Overview and Objectives

- Clouds significantly attenuate UV radiation
- UV may also be enhanced by cloud reflections
- Cloud effects were studied on a daily or hourly basis
- Automated instrumentation now provides 1-min data
- Opaque and thin cloud amounts can be separated
- Are cloud reduction factors the same for broadband solar global and UV global?
- Are cloud reduction factors the same for all UVB sensors?
- Do thin clouds attenuate UVB significantly?

Experimental Site

- Solar Radiation Research Lab of NREL at Golden, CO
- Located on a mesa at 1829 m
- Rocky Mountain range to the west, with peaks > 4000m
- Site overlooks the Denver agglomeration
- Sunny, clean/dry climate
- Frequent photochemical smog over Denver
- National calibration center, participates in IPC

NW view

SE view

Experimental Data

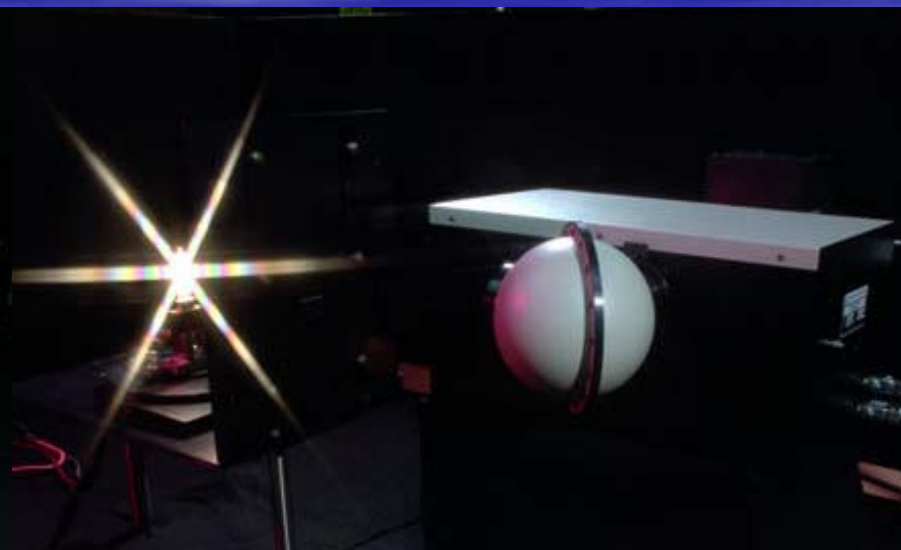
- Large number (≈60) of UV, Solar and IR radiometers
- Many ancillary data (cloud, albedo, p, T, RH…)
- UVB instruments: Eko MS-210W, K&Z UVS B-T and CUVB, Solar Light SL-501A, YES UVB-1
- UV instruments are temperature-controlled
- All data at 1-min intervals (4-sec samples)
- UVB's direct and diffuse components also measured

SP-Lite **CUVA1** **CUVB1** **MS-210W** **LI-200** **PSP** **CM6b**

501A **UVB-1** **TUVR** **PSP/RG780** **PSP**

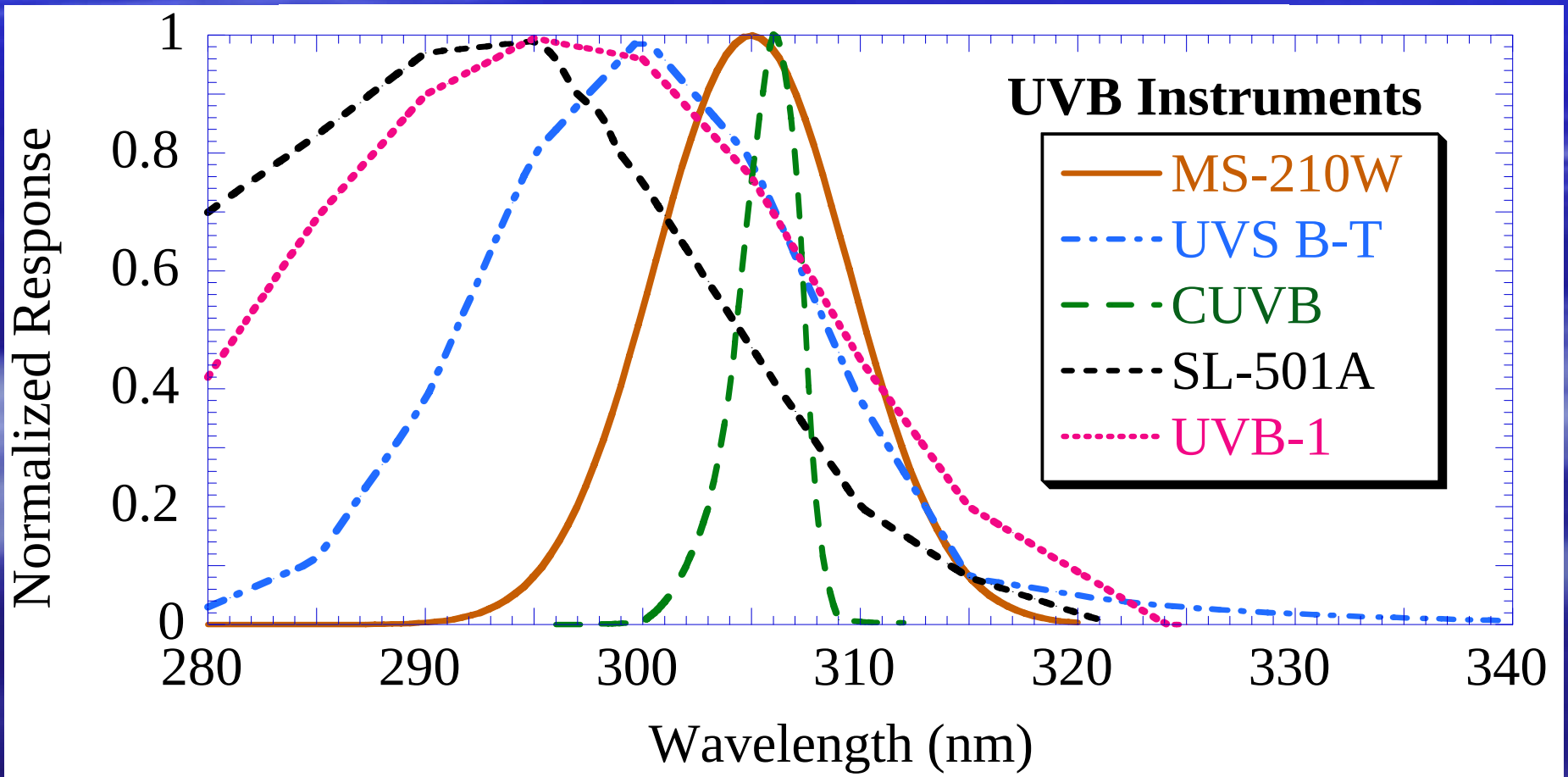
Calibration

- Outdoor calibration near solar noon in summer
- UV radiometers mounted near normal incidence for calibration
- Reference instrument: Optronic OL-754 + integrating sphere; lab-calibrated against NIST lamps
- Calibrations computed for 280–315 nm; mostly for material degradation purposes
- SL-501A also calibrated for erythemal irradiance (UVI)



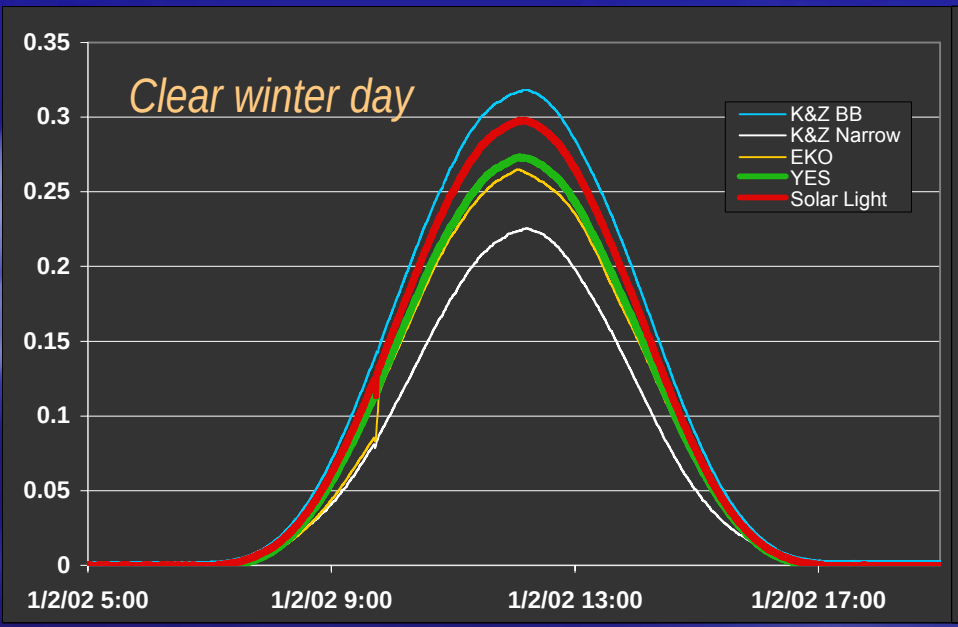
Spectral Response

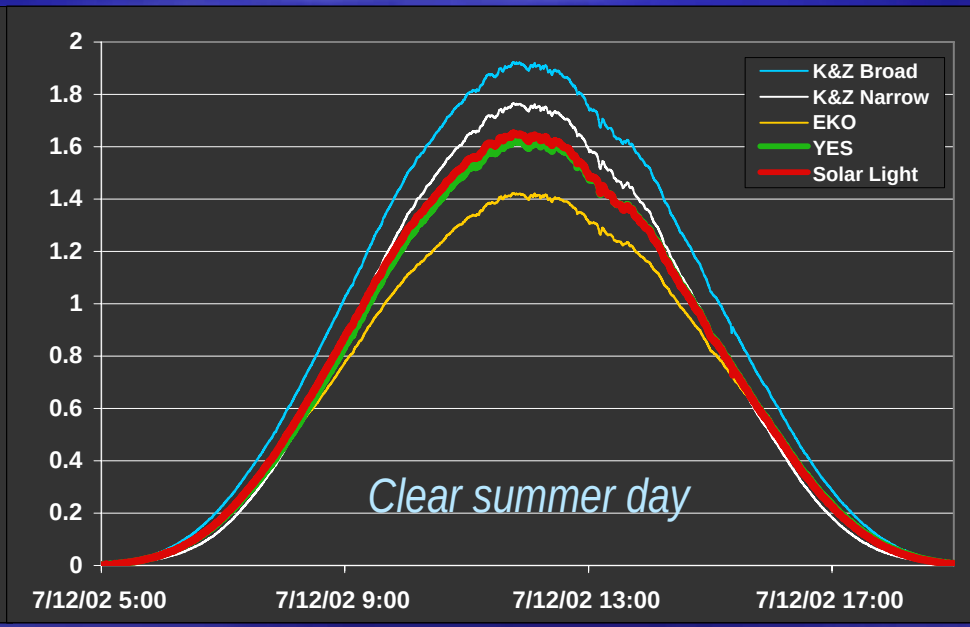
- Varies widely from one instrument type to the other
- Peak wavelength also varies
- Narrowband (CUVB) to wideband (SL-501A, UVB-1)



Typical Clear-Sky Irradiance

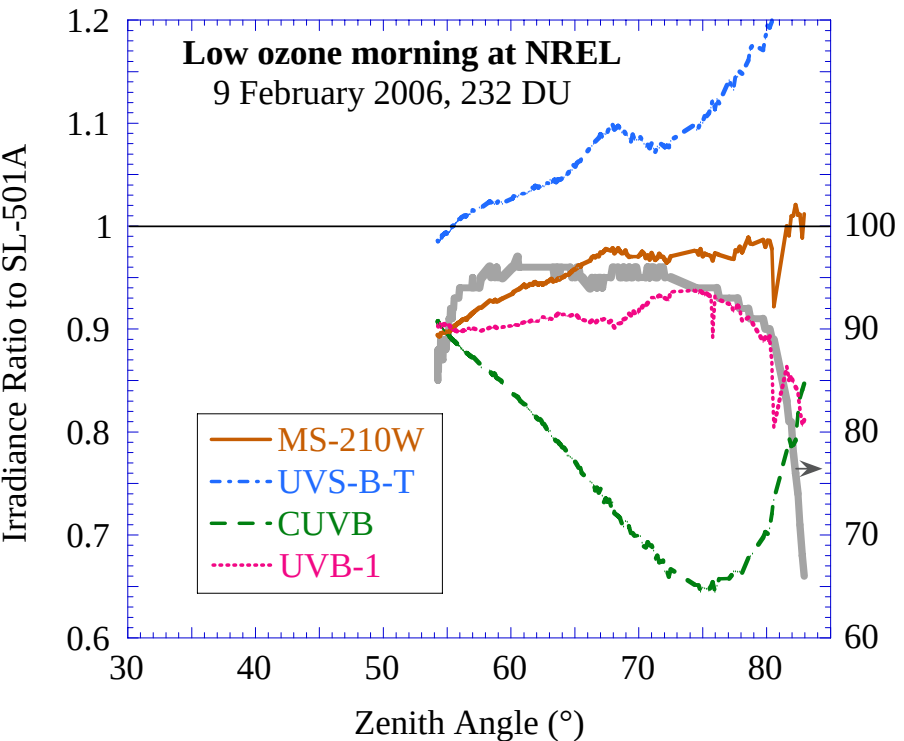
- Significant difference between instruments
- Seasonal effect (zenith angle, ozone, AOD…)
- In winter, differences of ≈10% between SL-501A and UVB-1

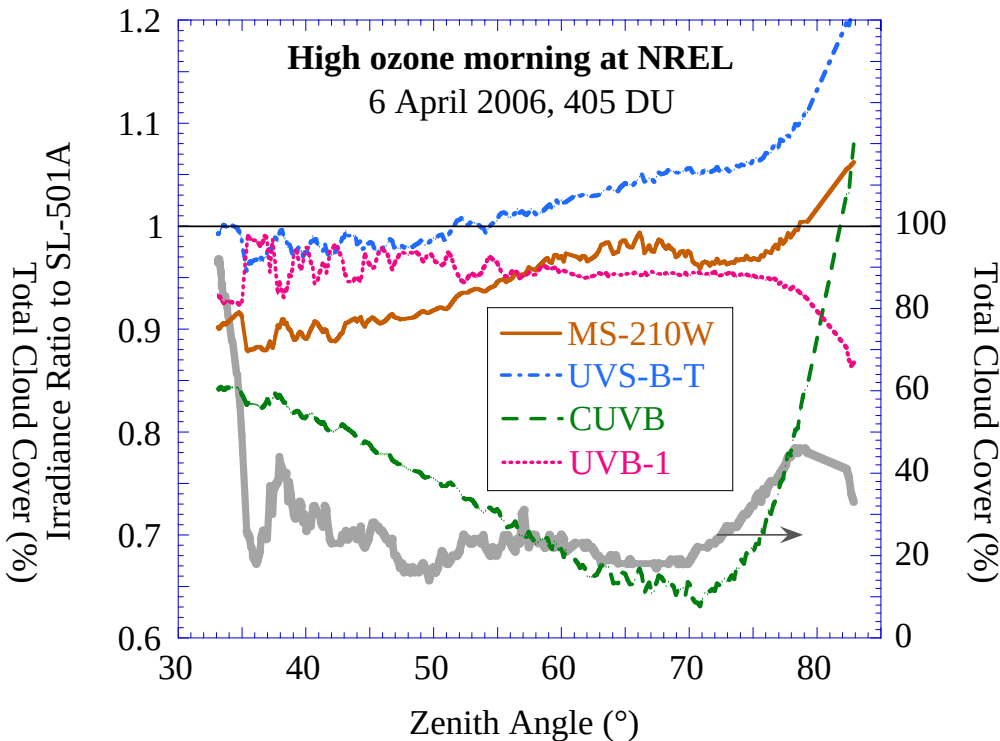




Effect of Ozone and Zenith Angle

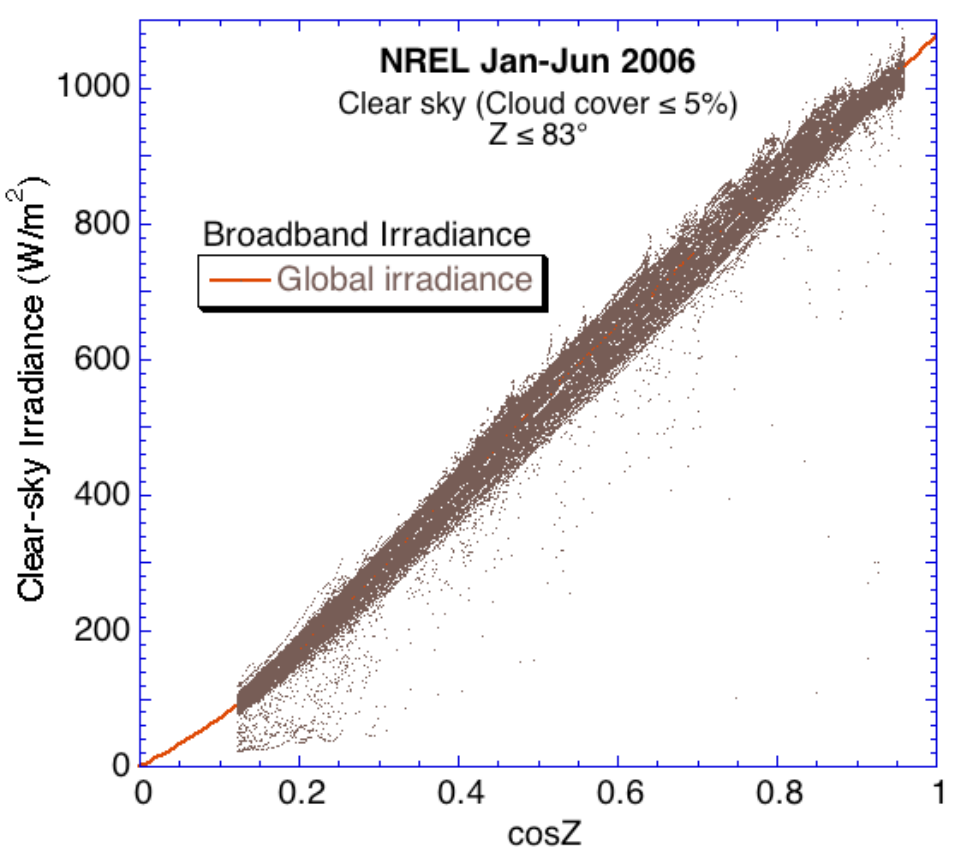
The relative instrument-to-instrument difference is more affected by their optical characteristics (spectral response, cosine error) and zenith angle than by ozone amount

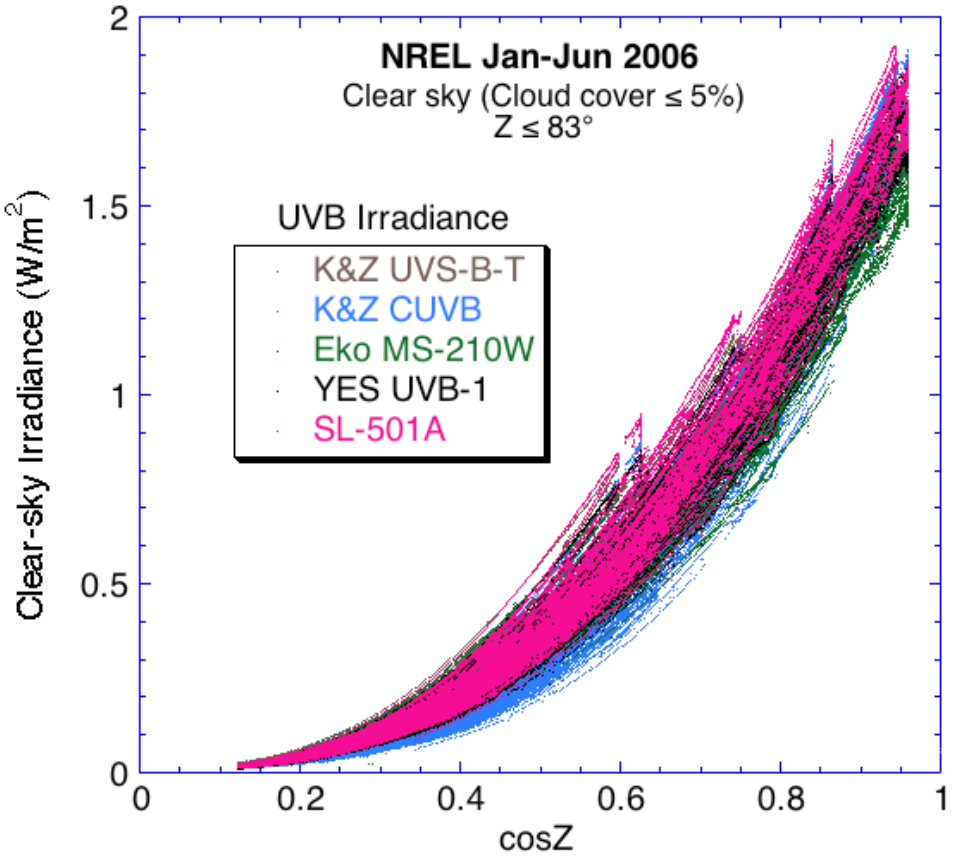




Clear-Sky Irradiance *vs* Zenith Angle

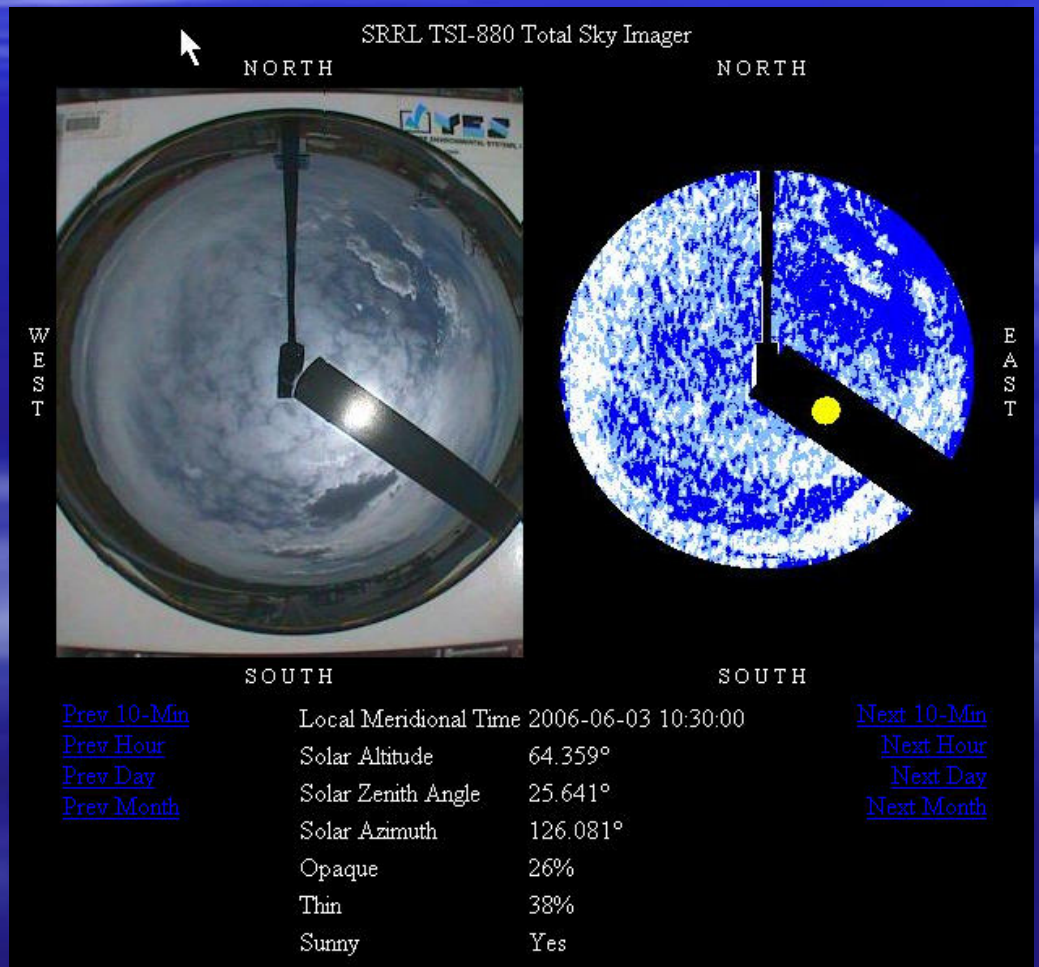
- *Z* affects broadband solar and UVB very differently
- Significant difference between UVB instruments
- Clear-sky irradiance was not predicted with RT model but as a sensor-dependent function of *Z*





Cloudiness Measurements

1-minute Total and Opaque cloud amounts measured with Total Sky Imager (YES TSI-880), 1% resolution



Cloud Effects on Irradiance

Definition:

- *Cloud Reduction Factor*
- *Cloud Attenuation Factor*
- *Cloud Cover Modifier*
- *Cloud Transmittance*

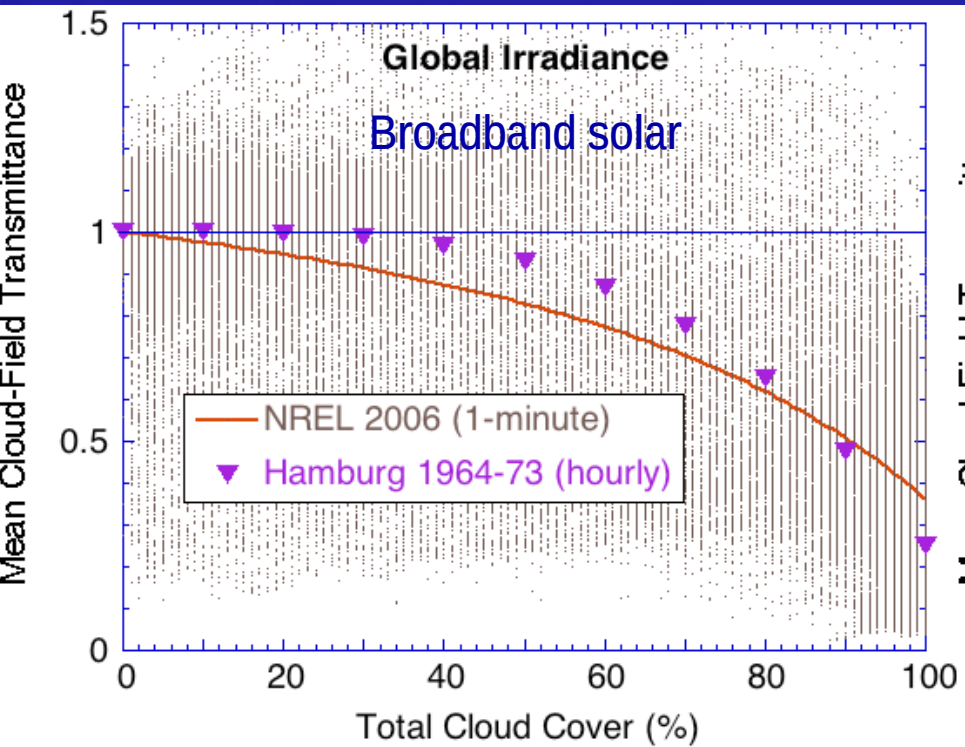
T = Actual Irradiance / Virtual Clear-Sky Irradiance

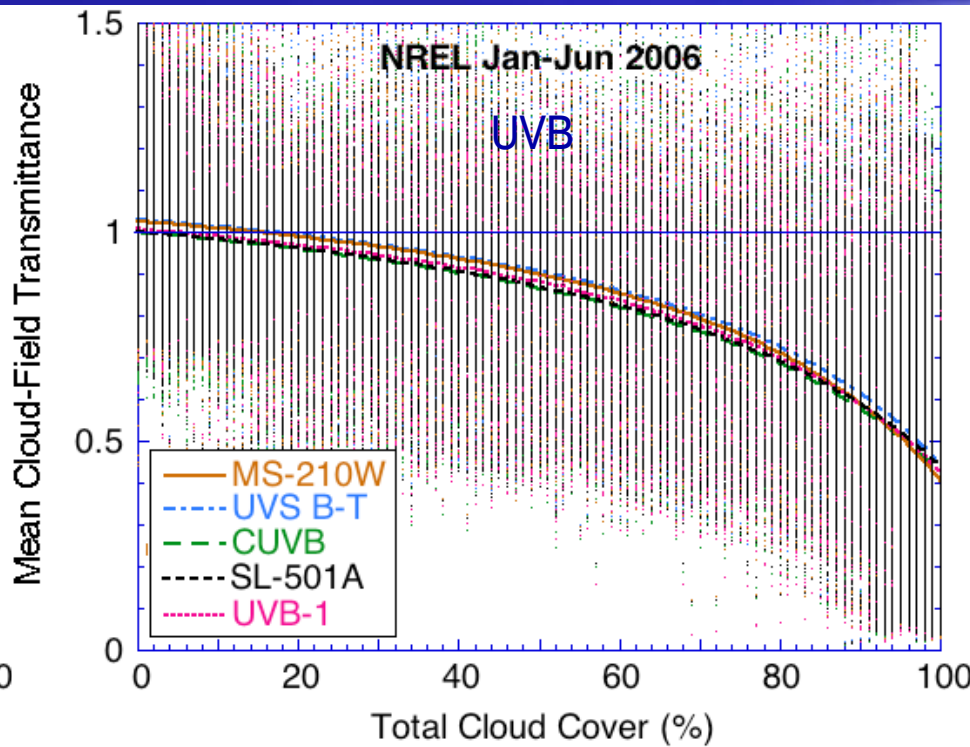
Data screening:

- *Z < 83°*
- *Albedo < 0.5*
- *Period: Jan–Jun 2006*
- *N = 107,867*

Total Cloud Amount

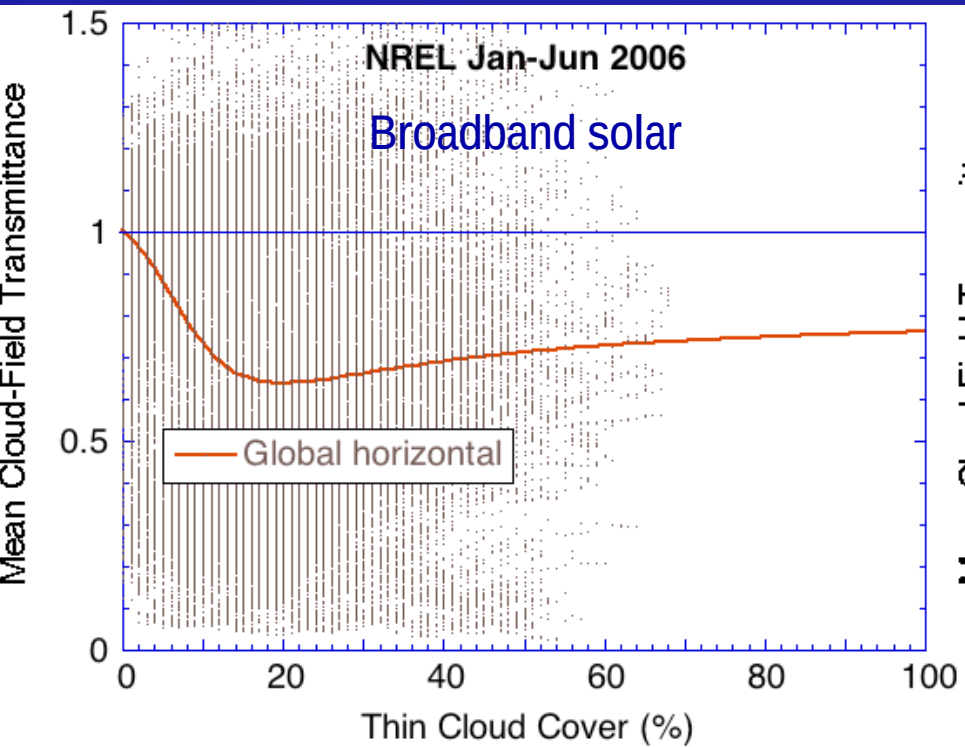
- Mean *T* for broadband global solar radiation is different from the classic data obtained with *hourly human observer* cloud data (e.g., Kasten's Hamburg data)
- Mean *T* for UVB radiation and any instrument is marginally higher than for global radiation at NREL

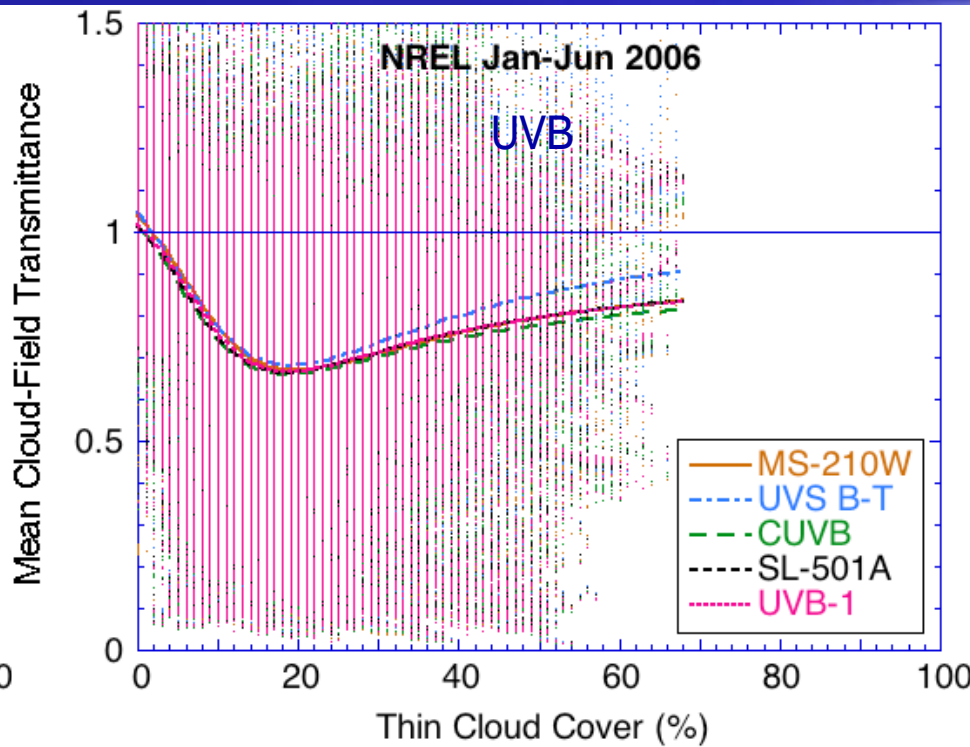




Thin Cloud Amount

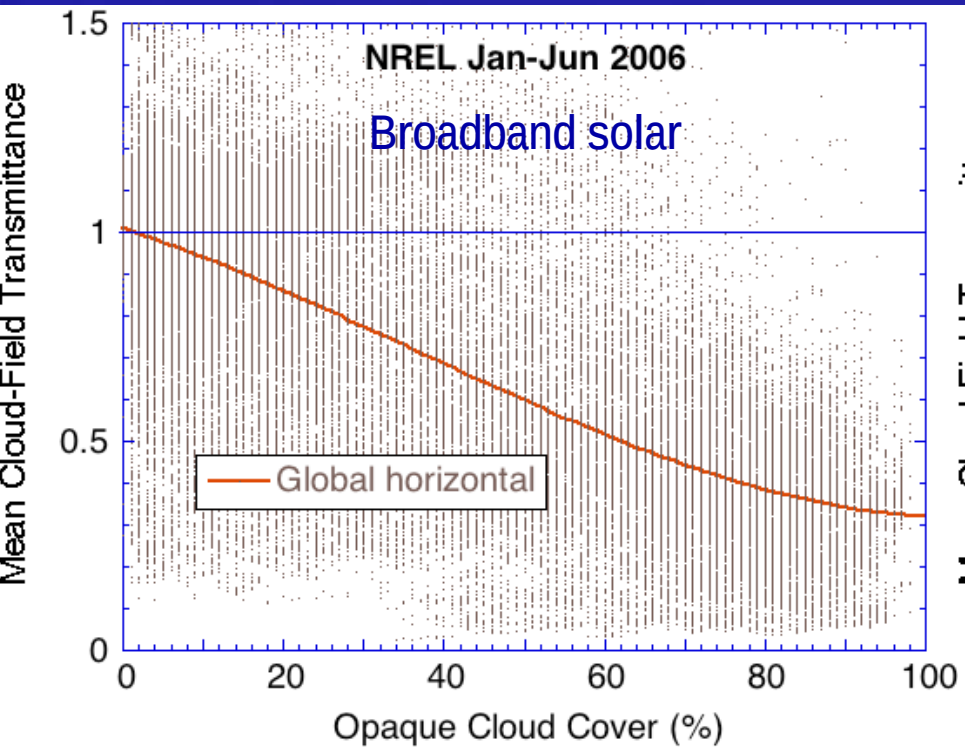
- Mean *T* for UVB radiation is marginally higher than for global radiation at NREL
- Mean *T* is possibly sensitive to instrument's optical characteristics

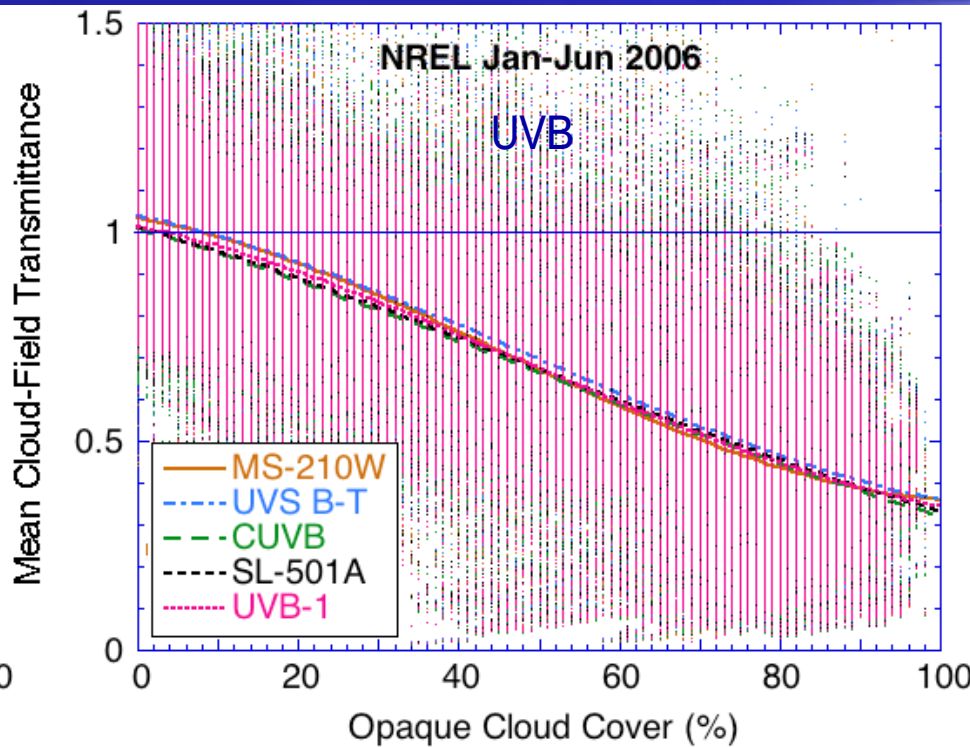




Opaque Cloud Amount

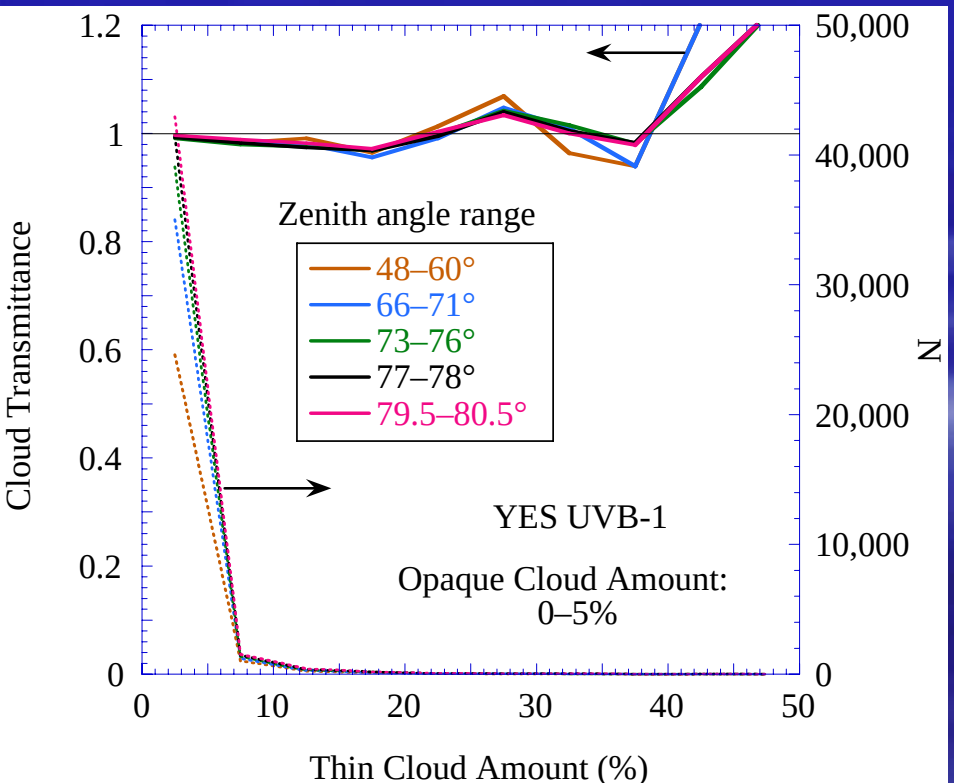
- Mean *T* for UVB radiation is marginally higher than for global radiation at NREL
- Mean *T* not significantly sensitive to instrument's optical characteristics

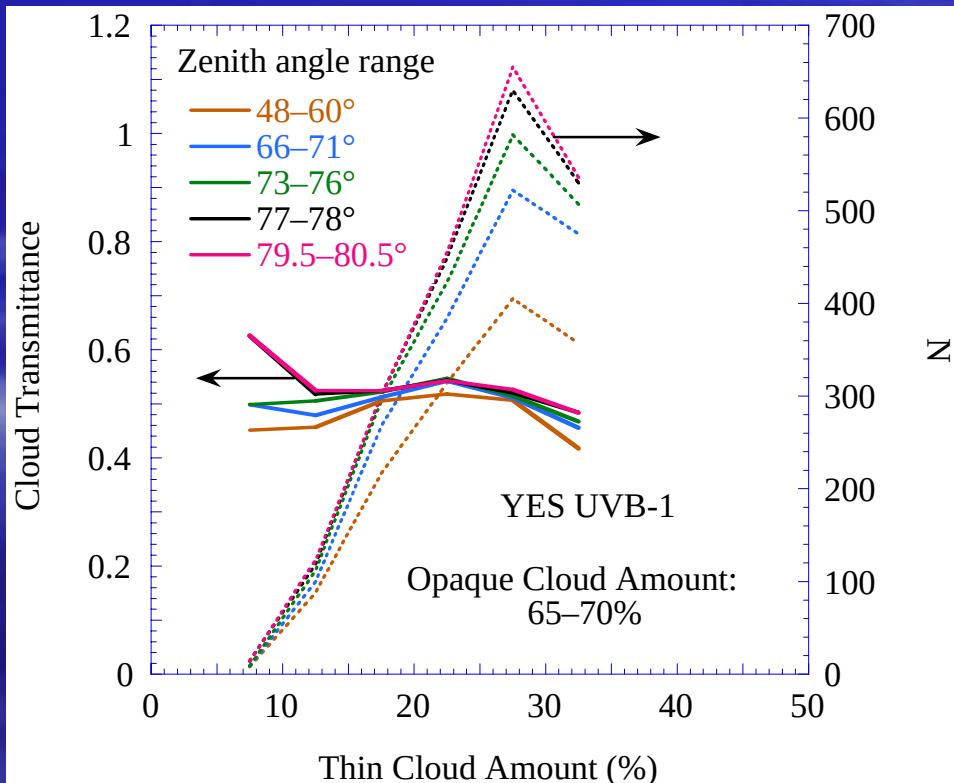




Do Thin Clouds Attenuate UVB?

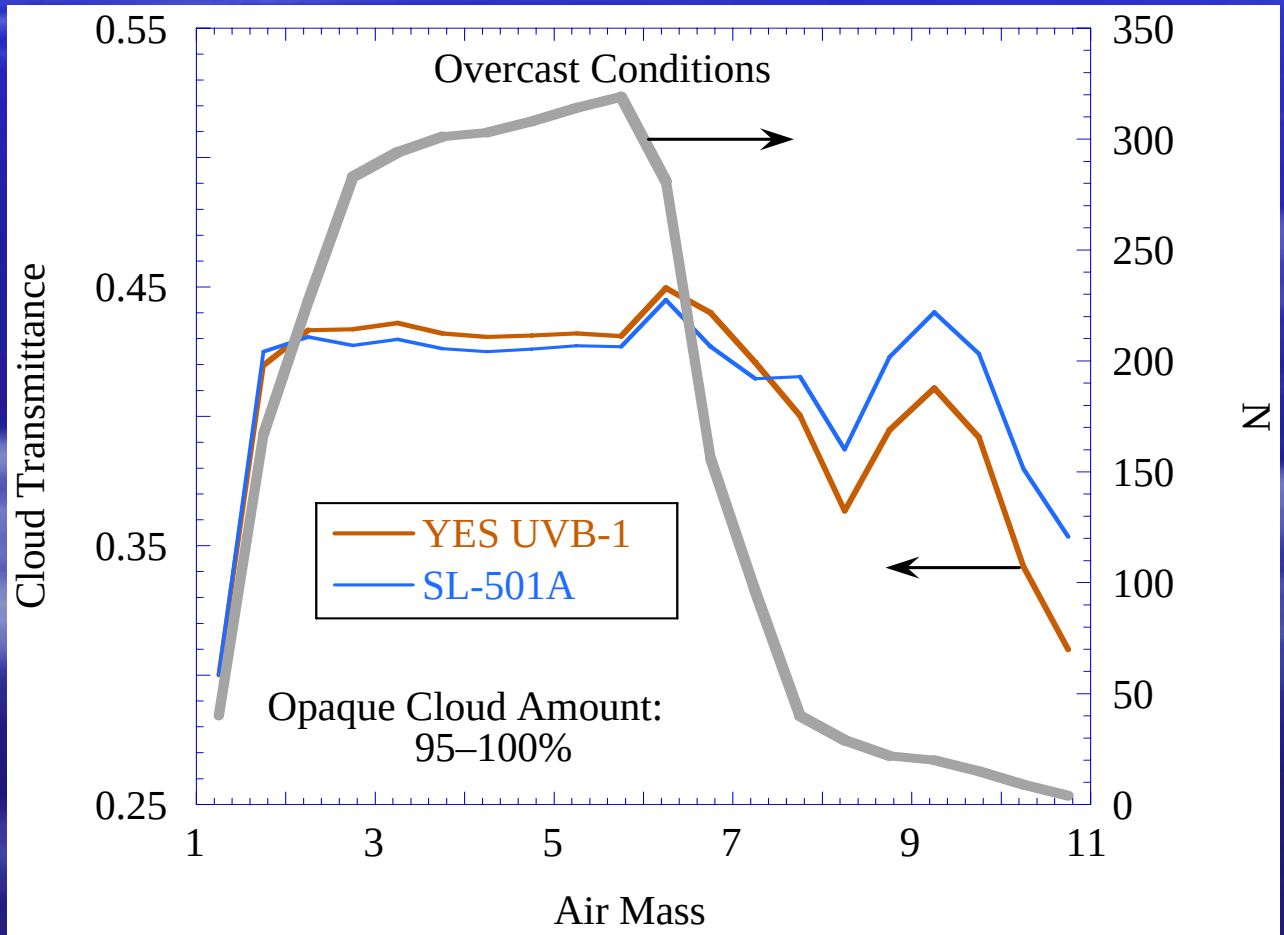
- Mean *T* does not seem to depend on Thin Cloud Amount or Zenith Angle (for a fixed Opaque Cloud Amount)
- No UVB attenuation if only thin clouds are present





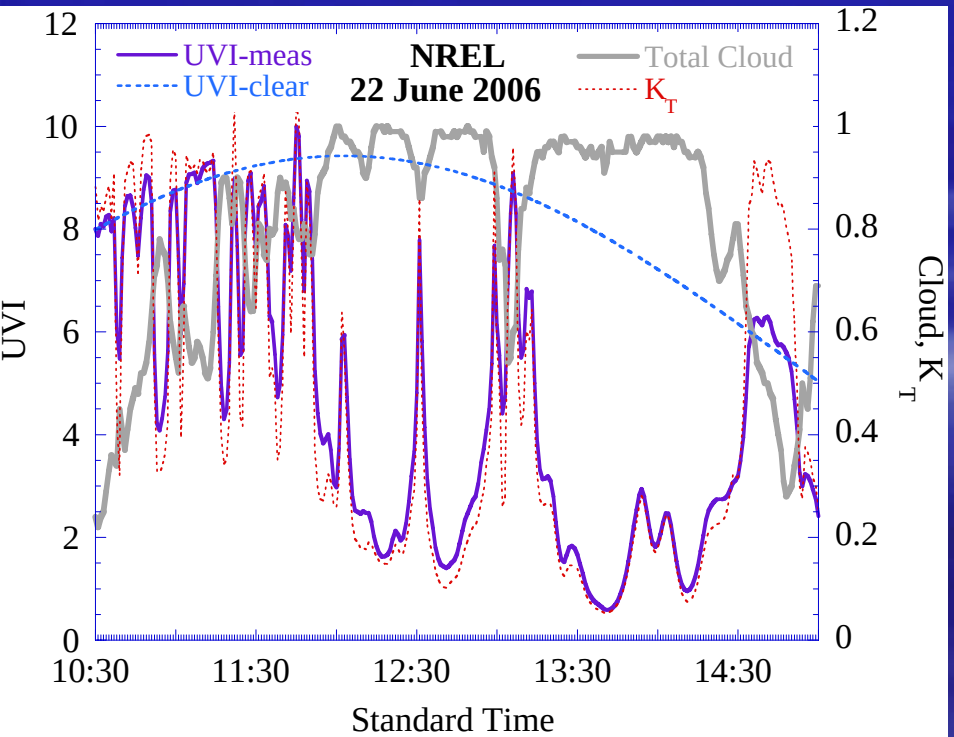
Response Under Overcast Sky

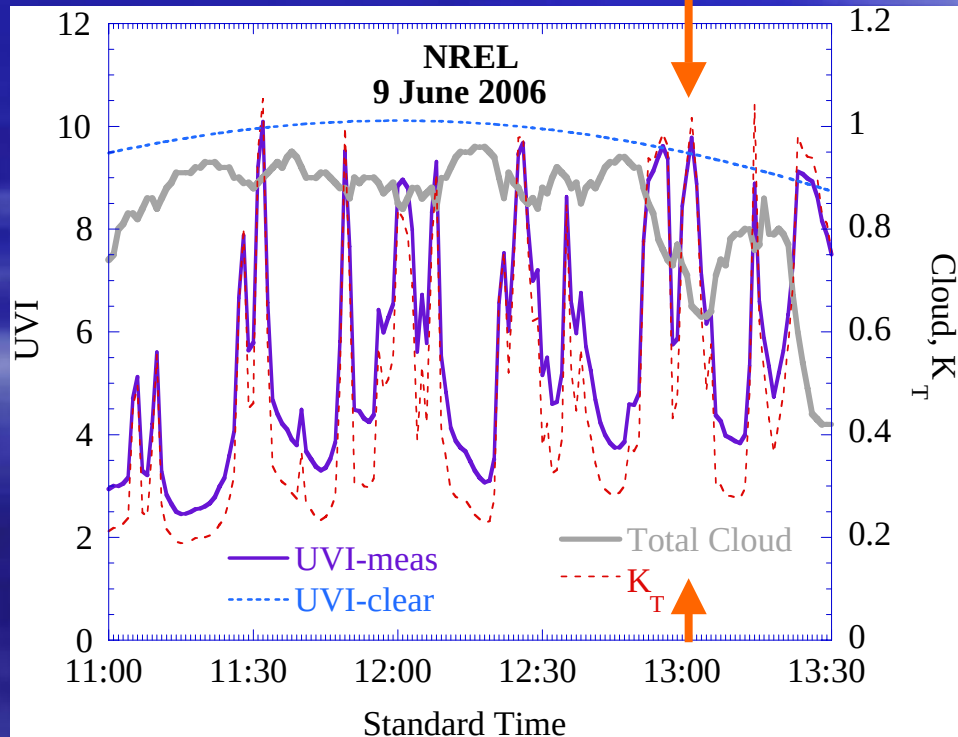
- Mean *T* slightly depends on instrument (cosine error?)
- Curious air-mass effect



Transient Cloud Effects

- Classical "funnel" effect when global solar can be > ET irradiance
- Global solar can increase by >20%
- UVB only increases by 0–10% over clear-sky value
- K_T good proxy for 10*UVI





Conclusions

- 1-minute UV radiation and objective cloud measurements provide invaluable information
- Solar and UV cloud transmittances are similar, but may depend on location and observation method
- Funnel effect is not very strong in the UVB
- Thin clouds do not seem to attenuate UVB
- Observable instrument-to-instrument differences, due to variance in bandwidth and cosine error