Predicting Material Performance in the Space Environment from Laboratory Test Data, Static Design Environments, and Space Weather Models

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Introduction

- **Materials are evaluated for use in space environments by laboratory exposure to VUV/UV, AO, and charge particle environments to determine effects on material properties**

- **Standard "static" design environments are typically used to establish exposure periods and the corresponding photon, AO, and charged particle fluence to meet mission requirements**

- **Questions:**
  – How well do static models represent the real environment?
  – What is the contribution of "space weather" events to material exposure environments?

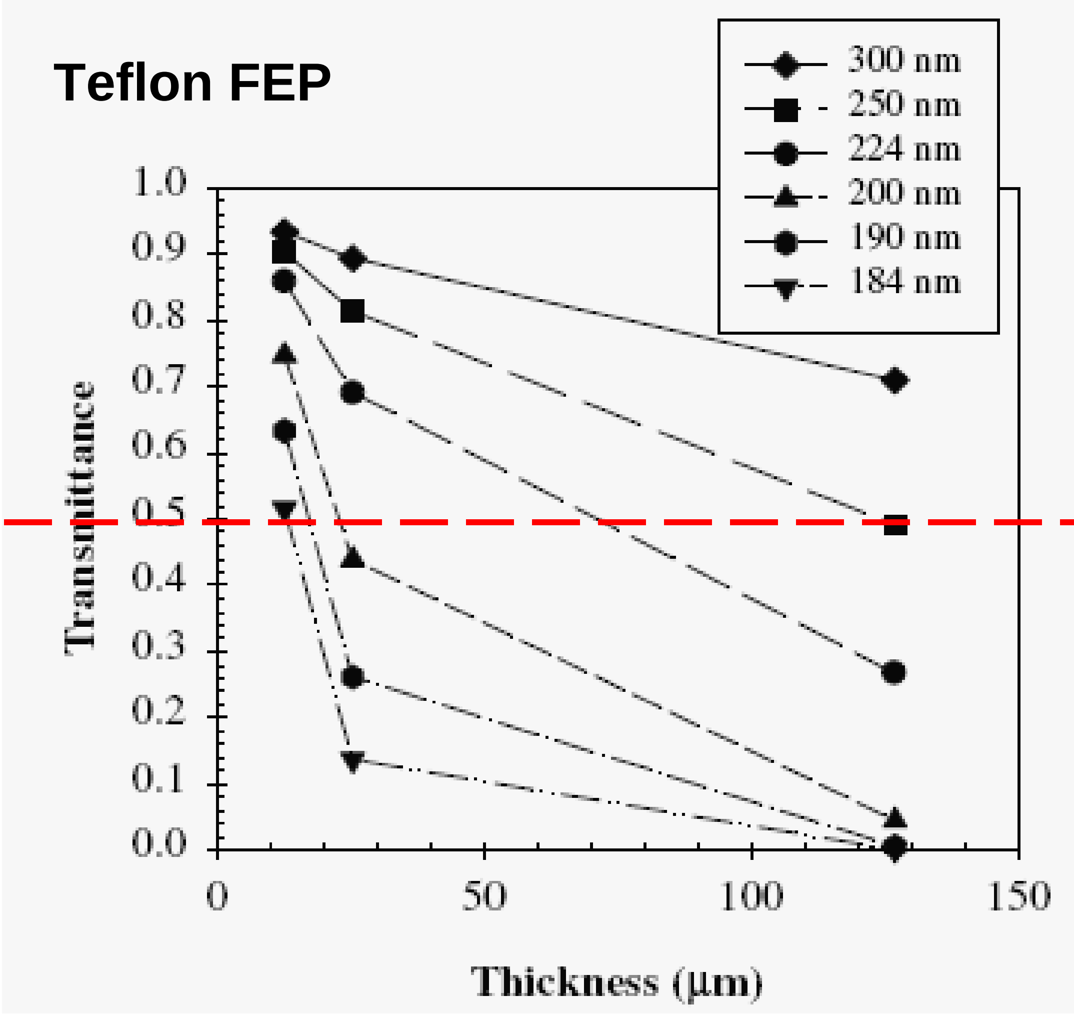
- **Today's presentation will**
  – Examine VUV/UV environments used in laboratory tests with emphasis on surface exposures
  – Examine importance of "space weather" event contributions to environment

VUV/UV Penetration Depth

- Long wavelengths penetrate deeper into polymers

λ (nm)	50% depth (μm)
300	----
250	128
224	65
200	22
190	17
184	14

- VUV wavelengths where solar variability is strongest primarily impacts material surfaces



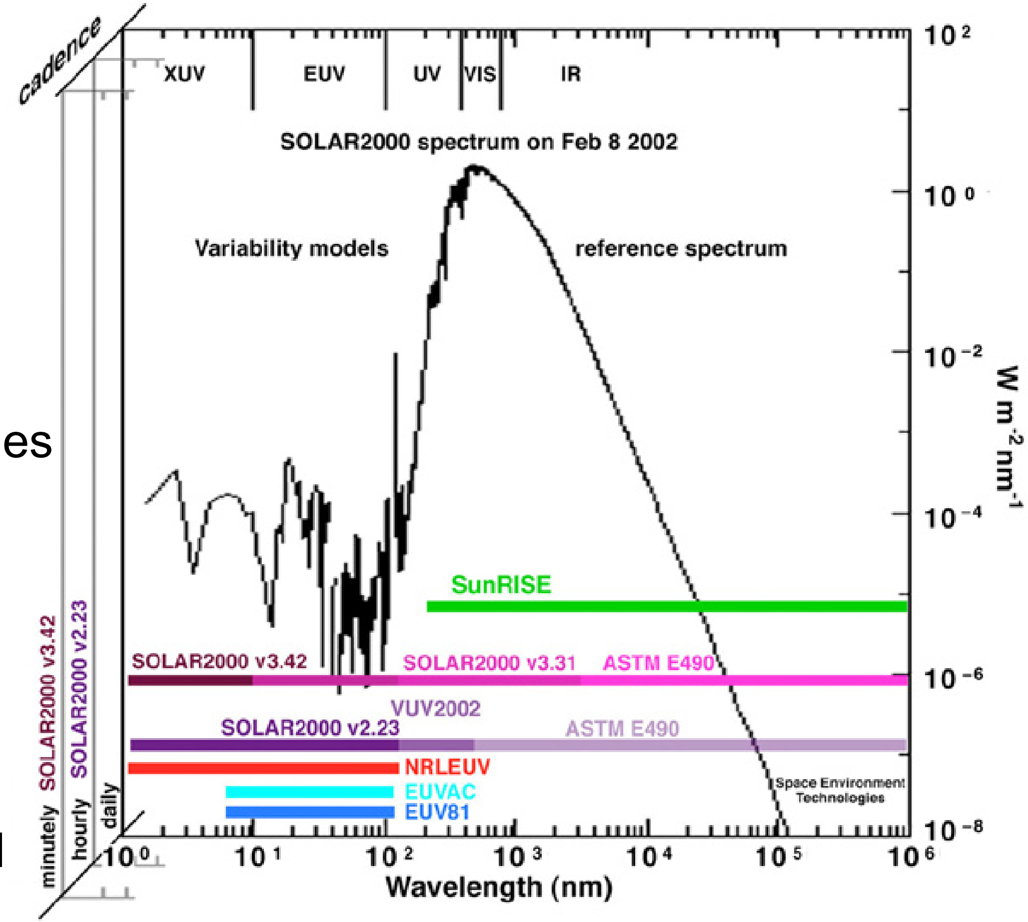
[*Dever et al*., 2002]

Solar Spectrum and Models

- Static models
  - NRLEUV
  - EUVAC
  - EUV81
  - ASTM E490

- Climatology
  - Solar2000 (S2K)
  - Space Environment Technologies
    Tobiska et al.
    constant 122.5 – 1x10^6 nm
    variable 0.5 – 121.5 nm
    Δt = 1 day

- Space weather
  - Flare Irradiance Spectral Model
  - LASP/CU Boulder
    Chamberlin et al.
    0.1 – 194 nm
    Δt = 1 minute



[*Tobiska and Nusinov* , 2004]

Solar XUV/EUV/UV Variability

Solar2000

- Static ASTM E490
- Variable XUV/EUV

Reference Spectrum

- Mean S2K

- Nomenclature

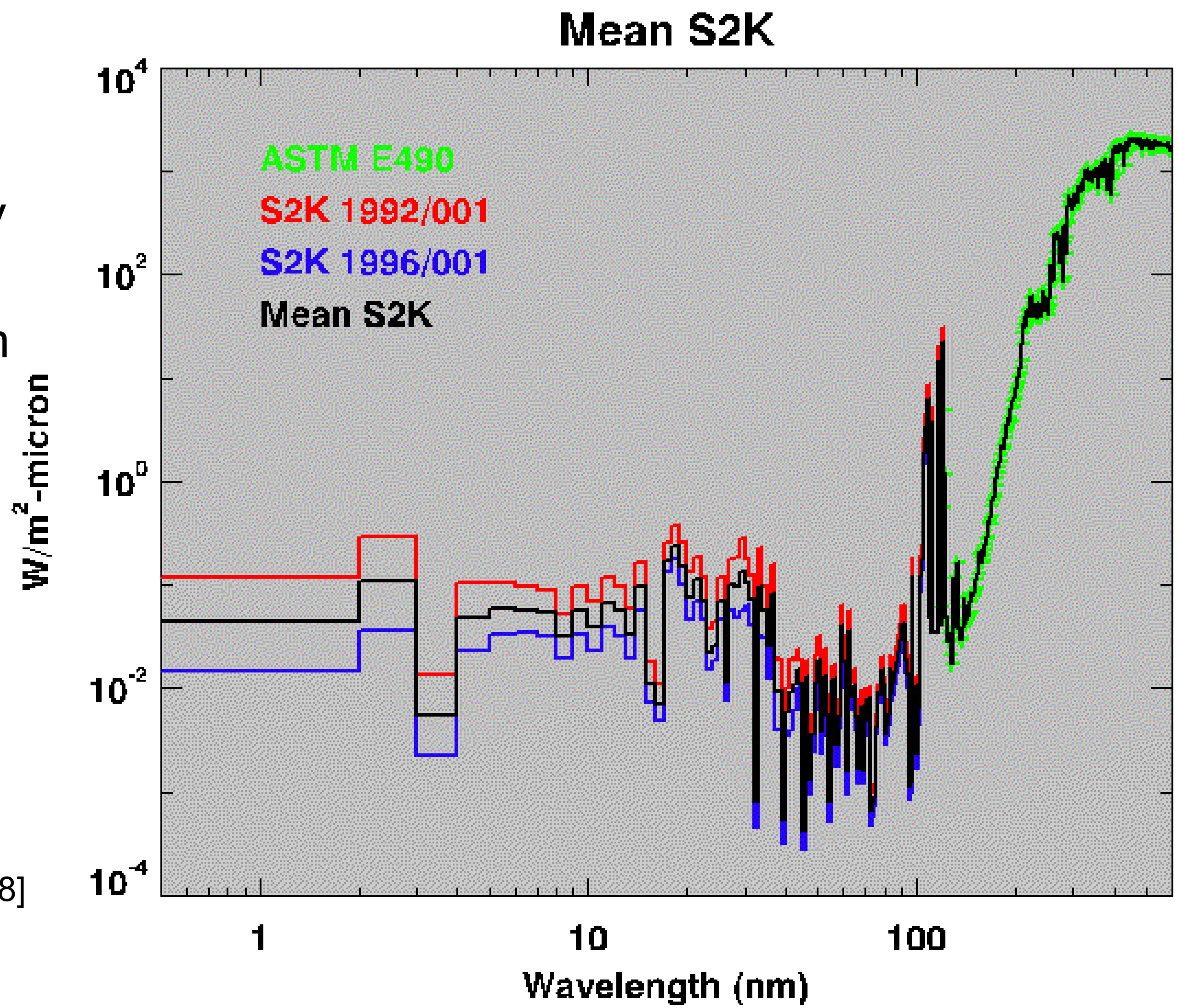
  XUV 0.1 ≤ λ < 10

  EUV 10 ≤ λ < 200

  UV 200 ≤ λ < 400

  VUV 20 ≤ λ < 200

[*ISO_DIS_21348_E_revB*, 2008]



Solar XUV/EUV/UV Variability

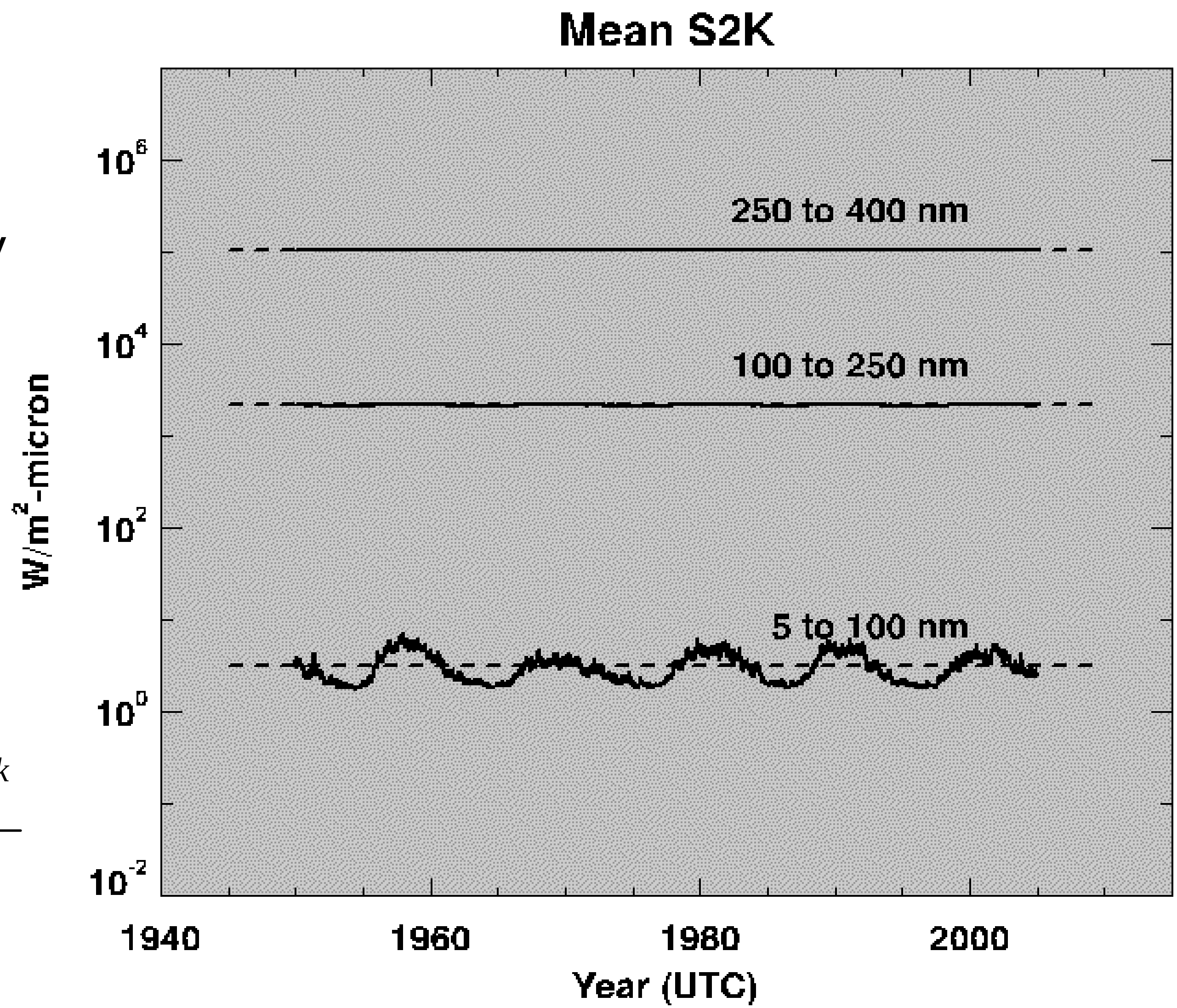
Solar2000

- Static ASTM E490
- Variable XUV/EUV

Reference Spectrum

- Mean S2K

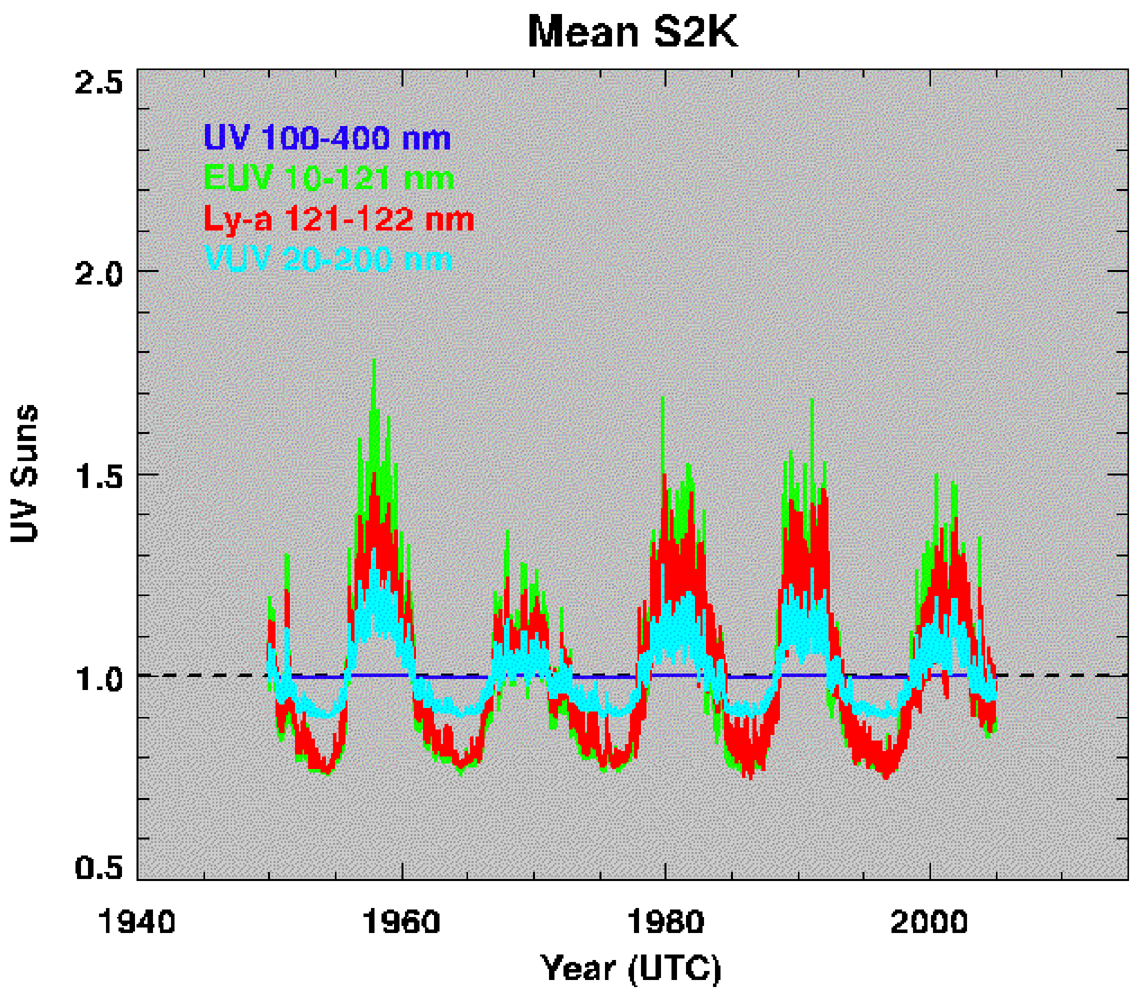
$$I_{\lambda_a-\lambda_b} = \frac{\sum_{k=1}^{n} I(\lambda_k)\,d\lambda_k}{\sum_{k=1}^{n} d\lambda_k}$$



Solar UV/VUV Variability

- Solar intensity in terms of UV Suns based on mean S2K design model

- Solar source yields UV Suns exceeding unity when mean model is used as reference spectrum



$$UV\ Suns_{\lambda_a-\lambda_b} = \frac{I_{\lambda_a-\lambda_b,source}}{I_{\lambda_a-\lambda_b,reference}}$$

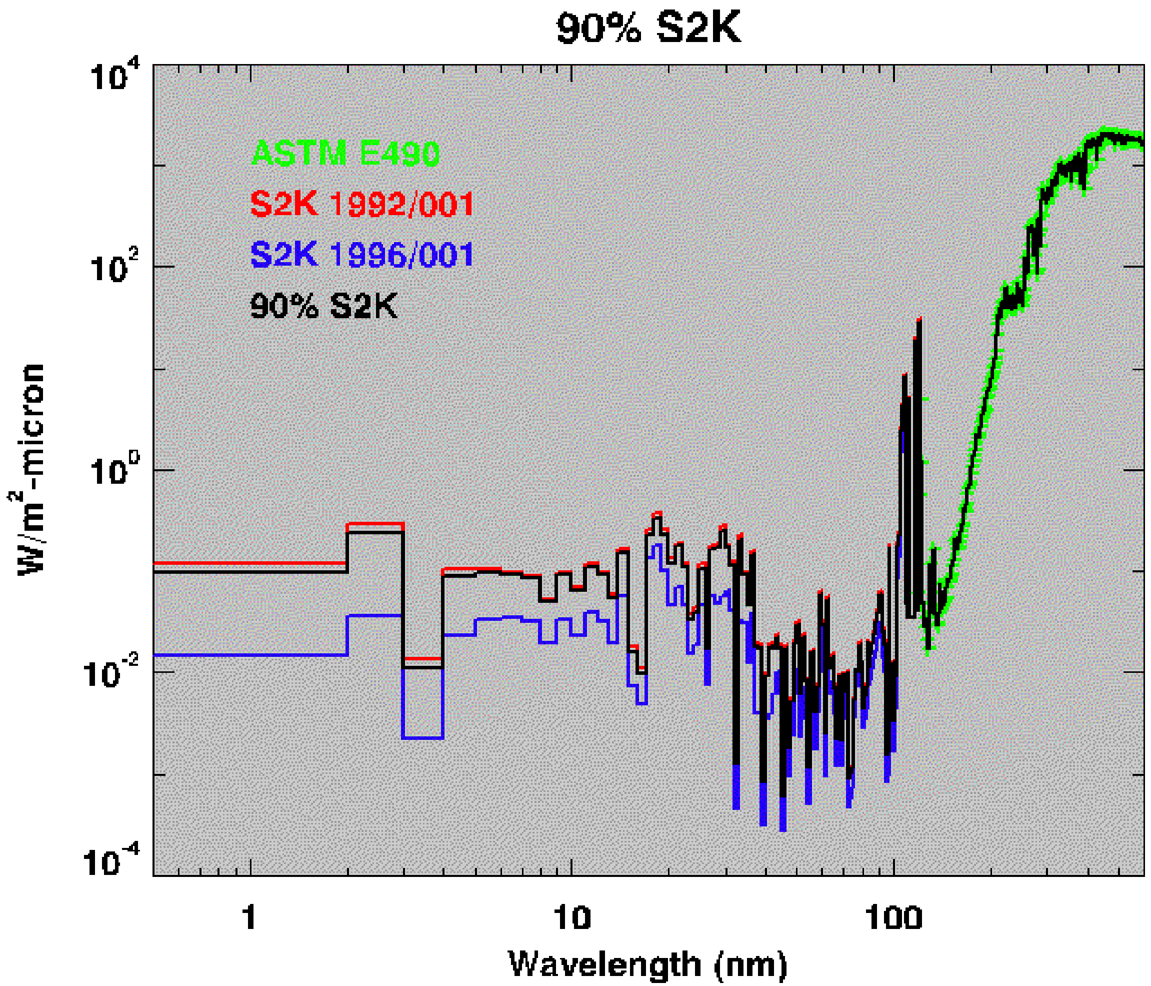
Solar UV/VUV Variability

Solar2000

- Static ASTM E490
- Variable XUV/EUV

Reference Spectrum

- 90% S2K



Solar XUV/EUV/UV Variability

Solar2000

- Static ASTM E490
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Reference Spectrum

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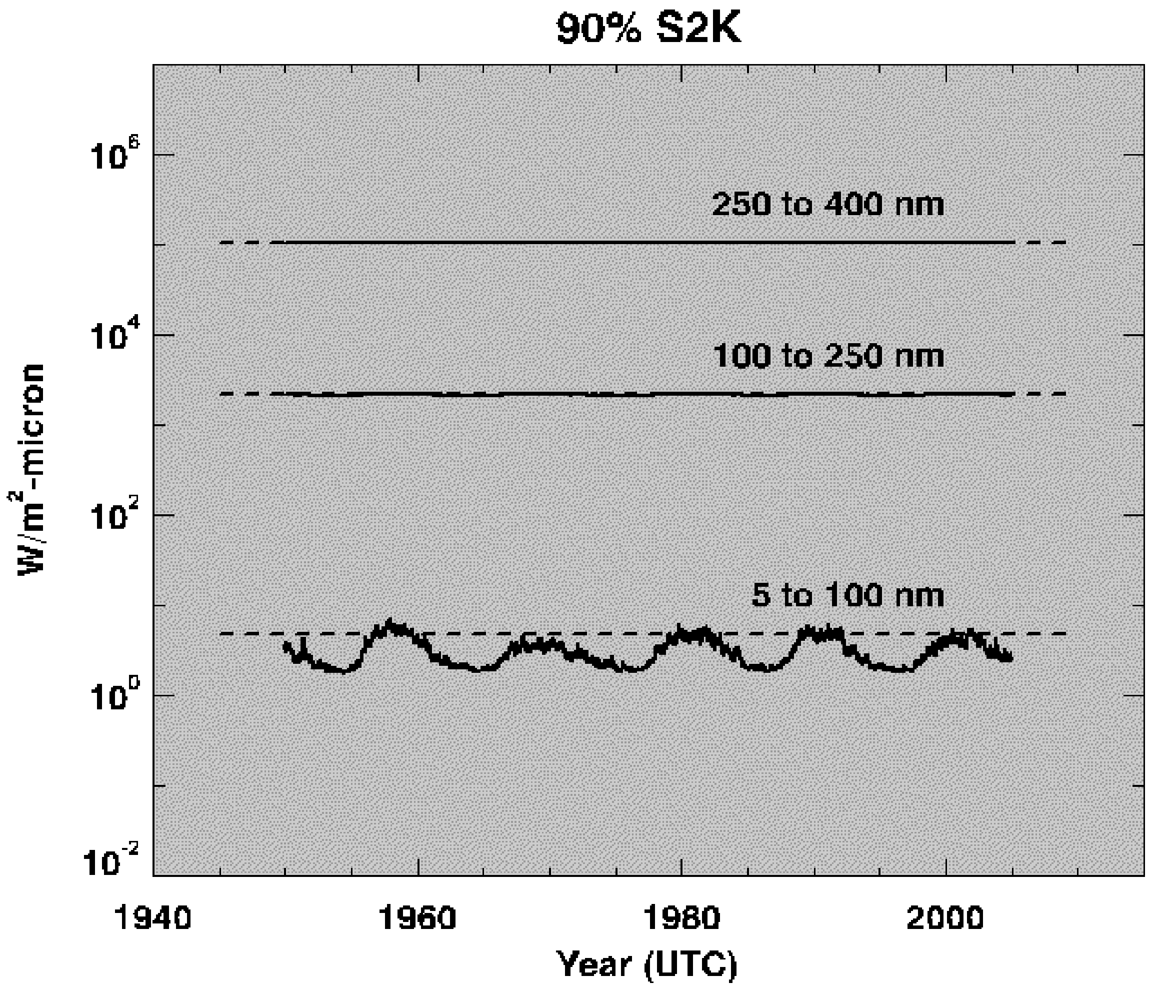
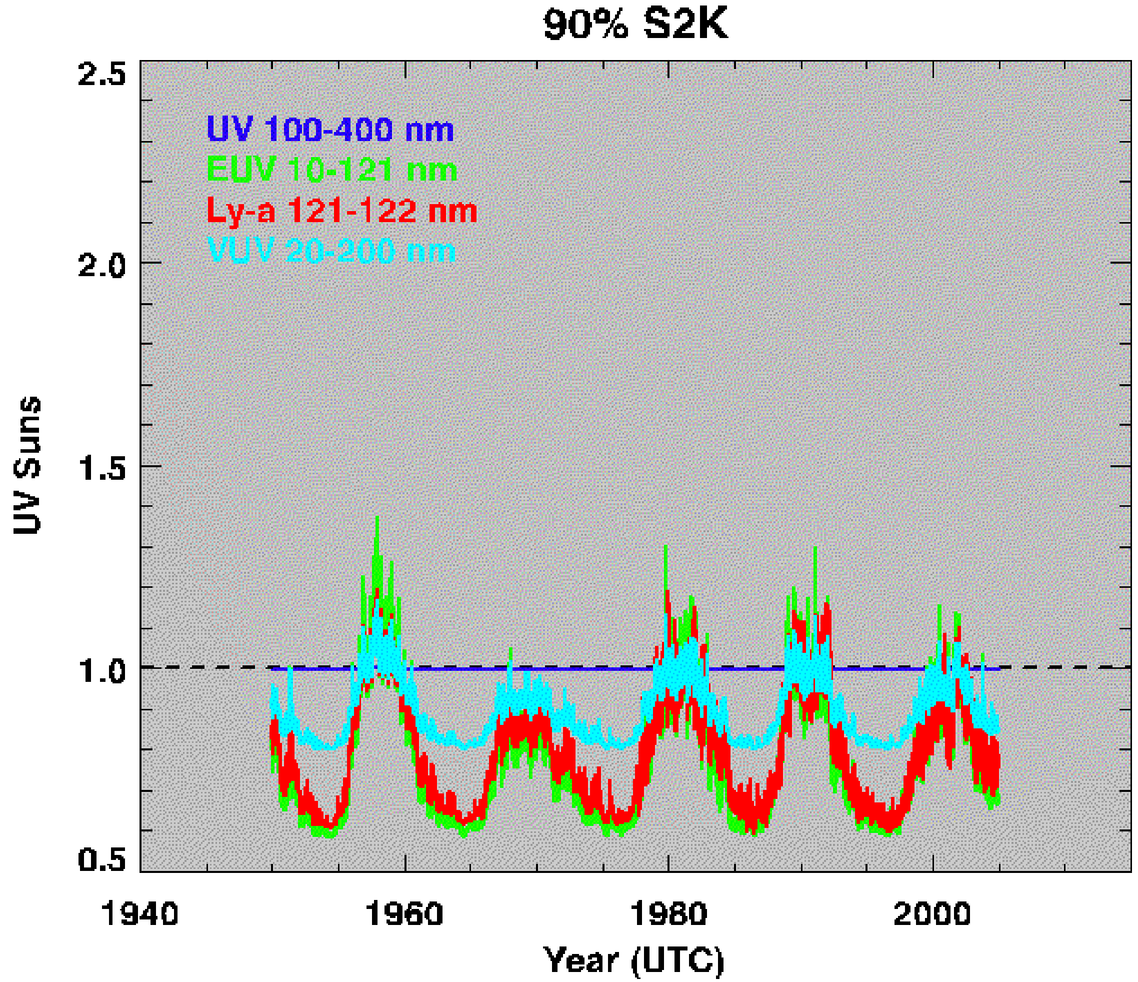


Solar UV/VUV Variability

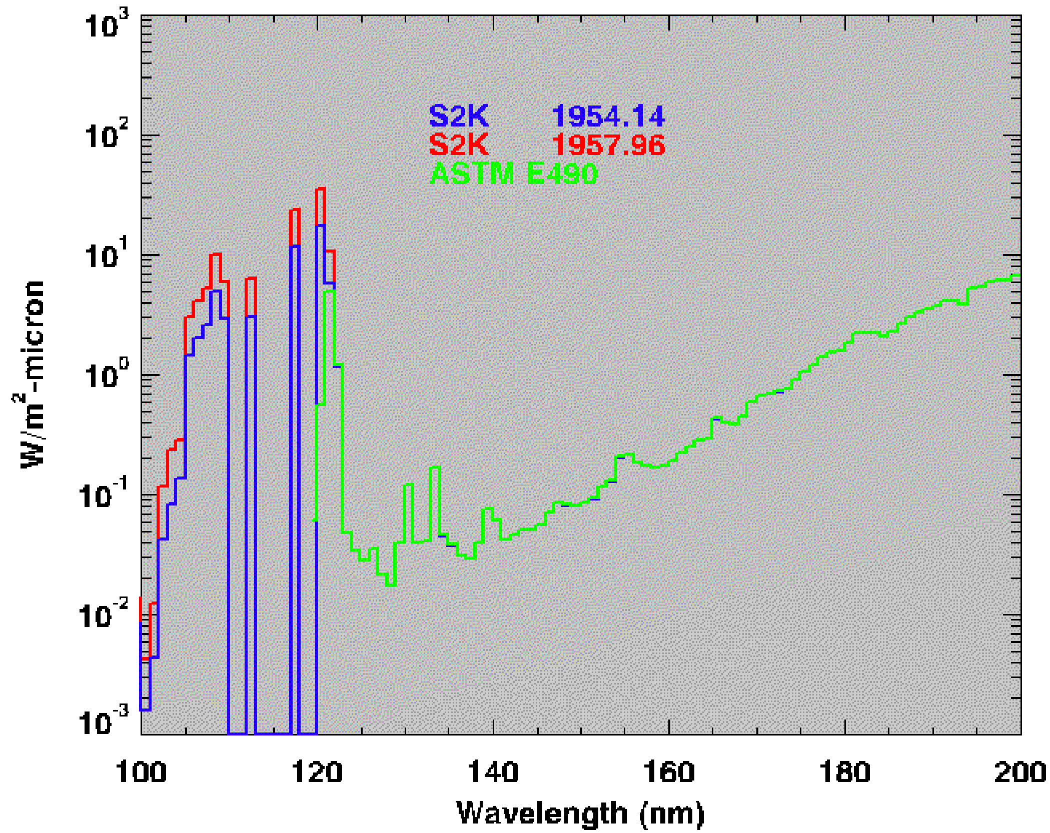
- Solar intensity in terms of UV Suns based on 90% S2K design model

- Conservative model yields fewer UV sun values exceeding design models



ASTM E490 and Solar Variability: Spectrum

- S2K model intensity exceeds ASTM-E490 at Lyman-α wavelengths
- S2K as ASTM-E490 for wavelengths longer than Lyman-α
- Materials sensitive to wavelengths shorter than Lyman-α may under perform i in space environment if
  - qualified only to ASTM-E490
  - degradation dominated by <200 nm environment



ASTM E490 and Solar Variability: Time

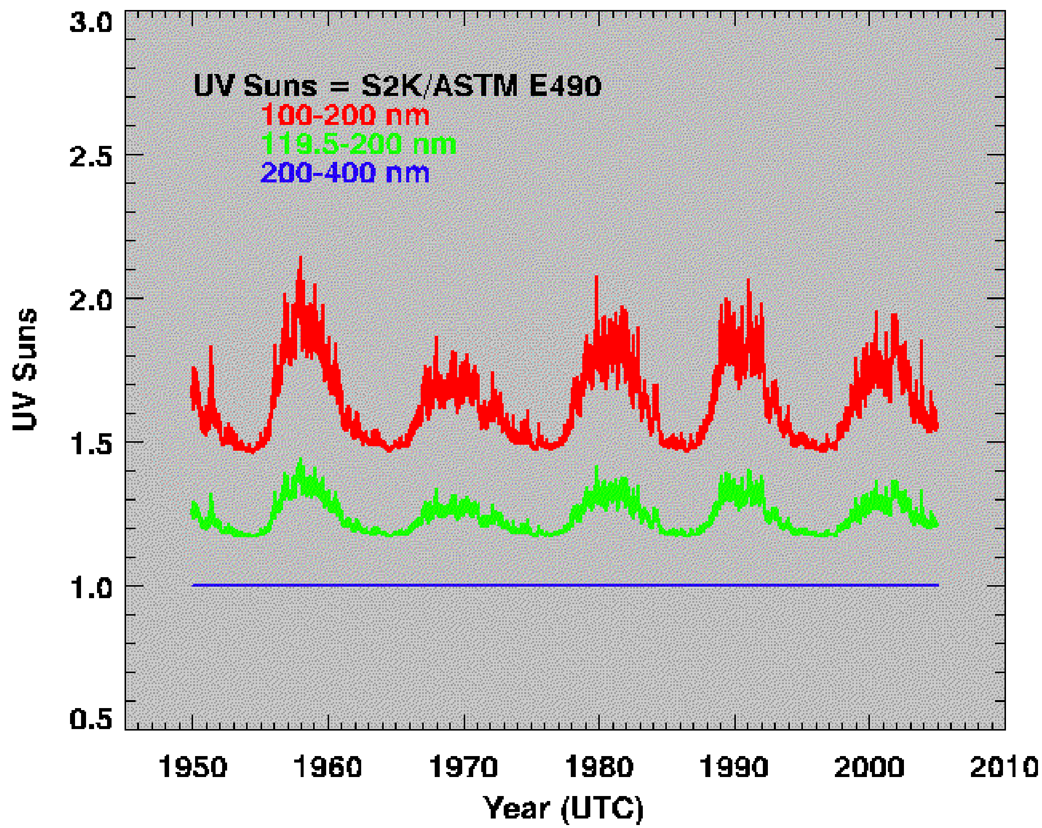
- UV Suns based on Solar2000 exceed the ASTM-E490 environments for all solar cycles from 1950 through 2004 for wavelengths shorter than Lyman-α

- ASTM under represents the solar spectrum?

  UV source: UARS

- Solar2000 XUV/EUV data measured on orbit [*Tobiska and Bouwer*, 2006]:

TIMED	AE-E
SOHO	SOLRAD
SORCE	YOHKOH
SNOE	



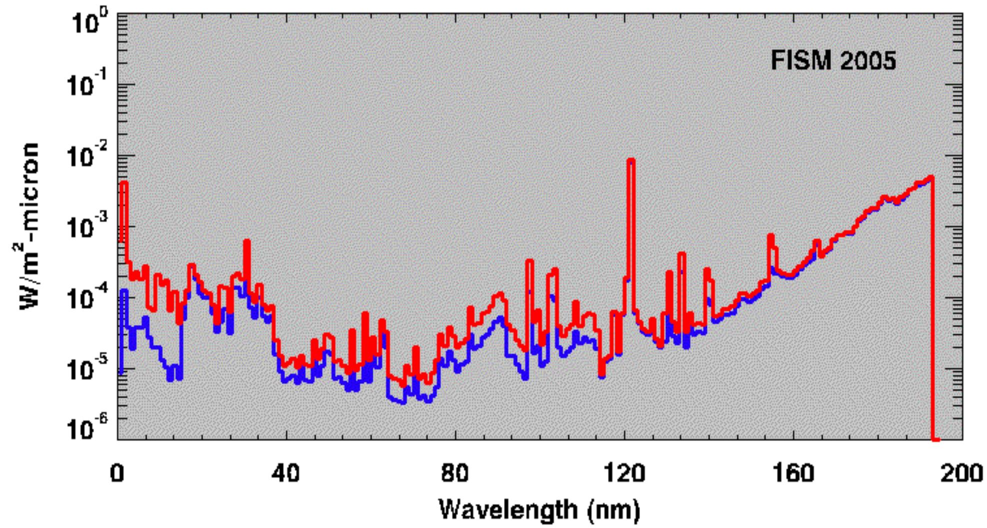
Flare Irradiance Spectral Model (FISM)

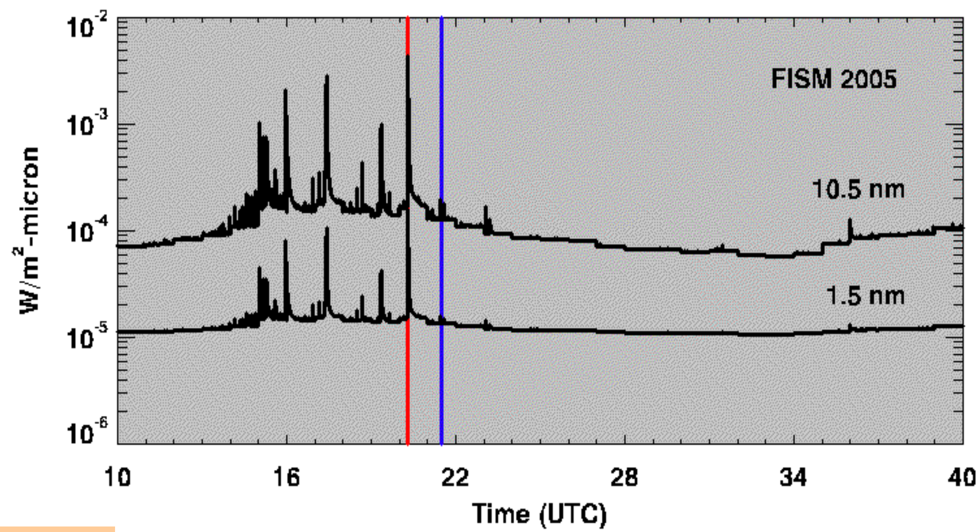
- Empirical solar irradiance model developed by LASP/CU [*Chamberlin et al*., 2007]
  - Resolution

    $\Delta\lambda$ = 1 nm   0.1 nm < λ < 194 nm

    Δt = 60 seconds
  - Data sources
    - Solar Extreme Ultraviolet Experiment (SEE)/TIMED
    - Solar Stellar Irradiance Comparison Experiment (SOLSTICE)/UARS

- FISM developed to provide VUV solar spectral irradiances for input to ionosphere, thermosphere models
  - 100% coverage from 1986 to present

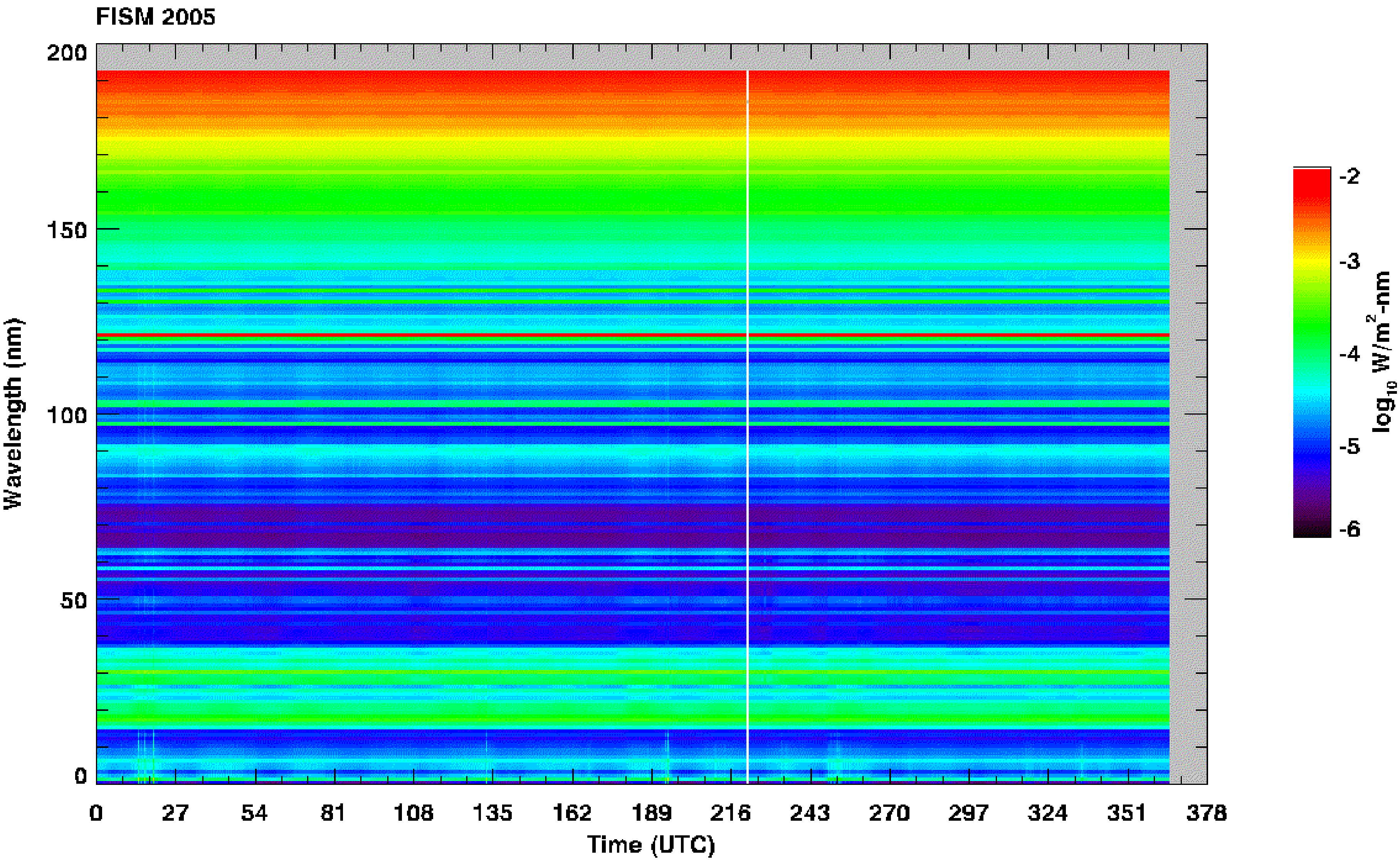




FISM URL:
http://lasp.colorado.edu/LISIRD/fism.htm

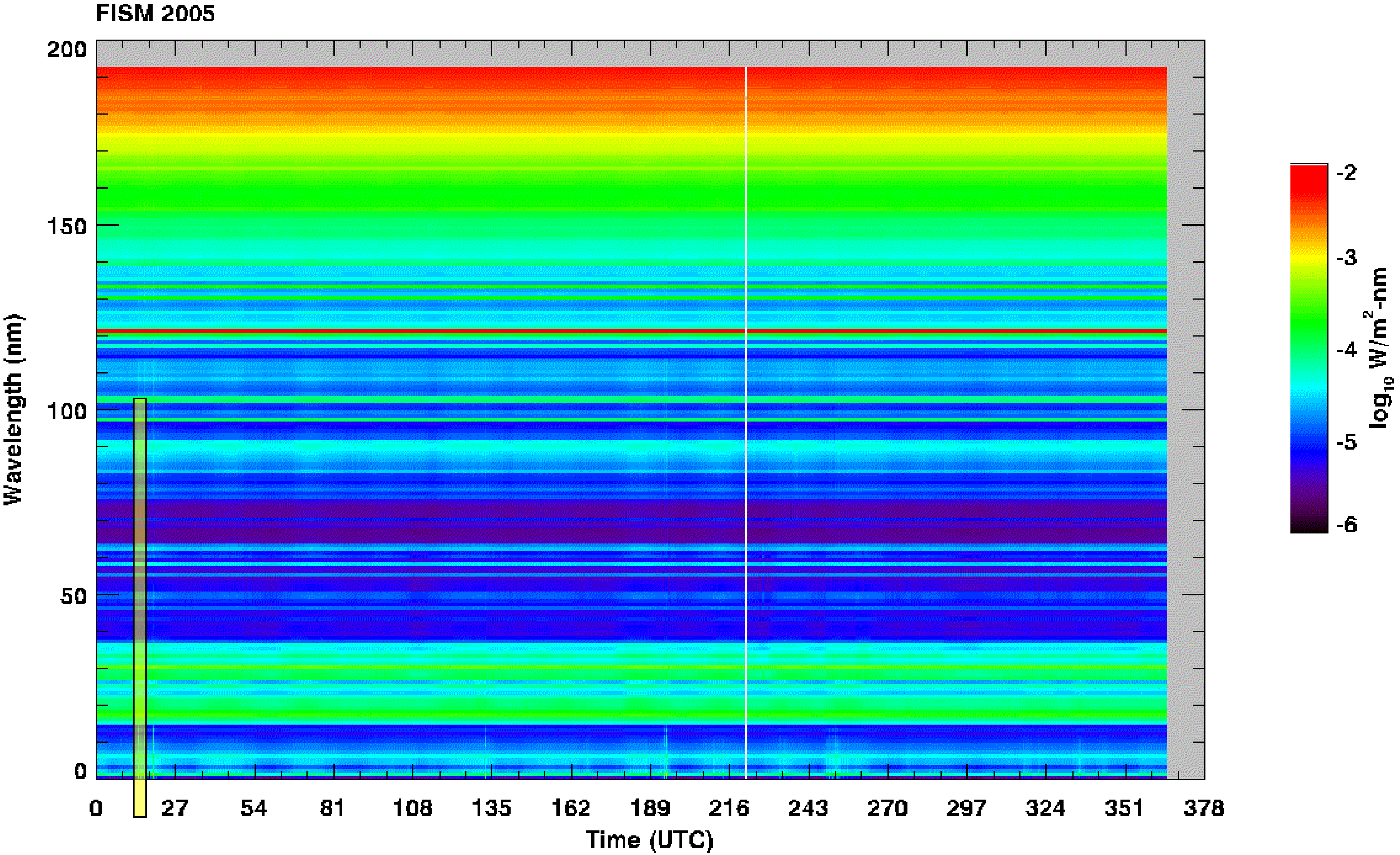
Solar VUV 2005

Solar minimum



Solar VUV 2005

Solar minimum



Solar VUV 2005

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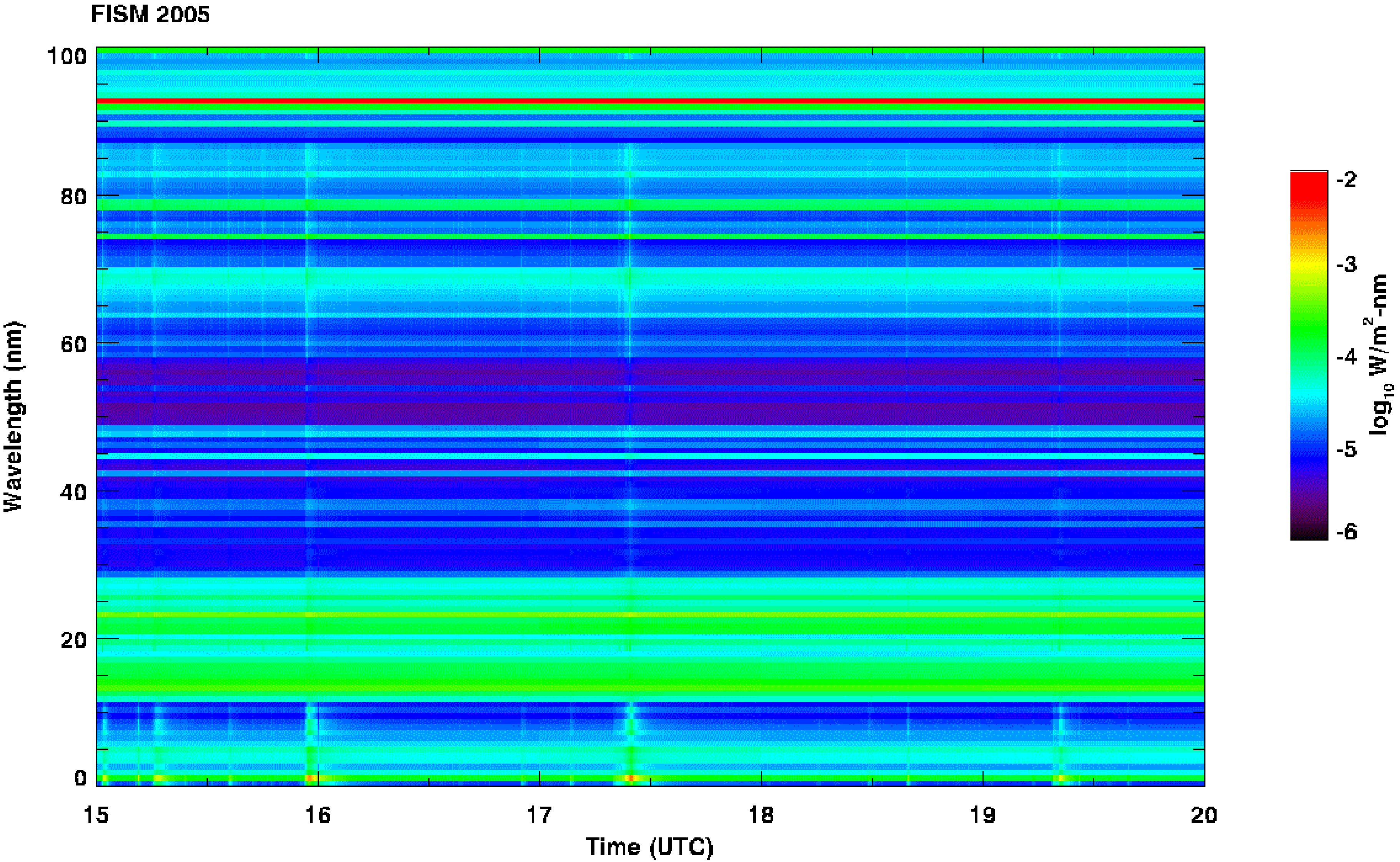
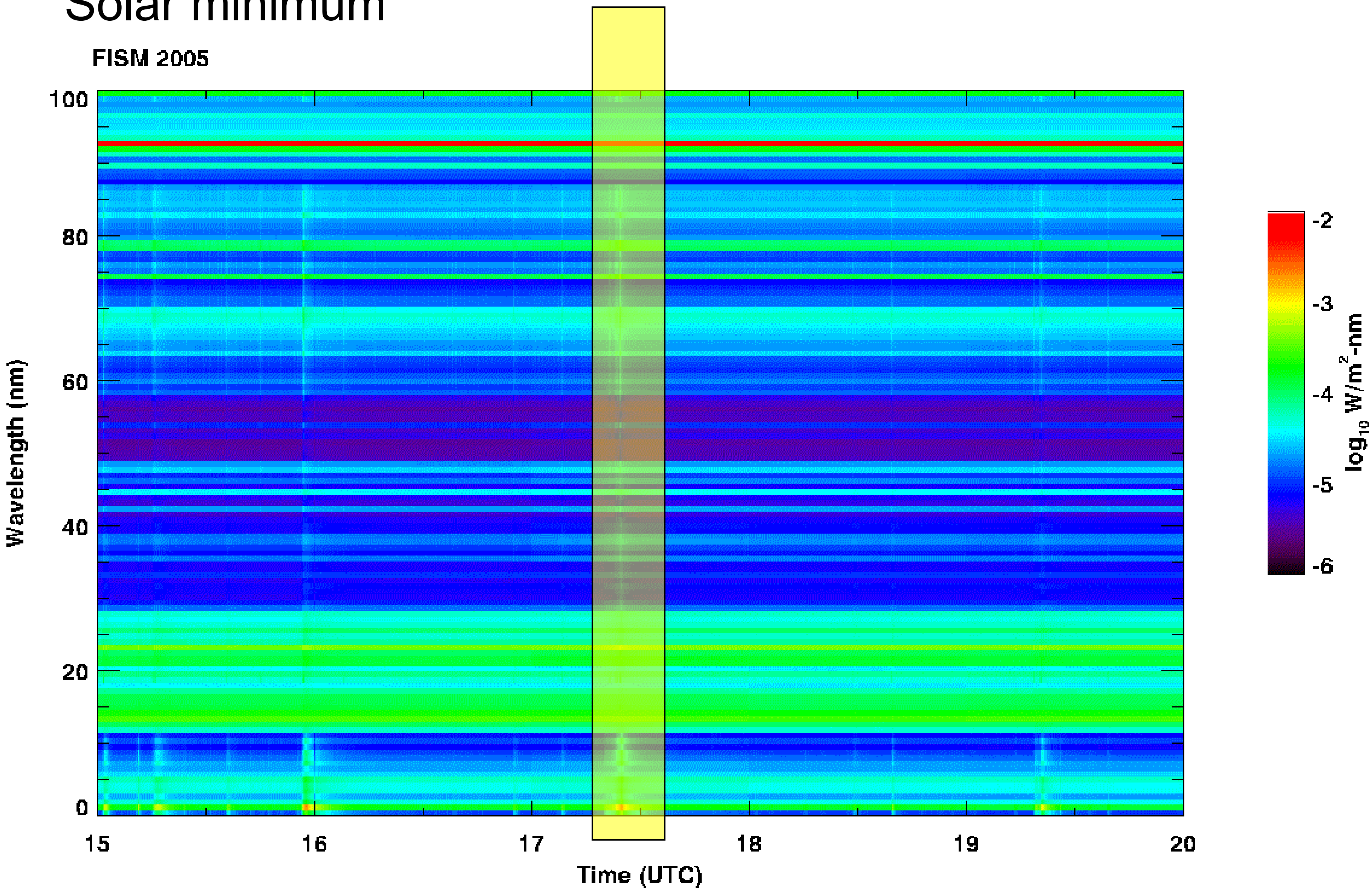


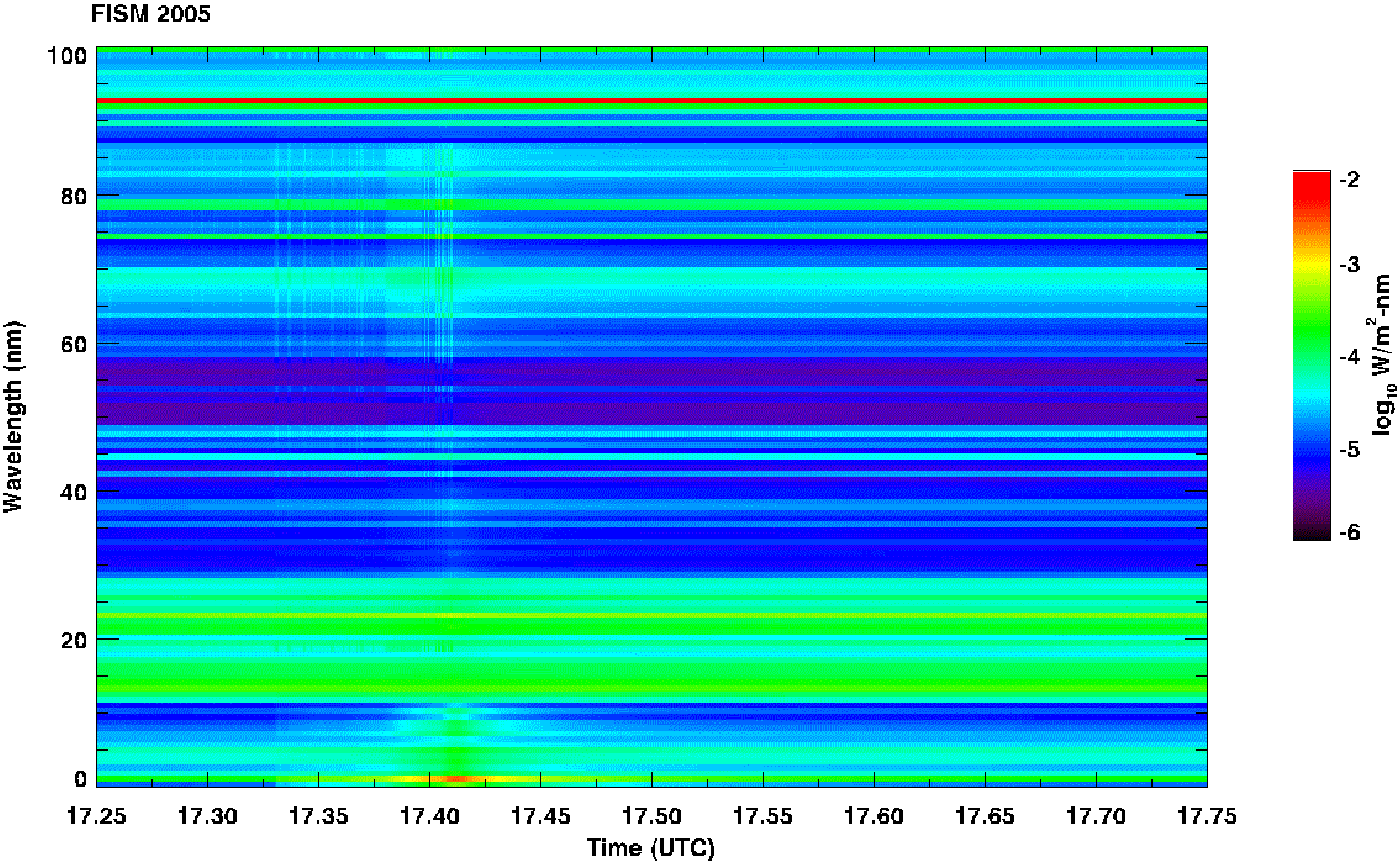
Solar VUV 2005

Solar minimum



Solar VUV 2005

Solar minimum



Summary

- **Static design models typically used to establish laboratory test protocols for determining material response to the UV/VUV space environment**
  - Need to be careful with choice of reference model if test results are to be used for qualifying materials for extended use in space

- **Space climatology and space weather models provide a useful technique for evaluating projected on orbit performance to a “static” design specification**

- **Solar2000 and FISM models are useful tools for**
  - Characterizing dynamic changes in on-orbit solar VUV environments
  - Developing appropriate design environments for screening materials to VUV environments