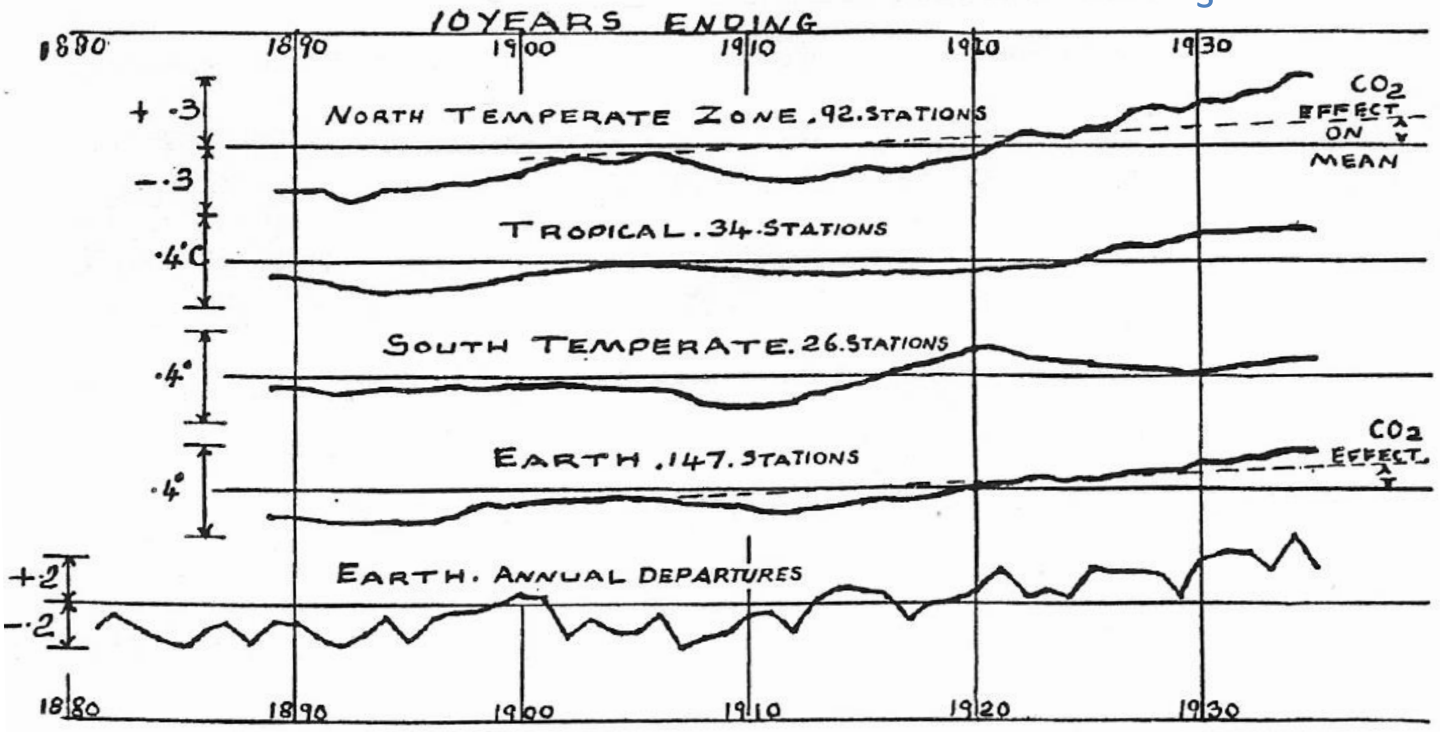


FIG. 4.—Temperature variations of the zones and of the earth. Ten-year moving departures from the mean, 1901-1930, °C.

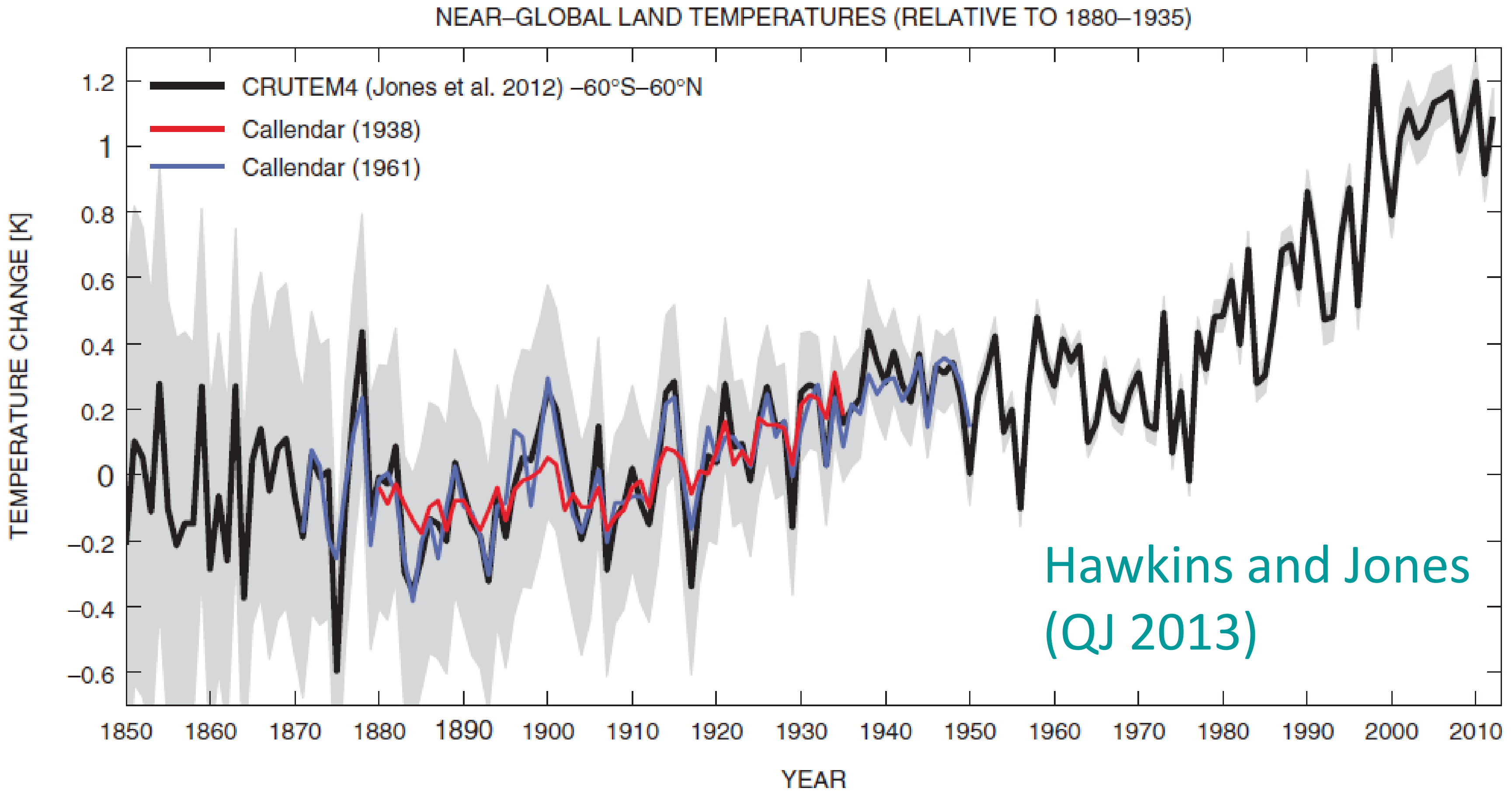


Figure 1. Comparison of historical reconstructions of near-global land temperatures using CRUTEM4 (black: Jones *et al.*, 2012) with results of Callendar (1938) (red) and Callendar (1961) (blue), using a reference period of 1880–1935. The CRUTEM4 estimates are for 60°S–60°N (to accord with Callendar's series), with grey shading representing 95% uncertainty.

Callendar (QJ 1938)

T_s calculations: C budget estimates & CO_2 absorp^n meas^{t}s

TABLE VI.—INCREASE OF MEAN TEMPERATURE FROM THE ARTIFICIAL PRODUCTION OF CARBON DIOXIDE.

Annual excess of CO_2 to the air = 4,300 million tons.
P (CO_2) is expressed in units of a ten-thousandth of an atmosphere.
ΔT = increase from mean temperature of 19th century.
Sea water equilibrium time 2,000 years.

Period	1910-1930	20th century	21st century	22nd century
Mean P (CO_2) . . .	2·82	2·92	3·30	3·60
Mean ΔT. °C. . . .	+0·07°	+0·16°	+0·39°	+0·57°
Polar displacement of climate zones . . .	15	36	87	127km.

Manley (QJ 1974)

Central England temperatures 1659-1973

decadal running averages

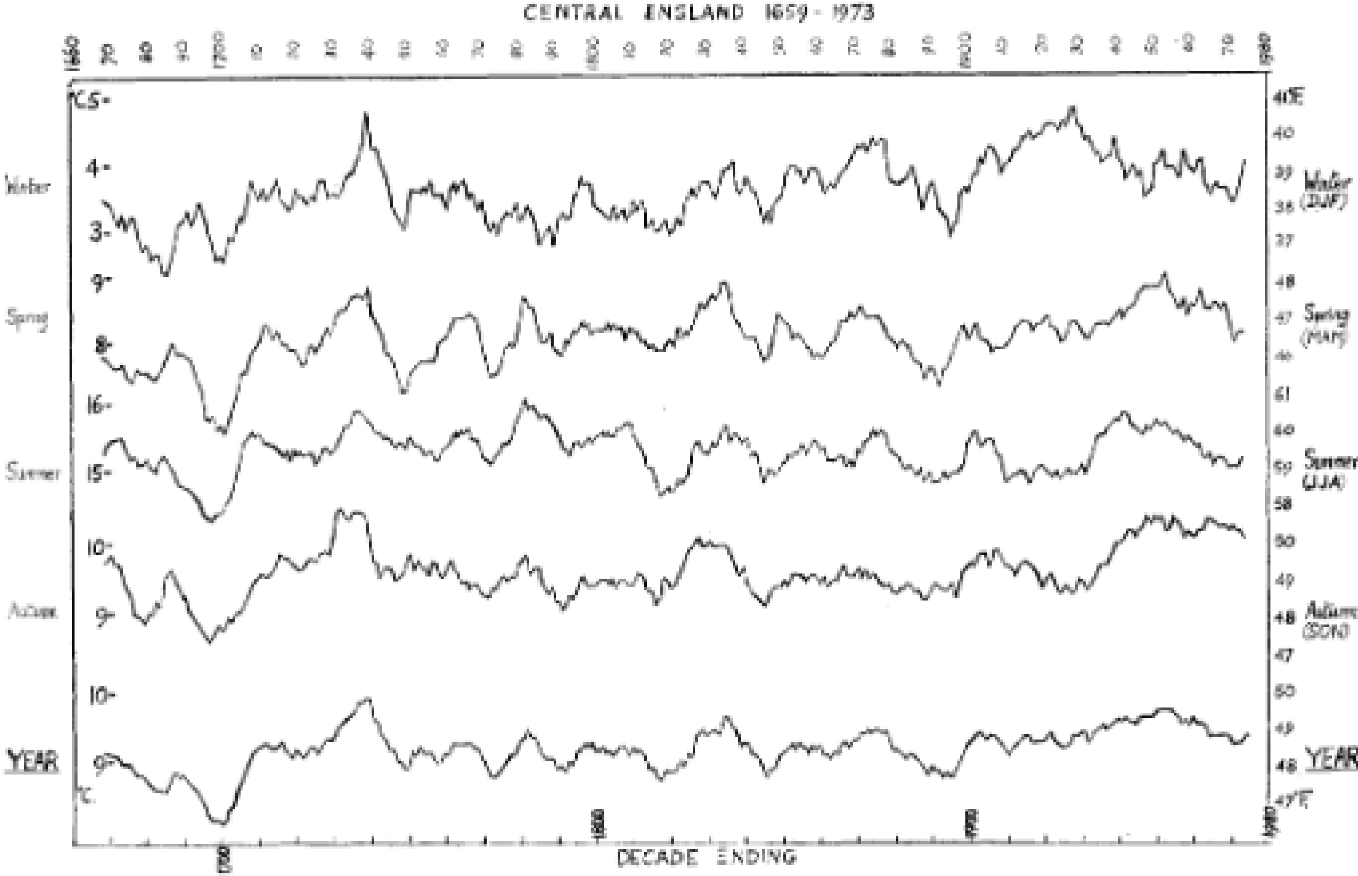


Figure 1. Decadal running averages of seasonal and annual mean temperatures.

Series updated to present: Hadley Centre Central England Temperature (HadCET) dataset
longest instrumental record of temperature in the world

Callendar (QJ 1941)

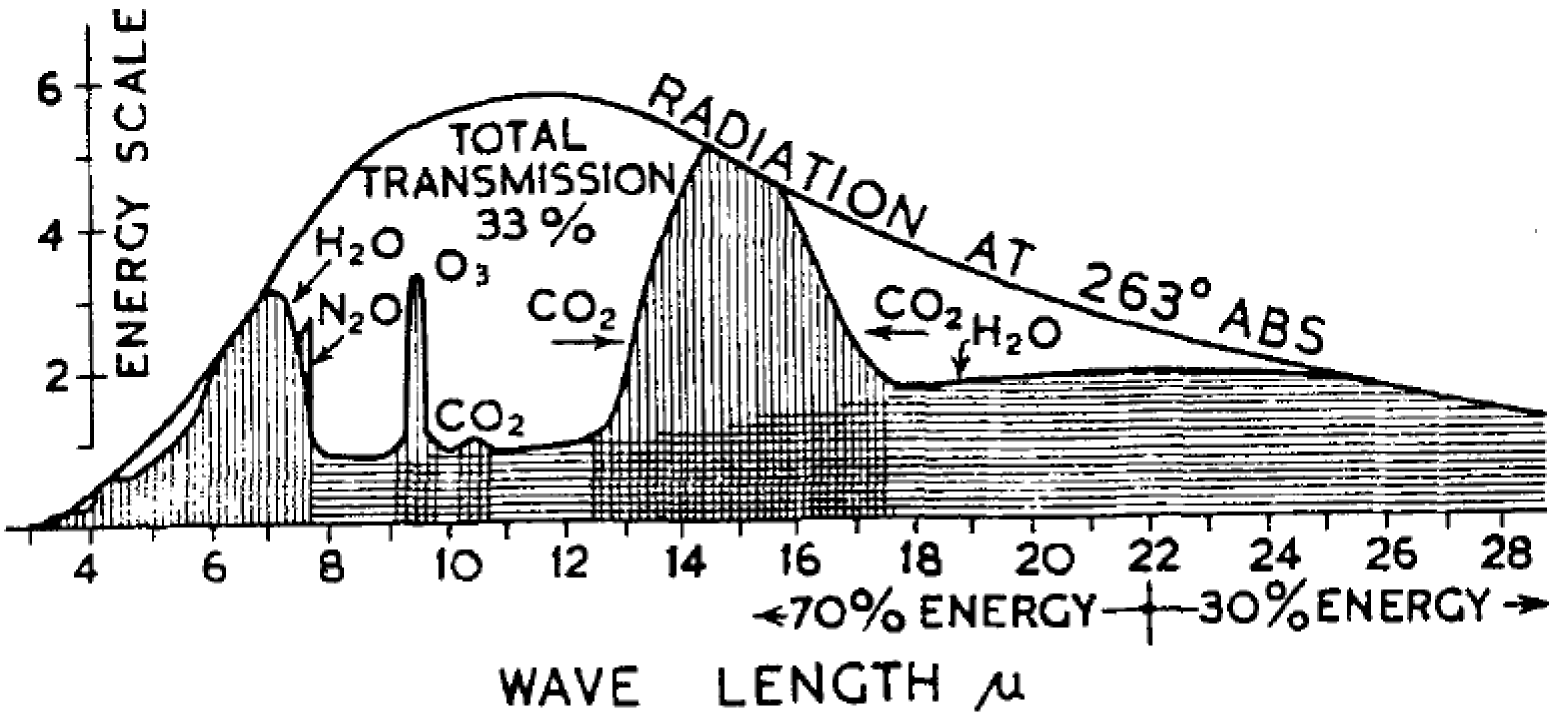
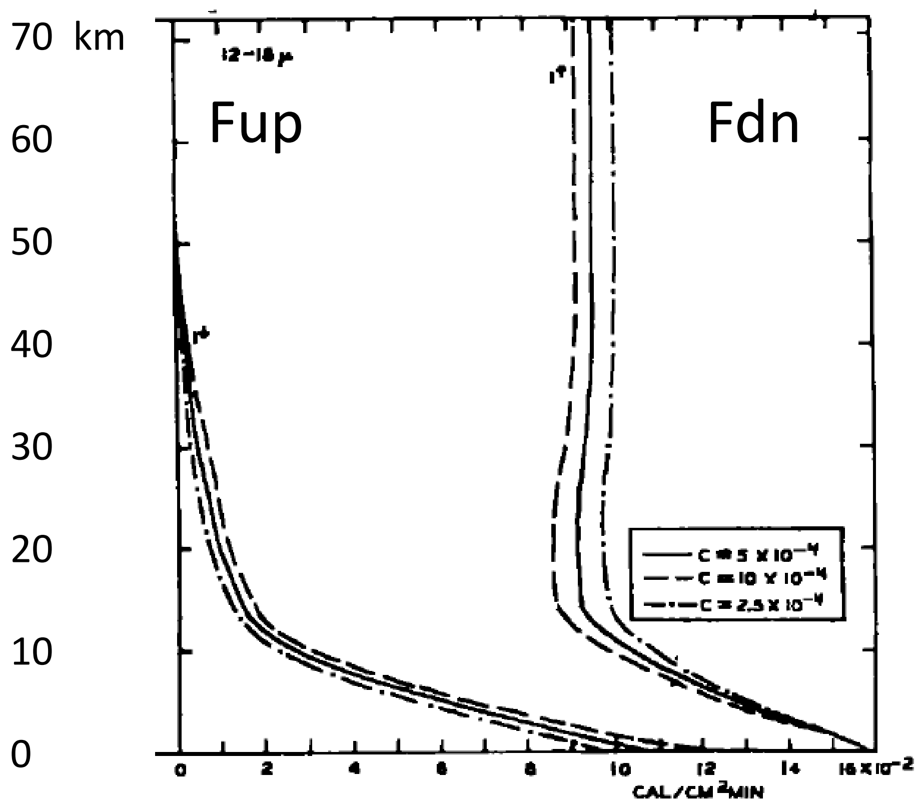


FIG. 4.—The approximate distribution of atmospheric absorption for 1 cm. pp. water.

Plass (QJ Jul1956)

CO_2 15µm band flux calculation

Based on parameterisation of lab transmission measurements



"At the surface of the Earth the average temperature would rise by 3.6˚C if the CO_2 concentration were doubled and would fall by 3.8˚C if it were halved"

Goody (QJ 1952)

A Statistical Model for Water Vapour Absorption

Assumption that spectral lines distributed randomly

Lorentz lineshape

Line strength distribution

$$P(k) = \frac{1}{\sigma} \exp\left(-k/\sigma\right)$$

Results in band transmission

$$\vec{T}(\alpha, m\sigma) = \exp\left[-\frac{m\sigma\alpha}{\delta\left(\alpha^2 + \frac{m\sigma\alpha}{\pi}\right)^{\frac{1}{2}}}\right]$$

m absorber amount α mean line width σ mean line strength δ mean line spacing

Rodgers and Walshaw (QJ 1966)

The computation of infra-red cooling rate in planetary atmospheres

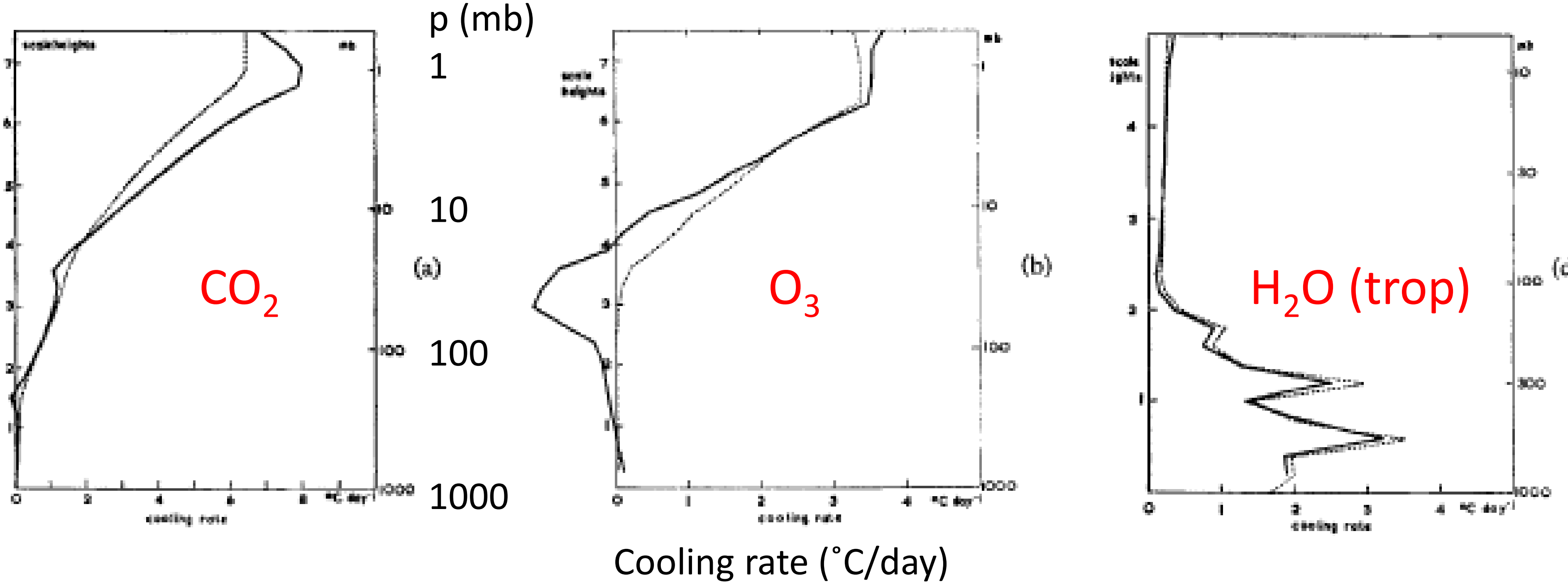
Estimates and approximations:

- Height integration using pre-calculated Curtis Matrix.
- Frequency integration using broad band models - using knowledge of spectral line properties and distributions (e.g. Goody random model).
- Path integration using Curtis-Godson approximation.
- Water vapour, ozone and carbon dioxide.
- Assessment of accuracy of cooling-to-space approximation.

Rodgers and Walshaw (QJ 1966)

Solid line: LW radiative heating rate

Dashed line: Cooling-to-space approximation



Edwards and Slingo (QJ 1996)

A flexible new radiation code

TABLE 2. THE BAND STRUCTURE, THE GASES INCLUDED, AND THE NUMBER OF ESFT TERMS FOR VERSIONS C AND D (SEE TEXT) OF THE 9-BAND LONG-WAVE SPECTRUM (AFTER WOODWARD *et al.*, PERSONAL COMMUNICATION)

Band	Wave numbers (cm^{-1})	$H_2O_{(l+f)}$	$H_2O_{(s)}$	CO_2	O_3	CH_4	N_2O	CFC11	CFC12
1	0–400	9							
2	400–550	8							
3	550–800	10							
4	800–880	6							
5	880–990	4							
6	990–1120	5							
7	1120–1200	4							
8	1200–1500	10							
9	1500–3000	8							

The subscript (l+f) refers to lines plus the foreign-broadened continuum, while the subscript (s) refers to the self-broadened continuum.

- Two-stream approach for LW & SW.
- ESFT frequency integration - resolution flexible.
- Various applications, multiple gases.
- SW scattering by cloud.

Phillips (QJ 1956)

The general circulation of the atmosphere: a numerical experiment

- Two-level quasi-geostrophic model
- Single hemisphere
- Friction, radiative heating, vertical stability specified

"One of the main purposes of this numerical experiment was the investigation of the energetics of the atmosphere"

"furnishing valuable experience in the numerical problems to be encountered in making long-range predictions"

Phillips (QJ 1956)

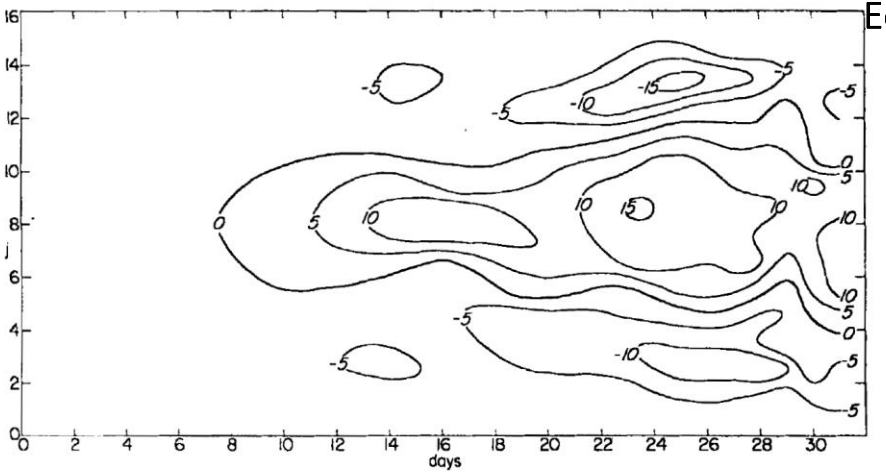


Figure 14. Variation of $\bar{u}_4$, at 1,000 mb with latitude (j) and time. Units are m sec^{-1}.

zonal wind at surface

Equator

Pole

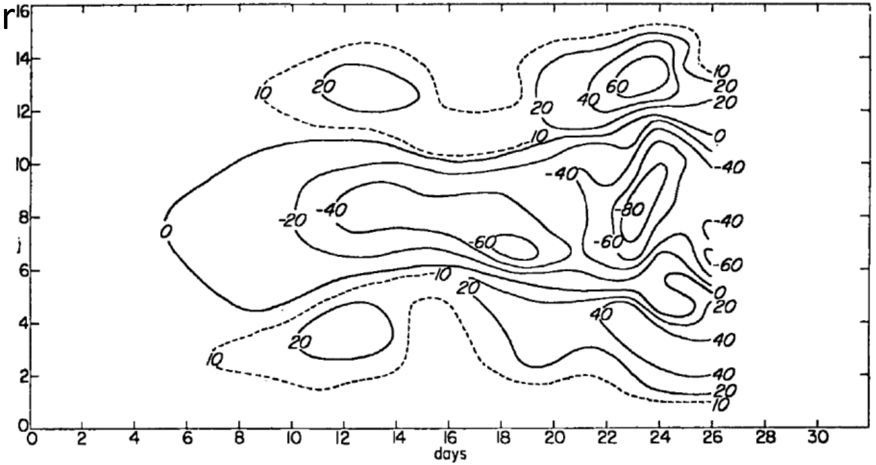


Figure 11. Variation with latitude (j) and time of the mean meridional velocity, $\bar{V}_1$, in the upper half of the atmosphere. Units are cm sec^{-1}.

meridional wind in upper level

Evolution over first 30 days

Phillips (QJ 1956)

Equations derived for all these terms.
Evaluated during integration.

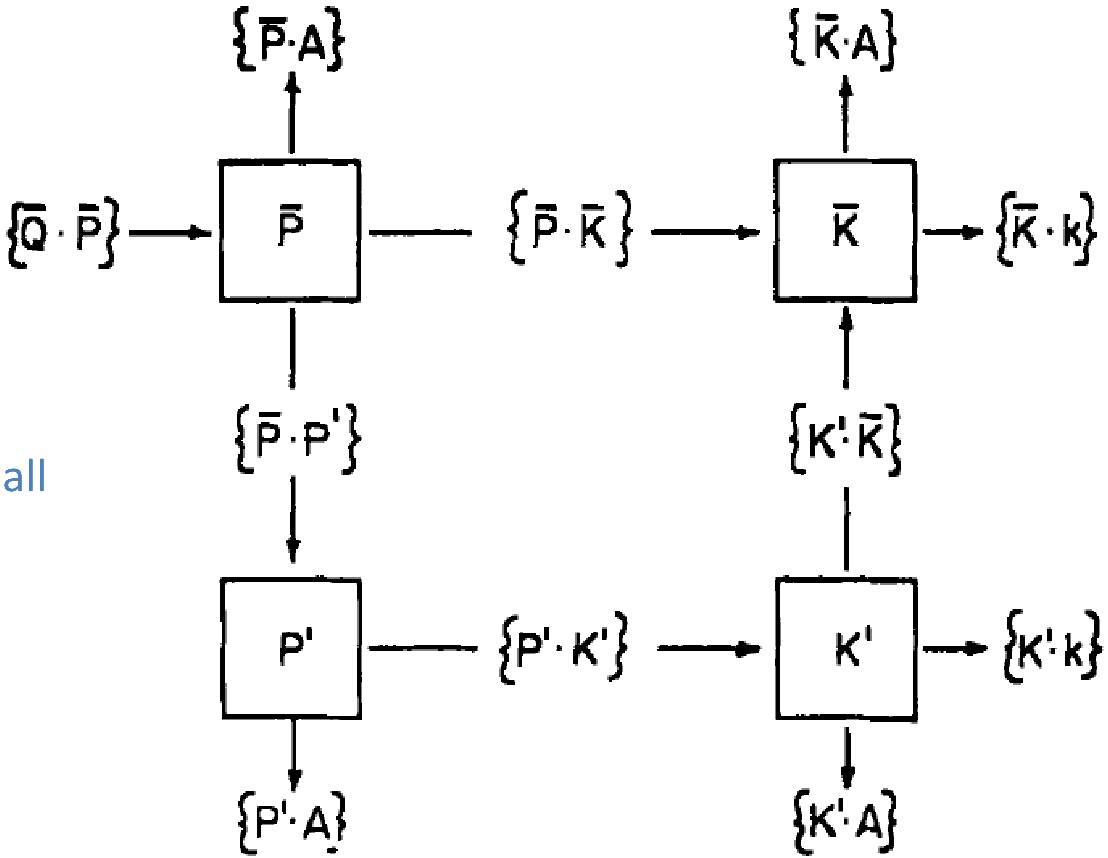


Figure 3. Energy flow diagram. The flow of energy is in the direction of the arrow if the associated transformation { · } is positive. The numerical computations give positive values for all the transformations except $\{\overline{P}\cdot\overline{K}\}$.

?due weak direct cells (Fig.11)

Phillips (QJ 1956)

TABLE 3. EVALUATION OF THE TERMS IN THE THERMODYNAMIC ENERGY EQUATION DURING THE PERIOD 10-20 DAYS. UNITS ARE DEG DAY^{-1}.

j latitude	$\frac{\partial \bar{T}_2}{\partial t}$	$-\frac{2H}{c_p}\frac{y}{W}$	$\frac{f_0^2}{R\lambda^2}\frac{\bar{\omega}_2}{p_2}$	$-\frac{\partial\,(\overline{v_1' T_2'})}{\partial y}$	$A\frac{\partial^2 \bar{T}_2}{\partial y^2}$

Radiative heating rate *H* determined from measurements of the mean non-adiabatic processes in the atmosphere

One conclusion:

the latitude of maximum $\frac{\partial \bar{T}}{\partial y}$ in the atmosphere may be determined to some extent dynamically, and not merely by the latitudinal gradient in radiation

Garth Paltridge (QJ1980)

T surface temperature
F_N downward flux TOA
C CO_2 concentration
u_i climate parameter

$$\frac{dT}{dC} = \left(\frac{dT}{dF_N}\right)\left(\frac{dF_N}{dC}\right)$$

$$= \left(\frac{\partial T}{\partial F_N}\right)\left(\frac{\partial F_N}{\partial C}\right)\left\{1 - \left(\frac{\partial T}{\partial F_N}\right)\sum_{i=1}^{n}\left(\frac{\partial F_N}{\partial u_i}\right)\left(\frac{du_i}{dT}\right)\right\}^{-1}.$$

see also Ray Bates (QJ 2007) on definition of climate feedback

Garth Paltridge - climate feedbacks

cloud feedback (QJ 1980)

1D RT model

3 cloud levels

R&W LW scheme

u_i:

liquid water path

cirrus cloud amount

low cloud amount

total cloud amount

Conclusion: cloud reduces sensitivity of climate to increased CO_2

rainfall-albedo feedback (QJ 1991) via change in land surf vegn

dT for double CO_2 :

4.16 K w/o this fbk

4.58-6.38 K inc this fbk

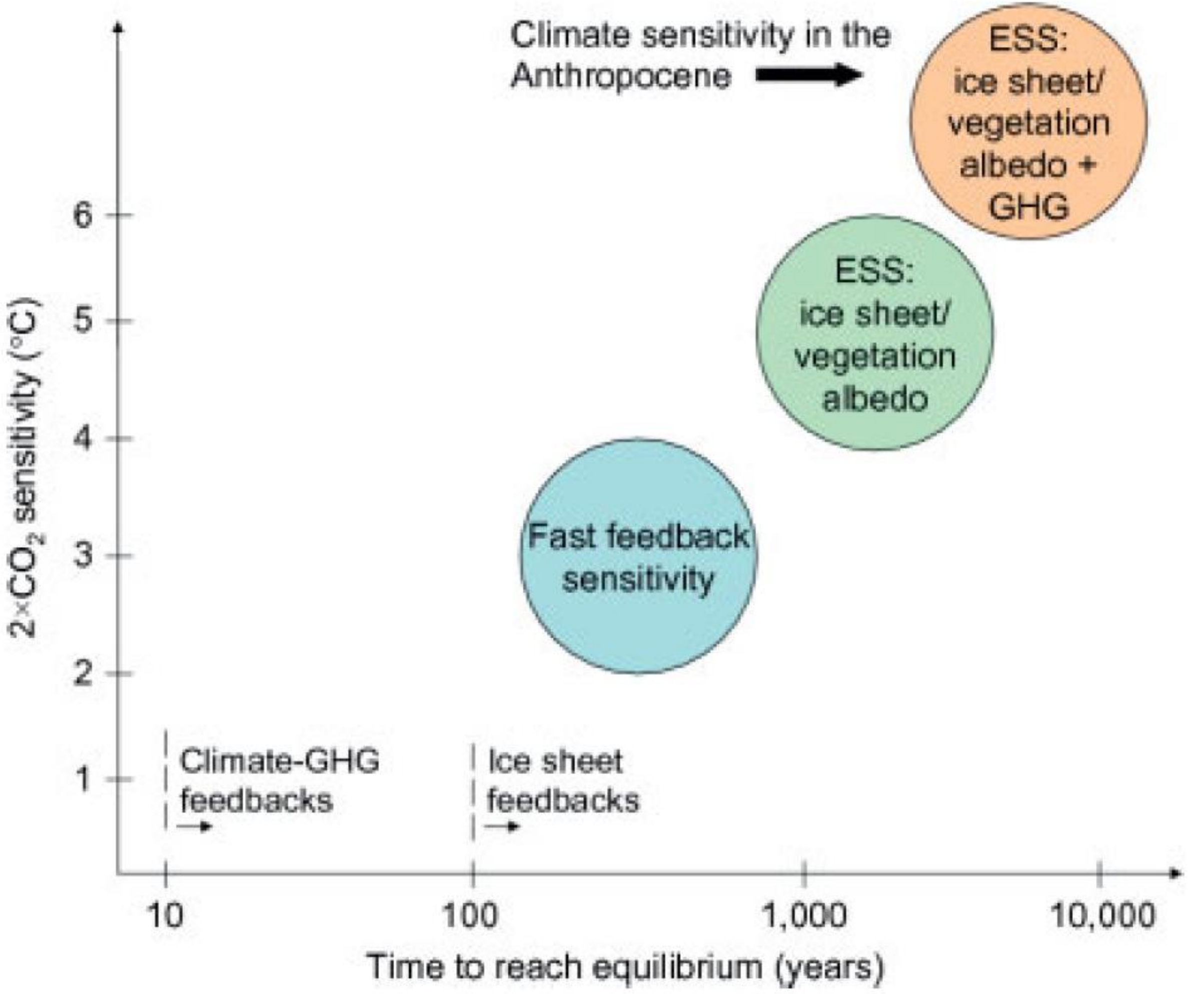
Paltridge (QJ 1991)

TABLE 2. COMPARISON OF THE FEEDBACK FACTORS IDENTIFIED IN THE GISS CLIMATE MODEL AND THE RAINFALL–ALBEDO FACTOR f_n DISCUSSED HERE

Mechanism		f_i	dT(K) (from Eq. (3))
None		0.000	
Water vapour amount		0.445	
Water vapour distribution		0.216	
Lapse rate		−0.264	
Surface albedo (sea-ice)		0.091	
Cloud height		0.123	
Cloud cover		0.101	
Total f of GISS model		0.712	4.16
Rainfall–albedo (f_n)	(Case A)	0.100	
	(Case B)	0.026	
Total f	(Case A)	0.812	6.38
	(Case B)	0.738	4.58

Previdi et al (QJ 2013)

Review Article: Climate sensitivity in the Anthropocene



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