Satellites in the hunt for the elusive cloud feedback

George Tselioudis
(Bill Rossow's first PH.D. student)

- Cloud feedbacks are the largest uncertainty in CMIP3,5,6,… climate model predictions of..blah, blah, blah,…..
- Yes but how did it all start? Let's try a brief yet educational history of the subject, with emphasis on the all important role of satellite observations (meaning mostly ISCCP of course…)

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Cloud Optical Thickness Feedbacks in the CO_2 Climate Problem

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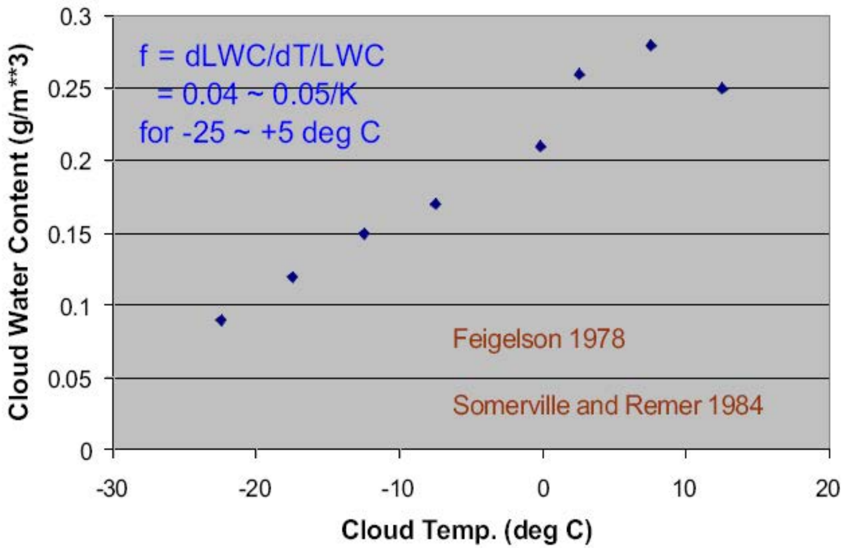
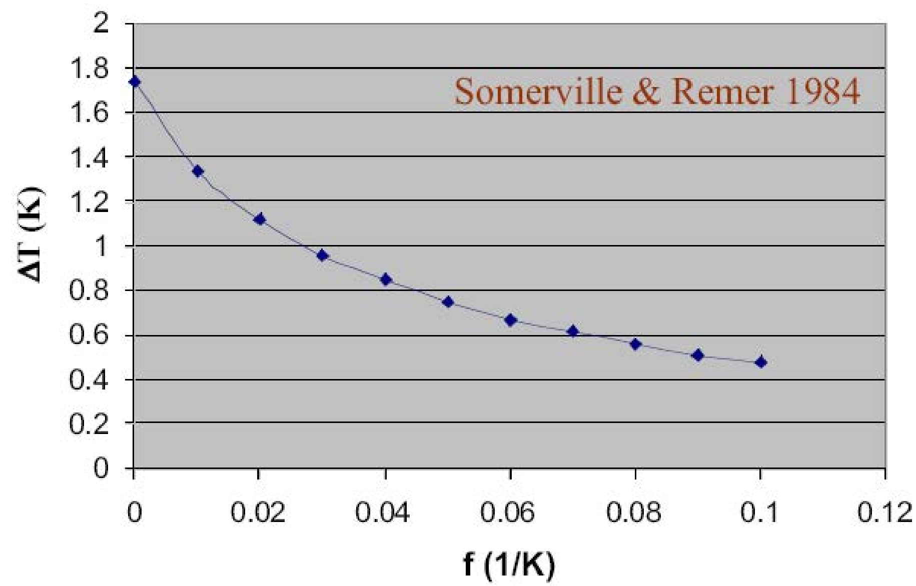
former USSR data



First ever (?) cloud feedback observational paper relied on measurements made by the Soviets! In the middle of the cold war nonetheless!

Surface Temp. Warming



And of course it showed that cloud optical depth feedback would decrease global warming by more than half!

It was crucial to look at the global picture. Why were we flying all those satellites anyway.

Meanwhile at GISS, scientists have been analyzing satellite cloud retrievals (or looking at pictures anyway) for quite a while, but they were of the wrong planets!

Microwave Boundary Conditions on the Atmosphere and Clouds of Venus[1]

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(Manuscript received 13 December 1974, in revised form 3 March 1975)

ABSTRACT

The dielectric properties of H_2O and H_2SO_4 at microwave frequencies have been calculated from the Debye equations. The derived frequency and temperature dependence agrees well with existing data. The dielectric properties of H_2O/H_2SO_4 mixtures are deduced and, for a well-mixed atmosphere, the structure of H_2O and H_2O/H_2SO_4 clouds is calculated. With the COSPAR model atmosphere and the calculated cloud models, the microwave properties of the atmosphere and clouds are determined. The 3.8 cm radar reflectivity of the planet, the Mariner 5 S-band occultation profile, and the passive microwave emission spectrum of the planet together set an upper limit on the mixing ratio by number of H_2O of $\sim 10^{-2}$ in the lower Venus atmosphere, and of H_2SO_4 of $\sim 10^{-5}$. The polarization value of the real part of the refractive index of the clouds, the spectroscopic limits on the abundance of water vapor above the clouds, and the microwave data together set corresponding upper limits on H_2O of $\sim 2\times 10^{-4}$ and on H_2SO_4 of $\sim 9\times 10^{-6}$. Upper limits on the surface density of total cloud constituents and of cloud liquid water are, respectively, ~ 0.1 g cm^{-2} and ~ 0.01 g cm^{-2}. The infrared opacities of 90 bars of CO_2, together with the derived upper limits to the amounts of water vapor and liquid H_2O/H_2SO_4, may be sufficient to explain the high surface temperatures through the greenhouse effect.

Bill's first ever paper was on the clouds of Venus (how cool is it to have Carl Sagan as your second author on your first paper!)

ICARUS 36, 1–50 (1978)

Cloud Microphysics: Analysis of the Clouds of Earth, Venus, Mars, and Jupiter

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Received May 31, 1977; revised April 3, 1978

A simple method of deducing the probable microphysics of a cloud is developed that uses only information about cloud particle mean size, composition, number density, and atmospheric structure. This analysis is applied to the sulfuric acid clouds of Venus, the water ice and dust clouds of Mars, and the ammonia–water and ammonia ice clouds of Jupiter. The Venus cloud layer most closely resembles smog and haze layers on Earth with no sharp concentration gradients. The cloud microphysics is dominated by coagulation, sedimentation, and turbulent mixing. No precipitation is formed. The water ice clouds on Mars resemble tenuous, non-precipitating cirrus clouds on Earth. Deposition of condensed water on Mars only occurs from surface fogs or direct condensation on the surface. These fogs can provide a very efficient dust deposition mechanism. The observed settling behavior of the great dust storm of 1971 suggests sedimentation at the surface from a turbulent cloud with coagulation growth of large particles to replace those lost by sedimentation, analogous to the nighttime evolution of submicron tropospheric aerosols on Earth. The ammonia–water and ammonia ice clouds on Jupiter produce precipitation on time scales $< 10^4$ sec. The vertical structure of all clouds is significantly altered. The activity of the lower ammonia–water cloud has significant effects on the vertical distribution of other gases and aerosols, on the vertical transport of heat, and on the dynamics in this portion of the atmosphere.

But then he decided to analyze the clouds of any planet that dared have a cloudy atmosphere.

This made him the natural candidate to lead the first global cloud climatology effort (not!).

[Reprinted from BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY, Vol. 64, No. 7, July 1983]
Printed in U.S.A.

The International Satellite Cloud Climatology Project (ISCCP): The First Project of the World Climate Research Programme

R.A. Schiffer[1] and W.B. Rossow[2]

"Who is wise enough to number all the clouds?" *Job 38:37*

cloud types and meteorological conditions. Complimentary efforts within the framework of WCRP will promote the use of the resulting ISCCP data sets in climate research.

So the kick off of the ISCCP project was announced to the world in a 1983 BAMS paper, which included the most clever header that I have ever seen!

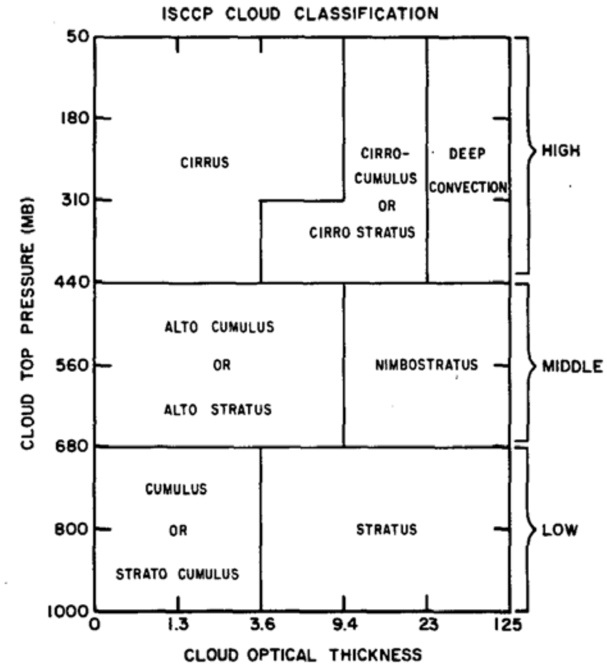
Bill was hard at work throughout the 80s, using the most advanced machinery known to man (1980s man anyway).

Of course it was not all hard work, there was always time for a single malt!
This Bud's for Jim! Yes, this is Tony with the beard!

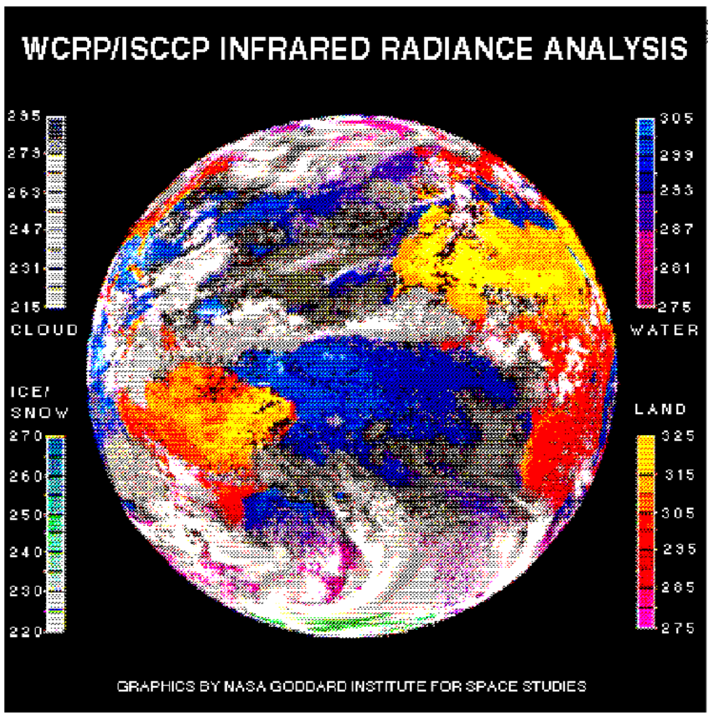
[Reprinted from BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY, Vol. 72, No. 1, January 1991]
Printed in U.S.A.

ISCCP Cloud Data Products

William B. Rossow and
Robert A. Schiffer



And then in 1991 the release of the first ISCCP C-version dataset was announced. Insiders of course had access to the data since the late 80s.



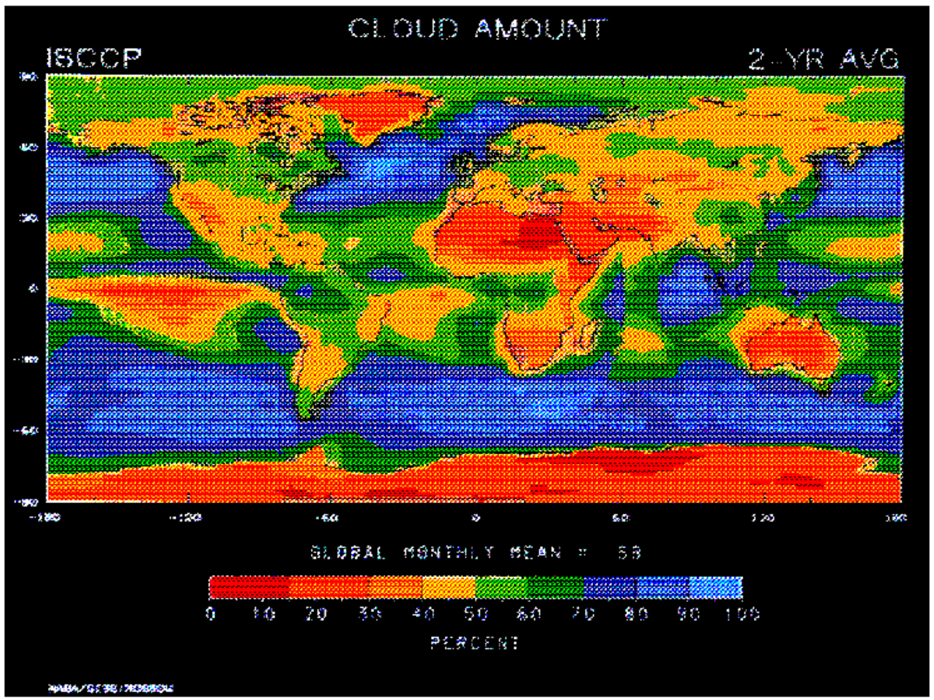
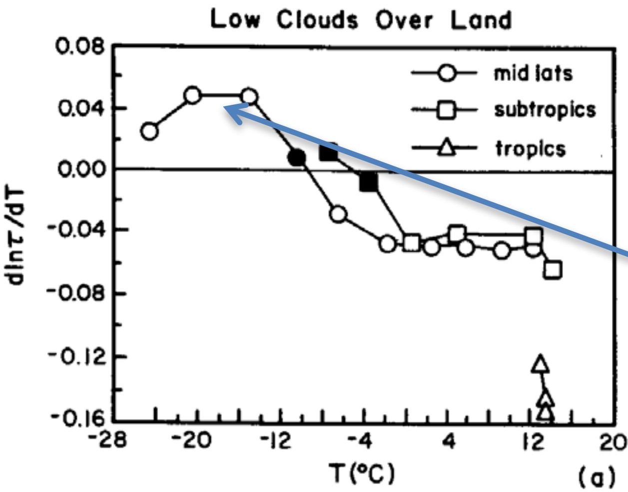


PLATE 1. Geographic distribution of cloud amount averaged over the first two years of ISCCP results: July 1983– June 1985

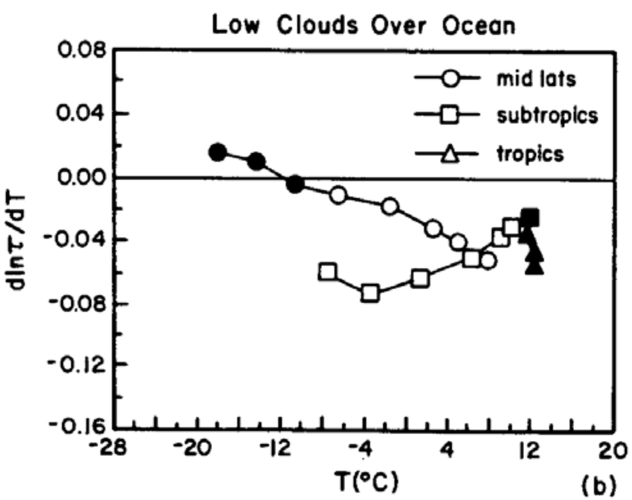
Global Patterns of Cloud Optical Thickness Variation with Temperature

GEORGE TSELIOUDIS,* WILLIAM B. ROSSOW, AND DAVID RIND
NASA Goddard Institute for Space Studies, New York, New York
(Manuscript received 7 June 1991, in final form 18 February 1992)



So, here was the global picture of the f-parameter, from my first published paper.

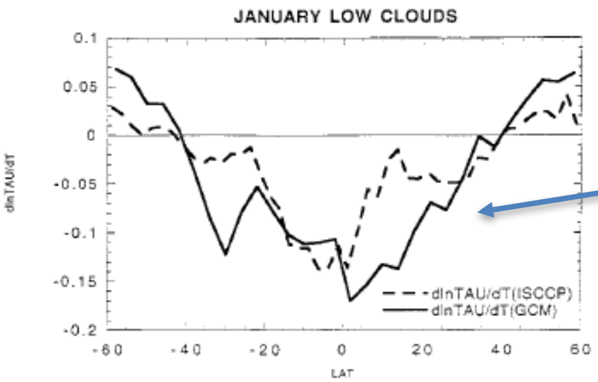
In Soviet Union conditions we agreed with the S&R paper, but everywhere else f was negative, implying a positive cloud optical depth feedback



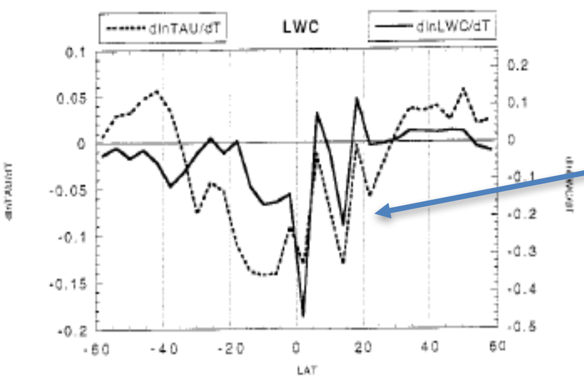
Observations did not provide sufficient information to resolve the processes responsible for the optical depth changes.

As luck would have it, the GISS GCM had just obtained a prognostic cloud water scheme, courtesy of Tony DelGenio, so we embarked on an analysis of model output

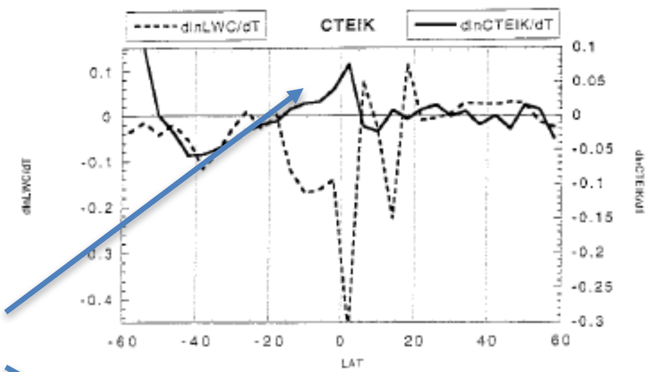
Temperature Dependence of Low Cloud Optical Thickness in the GISS GCM: Contributing Mechanisms and Climate Implications

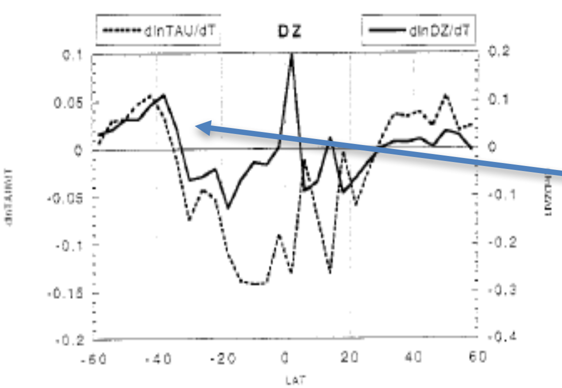


Thankfully, the model f-parameter current climate behavior agreed very well with the satellite observations

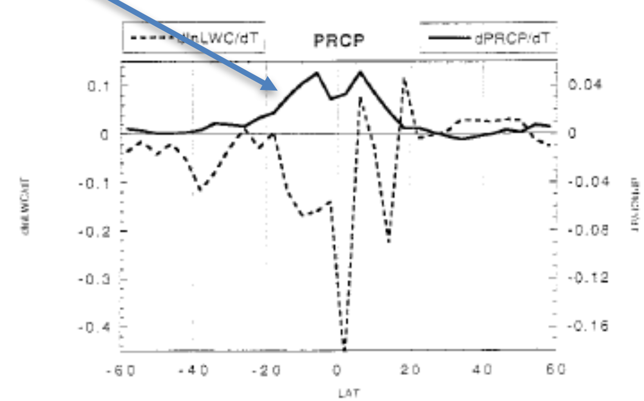


Tropical optical thickness decreases with temperature were related to LWC decreases, caused by increased efficiency of water depleting processes like CTEI and precipitation





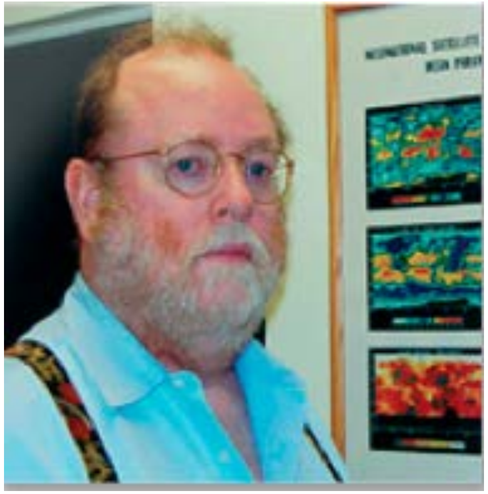
Midlatitude optical thickness increases with temperature were mostly related to increases in cloud physical extent



The synergy of observations and models is necessary to resolve the complexity of cloud feedback processes. This synergy carries with it significant problems, but we have already found some first order solutions.

Problem:	Solution:
• Satellite top-down view vs model layer output	• Instrument simulators – e.g. the ISCCP simulator or the COSP (ISCCP, MODIS, MISR, CloudSat, CALIPSO) simulator package
• Volume of high resolution data and complexity of high resolution model-data comparisons	• Data mining techniques – e.g. clustering, to derive physically meaningful subsets of satellite data and model output

The talks of this symposium constitute an incredibly comprehensive representation of the progress we have made in understanding cloud properties and processes and of the challenges that still lie ahead. Let's keep moving on this path and we can always count on Bill to keep us straight if we stray!



Regime definitions:

1. Using dynamic/thermodynamic parameters

SLP – e.g. Tselioudis et al. 2000
Vertical Velocity – e.g. Tselioudis and Jakob 2002, Bony et al. 2004. Wyant et al. 2006
W-SST-Static Stability combinations – e.g. Norris and Iacobellis 2005, Williams et al. 2006
Large scale circulation proxies – Clement et al. 2009

2. Using cloud parameters

TAU-PC Clustering – e.g. Jakob and Tselioudis 2003, Rossow et al. 2005

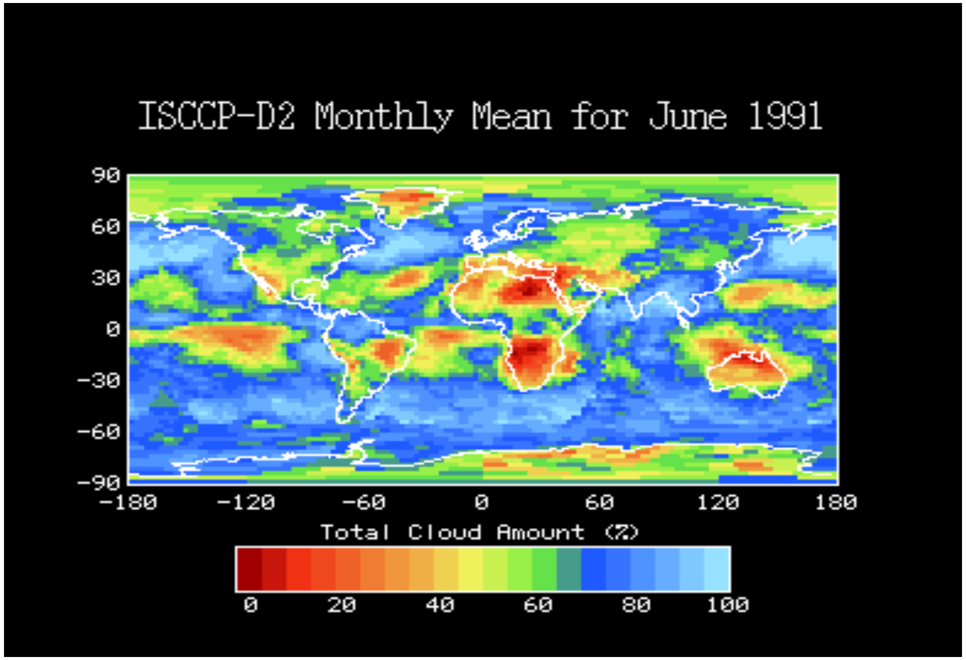
How do we know how regime frequency will change with climate warming?

- *SST increase only reliable bet*
- *GCM projections*
- *Last 30 years as a warming proxy*

Optimizing the use of satellite observations in climate process and climate model evaluation studies

George Tselioudis, William Rossow, Mike Bauer, Cristian Jakob.....

ISCCP (International Satellite Cloud Climatology) Dataset: 3-hourly global cloud property dataset



- Vast majority of model evaluation studies (and many climate process studies) use the monthly mean version of the dataset

- Using monthly means implies that (volume wise at least) 0.4% of the data is used or 99.6% is wasted

The GISS Mystique

"In New York City . . . on a street in the east 40's . . . there's an ordinary tailor shop. Or is it ordinary?"
– The Man from U.N.C.L.E. (1964 television series)

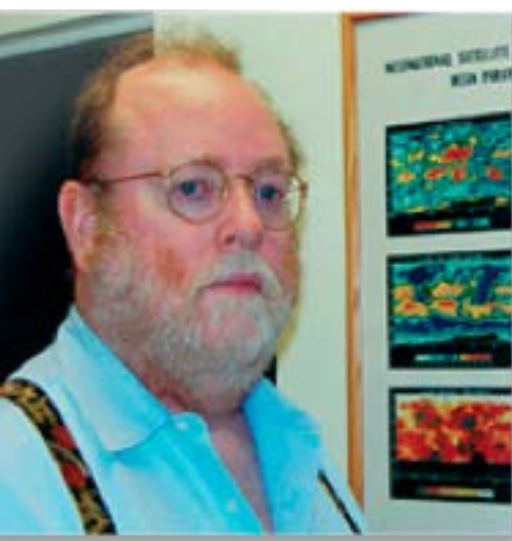
"*2880 Broadway? . . . That's* this *address!*"

–Tom's Restaurant cashier, to a bewildered visiting graduate student, c. June 1981

"*. . . NASA in New York City? That sounds like a dream.*"
– Pascal Lee, planetary scientist – SETI/Ames

"*. . . I'd be really curious about this top-secret operation you have going above Tom's.*"
– Email from a Columbia Astronomy colleague, 2013 Feb 4

Your speaker's NRC Advisor.



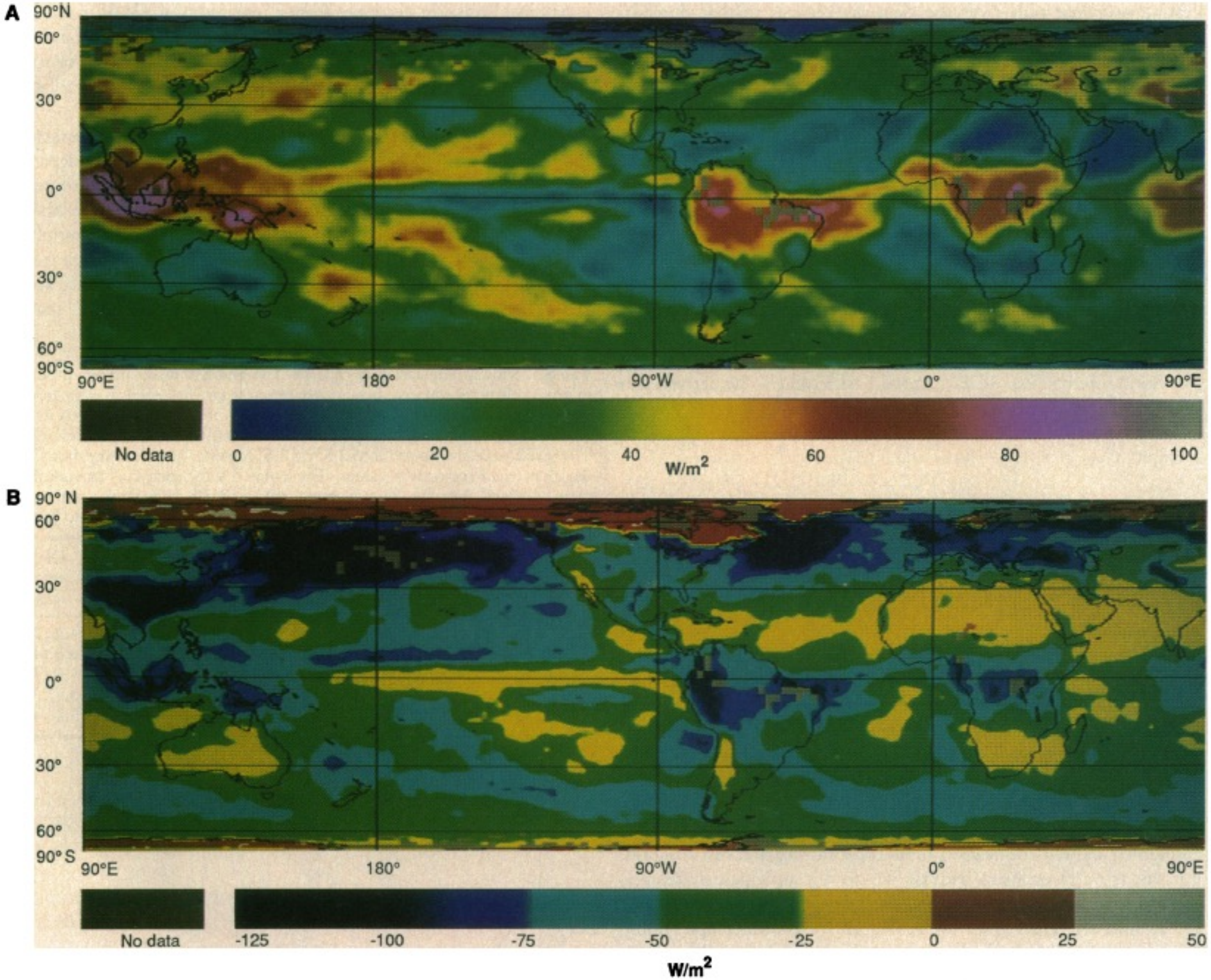


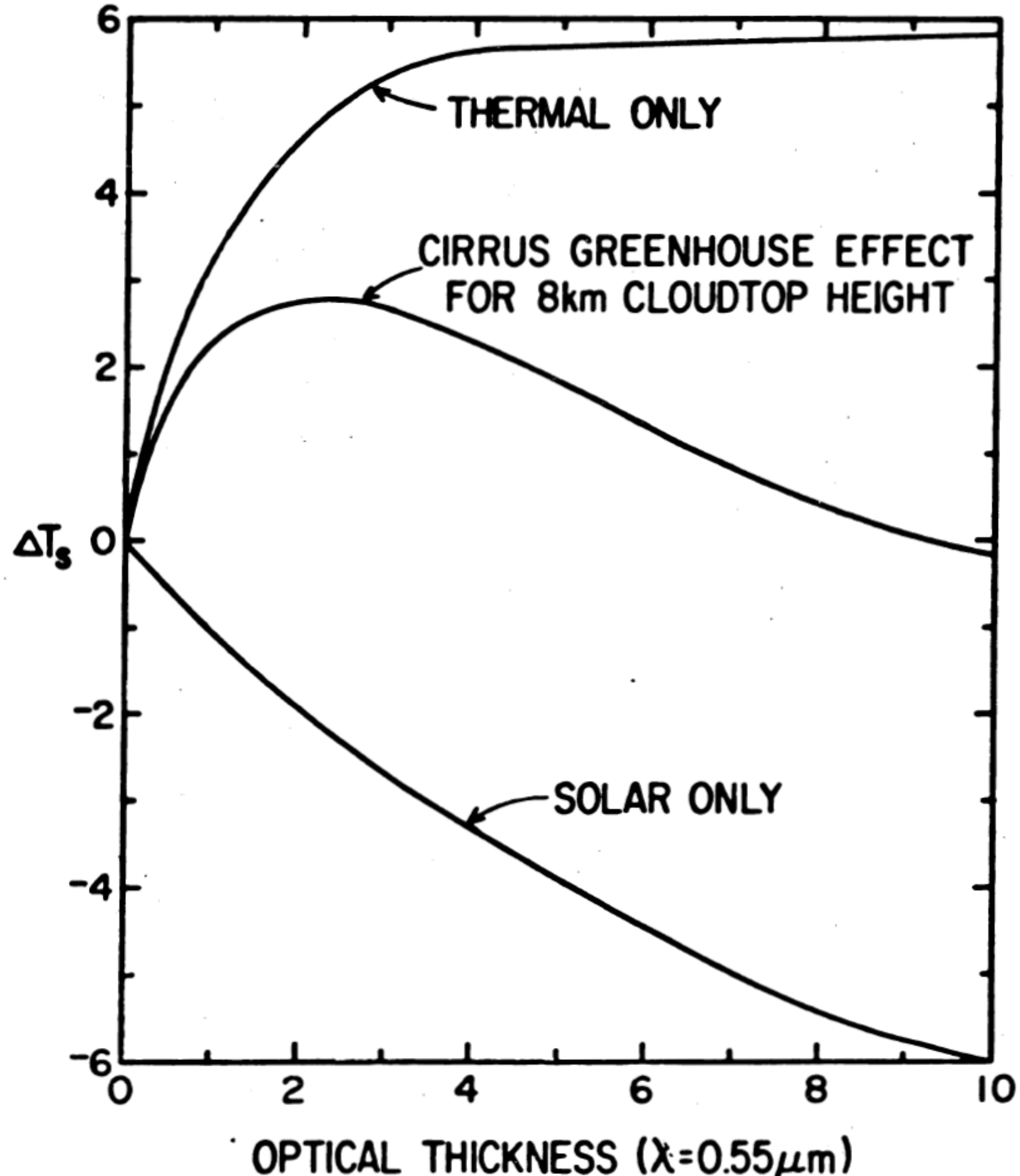
Fig. 3. The LW (**A**) and SW (**B**) cloud forcing for April 1985. The uncertainties in the estimated values are about ±10 W/m². Estimates over snow-covered regions may potentially have larger uncertainties because of difficulty in distinguishing clear from cloudy regions over the bright snow-covered regions.

THE INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT

A 24 year climatology of cloud properties derived from VIS and IR radiances obtained from the operational weather satellites

Cloud properties are derived every three hours thus resolving the diurnal cycle, and the main cloud parameters in the dataset are cloud cover, top temperature/pressure, and optical depth.

Main problems arise from the absolute callibration and the intercallibration of the weather satellites and from the relatively coarse resolution (~30km) of the dataset.



THERMAL ONLY
CIRRUS GREENHOUSE EFFECT
FOR 8km CLOUDTOP HEIGHT
SOLAR ONLY
ΔTs
6
4
2
0
-2
-4
-6
0
2
4
6
8
10
OPTICAL THICKNESS (λ=0.55μm)

Cloud-Radiative Forcing and Climate: Results from the Earth Radiation Budget Experiment

V. RAMANATHAN, R. D. CESS, E. F. HARRISON, P. MINNIS, B. R. BARKSTROM, E. AHMAD, D. HARTMANN

SCIENCE, VOL. 243 6 JANUARY 1989

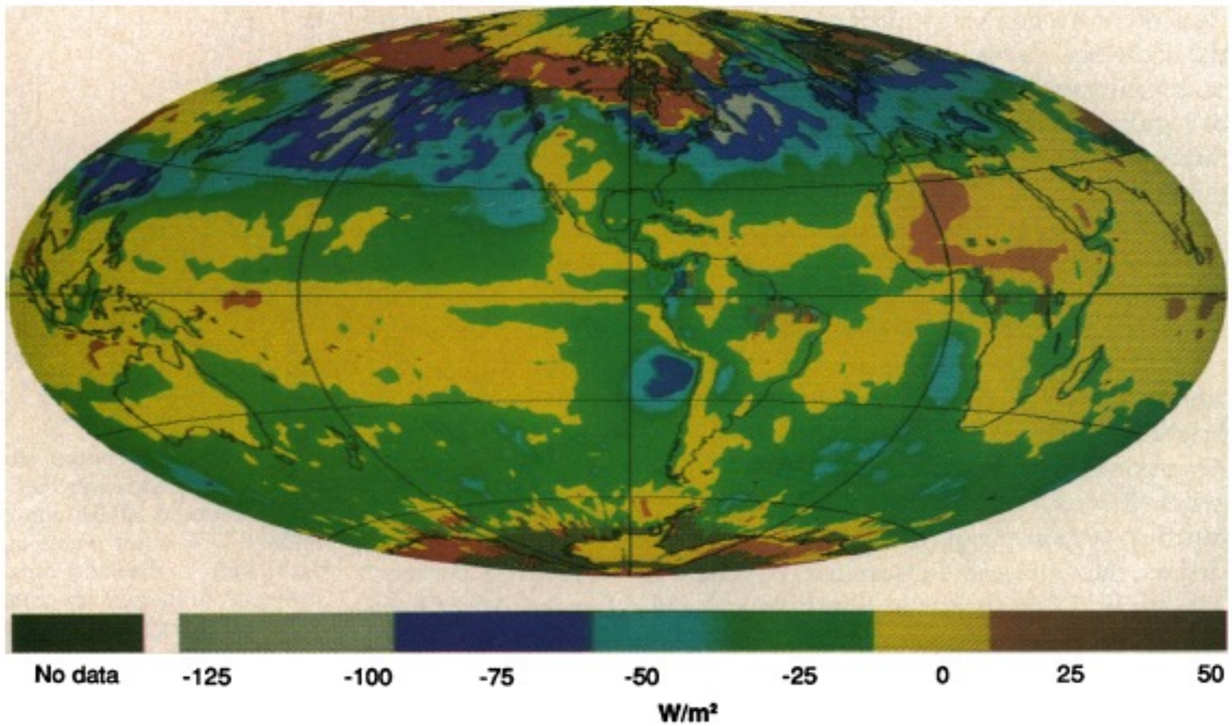
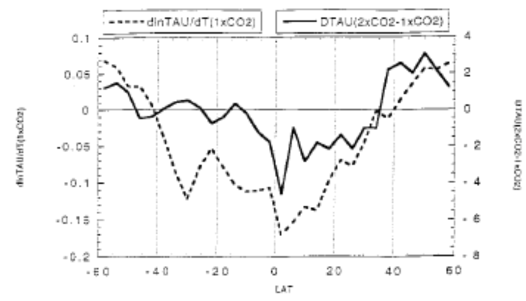


Fig. 4. Net (C_{LW} + C_{SW}) cloud forcing for April 1985. The positive values of cloud forcing, including those seen in North America and in the polar regions, do not exceed 25 W/m^2.

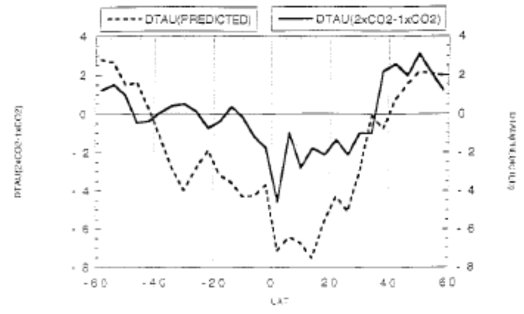
Table 3. Comparison of global cloud forcing estimates in watts per meter squared.

	ERBE data (W/m^2)				GCM's†
	April 1985	July 1985*	October 1985*	January 1986*	
C_{LW}	31.3	30	32	30.6	23 to 55
C_{SW}	−44.5	−46.4	−49.4	−51.9	−45 to −74
C	−13.2	−16.4	−17.4	−21.3	+1 to −34

*Analysis not completed for these months. †On the basis of a summary of six model studies (*16*) for model simulations with January and July boundary conditions.



dlnTAU/dT(1xCO2)
DTAU(2xCO2-1xCO2)
LAT



DTAU(PREDICTED)
DTAU(2xCO2-1xCO2)
LAT