DISCREPANCY IN AEROSOL FORCING OF DIFFUSE DOWNWELLING SHORTWAVE IRRADIANCE

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References: *JGR* **105**, 20165 (2000); *GRL* **25**, 3591 (1998); *JGR* **102**, 29991 (1997)

Acknowledgment: DOE Atmospheric Radiation Measurement (ARM) Program ARM

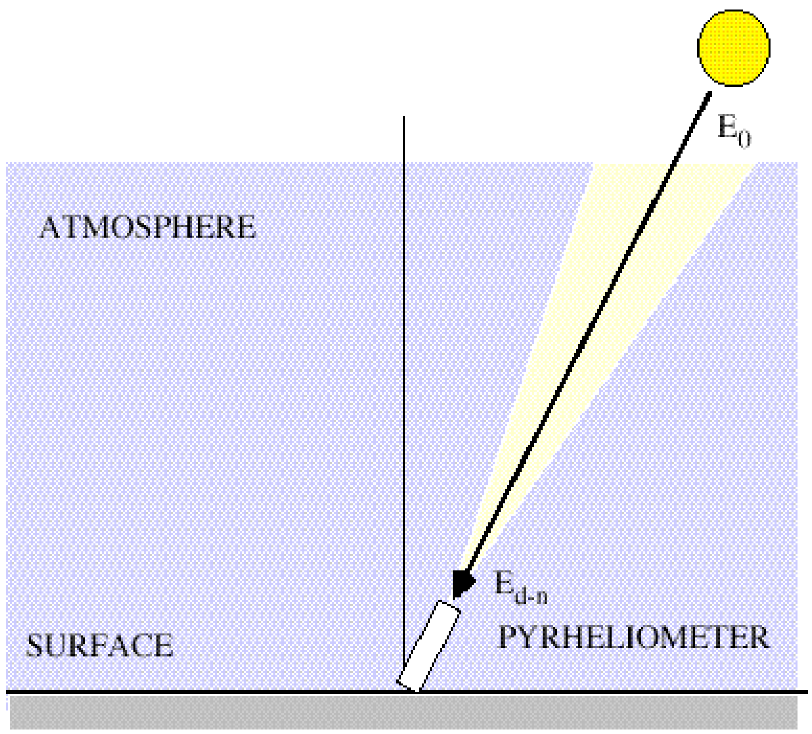
OBJECTIVES

- ***Compare*** measured and modeled shortwave radiation components.
- ***Test ability to model*** radiation components, especially aerosol influences.
- ***Identify problems*** in measurements and/or understanding.

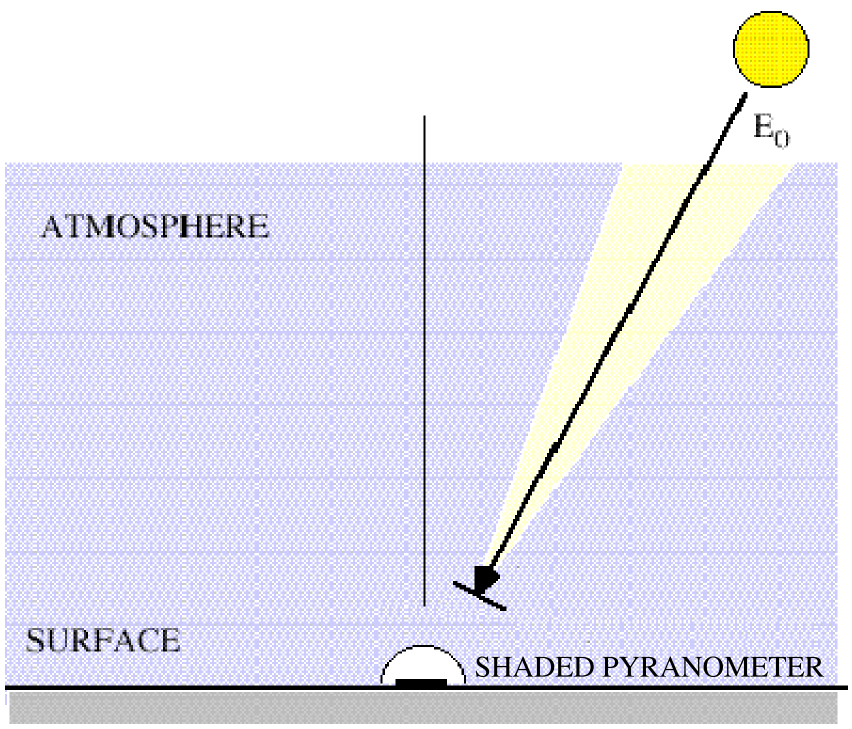
TWO CLOSURE EXPERIMENTS

Compare measured and modeled irradiance components

Direct Normal Solar Irradiance
DNSI



Diffuse Downwelling Irradiance
DDI



DNSI CLOSURE EXPERIMENT

Direct Normal Solar Irradiance (DNSI):

Measure: Normal incidence pyrheliometer, Active cavity radiometer

Model: $\text{DNSI} = \int E_0(\lambda)\exp(-\tau_\lambda)d\lambda$

$E_0(\lambda)$ = solar spectral irradiance at top of atmosphere: *Kurucz* (1995)

$$\tau_\lambda = \tau_{\text{Rayleigh}} + \tau_{\text{water}} + \tau_{\text{ozone}} + \ldots + \tau_{\text{aerosol}}$$

Gaseous absorption: FASCODE (1997) via MODTRAN-3

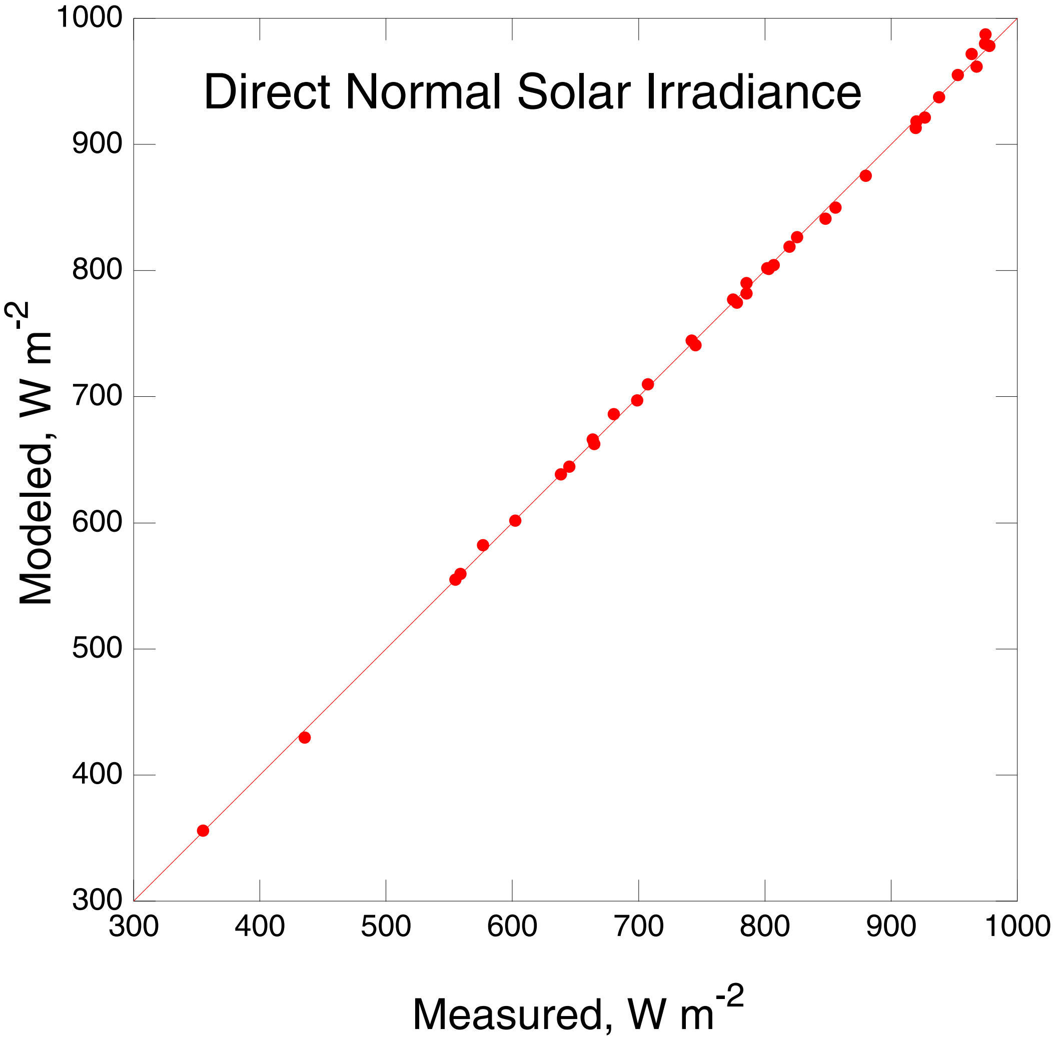
Aerosol extinction τ_{aerosol} is determined by sun photometry by ***difference*** at ***discrete*** wavelengths as

$$\tau_{\text{aerosol}} = \tau_\lambda - (\tau_{\text{Rayleigh}} + \tau_{\text{water}} + \tau_{\text{ozone}} + \ldots)$$

Continuous $\tau_{\text{aerosol}}(\lambda)$ required for wavelength integration is obtained by the Ångström exponent $\alpha = -d\ln\tau_{\text{aerosol}} / d\ln\lambda$.

DNSI CLOSURE EXPERIMENT - RESULTS

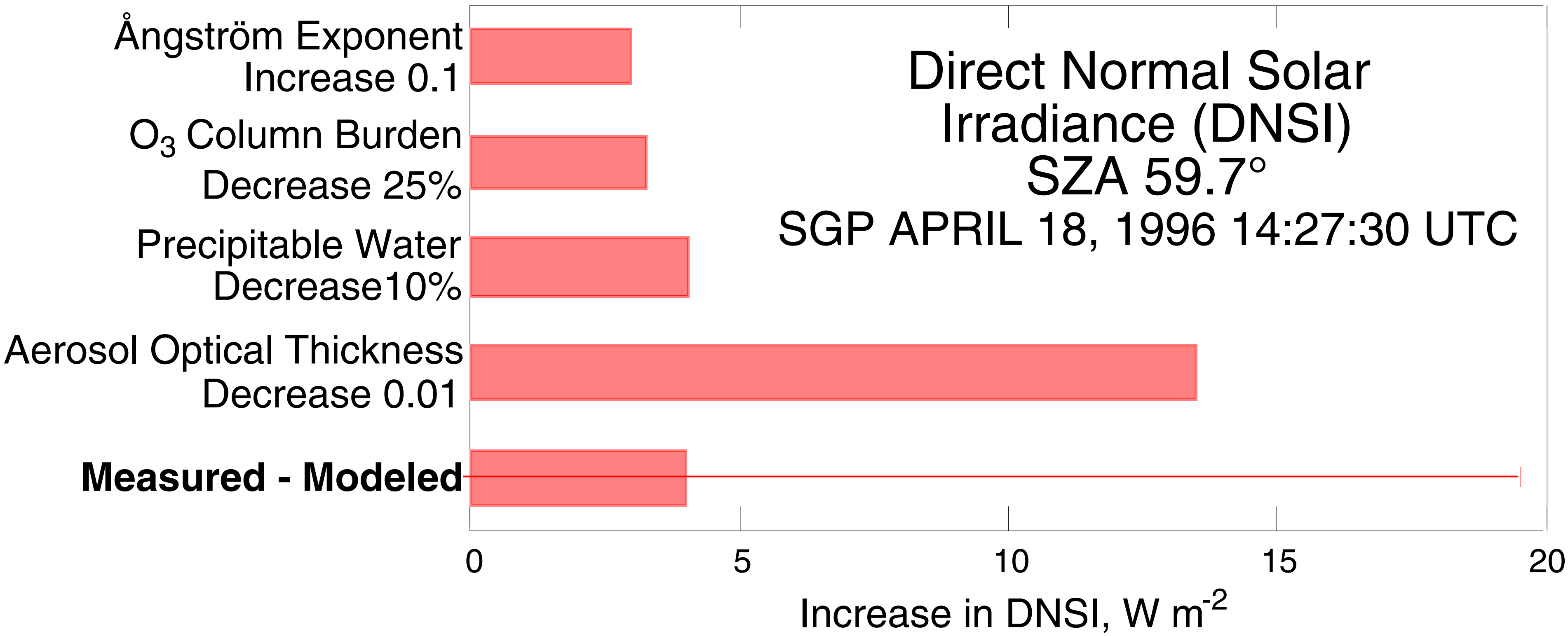
Measurements at DOE ARM site, north central Oklahoma



DNSI CLOSURE EXPERIMENT - FINDINGS

- For 36 independent comparisons, the agreement between measured and model estimated values of DNSI falls within the combined uncertainties in the measurement (0.3 - 0.7%) and model calculation (1.8%).
- On average model underestimates DNSI by (-0.18 ± 0.94)%
- For a DNSI of 839 W m^{-2}, this corresponds to -1.5 ± 7.9 W m^{-2}.
- The agreement is nearly independent of airmass and water-vapor path abundance.

SENSITIVITY OF MODELED DNSI TO INPUT PARAMETERS



- DNSI closure is highly sensitive to aerosol optical thickness.

THE DNSI CLOSURE EXPERIMENT

IS IT TAUTOLOGICAL?

- Closure of DNSI implies accurate knowledge of wavelength dependence of all contributions to column extinction plus knowledge of the solar spectrum at the TOA.

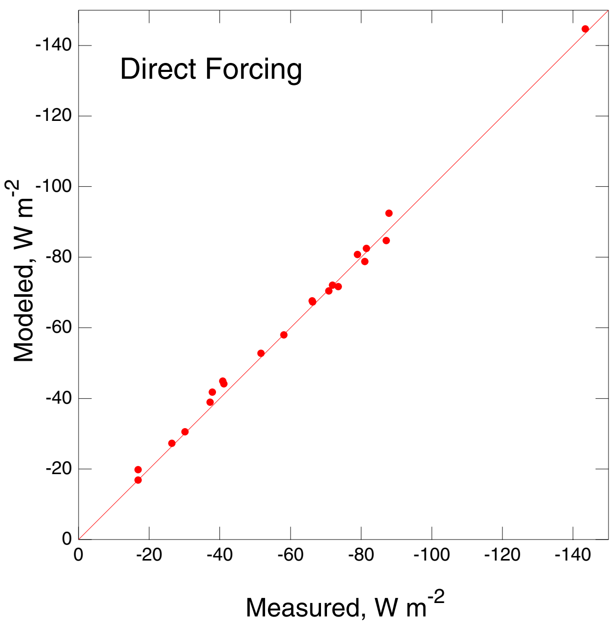
- So-called aerosol extinction is obtained as a difference between measured extinction minus extinction due to Rayleigh scattering and known gaseous absorption.

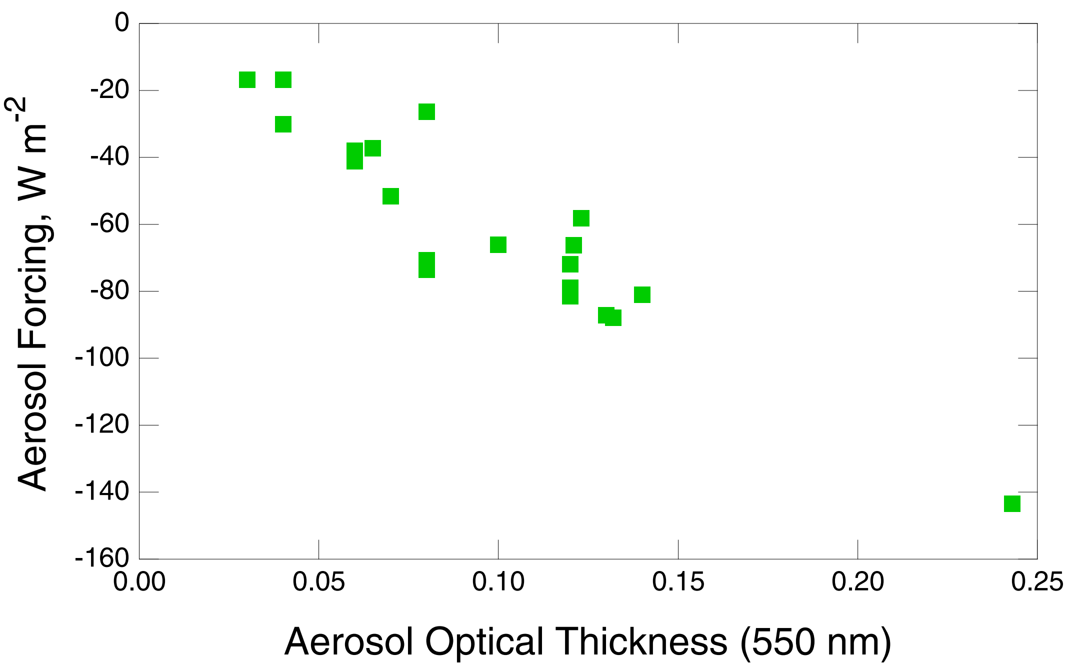
- Agreement between measured and modeled DNSI means that this aerosol extinction is Ångström-like.

- In principle this closure would be consistent with an Ångström-like atmospheric absorption masquerading as an aerosol extinction coefficient.

AEROSOL FORCING OF DIRECT SURFACE IRRADIANCE

Measurements at DOE ARM site, north central Oklahoma





- Note close agreement between measurements and model even on expanded scale.
- Note strong sensitivity of direct beam irradiance to aerosol optical thickness.

DDI CLOSURE EXPERIMENT
Cloud-free skies

Diffuse Downwelling Irradiance (DDI):

Measure: Shaded pyranometer

Model: DDI = $\int E_{\mathrm{DD}}(\lambda)d\lambda$

$\int E_{\mathrm{DD}}(\lambda)$ from radiative transfer model (MODTRAN, DISORT, 6S)

Input variables: B_{water}, B_{ozone}, $\tau_{\mathrm{aerosol}}(\lambda)$, single scattering albedo ω_0, asymmetry parameter g.

As with DNSI experiment, aerosol extinction τ_{aerosol} is determined by sun photometry by difference at discrete wavelengths as

$$\tau_{\mathrm{aerosol}} = \tau_{\lambda} - (\tau_{\mathrm{Rayleigh}} + \tau_{\mathrm{water}} + \tau_{\mathrm{ozone}} + ...)$$

and the continuous $\tau_{\mathrm{aerosol}}(\lambda)$ required for wavelength integration is obtained by the Ångström exponent $\alpha = -d\ln\tau_{\mathrm{aerosol}} / d\ln\lambda$.

MEASUREMENT ISSUE

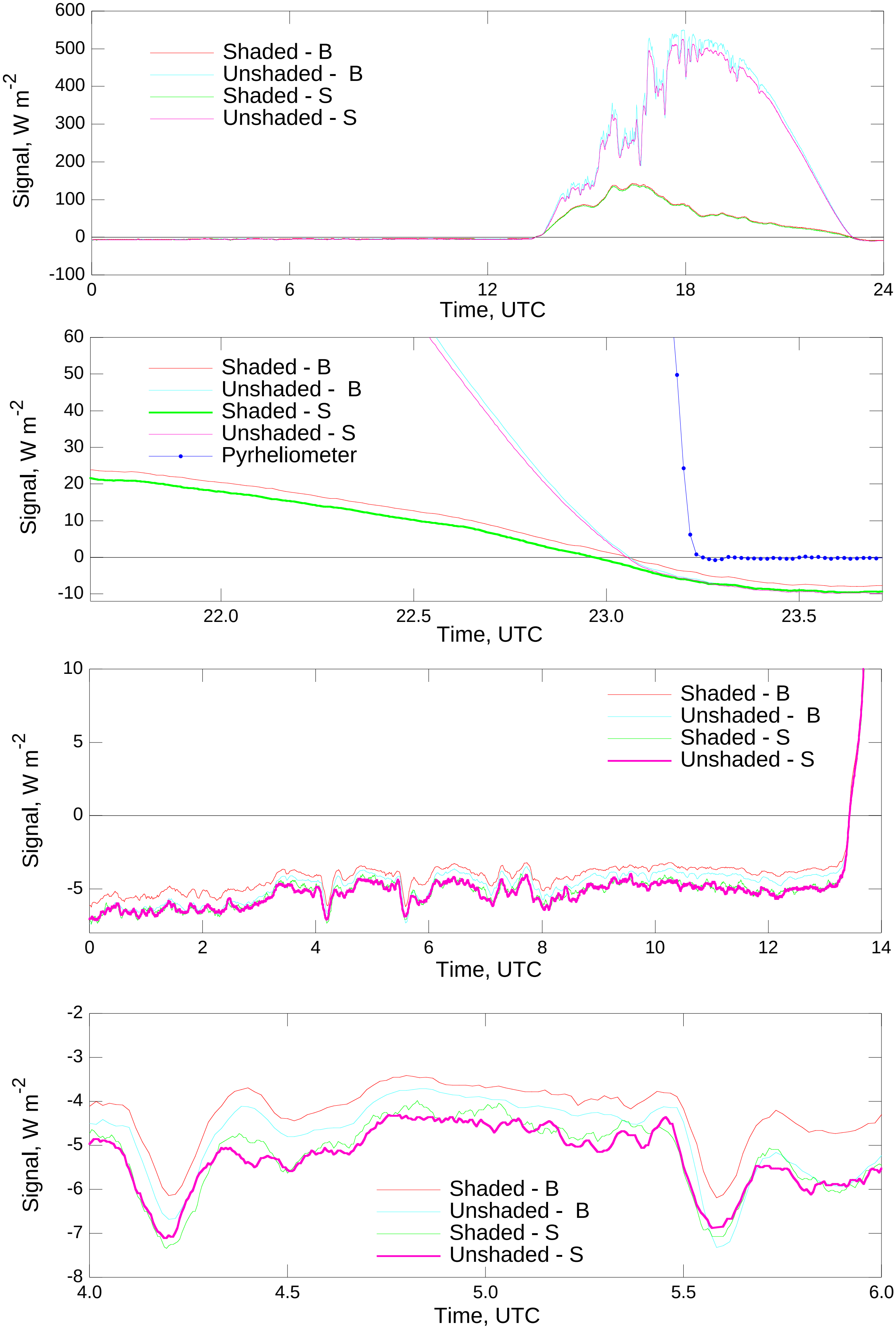
The shaded pyranometer radiates in the infrared.

This is manifested by a negative signal at night ("nighttime offset").

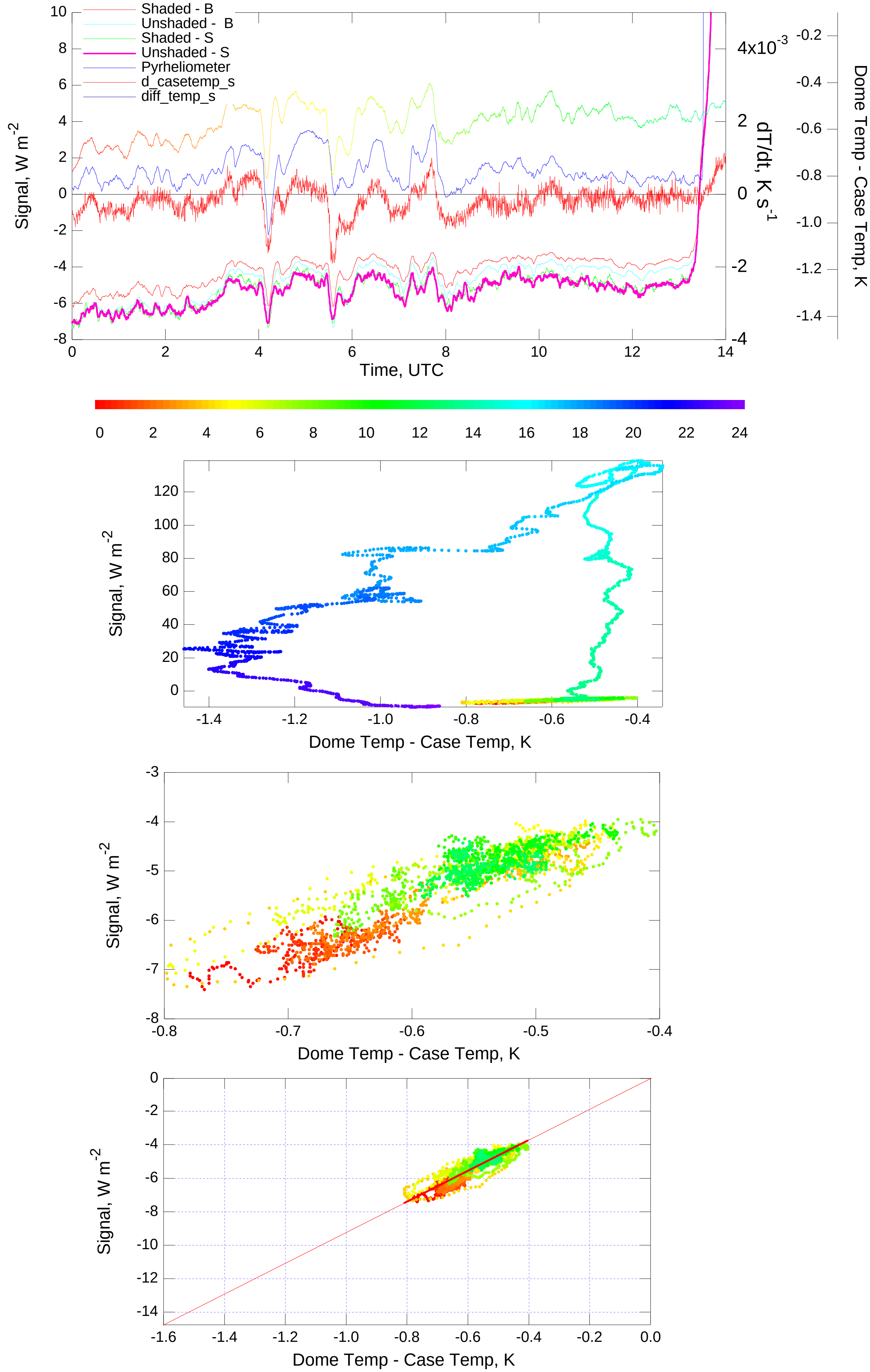
Presumably an offset is present during the day, but how much?

TIME DEPENDENCE OF PYRANOMETER SIGNAL

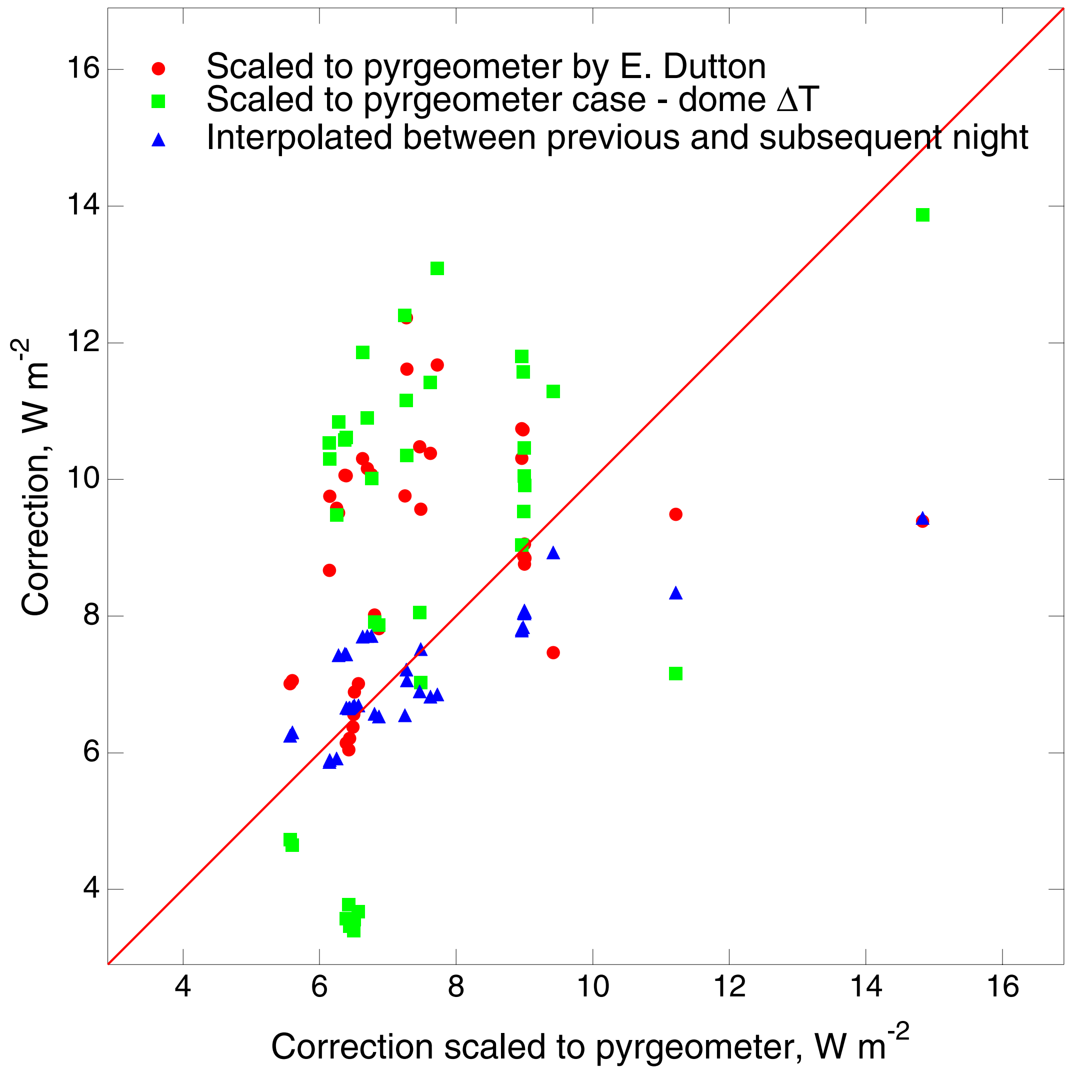
ARM Southern Great Plains, 1996 12 09



CORRELATIONS OF NIGHTTIME RADIATION COMPONENTS



CORRECTION FOR INFRARED OFFSET



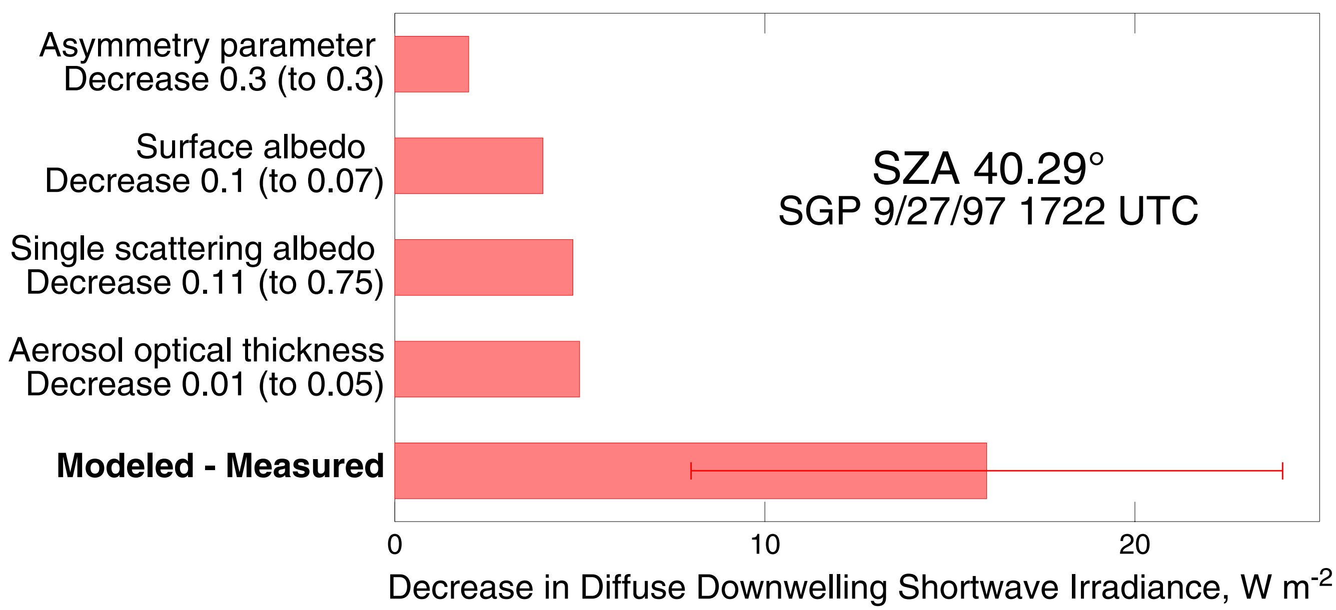
Uncertainty in correction may be as great as 3 to 4 W m^{-2}.

UNCERTAINTIES IN MODELED DIFFUSE IRRADIANCE

Cloud-free skies

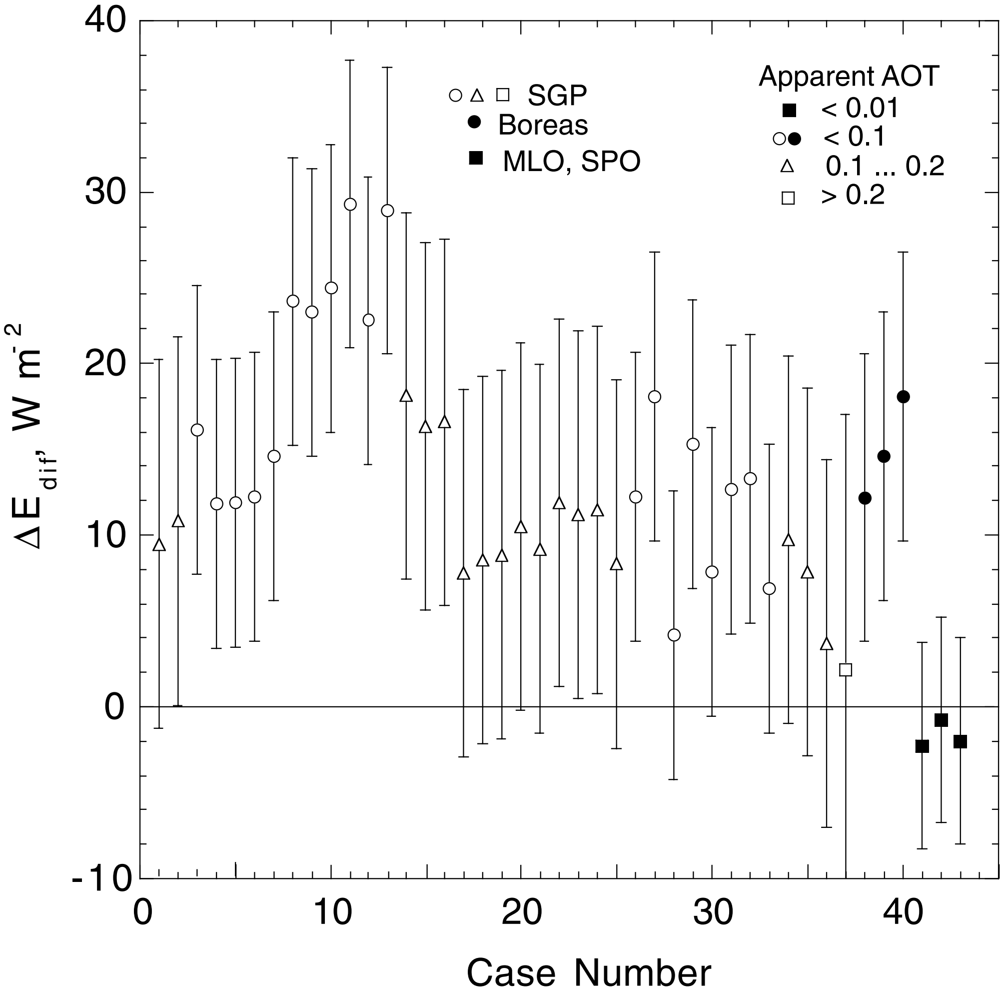
Propagated from sensitivities to input variables, evaluated as uncorrelated:

$$\delta E_{DD} = \left[\sum \left(\frac{\partial E_{DD}}{\partial \chi_i} \right)^2 \delta \chi_i^{\,2} \right]^{1/2}$$



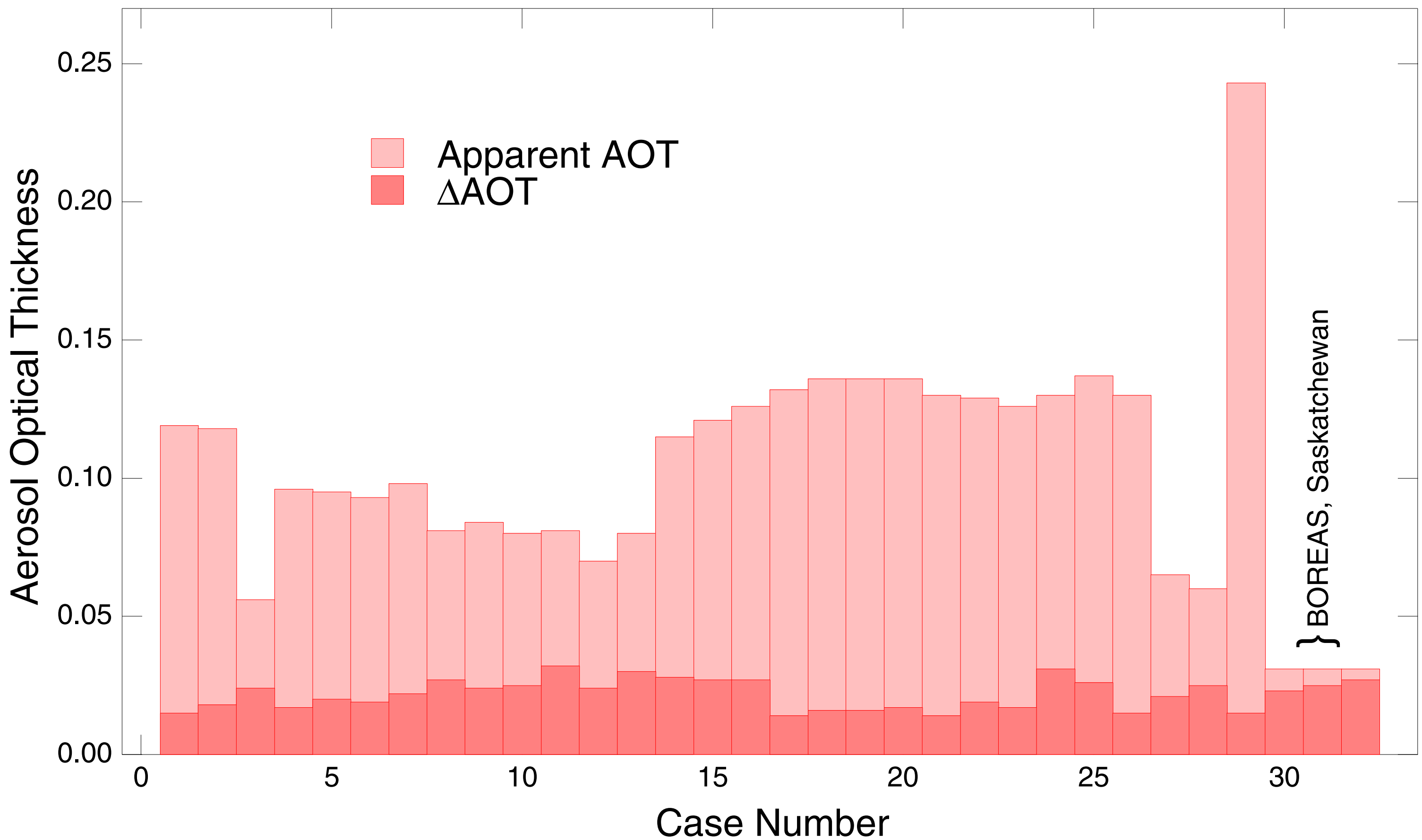
DIFFERENCE IN MODELED - MEASURED DIFFUSE IRRADIANCE

Cloud-free skies



Modeled diffuse irradiance systematically exceeds measured except at high altitude sites.

DIFFERENCE IN MODELED - MEASURED DIFFUSE IRRADIANCE EXPRESSED AS OPTICAL THICKNESS

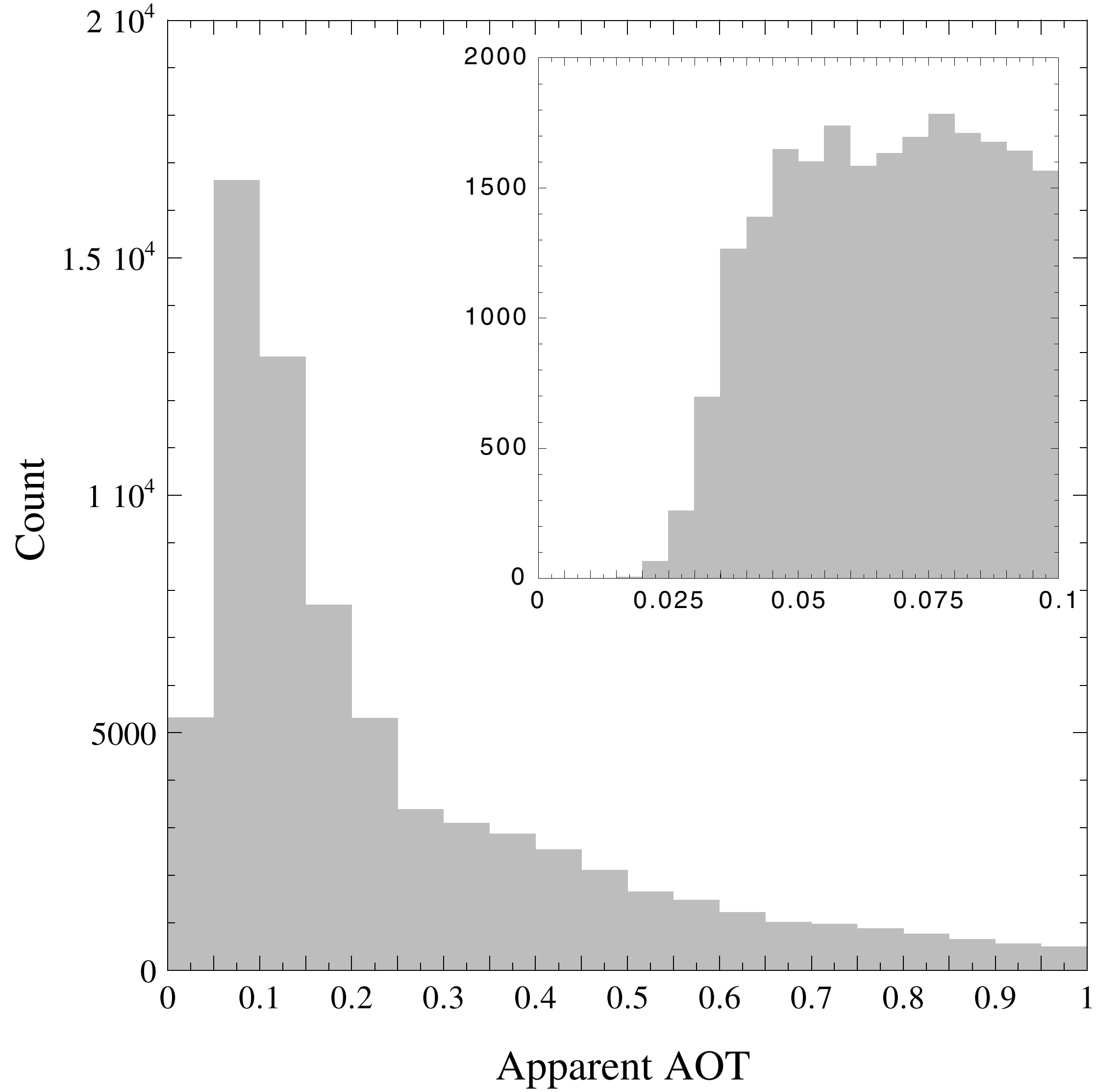


There is an apparent excess optical thickness of ~0.02 at low-altitude mid-latitude sites.

SUNPHOTOMETER MEASUREMENTS OF APPARENT AOT (440 nm)

About 80000 Measurements (1993 - 1998)

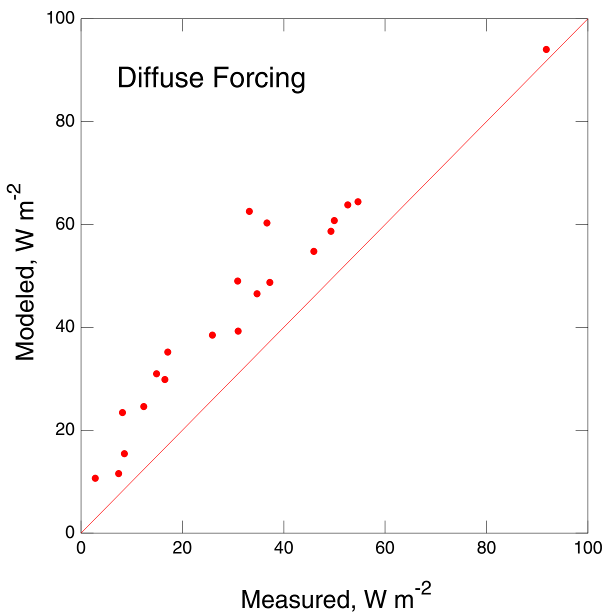
32000 Western U.S., 10000 Eastern U.S., 10000 Mid-Continental Canada, 12000 Brasilia, 16000 Western Sahara

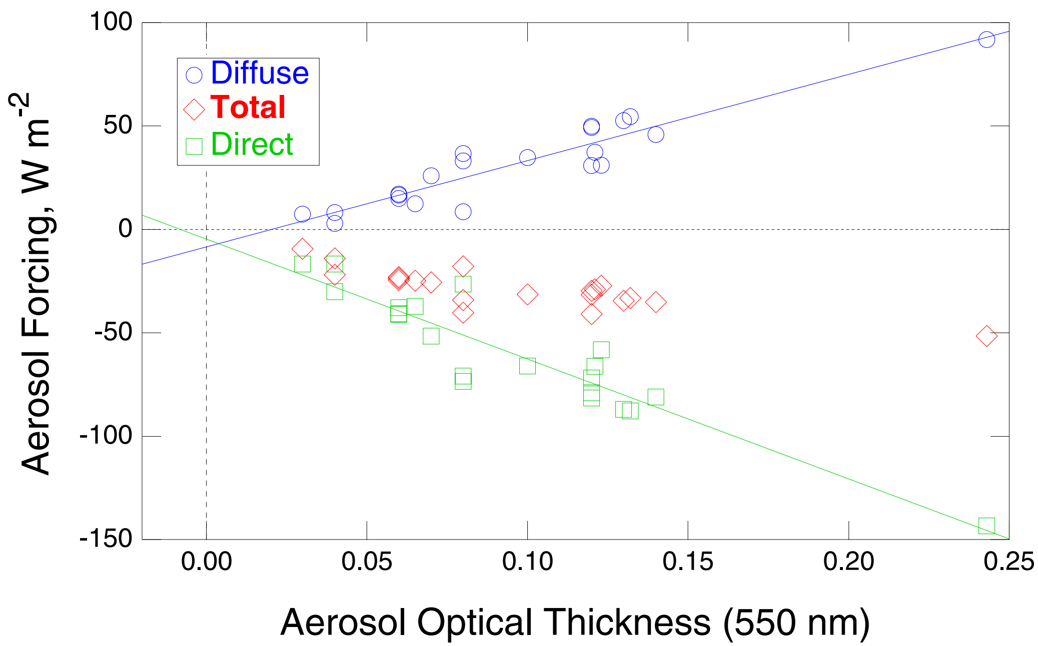


Data from Aeronet (Holben et al.)

AEROSOL FORCING OF IRRADIANCE COMPONENTS

Measurements at DOE ARM site, north central Oklahoma





- Note discrepancy between measured and modeled aerosol forcing of diffuse downwelling irradiance.
- Diffuse forcing cancels much of the direct beam forcing, but aerosols remain a strong irradiance forcing agent.

CONCLUSIONS

- There is ***excellent agreement*** between measured and modeled direct beam irradiance when measured apparent AOT is input into radiation transfer model.
- There is ***systematic disagreement*** between measured and modeled diffuse downwelling irradiance when measured apparent AOT is input into radiation transfer model.
- This disagreement is consistent with an ***unknown absorption of about 0.02*** in optical thickness at mid-visible wavelengths.