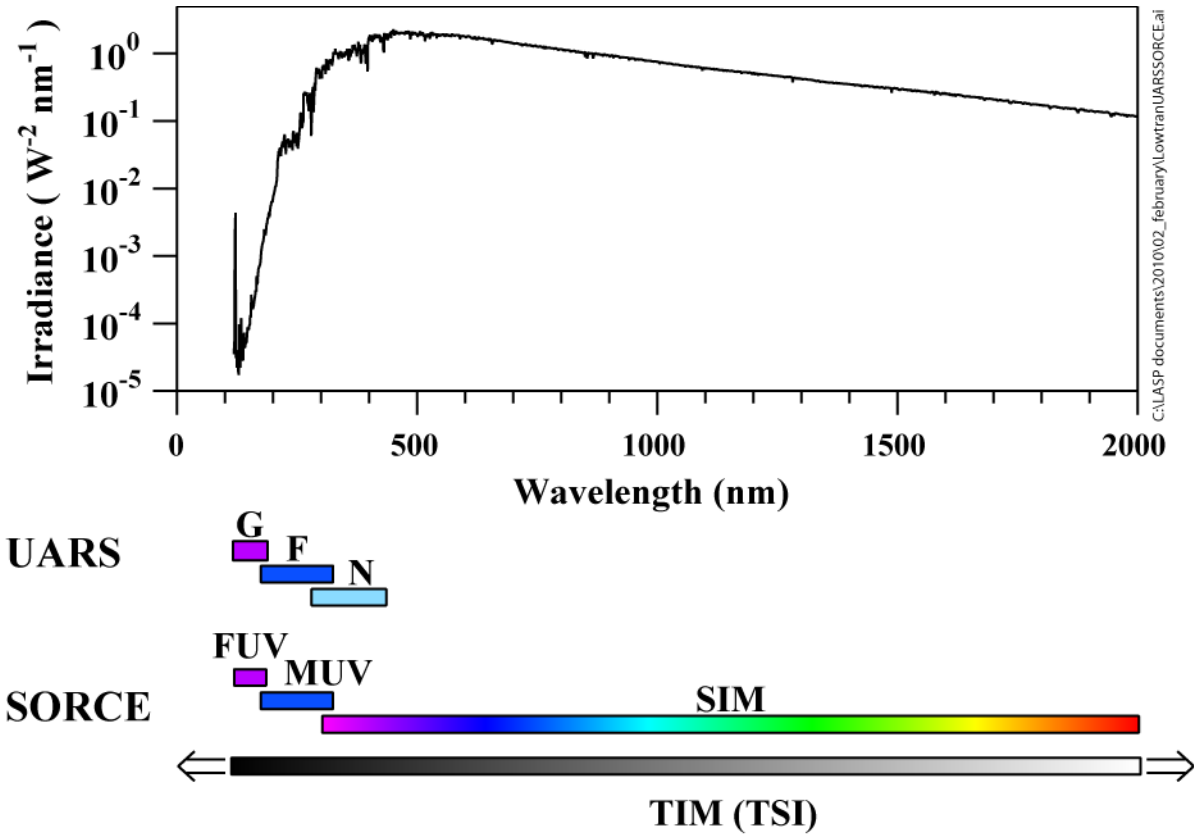
Modeling the SORCE solar variability in WACCM

Aimee Merkel
Jerry Harder
Tom Woods

Laboratory for Atmospheric and Space Physics
University of Colorado

SORCE is a continuation of UARS SOLSTICE



- **Lessons learned from UARS:**
  - **The very small variability for λ>400 is critical to understanding changes in TSI**
    - The variability must be measured out to the infrared
  - **Different technologies must be 'invented' to track instrument degradation – especially at longer wavelengths**

Why measure solar spectral irradiance?

Solar Forcing and Response Mechanisms are Wavelength Dependent

Chemistry Climate Models Need SSI

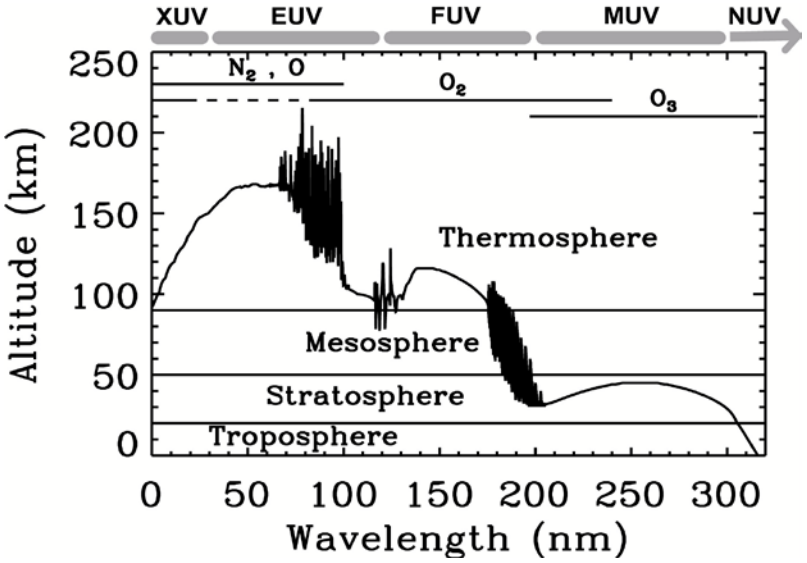
GISS GCM [Rind et al., 2004; Shindell et al., 2006]

NCAR WACCM [Marsh et al., 2007]

HAMMONIA [Schmidt and Brasseur, 2006]

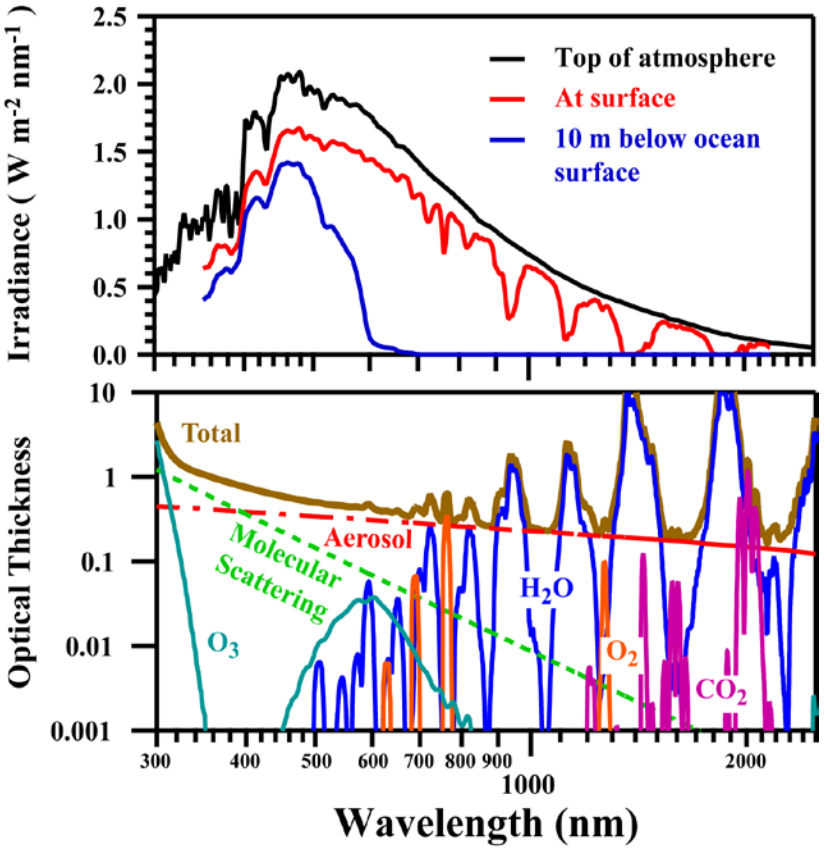
CMAM [Beagley et al., 1997]

Ultraviolet (UV) radiation drives many atmospheric processes



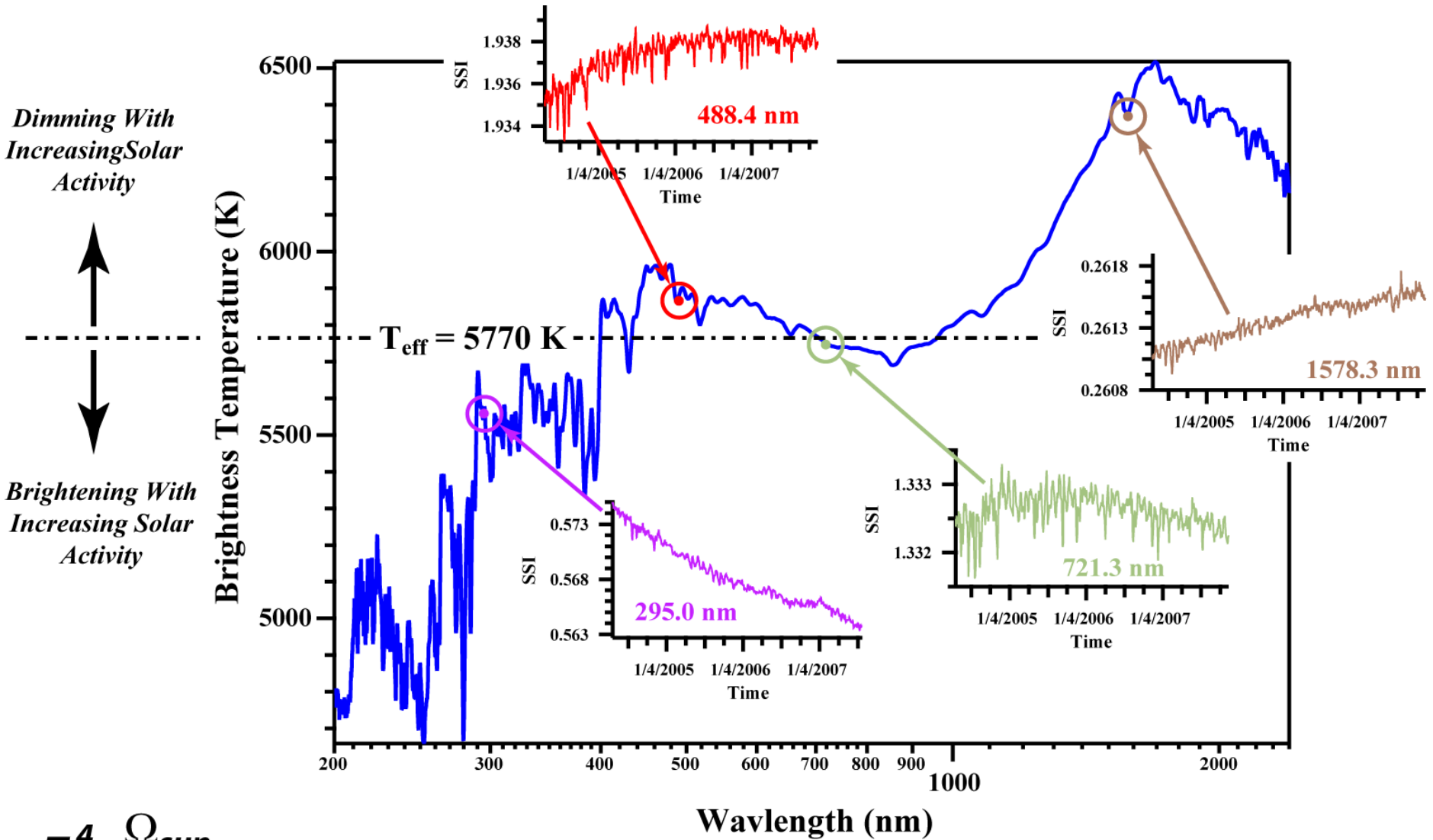
Altitude contour for attenuation by a factor of 1/e

Near UV, visible, near infrared radiation affect surface and ocean processes



[Adapted from P. Pilewskie, *Solar Physics,* 2005]

Spectral Variability Nomogram



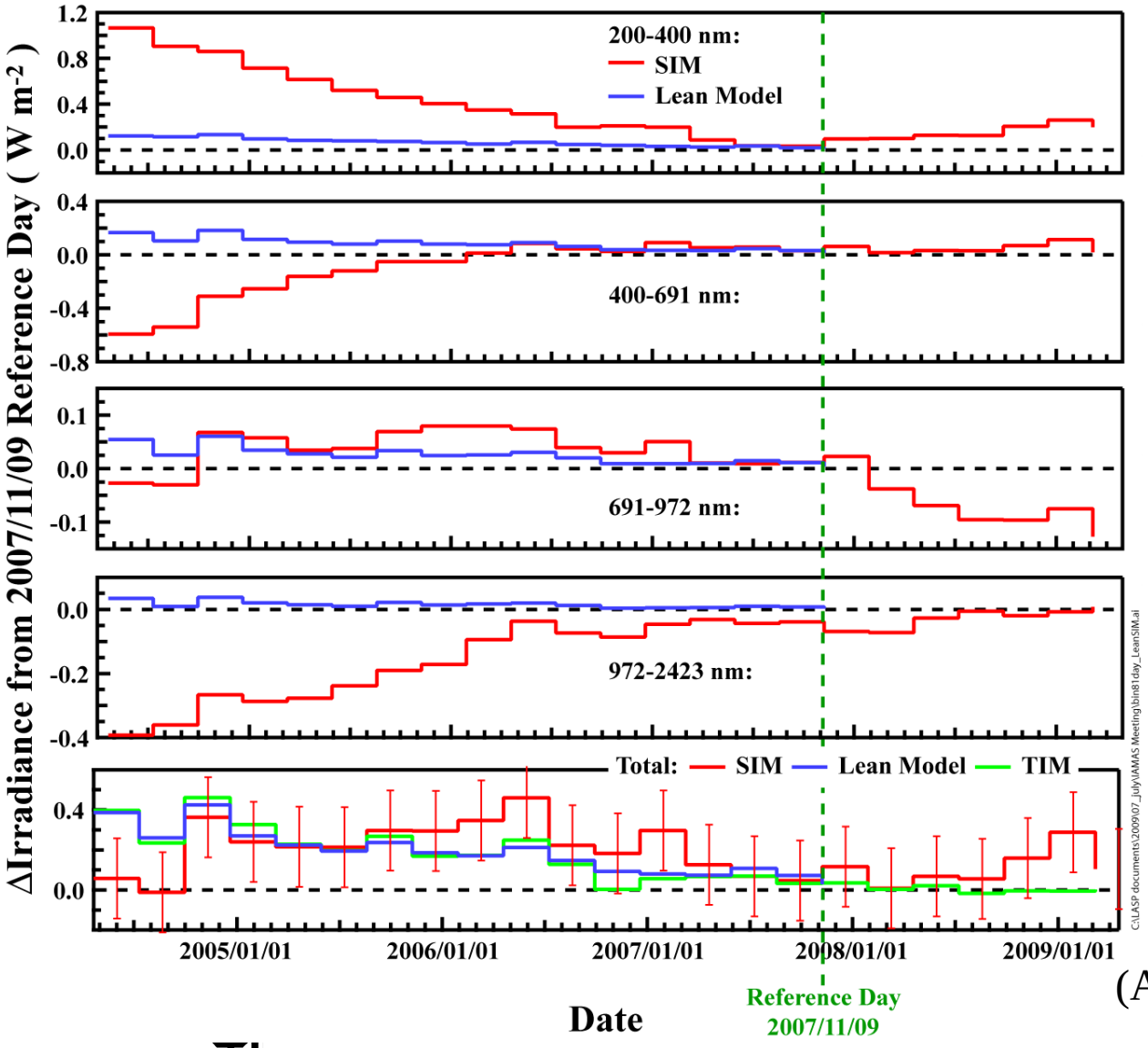
$$\sigma T_{eff}^4 \frac{\Omega_{sun}}{\pi} \approx 1361 \text{ W m}^{-2}$$

Harder et al. 2009

Basis of Lean Model

- J. Lean, GRL, 27, pp 2425-2428, 2000
- Covers the time range of 2000-2007 (full descending phase of SC23).
- Produces excellent agreement with TSI.
- Spectral Variability based on UARS SOLSTICE model for λ<400 nm and 2 component model of sunspot darkening and facular brightening for the visible and IR.
- Model derived from solar rotational modulation.
  - ***Represents a lower limit of solar cycle variability.***

SORCE vs. Modeled Spectral Variability



Plot is for same time period and uses the solar minimum reference day of 2007/11/09

81-day binned data to suppress solar rotational modulation

SIM data show considerably more variability in the UV

Offsetting trend in UV/Vis/IR compensate to produce TSI

Refinements to the degradation corrections needed (~1 more year of data required)

(Adaption from Harder et al. 2009)

WACCM Simulations

Objective: Put SORCE variability into WACCM control study. Use WACCM 3.5.48 REFB1 Initialization files from SPARC CCMVal simulations.

Approach: Case study rather than transient. Simulate Quiet Sun and Active Sun.
Quiet Sun = Year 2007 (133 spectra averaged between 8/8/2007 to 10/19/2007)
Active Sun = Year 2004 (50 spectra averaged between 10/1/2004 to 10/24/2004)
(Active but quiescent Sun, No sunspots, plages, etc.)

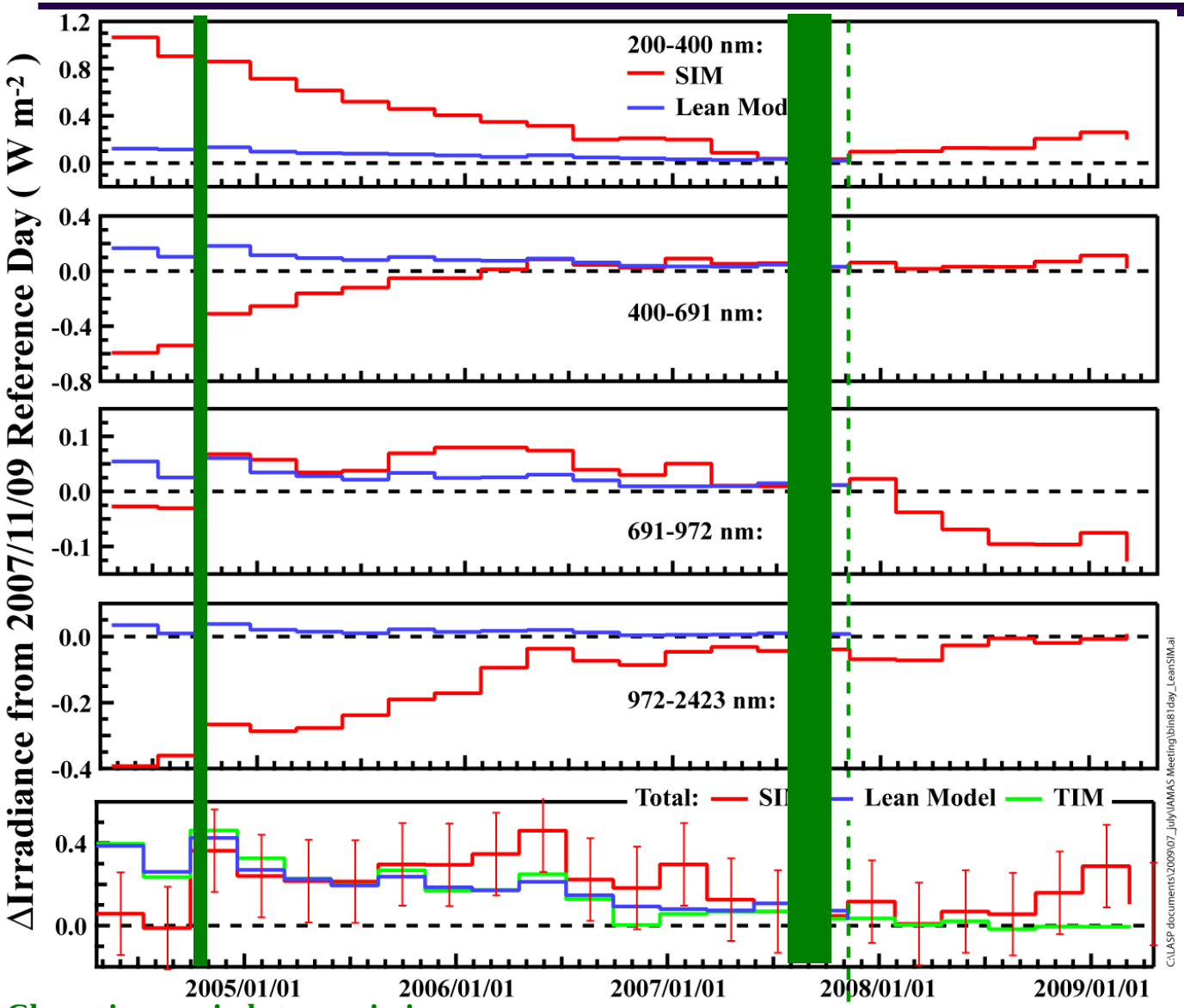
Three control cases: Fixed solar input in each case. Highlight Solar max/solar min conditions
Each run will be 15 year (FIXED year) simulations to build up stats

Case 1: Solar Quiet Simulation using Lean spectra
Solar Input: Average Lean spectra for 2007

Case 2: Solar Active Simulation Using Lean Spectra
Solar Input: Average Lean Spectra for 2004

Case 3: Solar Active Simulation representing SORCE variability
Solar Input: SORCE 2004 variability imposed on Lean Spectra
Eliminates differences in calibrations of SORCE vs Lean spectra.

SIM and Modeled Spectra Integrated into Broad Bands



Composites to characterize SORCE variability

Using Solstice FUV, MUV, SIM Photodiodes, SIM ESR, SRPM and Lean we create a composite Average Spectra for 2004 and 2007

<u>Composite is built with the following data:</u>

Solstice FUV – 115.5nm to 179.5 nm

Solstice MUV – 180.5 nm to 239.5 nm

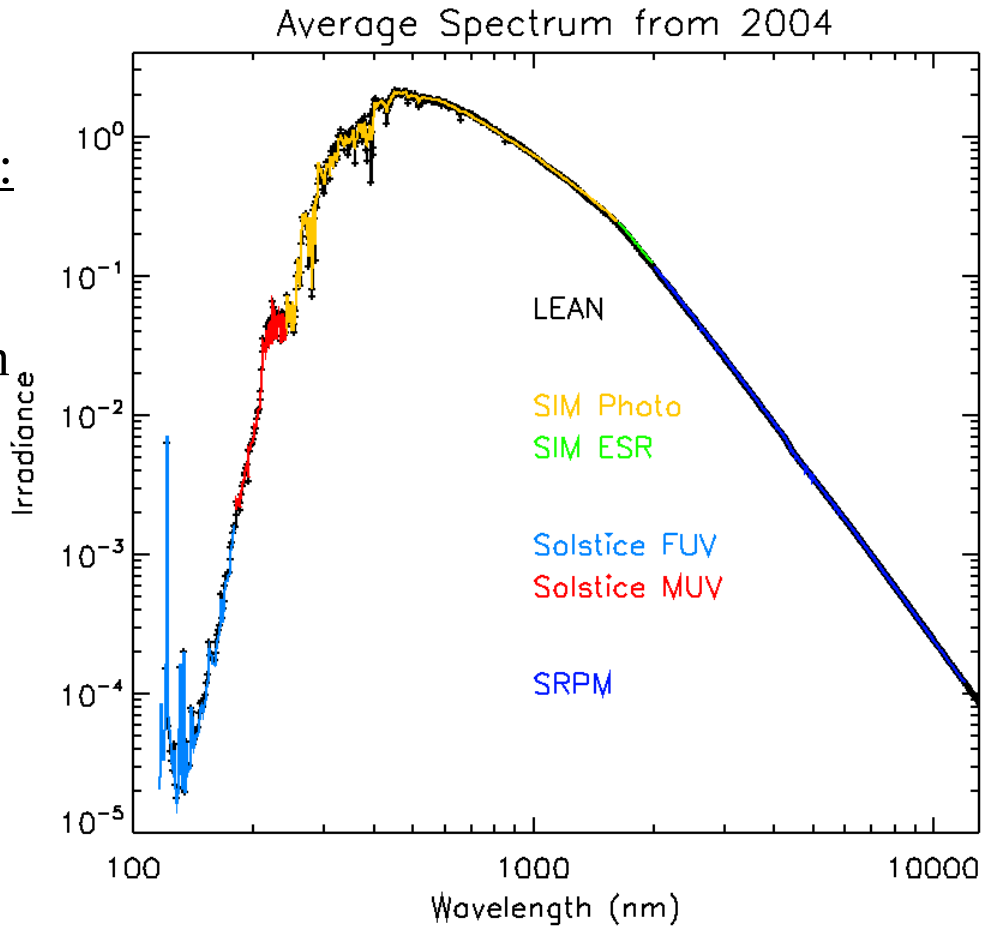
SIM Photodiodes – 240.5 nm to 1619.3nm

SIM ESR – 1632.4nm to 1991.9nm

SRPM – 1997.5nm to 11.975μ

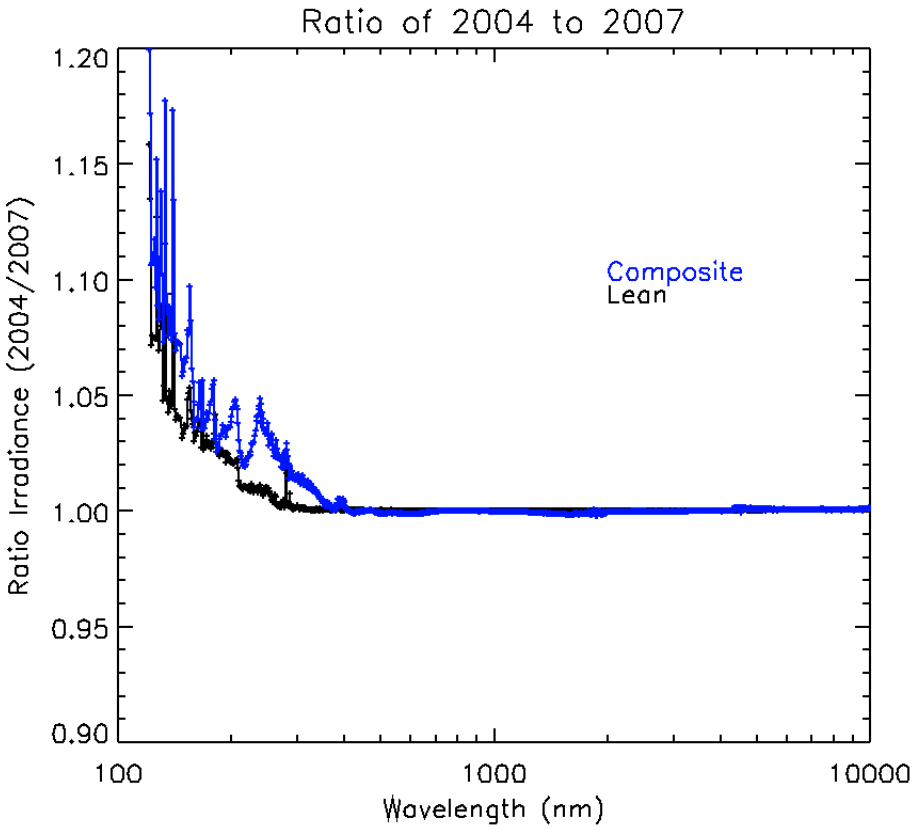
(Solar Radiation Physical Modeling)

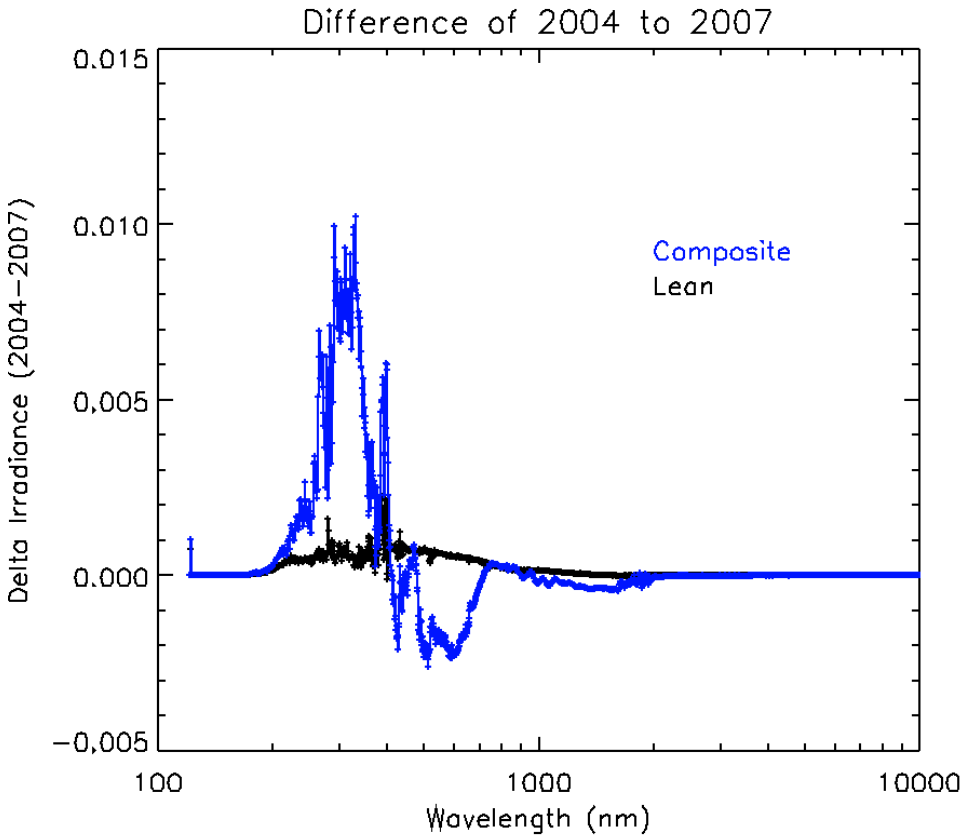
Lean – 12.025μ to 100μ



Ratio and Difference of SORCE Composites

Use ratio of 2004/2007 from composites to scale Lean 2007 to parameterize the 2004 composite variability in WACCM.

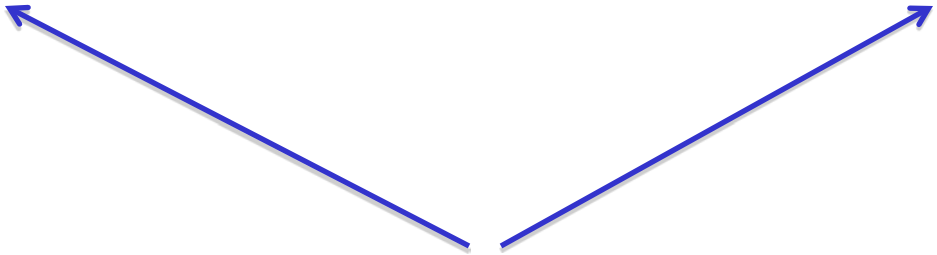




Ratio = SSI_2004 / SSI_2007

TSI for each Case

Year	TIM	Lean	Composites	Case 1 (Lean 2007)	Case 2 (Lean 2004)	Case 3 (2004 Param)
2004	1361.34	1366.7	1373.89		1366.7	1366.56
2007	1360.89	1366.29	1373.63	1366.29		
Difference (from 2007)	0.45	0.41	0.25		0.41	0.28



We don't quite add up to TSI difference, but performed a normalization to conserve the total energy difference.

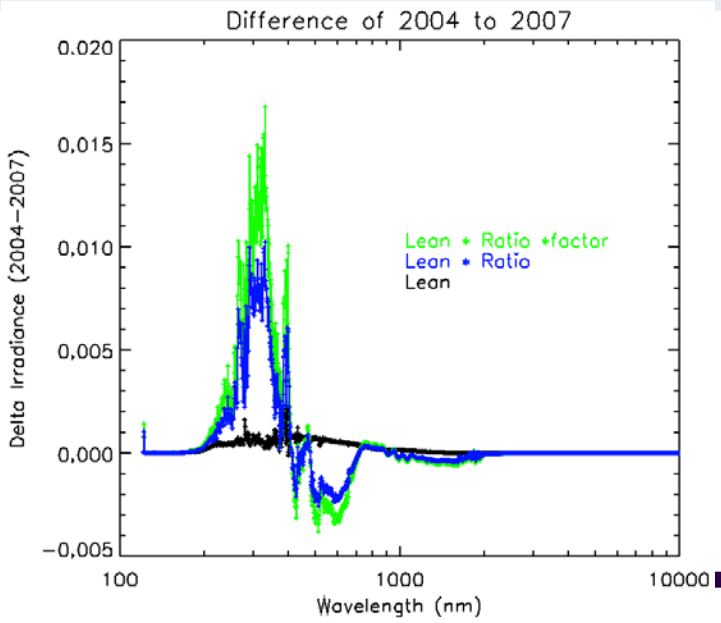
TSI Normalization

Ratio = SSI_2004 / SSI_2007

Scaled_Ratio = (Ratio – 1.) * FACTOR + 1.

FACTOR = 0.41 / 0.28 = 1.46

Case	TSI w/o factor	w/ factor
Case 1: Lean 2007	1366.29	1366.29
Case 2: Lean 2004	1366.7	1366.7
Case 3: Lean 2007 scaled to SORCE 2004	1366.56	1366.70
Difference: 2004 Param - 2007	0.28	0.41



Difference now conserved.

Will the SORCE variability be maintained in CAMRT heating rate bands?

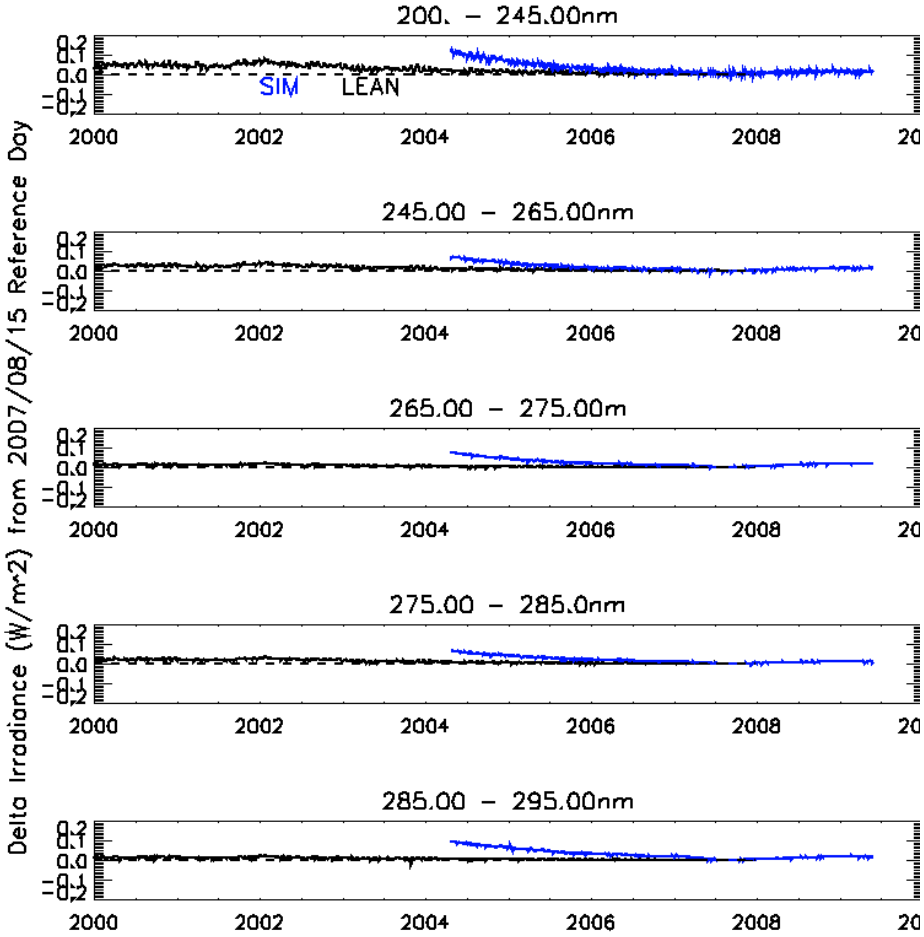
WACCM CAMRT has 19 spectral bands
The bands highlighted here are the bands that overlap with the Solstice and SIM measurements.

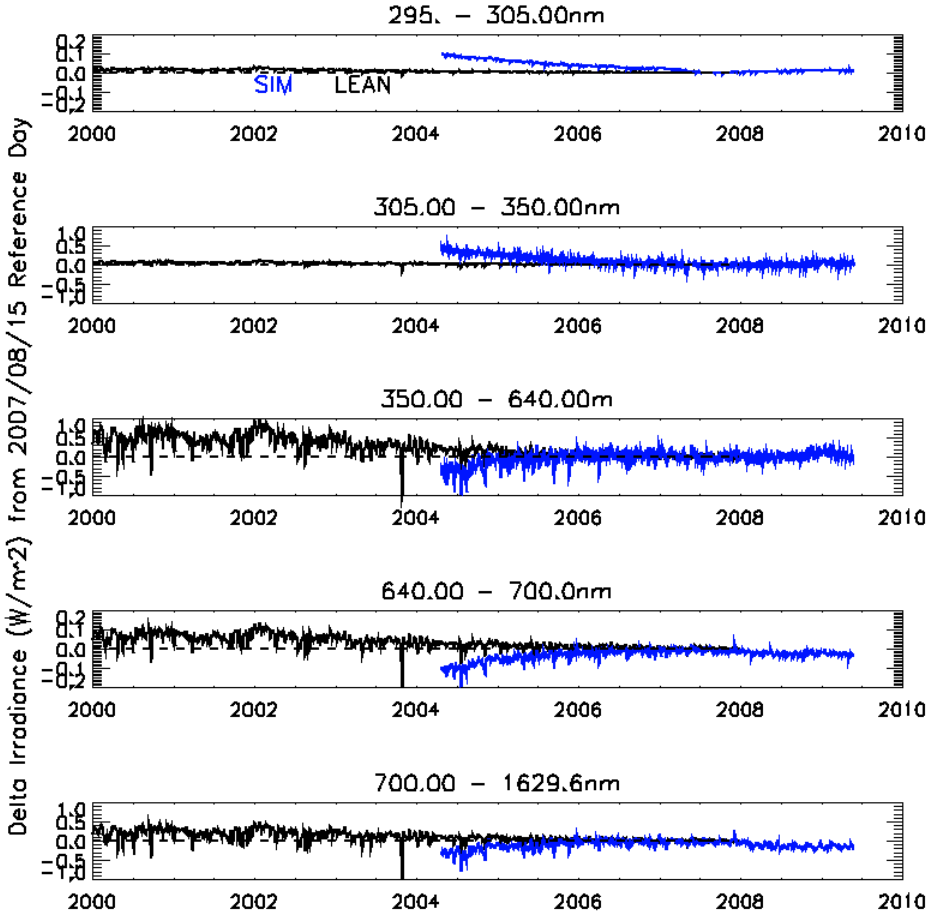
200-245	295-305
245-265	305-350
265-275	350-640
275-285	640-700
285-295	700-5000

Wavelength centers are 222 255 270 280 290 300 327 495 670 2850

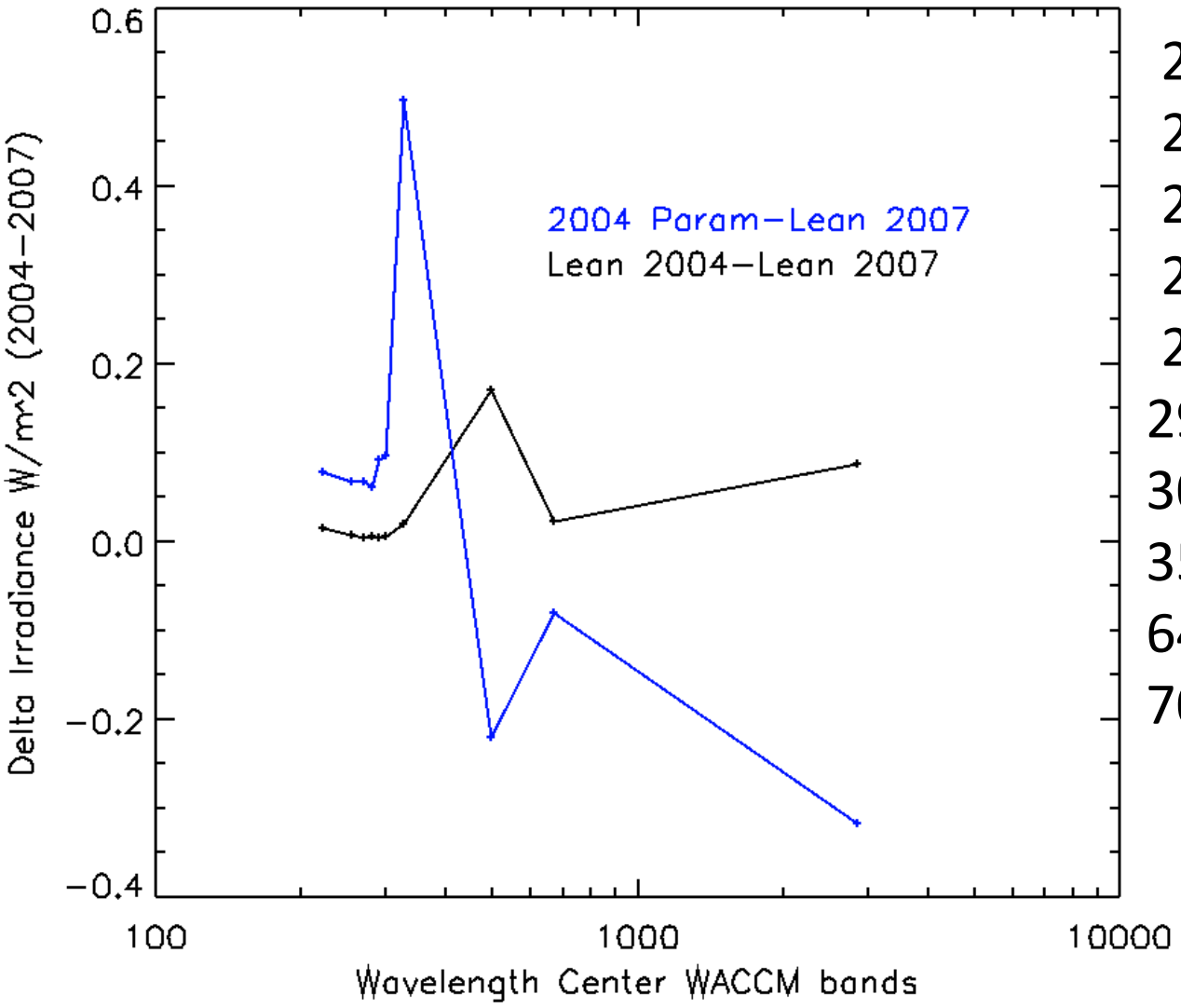
SIM and Modeled Spectra Integrated into WACCM bands
Delta Irradiance (Reference 11/2007)

Shows SIM Photo variability Compared to Lean at WACCM wavelengths
We want to maintain this variability in WACCM





Delta irradiance (2004-2007) in WACCM bands



Wavelength Range	Center
200-245	222
245-265	255
265-275	270
275-285	280
285-295	290
295-305	300
305-350	327
350-640	495
640-700	670
700-5000	2850

Progress: Where are we at?

- We have identified and compiled the 3 case study spectra
- We are in the process of modifying namelists to handle new Solar input and FIXED year cases.
- We will begin processing this week.