Process Studies to Improve Radiative Transfer Models

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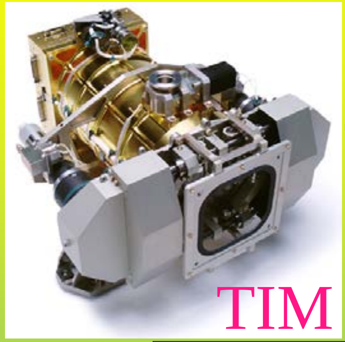
Proj Scientist for: SORCE, 3DRT (I3RC) and THOR

Chair, CCSP Observations Working Group

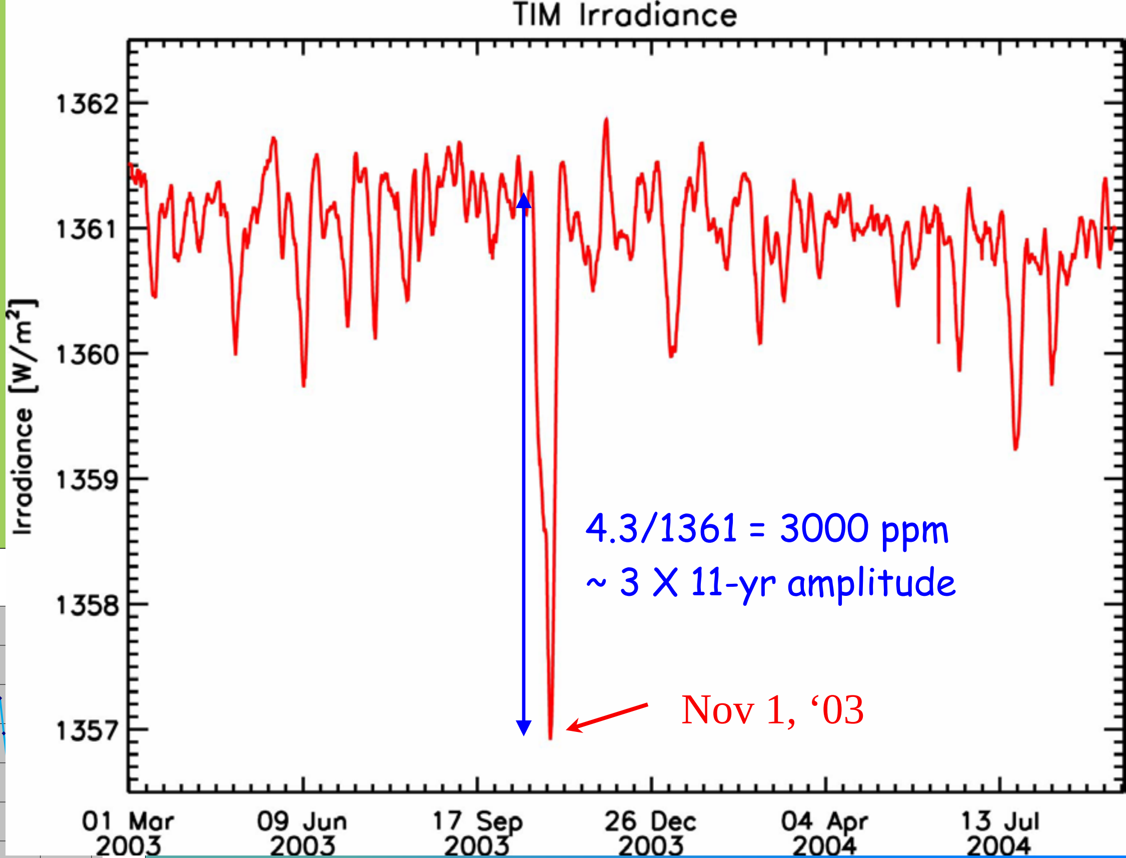
“Provide for continuity of solar and Earth-emitted radiation budget observations at the top-of-atmosphere and surface, to continue the satellite record that began with Nimbus-7 in 1978, continues with current Earth Observing System platforms, and is planned to be extended by NPOESS satellite missions beginning after 2010. Equally important is to maintain the related network of surface stations such as the Baseline Surface Radiation and Atmospheric Radiation Measurement sites.”

-- http://iwgeo.ssc.nasa.gov/ Appendix 3

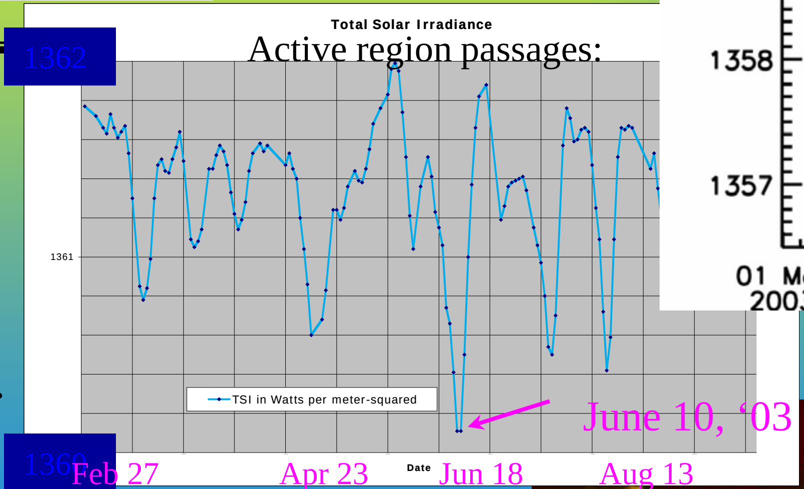
Solar Energy Variations



Greg Kopp, UCO/LASP
TIM Instrument Scientist

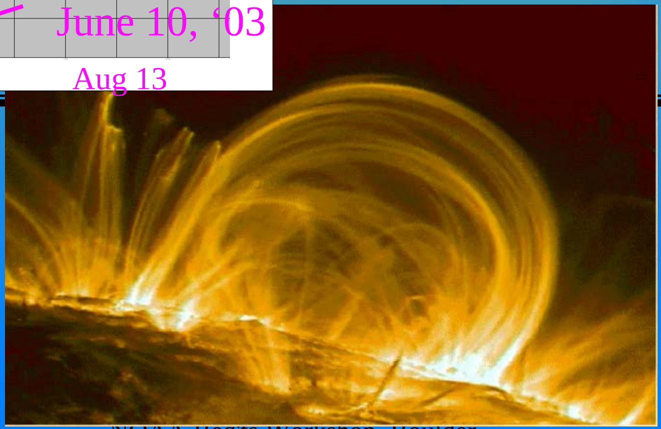


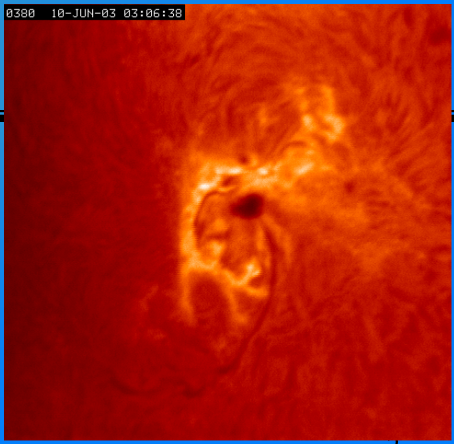
June 2003: Sun highly active.



TRACE

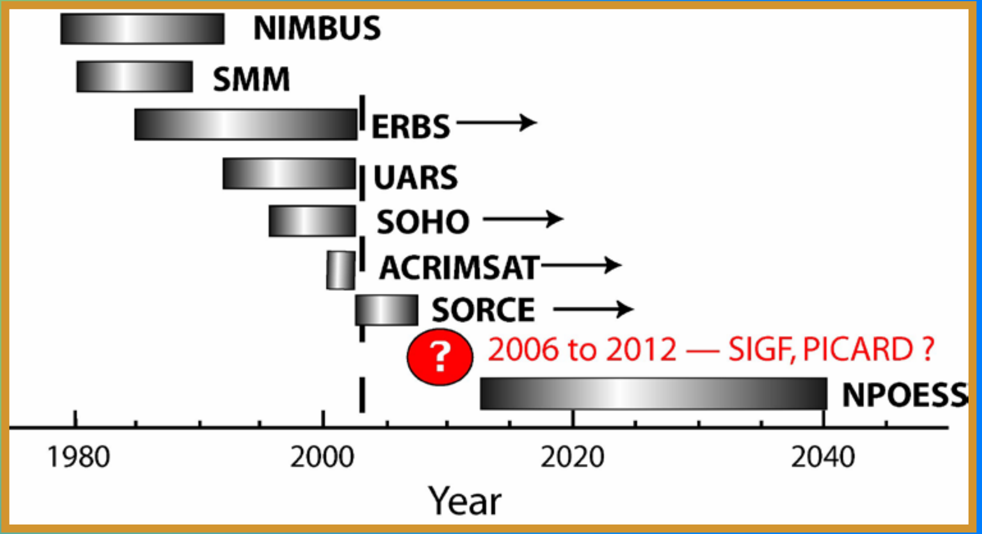
LHS - magnetic field in EUV. RHS - He 380 nm "S" precedes CME.





Solar Irradiance Measurement Program

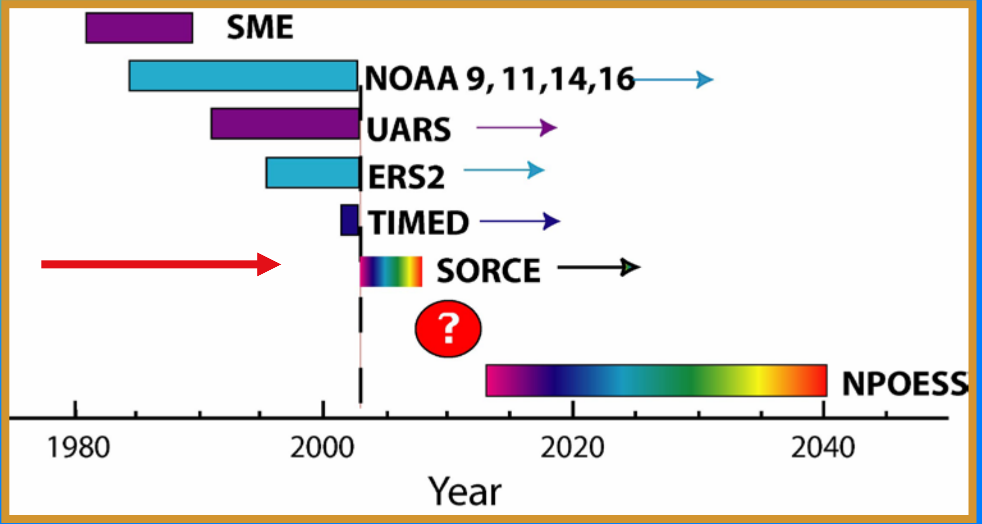
TSI Observations



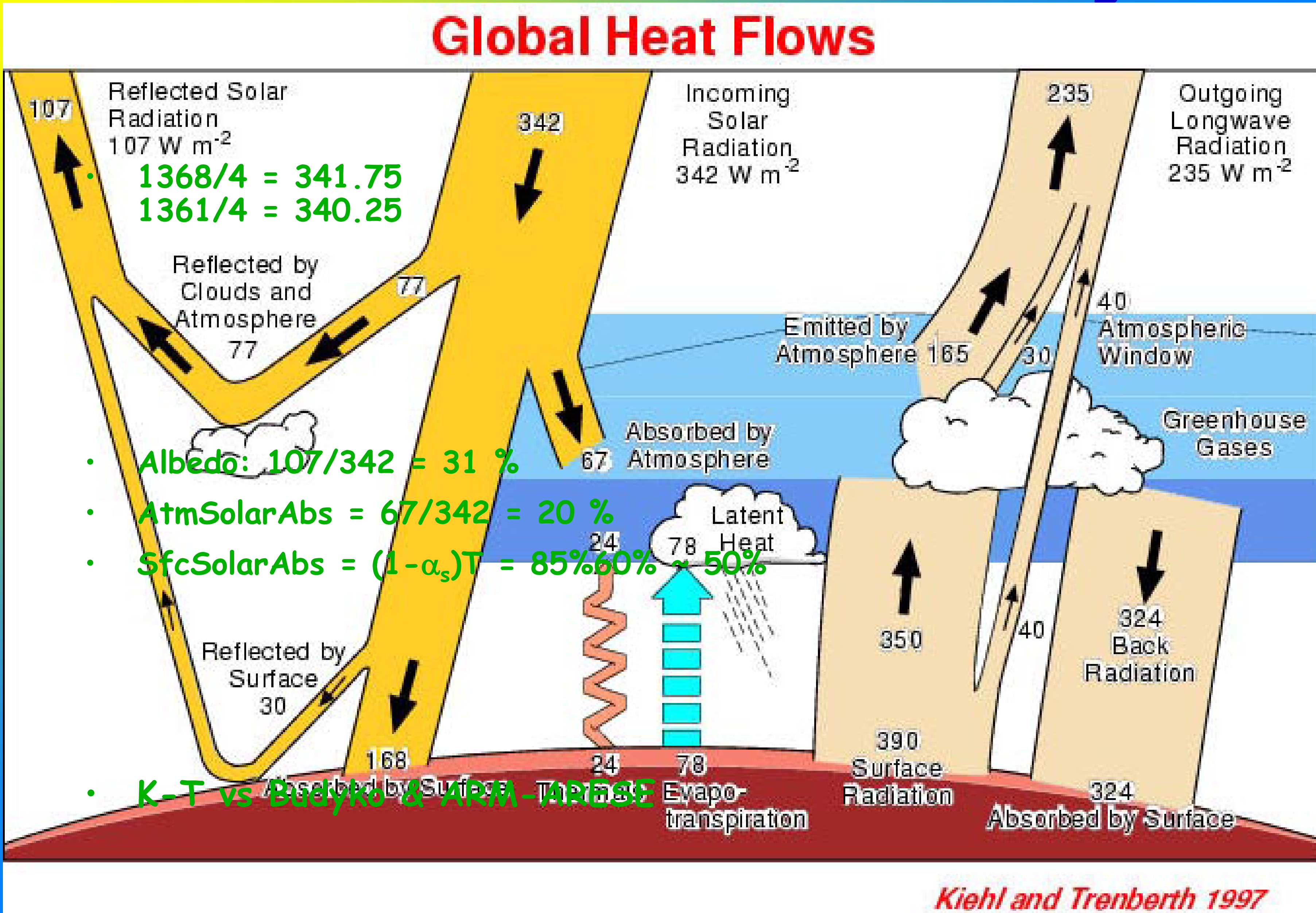
SORCE *may* overlap GLORY during solar min
Solar min *crucial* for trend
Glory *less likely* to overlap NPOESS
Glory so far includes *only TSI*, no *SSI*

UV Observations

First full spectral Observations



Radiation Budget



- 1368/4 = 341.75
  1361/4 = 340.25
- Albedo: 107/342 = 31 %
- AtmSolarAbs = 67/342 = 20 %
- SfcSolarAbs = $(1-\alpha_s)T$ = 85%60% ~ 50%
- K-T vs Budyko & ARM-ARESE

1995 trio of Science papers that re-ignited a historical brouhaha

Warm Pool Heat Budget and Shortwave Cloud Forcing: A Missing Physics?

V. Ramanathan,* B. Subasilar, G. J. Zhang, W. Conant, R. D. Cess, J. T. Kiehl, H. Grassl, L. Shi

Ship observations and ocean models indicate that heat export from the mixed layer of the western Pacific warm pool is small (<20 watts per square meter). This value was used to deduce the effect of clouds on the net solar radiation at the sea surface. The inferred magnitude of this shortwave cloud forcing was large (≈ −100 watts per square meter) and exceeded its observed value at the top of the atmosphere by a factor of about 1.5. This result implies that clouds (at least over the warm pool) reduce net solar radiation at the sea surface not only by reflecting a significant amount back to space, but also by trapping a large amount in the cloudy atmosphere, an inference that is at variance with most model results. The excess cloud absorption, if confirmed, has many climatic implications, including a significant reduction in the required tropics to extra-tropics heat transport in the oceans.

Absorption of Solar Radiation by Clouds: Observations Versus Models

R. D. Cess, M. H. Zhang, P. Minnis, L. Corsetti, E. G. Dutton, B. W. Forgan, D. P. Garber, W. L. Gates, J. J. Hack, E. F. Harrison, X. Jing, J. T. Kiehl, C. N. Long, J.-J. Morcrette, G. L. Potter, V. Ramanathan, B. Subasilar, C. H. Whitlock, D. F. Young, Y. Zhou

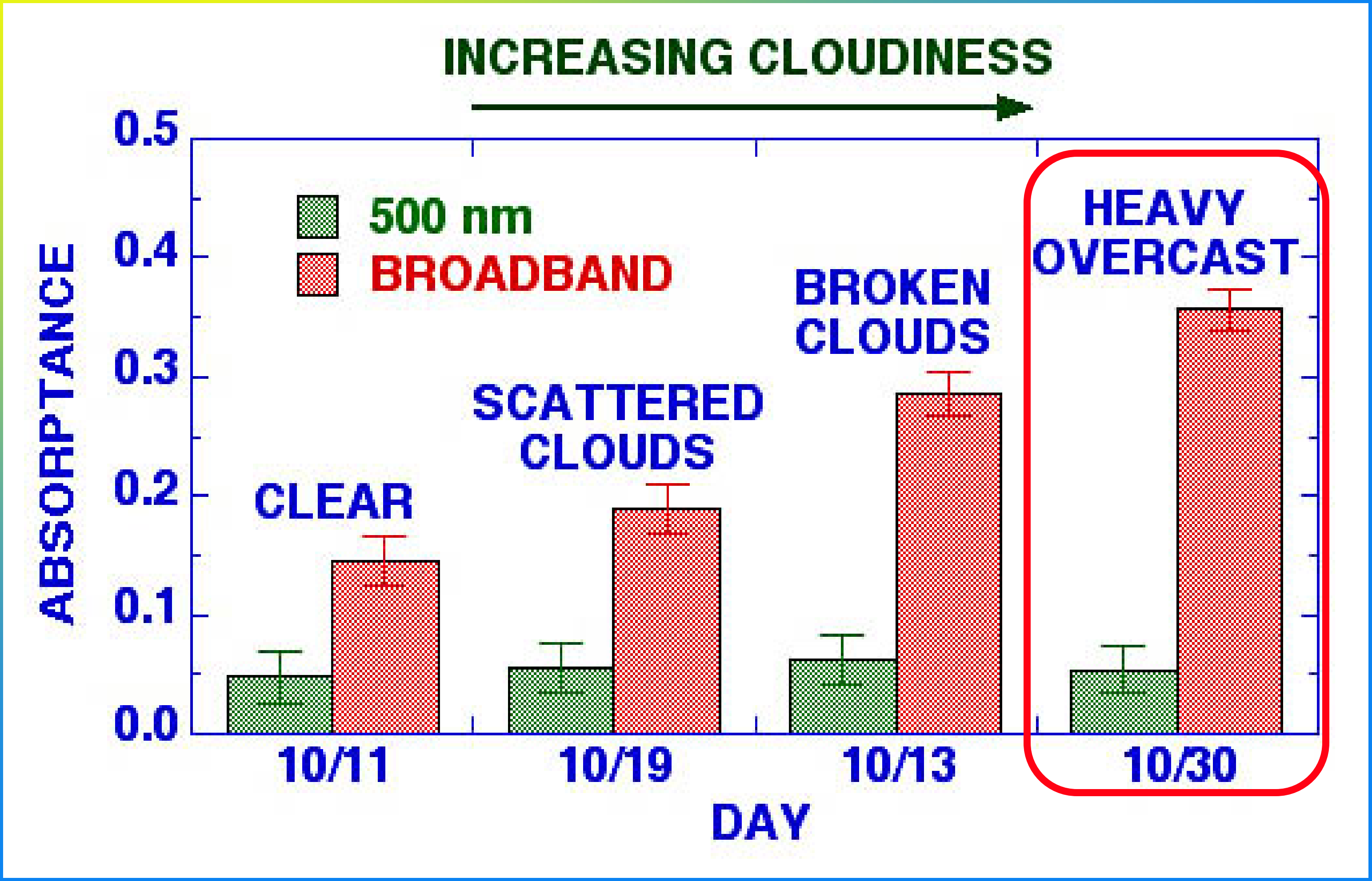
There has been a long history of unexplained anomalous absorption of solar radiation by clouds. Collocated satellite and surface measurements of solar radiation at five geographically diverse locations showed significant solar absorption by clouds, resulting in about 25 watts per square meter more global-mean absorption by the cloudy atmosphere than predicted by theoretical models. It has often been suggested that tropospheric aerosols could increase cloud absorption. But these aerosols are temporally and spatially heterogeneous, whereas the observed cloud absorption is remarkably invariant with respect to season and location. Although its physical cause is unknown, enhanced cloud absorption substantially alters our understanding of the atmosphere's energy budget.

Direct Observations of Excess Solar Absorption by Clouds

Peter Pilewskie* and Francisco P. J. Valero

Aircraft measurements of solar flux in the cloudy tropical atmosphere reveal that solar absorption by clouds is anomalously large when compared to theoretical estimates. The ratio of cloud forcing at an altitude of 20 kilometers to that at the surface is 1.58 rather than 1.0, as predicted by models. These results were derived from a cloud radiation experiment in which identical instrumentation was deployed on coordinated stacked aircraft. These findings indicate a significant difference between measurements and theory and imply that the interaction between clouds and solar radiation is poorly understood.

ARESE I (Oklahoma ARM site, Fall 1995) exacerbated the controversy



M. Budyko (1920-2001)

Theme …	Decades …
1. Moisture Evap, Precip, Runoff	1940's – 50's
2. Energy Albedo, Atmos, Sfc	1950's – 60's
3. Feedback Ice (+), Cloud (-)	1960's – 70's
4. Global Warming & Life	1970's – 90's

Budyko's Bucket: Soil Capacitance, Physical and ***Bio***-physical

"…The total flux reaching the outer boundary of the troposphere is about 1000 kcal/cm^2/yr. Due to the spherical form of the earth .. on the average 1/4., I.e. 250 kcal/cm^2/yr.

Assuming the earth's albedo as α_s = 0.33, we find short-wave radiation absorbed …167 kcal/cm^2/yr."

☝ X 1.3327 ☞ 222 *W/m^2*

Quantity …	Budyko …	Kiehl & Trenberth…
Qo	**333**	**342 (+9)**
α_s **Qo**	**111**	**107 (-4)**
(1-α_s) Qo	**222**	**235 (+13)**
Atmos Abs	***55***	***67 (+12)***
Sfc Abs	167	168 (+ 1)

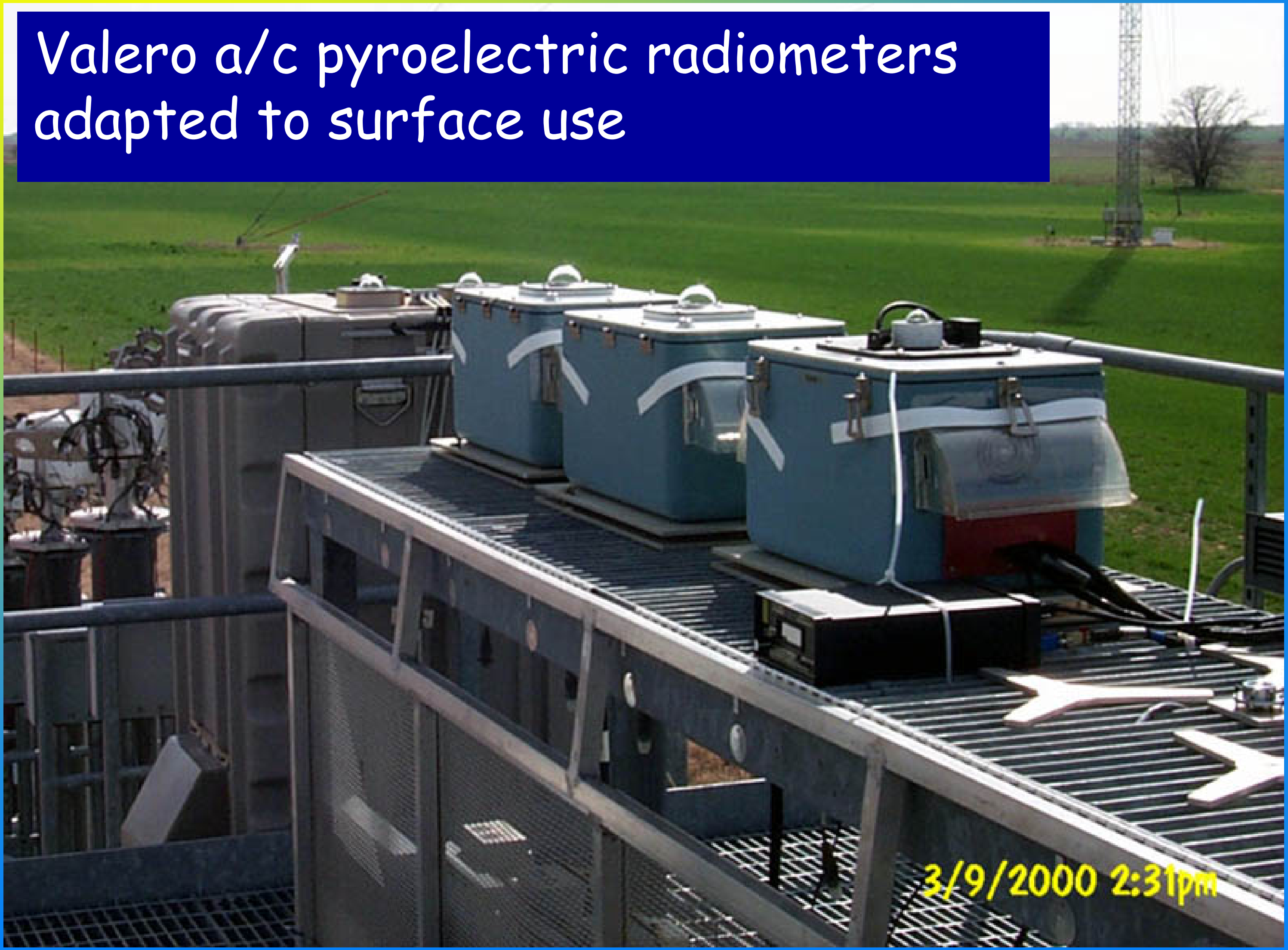
"The precision of these data is of importance in the study of climate."

New research was stimulated by the enhanced cloud absorption controversy

- Eppley pyranometer, had thermal offsets
- Kipp & Zonen increasingly competitive
- Thermistors added to aid understanding of dome temp sensitivity
- Design revived to deal with bias in diffuse flux

New kinds of radiometers were developed

Valero a/c pyroelectric radiometers adapted to surface use

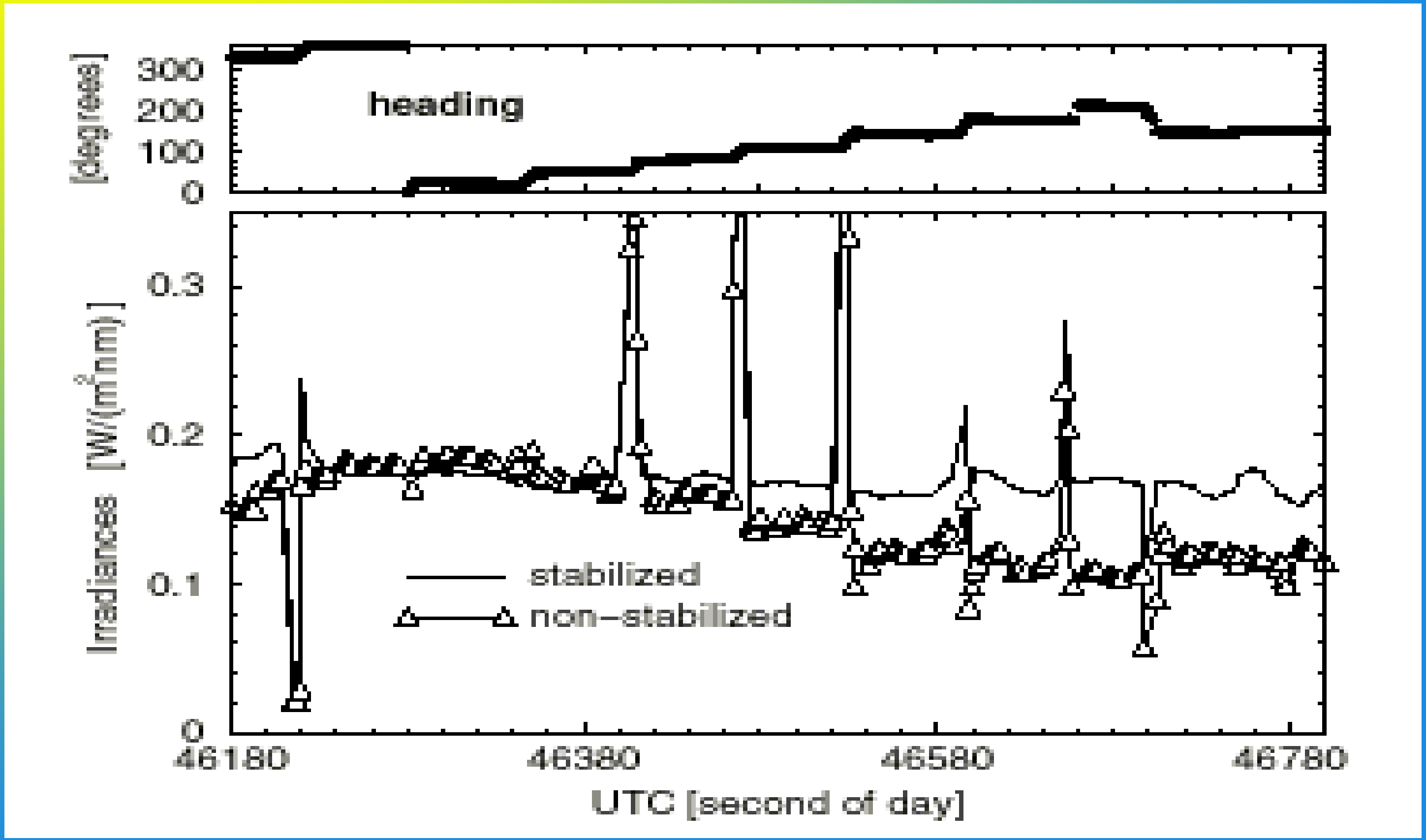


We learned to take better care of our radiometers...

Tom Stoffel, NREL, Golden CO.

Multiple radiometers were compared side-by-side on sfc and aircraft …

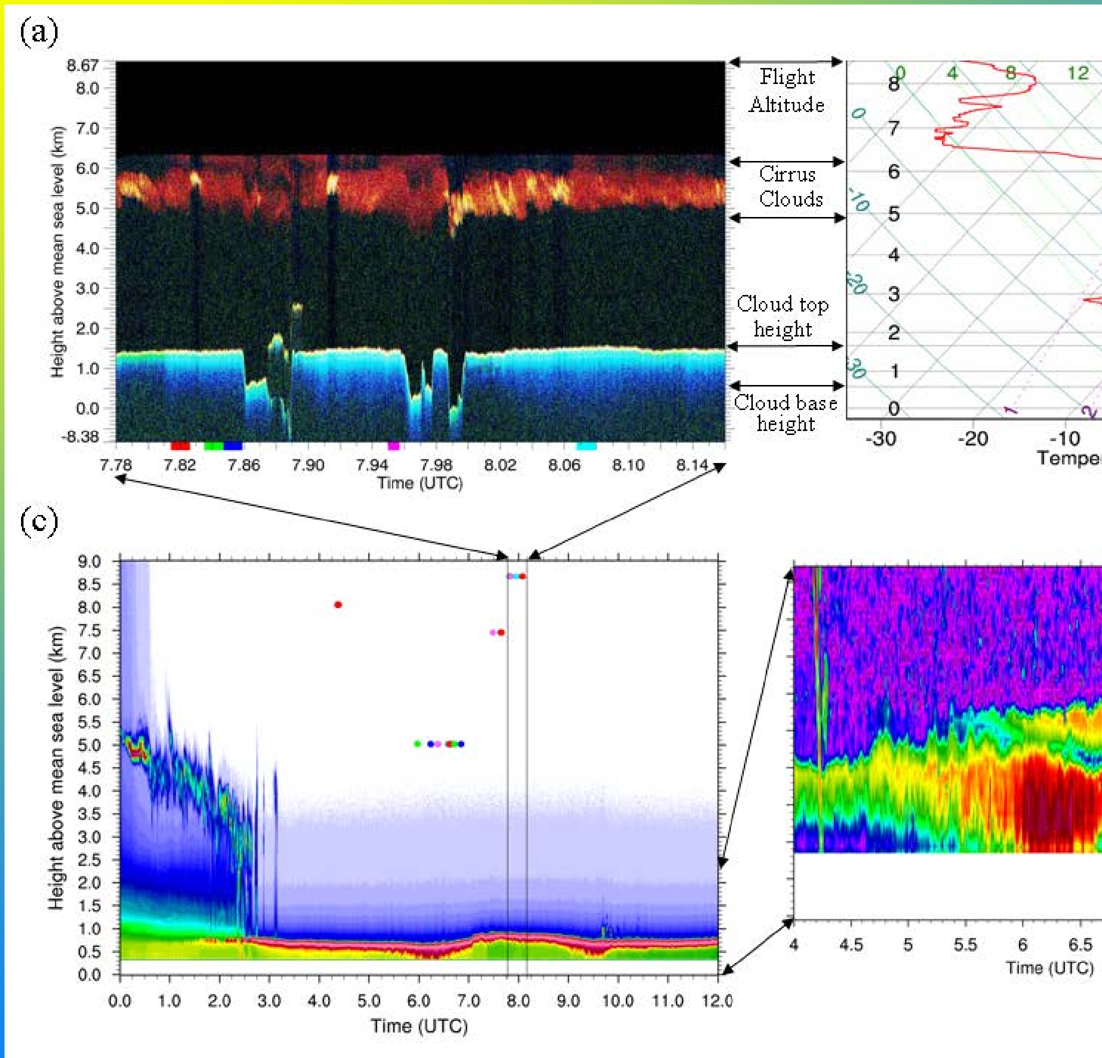
The Germans began precise levelling of airborne flux radiometers (Wendisch, et al, 2001)



DOE/ARM quickly followed suit...

Comparison of downwelling spectral irradiances at 700 nm measured by leveled and non- leveled radiation sensors.

3D Effects: loosely, horizontal fluxes

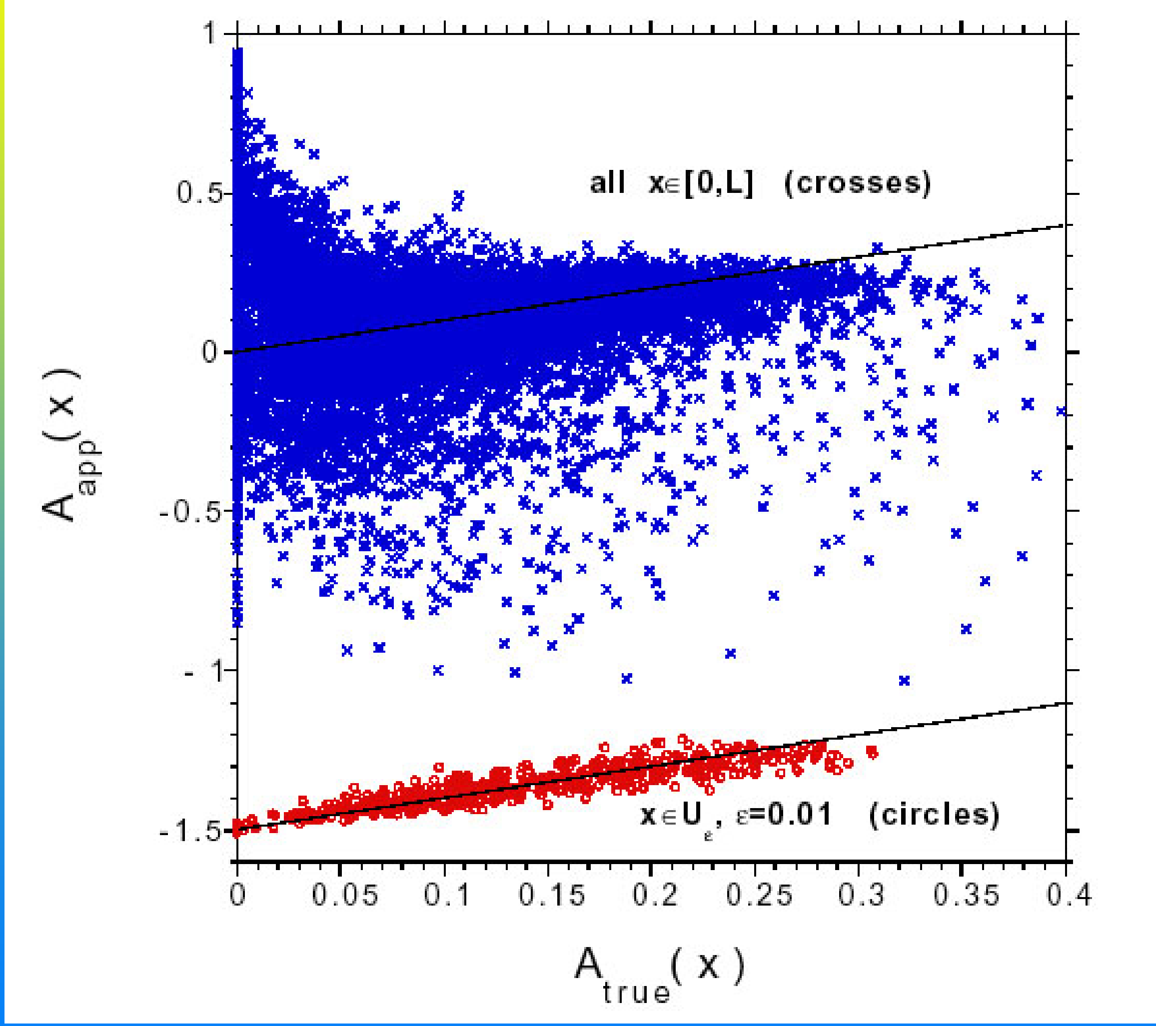


- Some thought 3D effects would “explain enhanced absorption”
- 3D solved several problems, but turned out 3D did *not* fully explain absorption observations
- But …
  - 3D simulations helped improve flight plans
- And new instruments were designed that exploit 3d effects

“Corrections” for 3D effects

- Ackerman-Cox (1981): bitter controversy developed around this method of “correcting” a/c fluxes for 3D effects
- Japanese used the method
- Ramanathan took advantage of Arrhenius centennial volume to denounce Ackerman-Cox

Marshak discovered an intelligent way to sub-sample a/c fluxes to get absorption right



avoids Ackerman-Cox "correction"

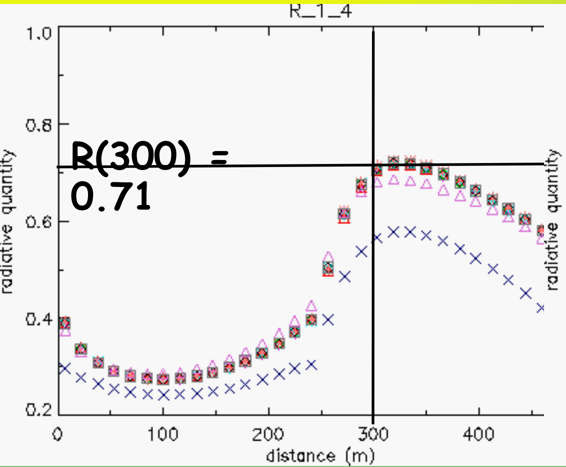
Step Cloud: R, T, A, and…

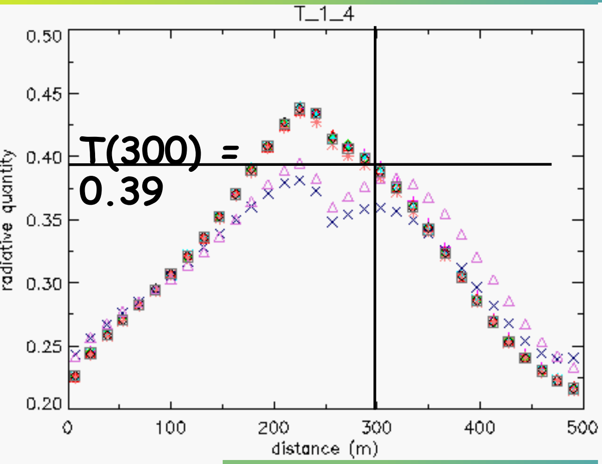
R = 0.71

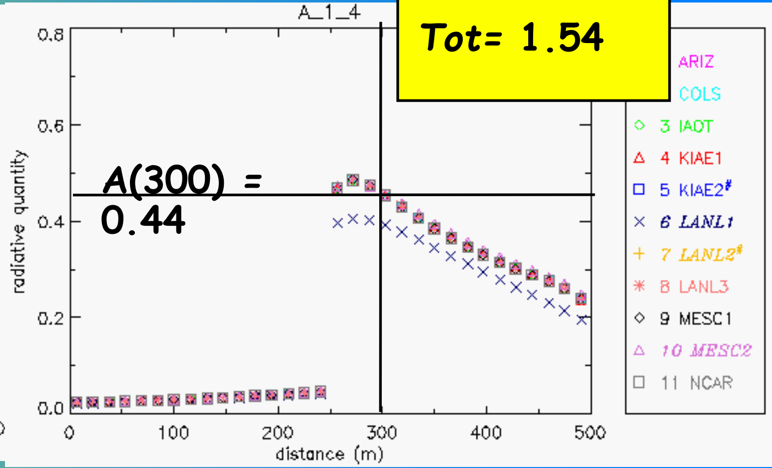
T = 0.39

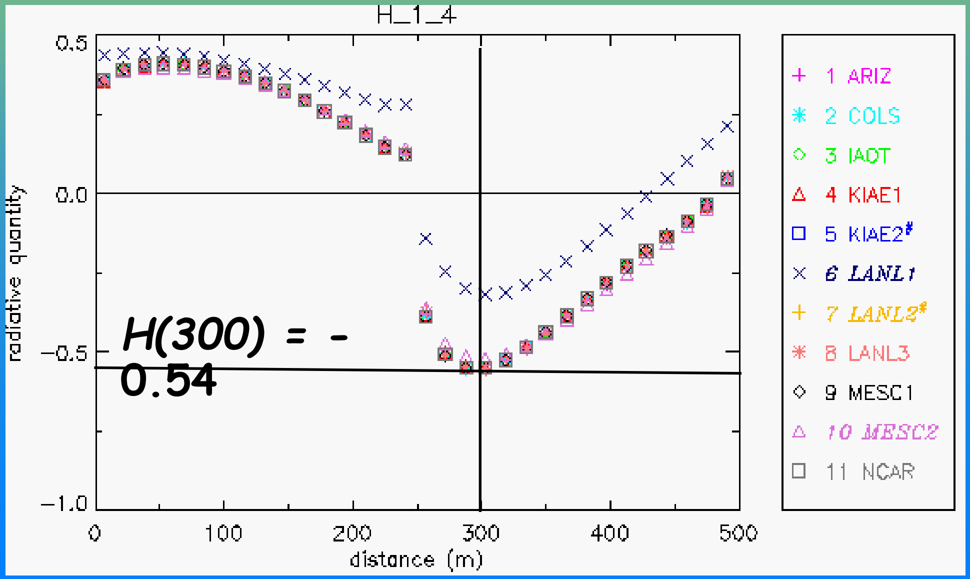
<u>A = 0.44</u>

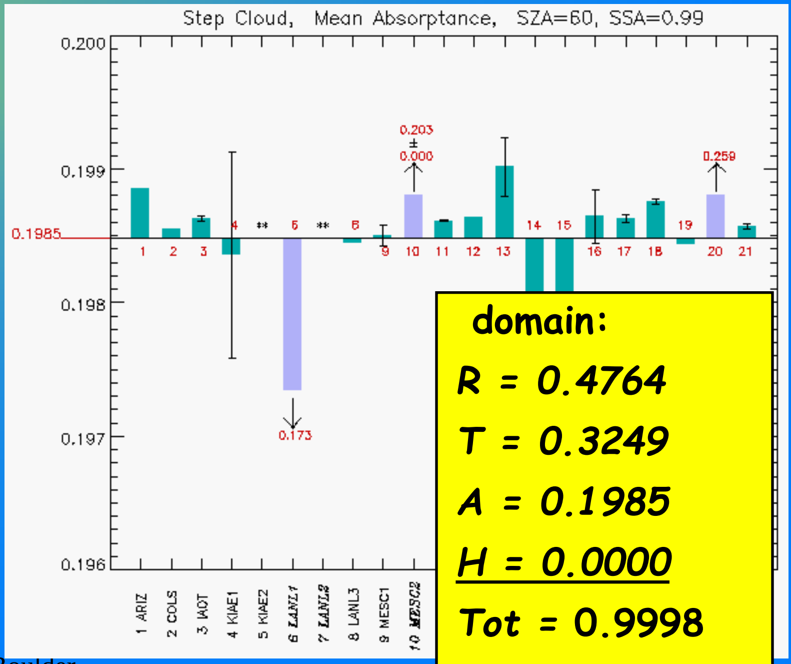
Tot= 1.54











domain:

R = 0.4764

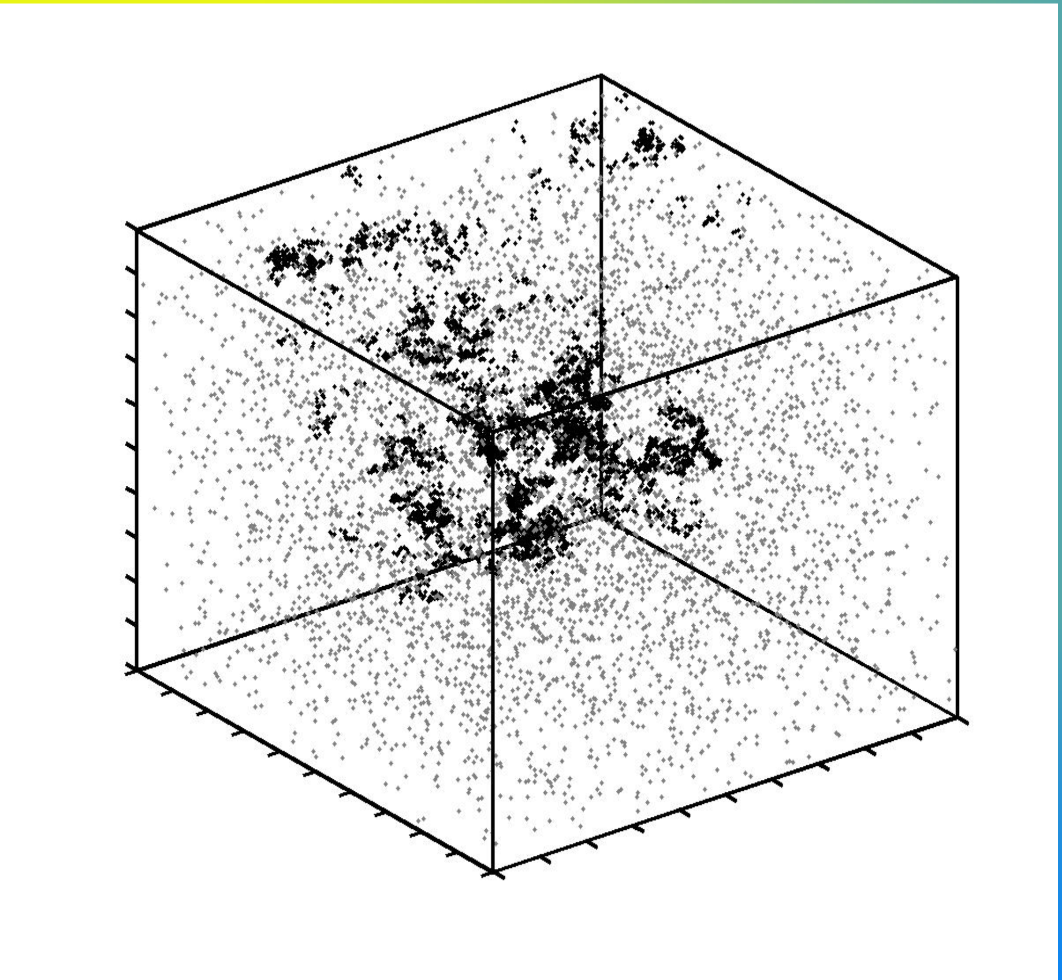
T = 0.3249

A = 0.1985

<u>H = 0.0000</u>

Tot = 0.9998

Drop clustering as an absorption-enhancer

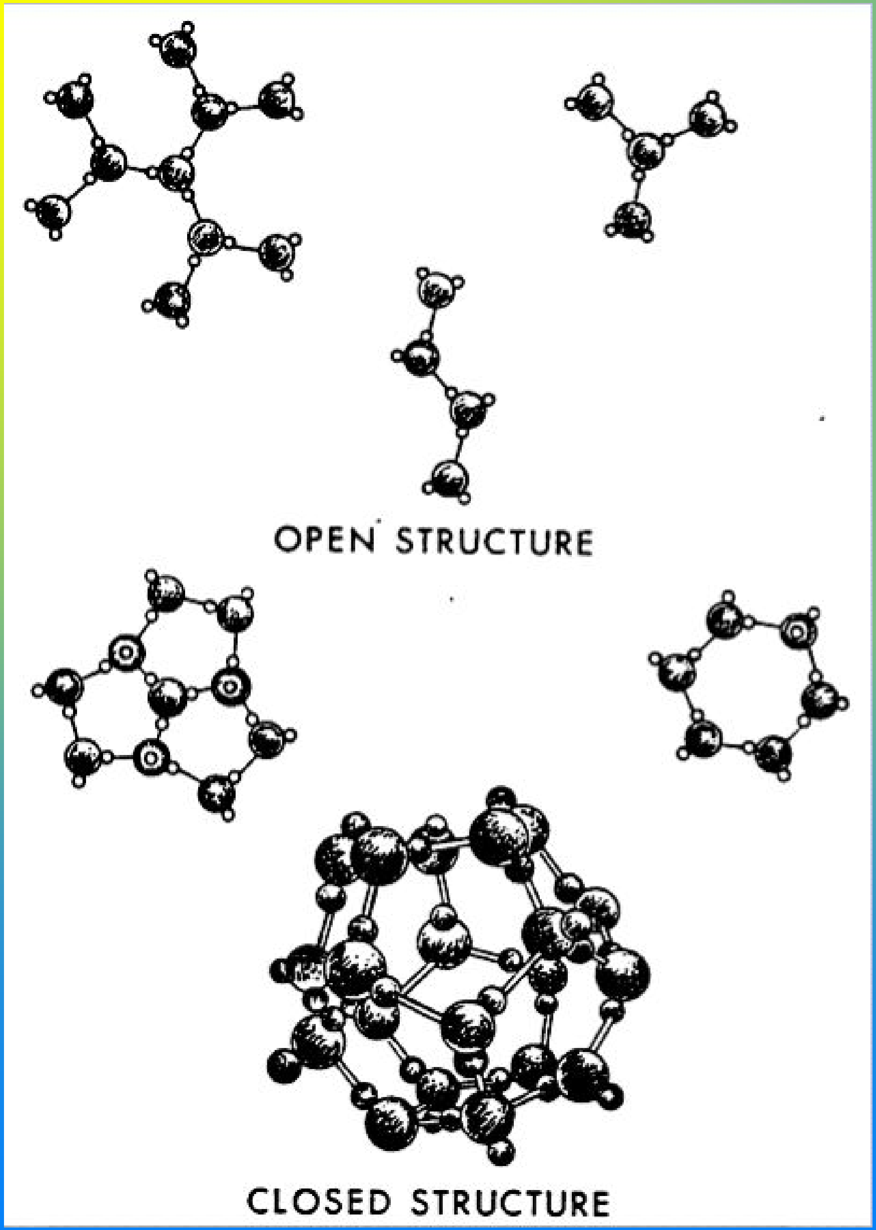


Number of drops n in a volume V turns out not to be linearly proportional to V if drops are over 14 microns:

$$\bar{n}(r,V) = \rho(r)V^{D(r)}$$

Black carbon in clouds

- Chylek pursued this more doggedly than anyone, but in the end had to conclude there wasn't much effect ... for realistic carbon amounts

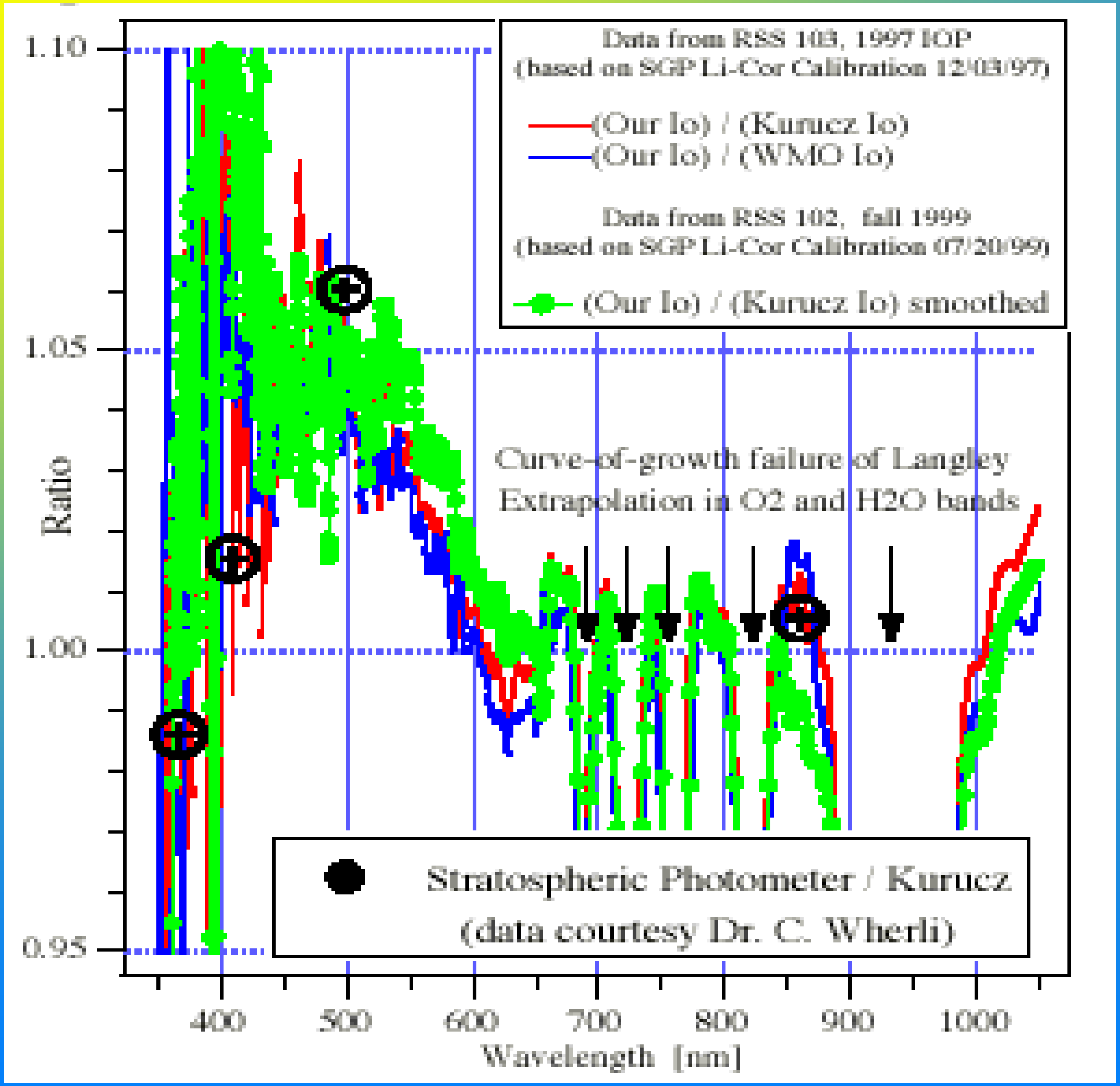


Water clusters

Chylek did massive quantum mechanical calculations for water dimers.

Solomon looked for their effect with visible spectroscopy and concluded they are present in too low concentrations to absorb significantly

Ratio, Langley I_0 to standard I_0 vs. wavelength (Harrison)

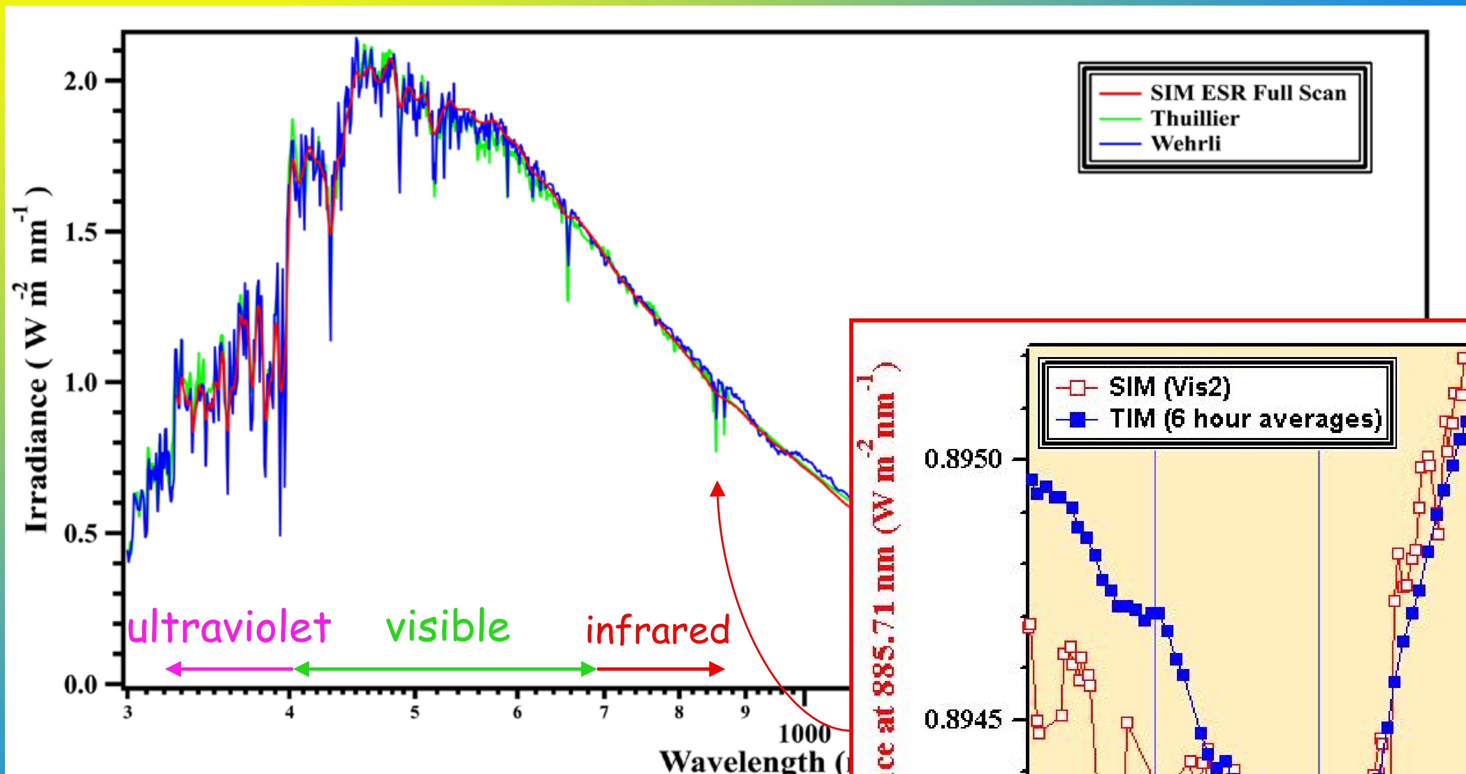


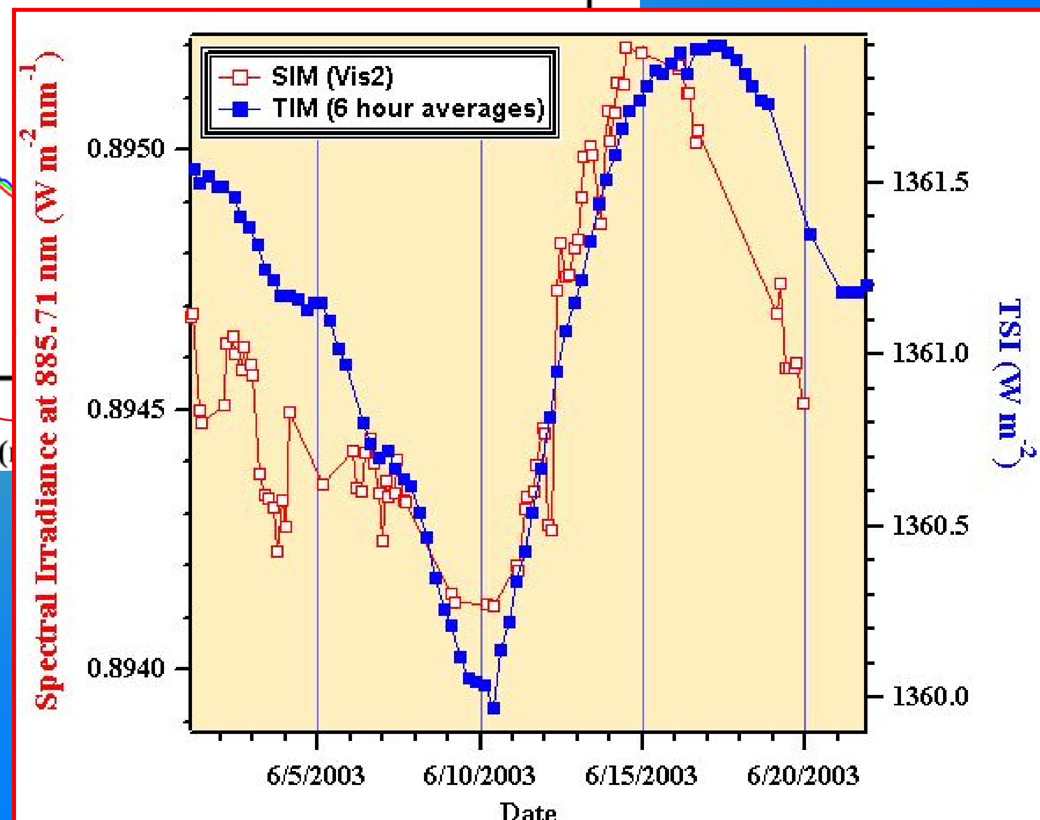
The accepted Extraterrestrial Solar Spectrum I_0 was challenged...

4-5% disagreements in visible region

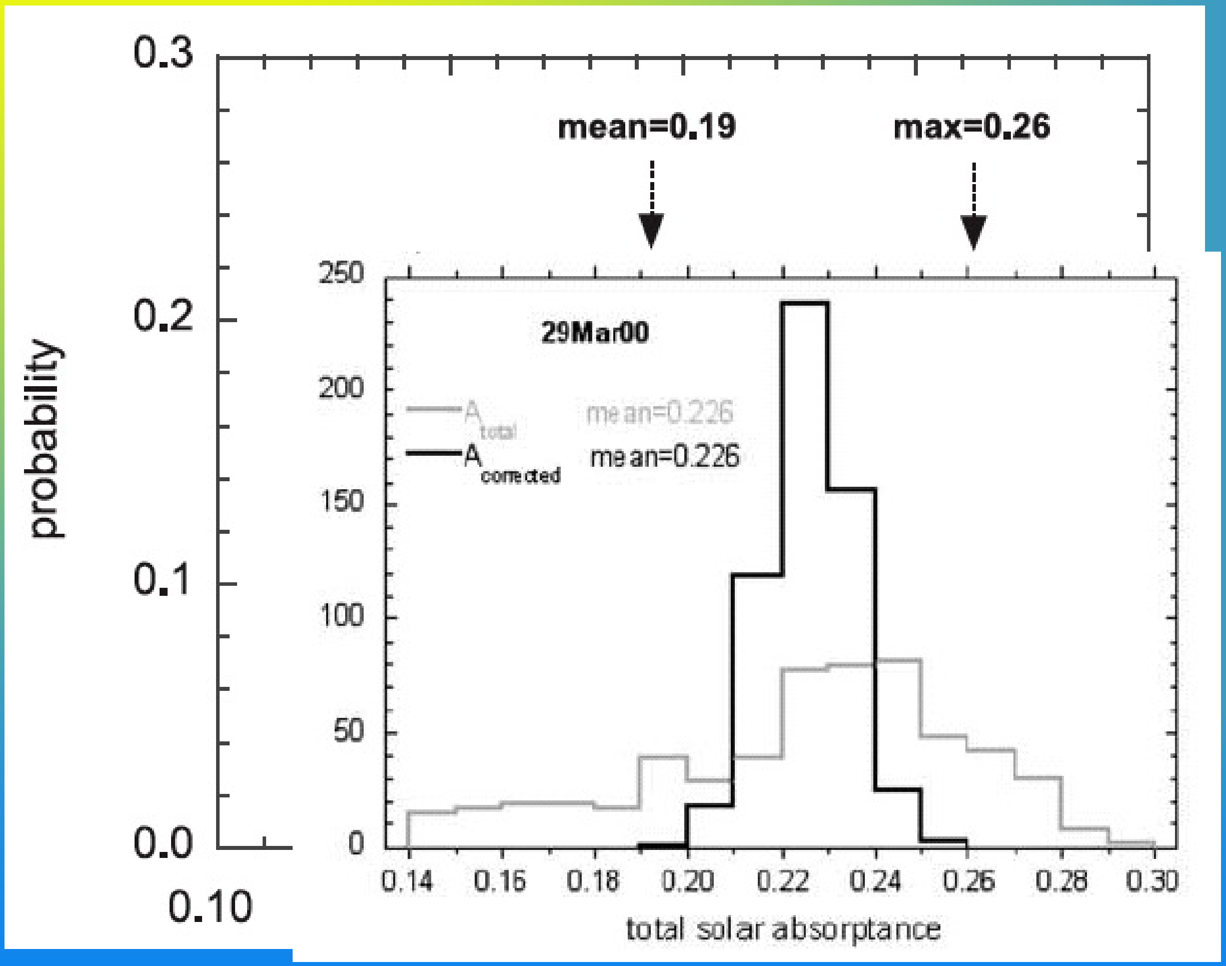
SIM – Spectral Irradiance Monitor

Jerry Harder, SIM Instrument Scientist, UCO/LASP





Valero et al. (2003): "23-28% is obtained from a/c and satellite observ'ns"



- Prob. dist'n of daily mean absorptance for column over ARM Oklahoma site, 1979-1998, NCAR model

- 10-sec-avg absorptance from a/c meas'ts, 29 Mar 2000, with and without the Marshak correction

Sources of atmospheric absorption

neglected in current climate models

- *"Large" drops & drop clustering*
- *Water vapor weak lines, extra continuum*
- *Black carbon, other absorbing aerosol*
- *3-D Cloud Effects*

Above "Non-exotic" sources ~ 1-2 W/m^2 each.

Goal: reduce *in situ* uncertainties to < O(1 W/m^2). This requires:

- Aircraft (& sfc!) navigation to better than 0.1° pitch, roll, 10 m location
- Aircraft (& sfc!) T, T_d & other "environment" monitoring
- Side-by-side "blind" calibration intercomparisons
- Thoroughly documented transfer functions (spectral, angular, etc)
- Extensive sampling (Are flight hours *really* getting cheaper?)
- Program of continuous monitoring, and continuous improvement.
- Some funding *after* requirements are verified, as intended in "Longitude"
- Instruments tested extensively in lab & in flight, with trained *human* observers.

Group on Earth Observations (GEO) 10 Year Plan

Within 10 years, a well-funded and sustained capacity building strategy will have significantly strengthened the capability of all countries, and particularly of developing countries, to:

- Use Earth observation data and products (e.g., process, integrate, model) following accepted standards;
- Contribute to, access, and retrieve data from global data systems and networks;
- Analyze and interpret data to enable development of decision-support tools;
- Integrate Earth observation data and products with those from non-Earth-observation sources, for a more complete view and understanding of problems and derived solutions;
- Develop the necessary infrastructure development in areas of poor observational coverage;
- Develop recommended priorities for new or augmented efforts in capacity building.