Possible Extraterrestrial Solar Radiation (ETR) Spectral Variations from the UV to Visible: A Test for Ground-based Observations

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With special thanks to:
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Barry Bodhaine
Mike O'Neill
Paul Johnston

Possible Extraterrestrial Solar Radiation (ETR) Spectral Variations from the UV to Visible: A Test for Ground-based Observations

Outline

- Motivation: Questions about recently-suggested ETR spectral variations over the solar cycle and their climatic impact
- Potential for surface-based observations to contribute
- GMD's relevant(?) observations-of-opportunity
- Preliminary comparisons of model-, satellite- and ground-based relative solar spectra for periods of high vs. low solar activity
- Path forward

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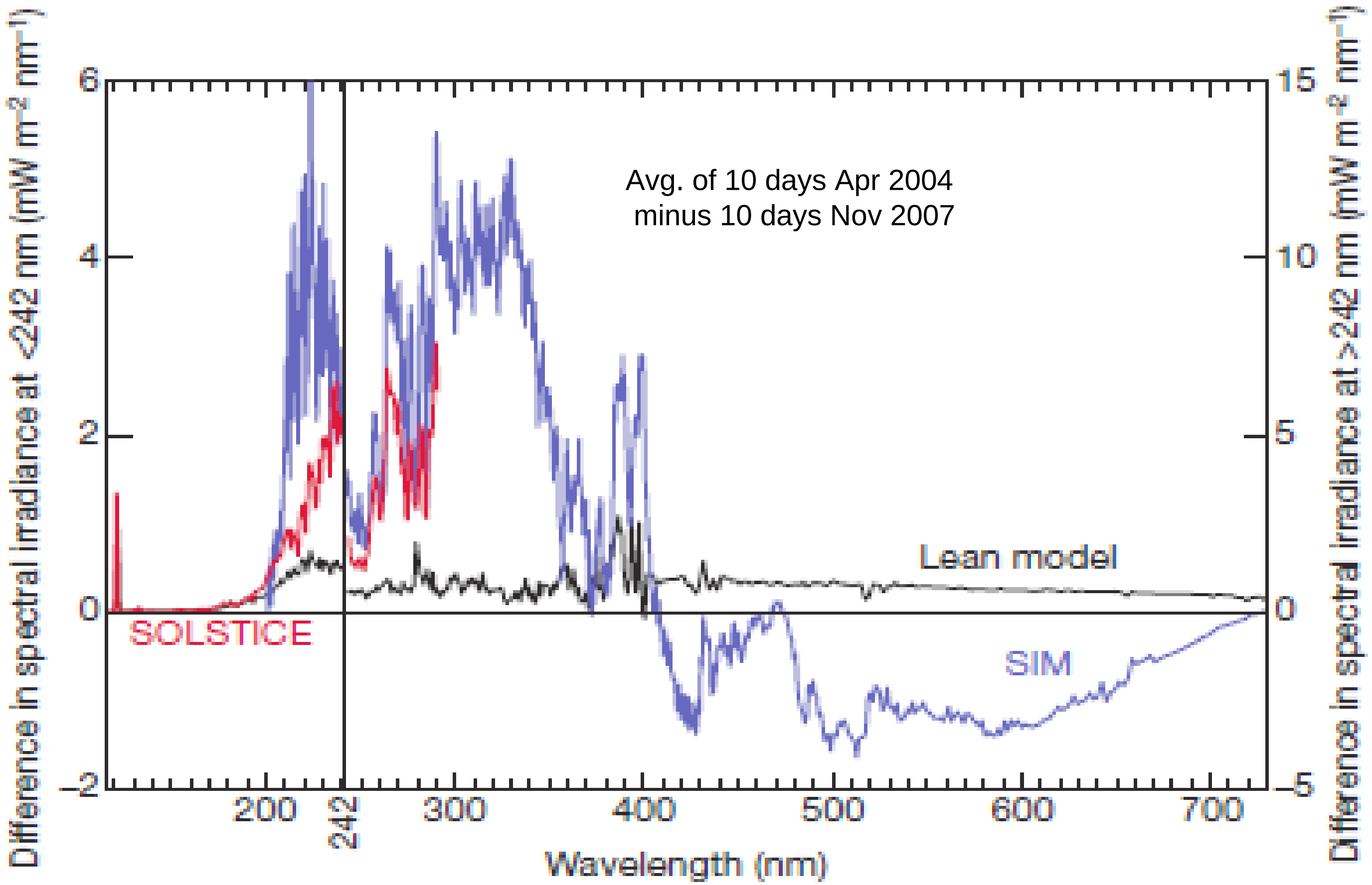
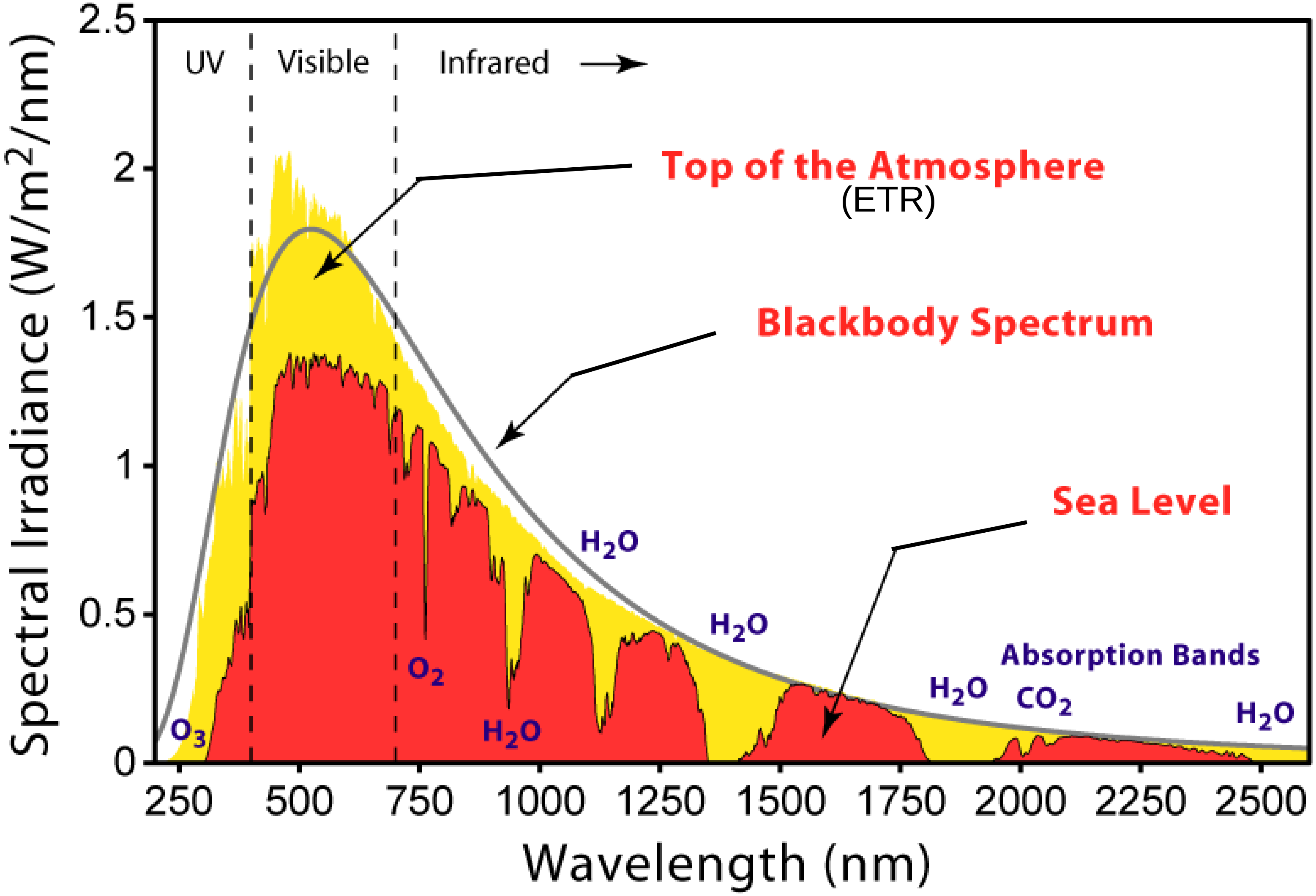
Modeled and Satellite-Observed Changes in Spectral ETR Between an Active and Inactive Sun (Active, 2004 - Inactive, 2007)



From J. Haigh et al., 2010, Nature using:
G. Harder et al., 2009, 2010 (SIM satellite)
and J. Lean, 2000, 2010 (model)

Solar Spectra



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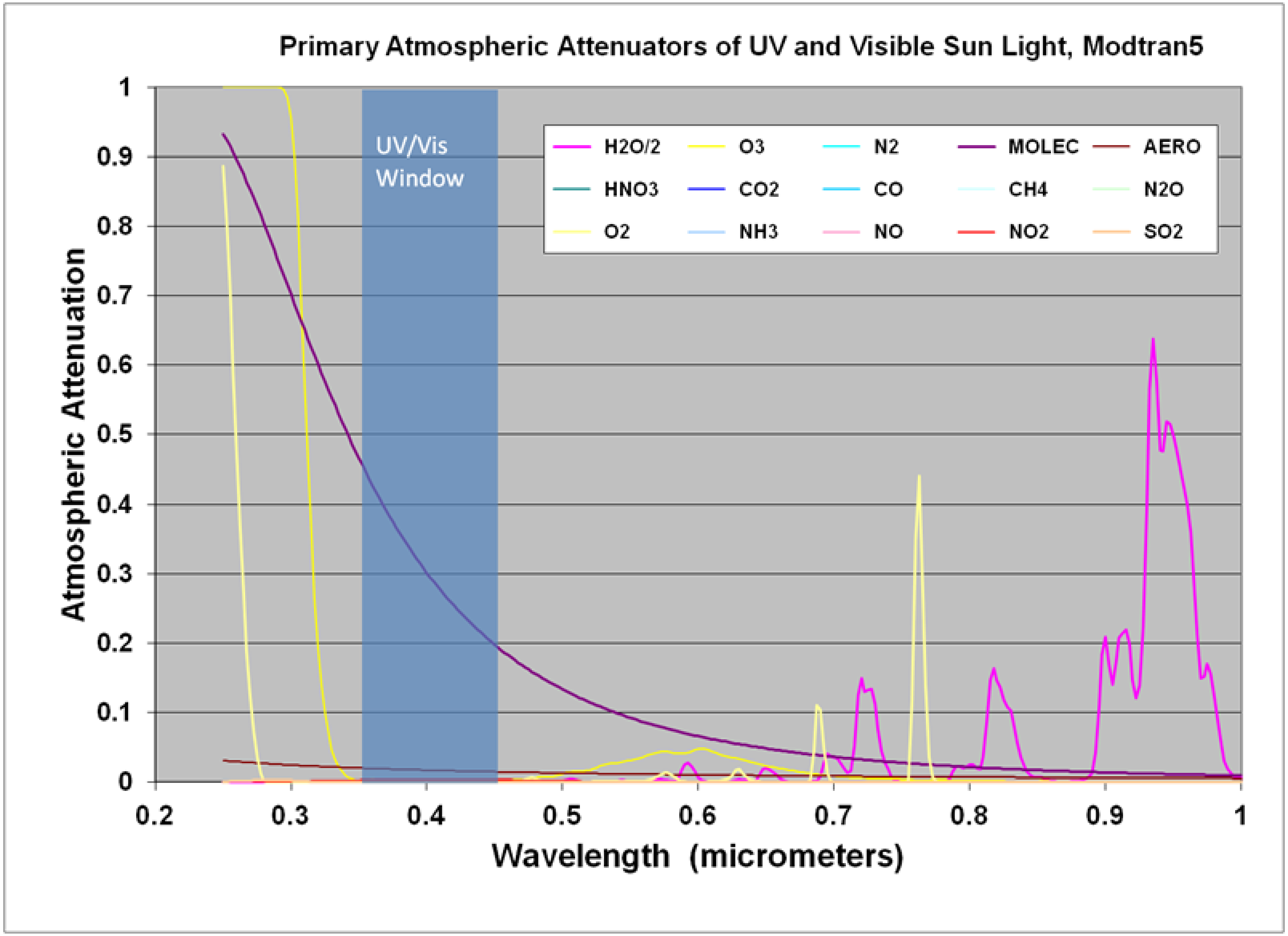
Looking through the UV/Vis window to the ETR



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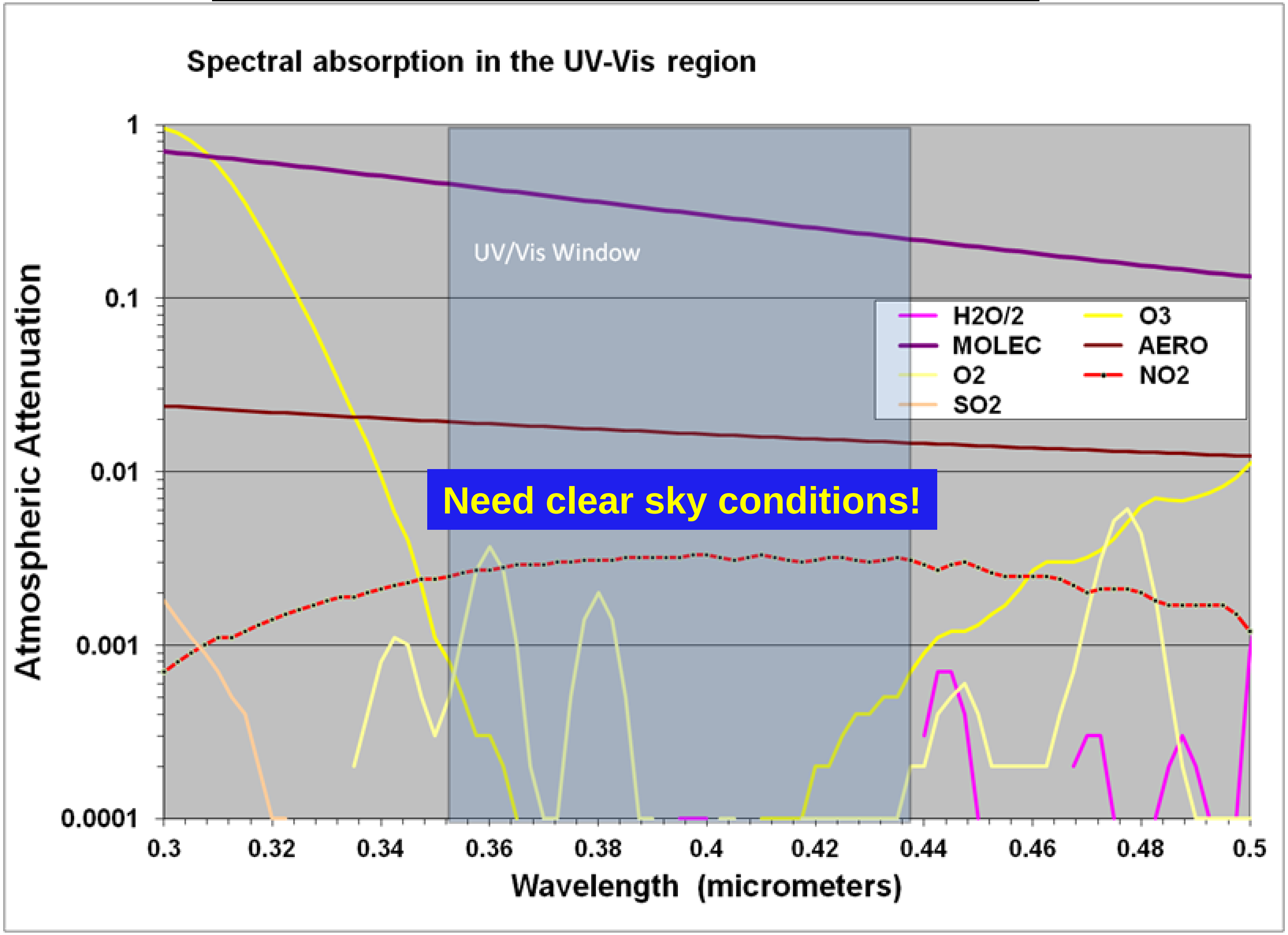

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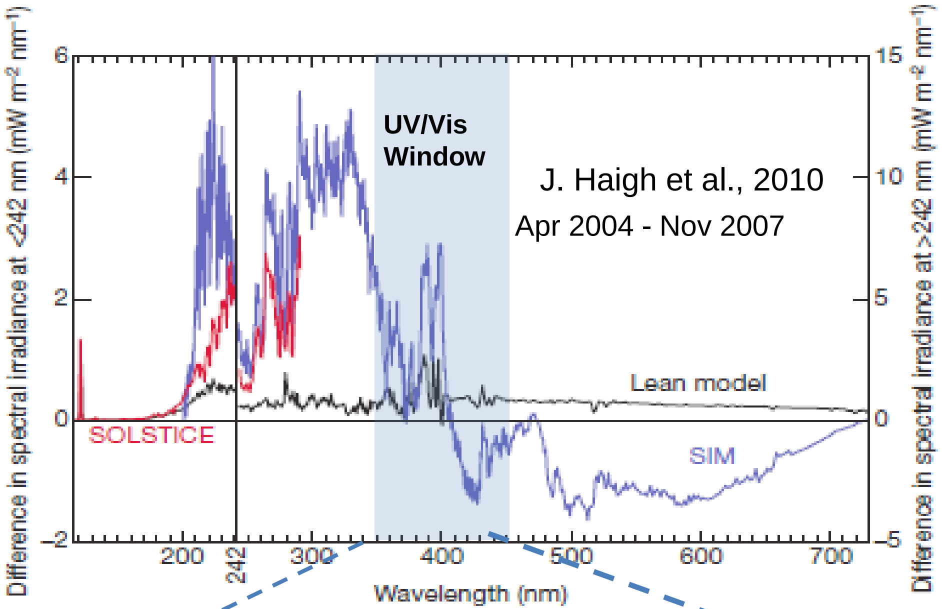
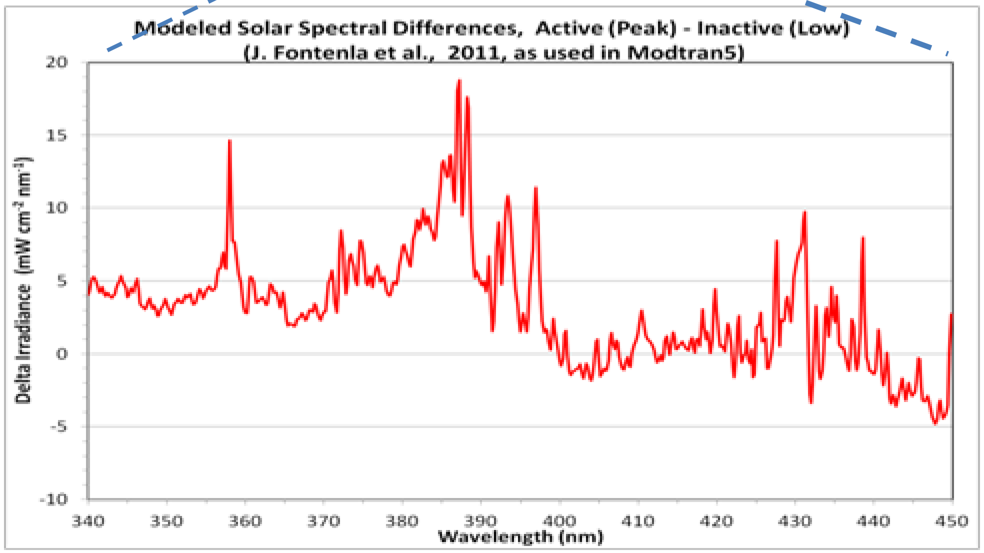
Modeled and Satellite-Observed Changes in Spectral ETR Between an Active and Inactive Sun





Another Model for Active vs. Inactive ETR Spectra from J. Fontenla et al., 2011 as used in MODTRAN5

(Peak day minus Low day)

Note: Not same days as Haigh et al.

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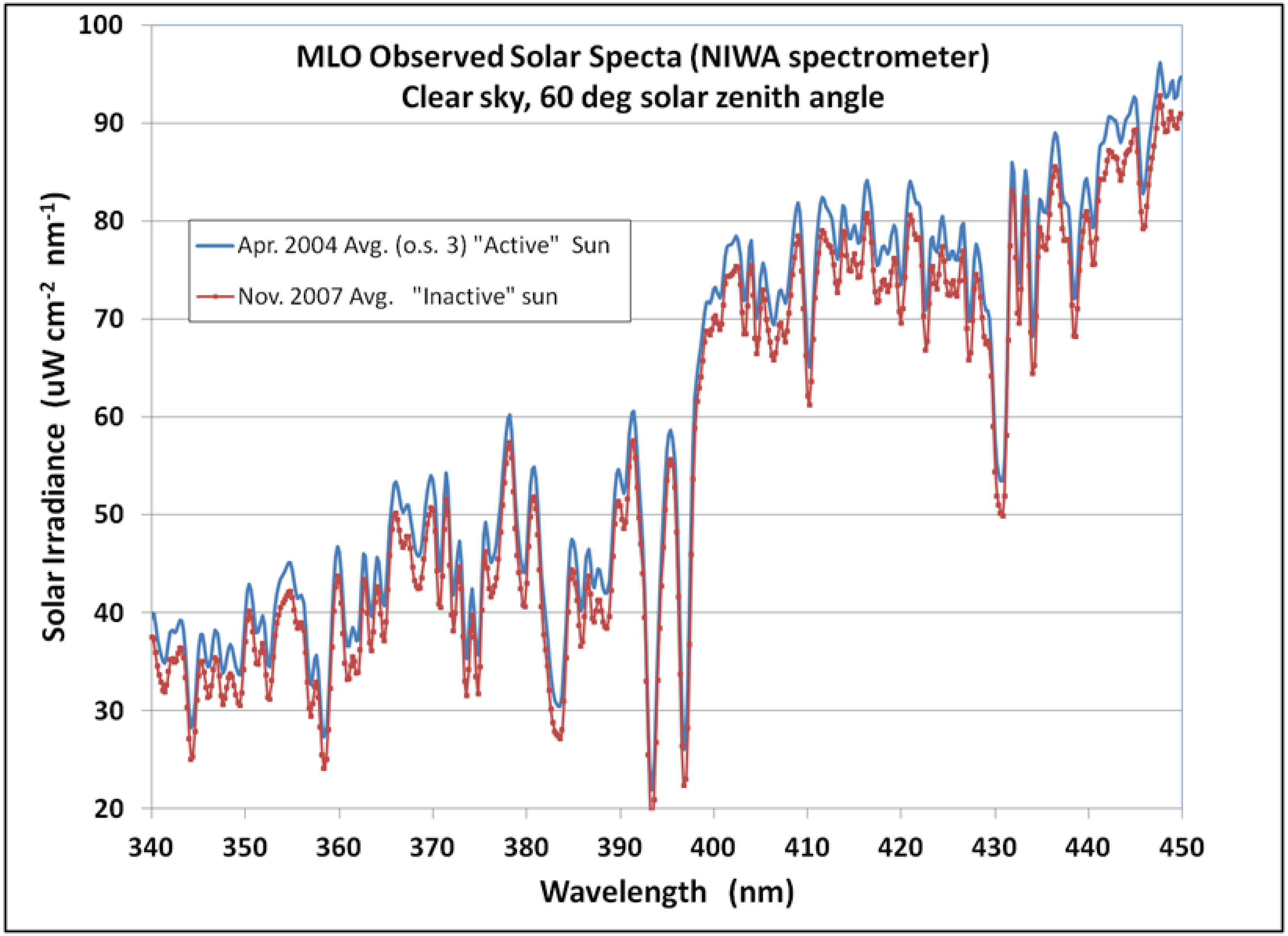
GMD Spectral (UV/Vis) Solar Observations

- Sites : Mauna Loa (MLO), Boulder (NIWA), and recently S. Pole, Palmer, and McMurdo, Antarctica (BSI) – all running since mid 1990s, NDACC contibutors
- Originally intended for UV-ozone atmospheric studies
- For this talk –
  - MLO automated scanning double monochromator, NIWA (New Zealand)
  - 295 nm to 450 nm, 0.8 slit wdth, samp. at 0.2 nm, accuracy 0.03 nm
  - Total horizontal (all-sky flux) radiation measured
  - Routine internal and external lamp calibrations performed
  - Data processing at GMD/Boulder and NIWA
  - Daily data since 1996 - clear early mornings – 50%

(See poster by Patrick Disterhoft for more info.)



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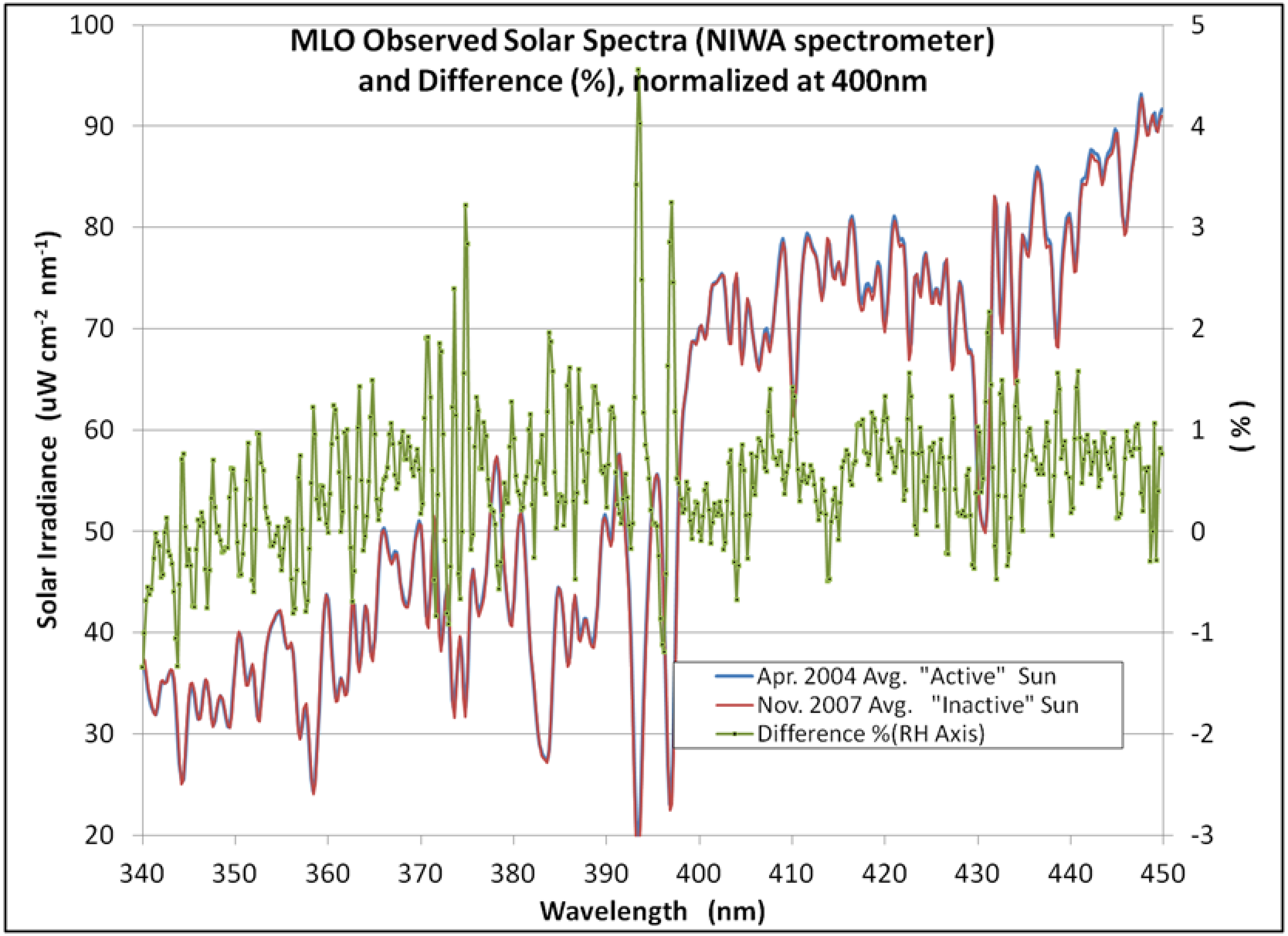

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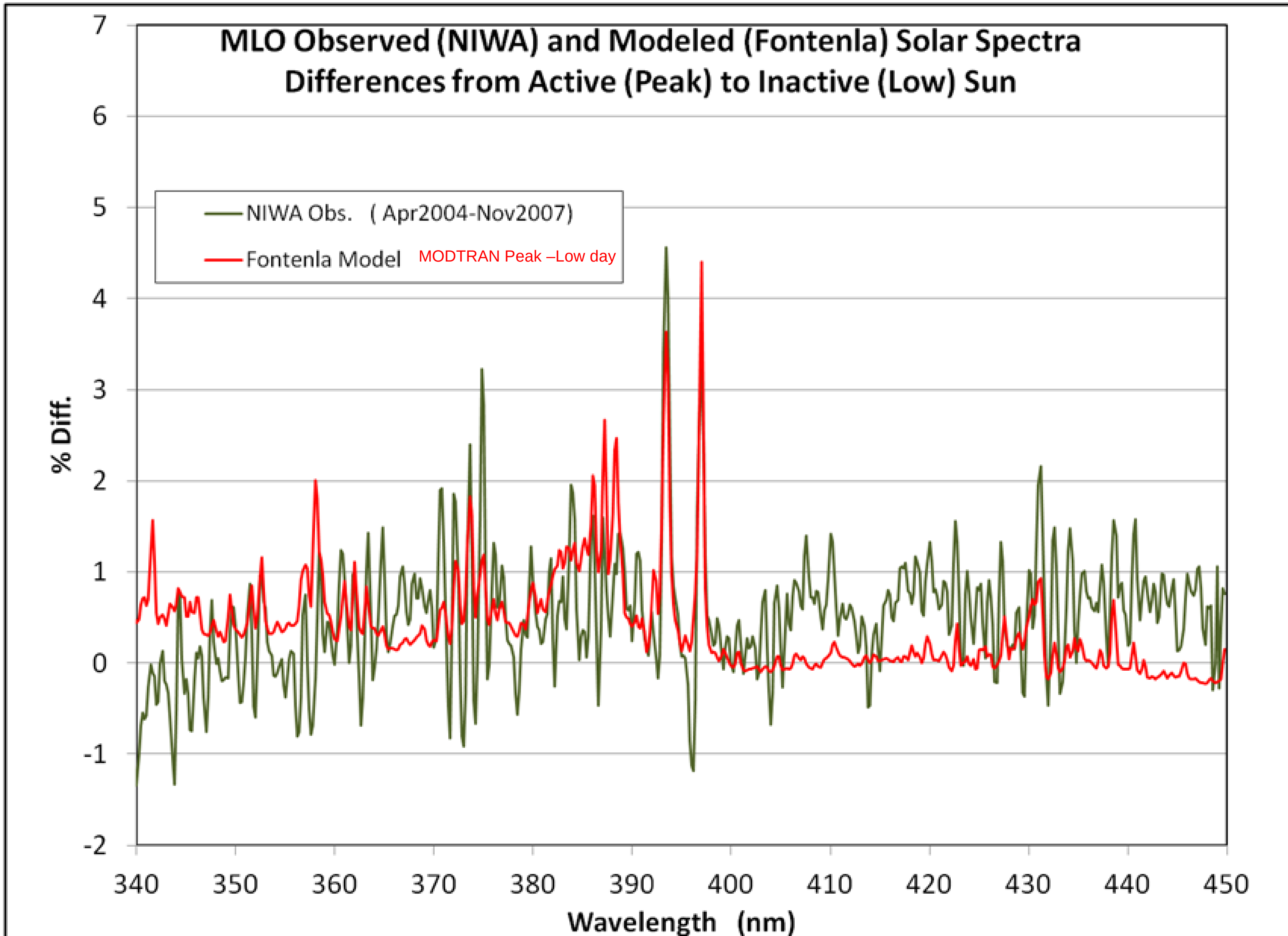

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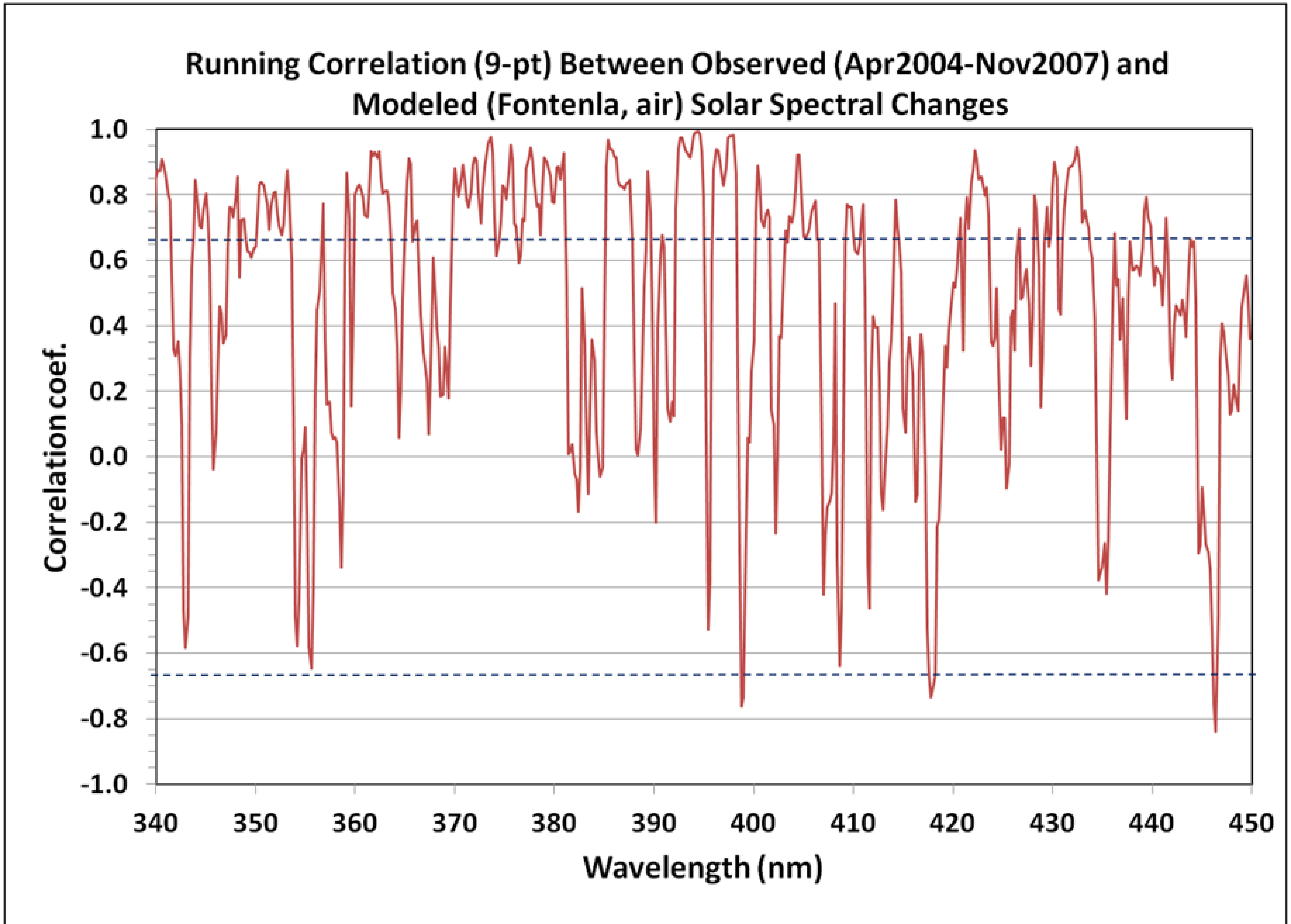
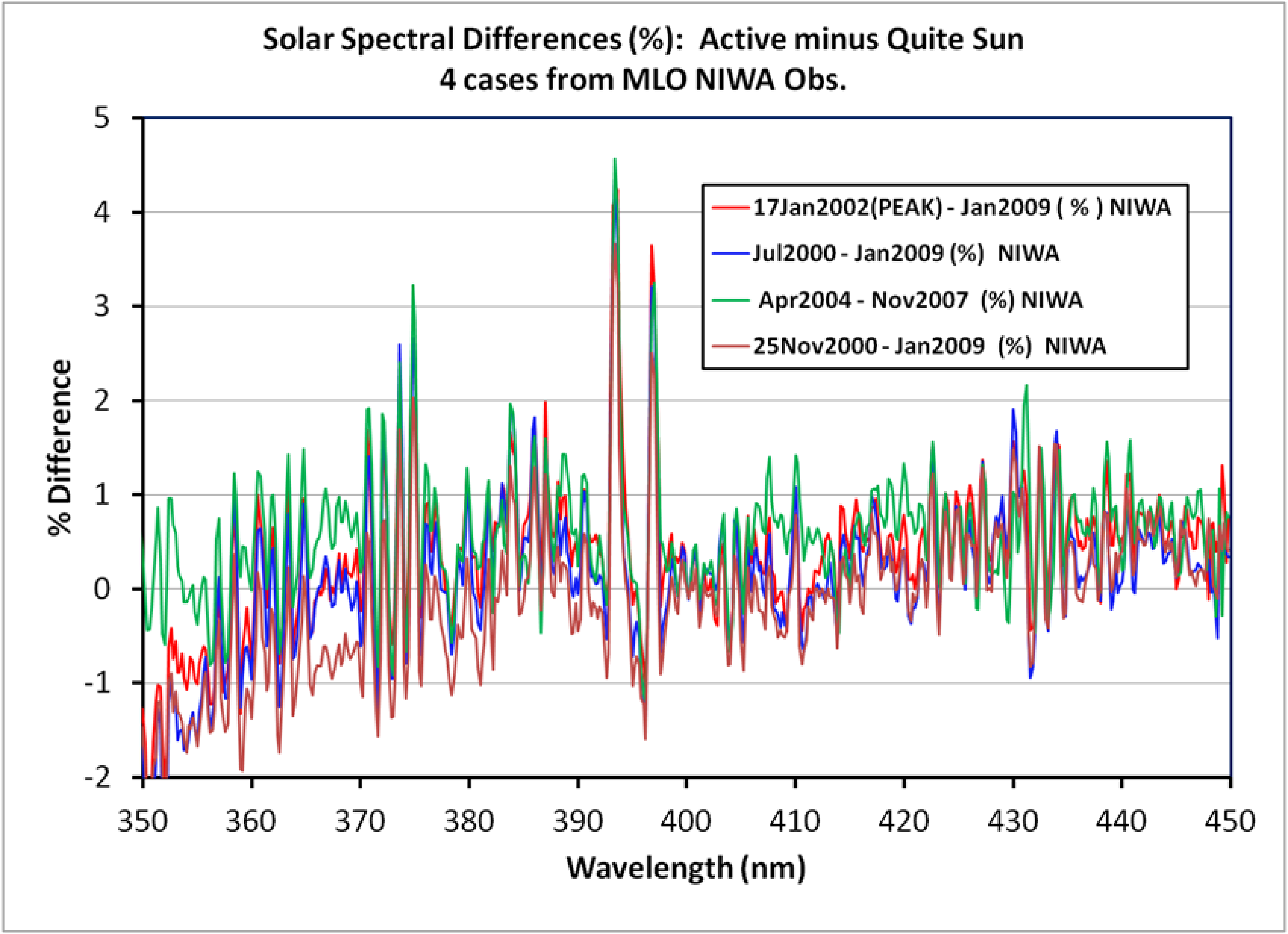


Running Correlation (9-pt) Between Observed (Apr2004-Nov2007) and Modeled (Fontenla, air) Solar Spectral Changes
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
Correlation coef.
340
350
360
370
380
390
400
410
420
430
440
450
Wavelength (nm)



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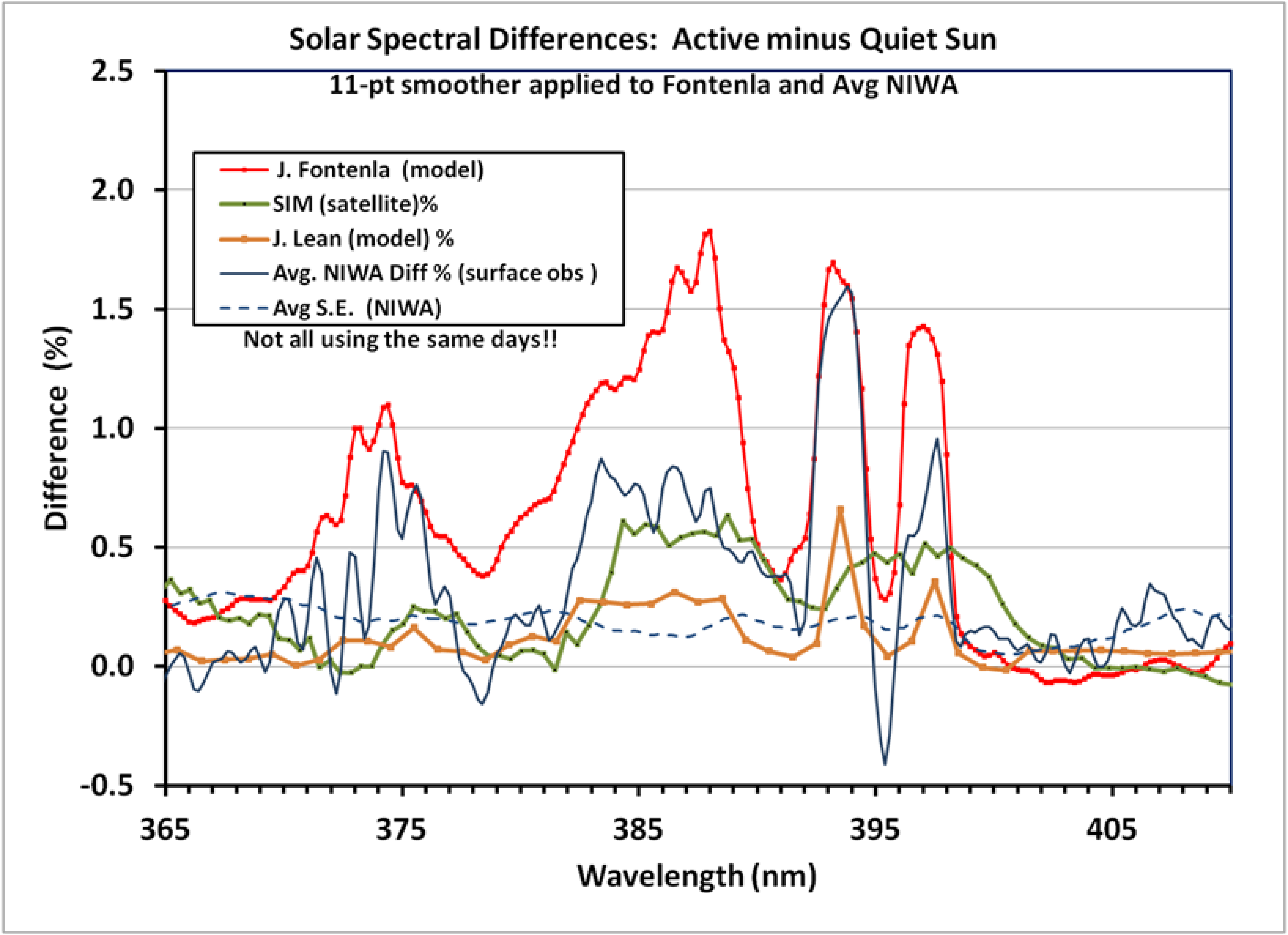

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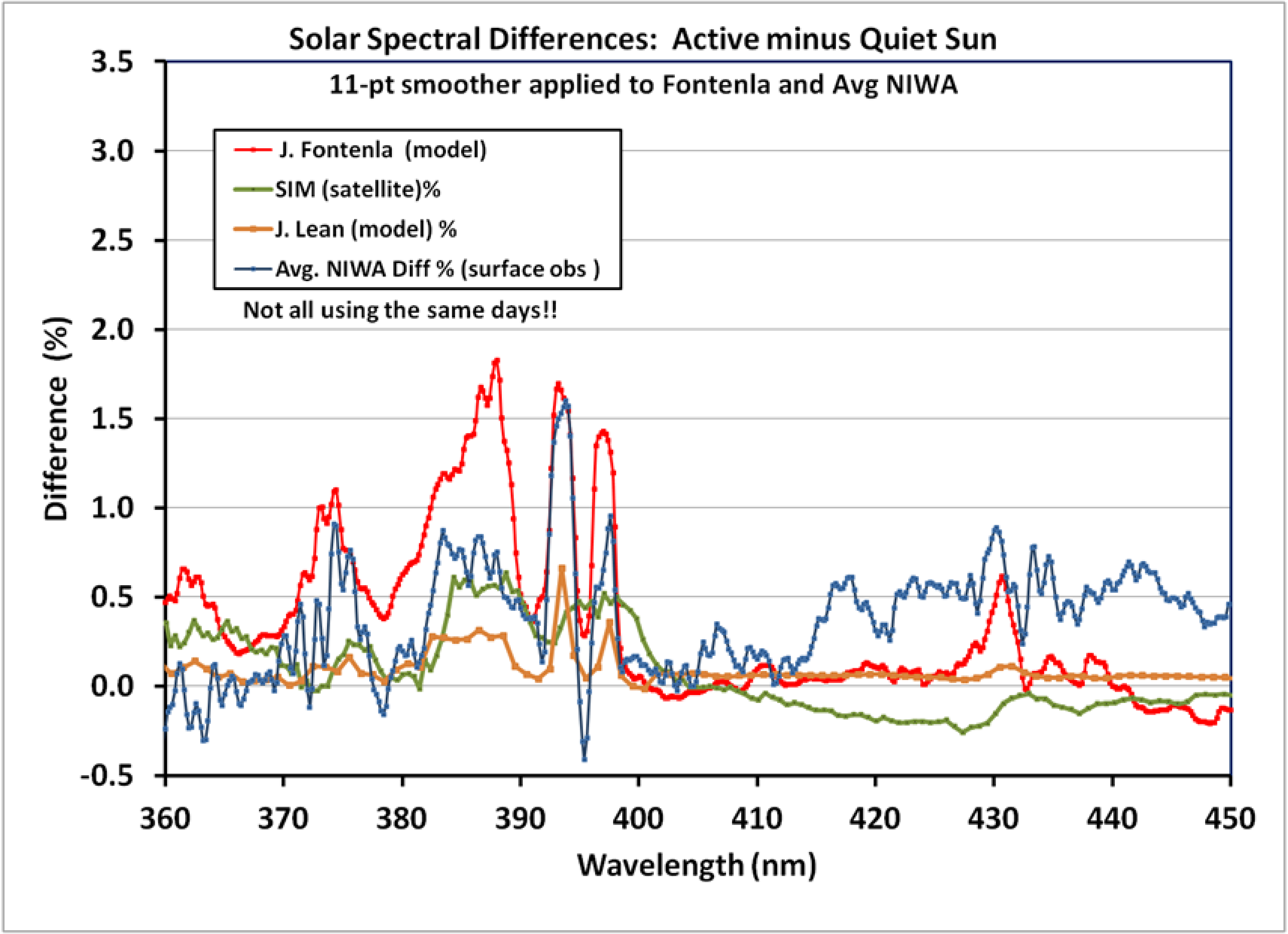

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Conclusions

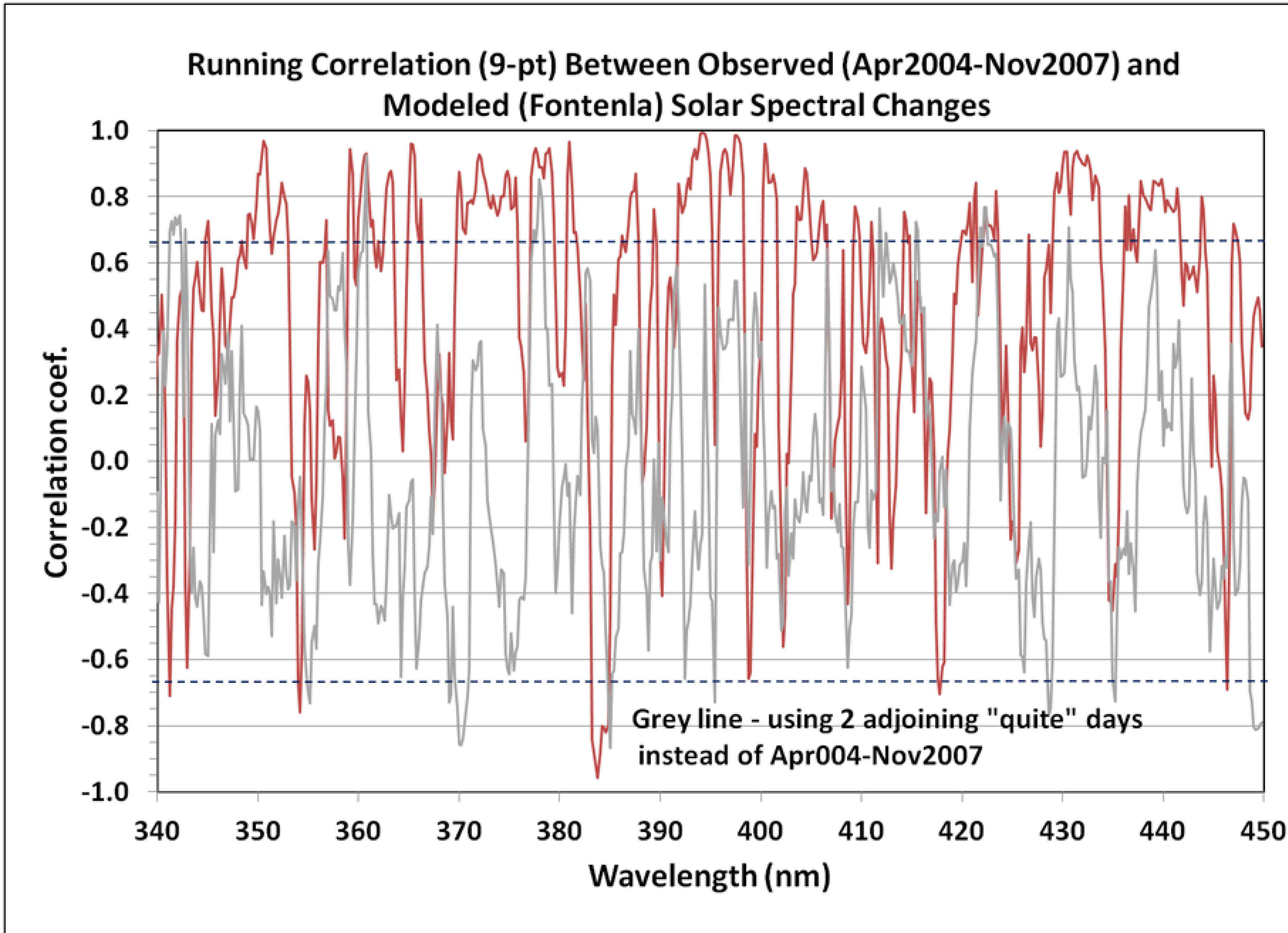
- Many narrow bandwidth (≈2 nm) features of spectral changes over the solar-cycle suggested by the Fontenla model appear to be captured in the MLO surface data.

- The MLO data also capture the main larger (4-10 nm) spectral features apparent in all data sets, but different amplitudes, in the 365- 415 nm region.

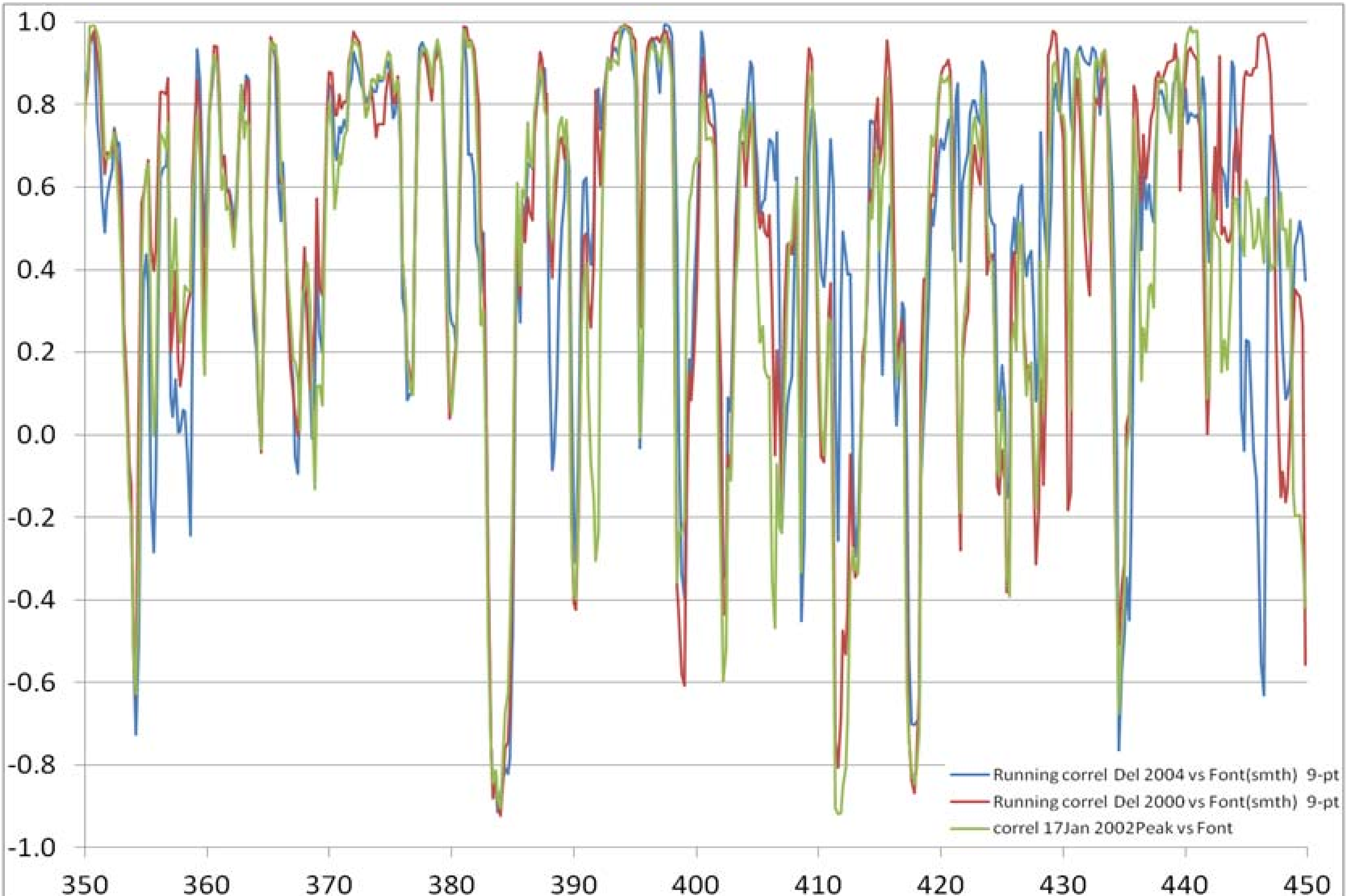
- MLO obs. suggest higher amplitude variations in the 4-10 nm-wide features than the Lean model. However, further addressing SIM satellite vs. model issues at this time is not warranted.

- Surface data warrant further application to this topic. Refinements should include: atmos. correction (to extend spectral range to near 305 nm), use of higher available precision, closer date matching, consider time evolution of features, convolve spectra to the same resolution, and further specific review of surface obs. relative to this new application...

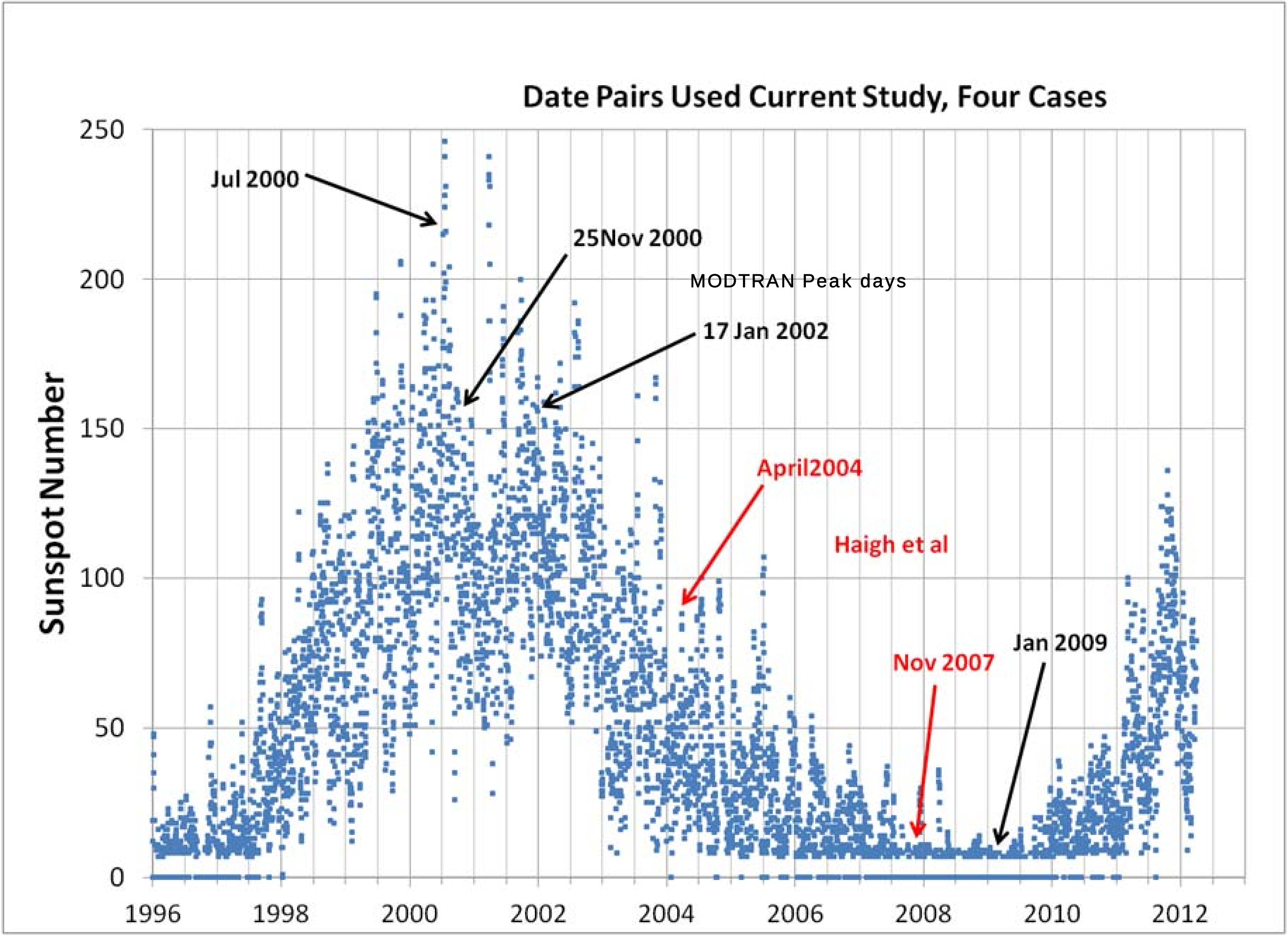
END



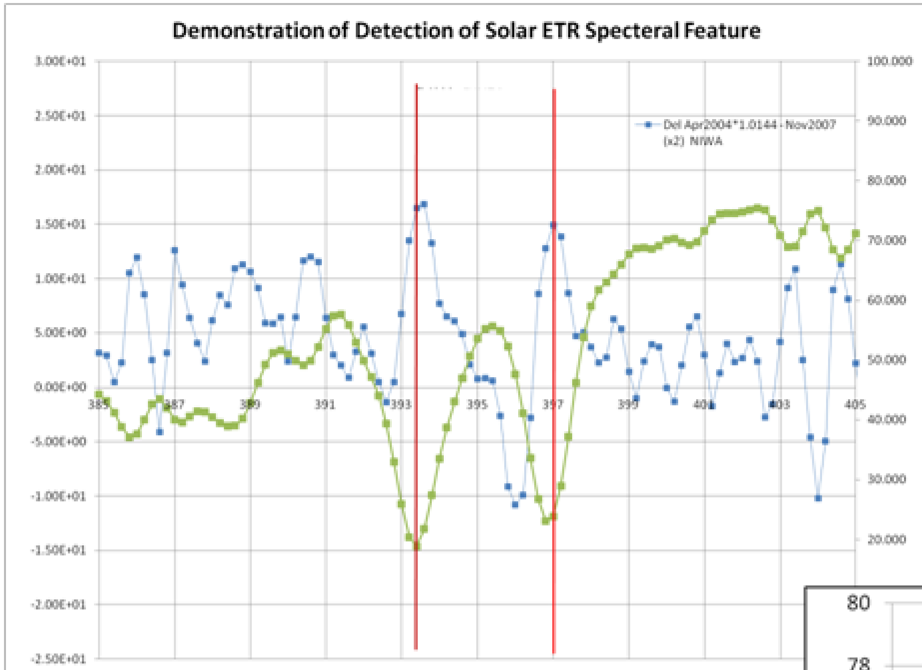
Running Correlation (9-pt) Between Observed (Apr2004-Nov2007) and Modeled (Fontenla) Solar Spectral Changes
Correlation coef.
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
340
350
360
370
380
390
400
410
420
430
440
450
Wavelength (nm)
Grey line - using 2 adjoining "quite" days instead of Apr004-Nov2007



1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
350
360
370
380
390
400
410
420
430
440
450
Running correl Del 2004 vs Font(smth) 9-pt
Running correl Del 2000 vs Font(smth) 9-pt
correl 17Jan 2002Peak vs Font



Date Pairs Used Current Study, Four Cases
Sunspot Number
250
200
150
100
50
0
1996
1998
2000
2002
2004
2006
2008
2010
2012
Jul 2000
25Nov 2000
MODTRAN Peak days
17 Jan 2002
April2004
Haigh et al
Nov 2007
Jan 2009



Demonstration of Detection of Solar ETR Specteral Feature
Del Apr2004*1.0144 - Nov2007 (x2) NIWA
3.00E+01
2.50E+01
2.00E+01
1.50E+01
1.00E+01
5.00E+00
0.00E+00
-5.00E+00
-1.00E+01
-1.50E+01
-2.00E+01
-2.50E+01
100.000
90.000
80.000
70.000
60.000
50.000
40.000
30.000
20.000
385
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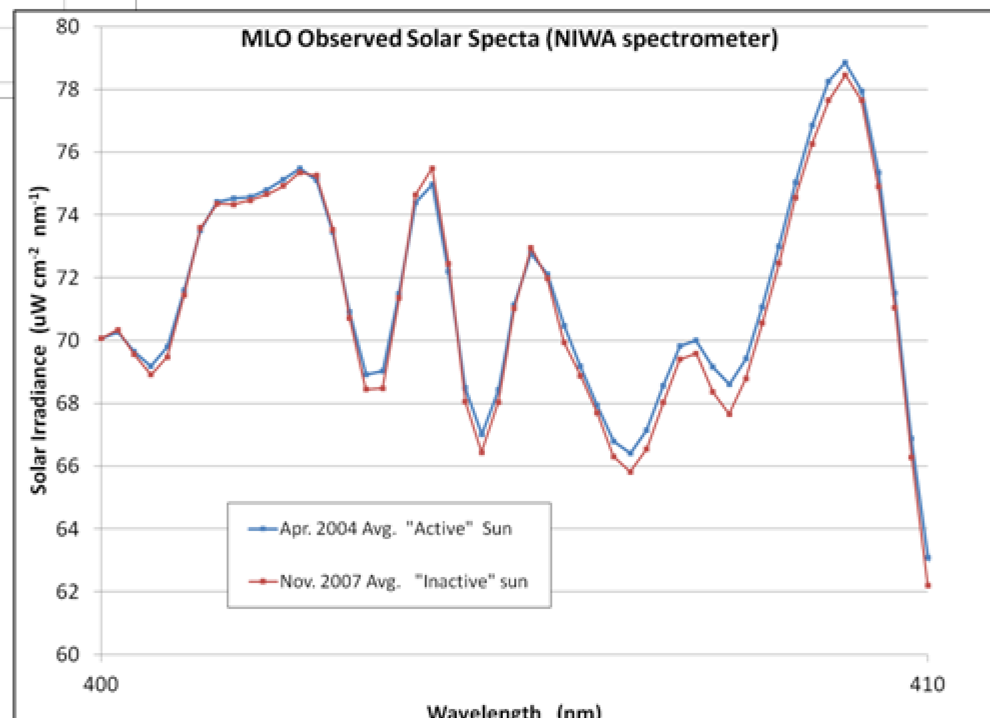
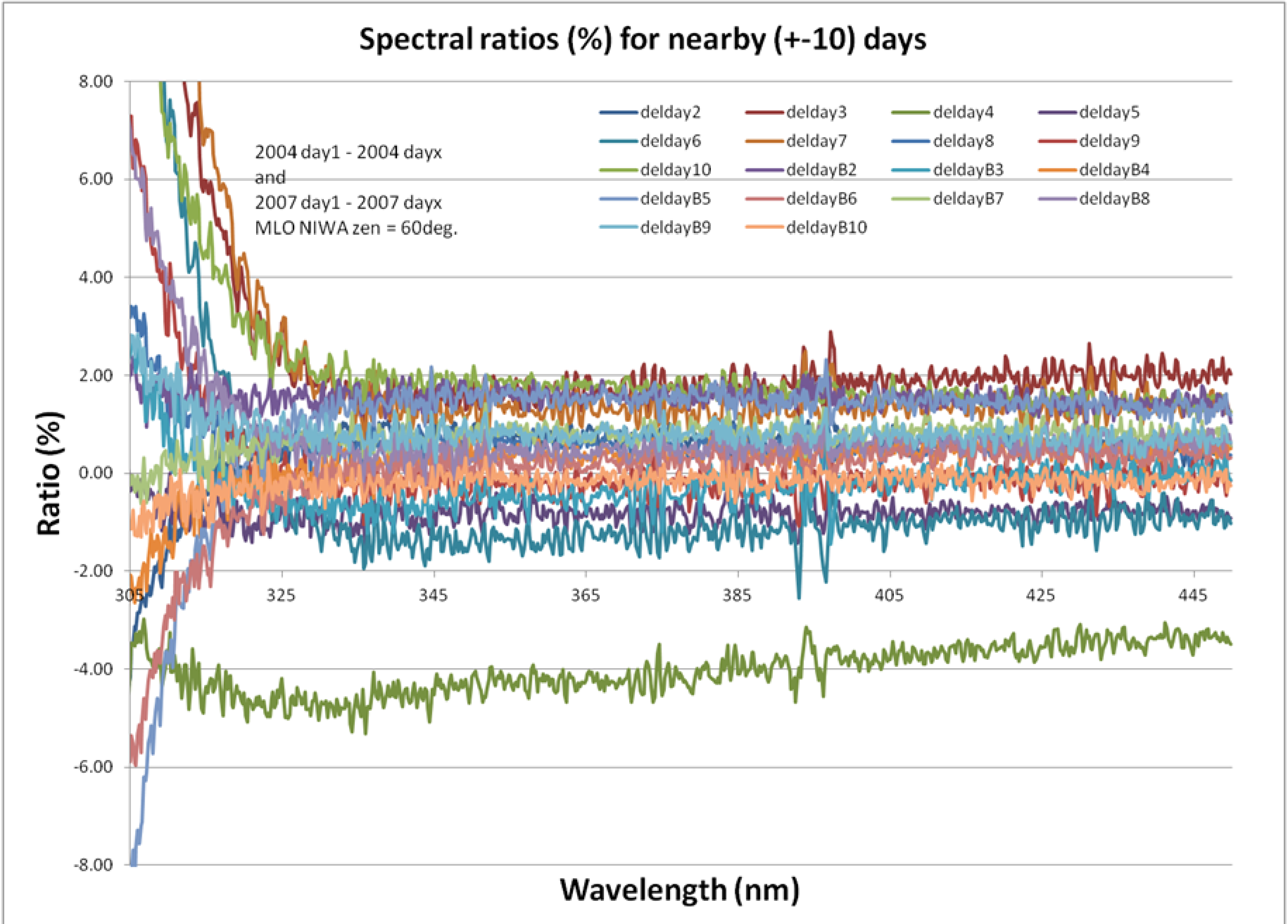
389
391
393
395
397
399
401
403
405

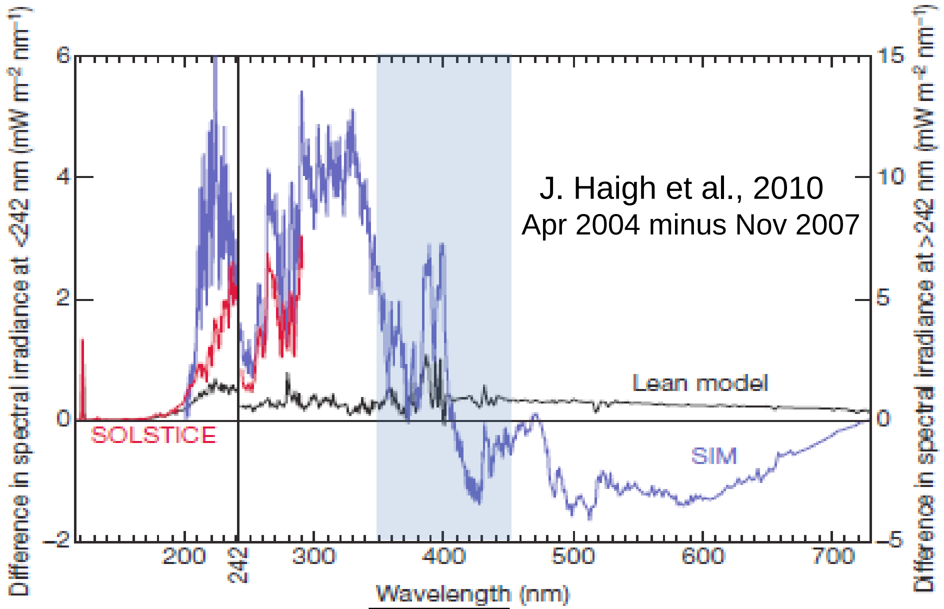


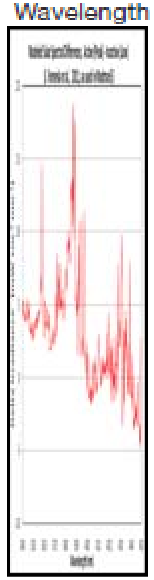
MLO Observed Solar Specta (NIWA spectrometer)
Solar Irradiance (uW cm-2 nm-1)
Wavelength (nm)
Apr. 2004 Avg. "Active" Sun
Nov. 2007 Avg. "Inactive" sun
80
78
76
74
72
70
68
66
64
62
60
400
410



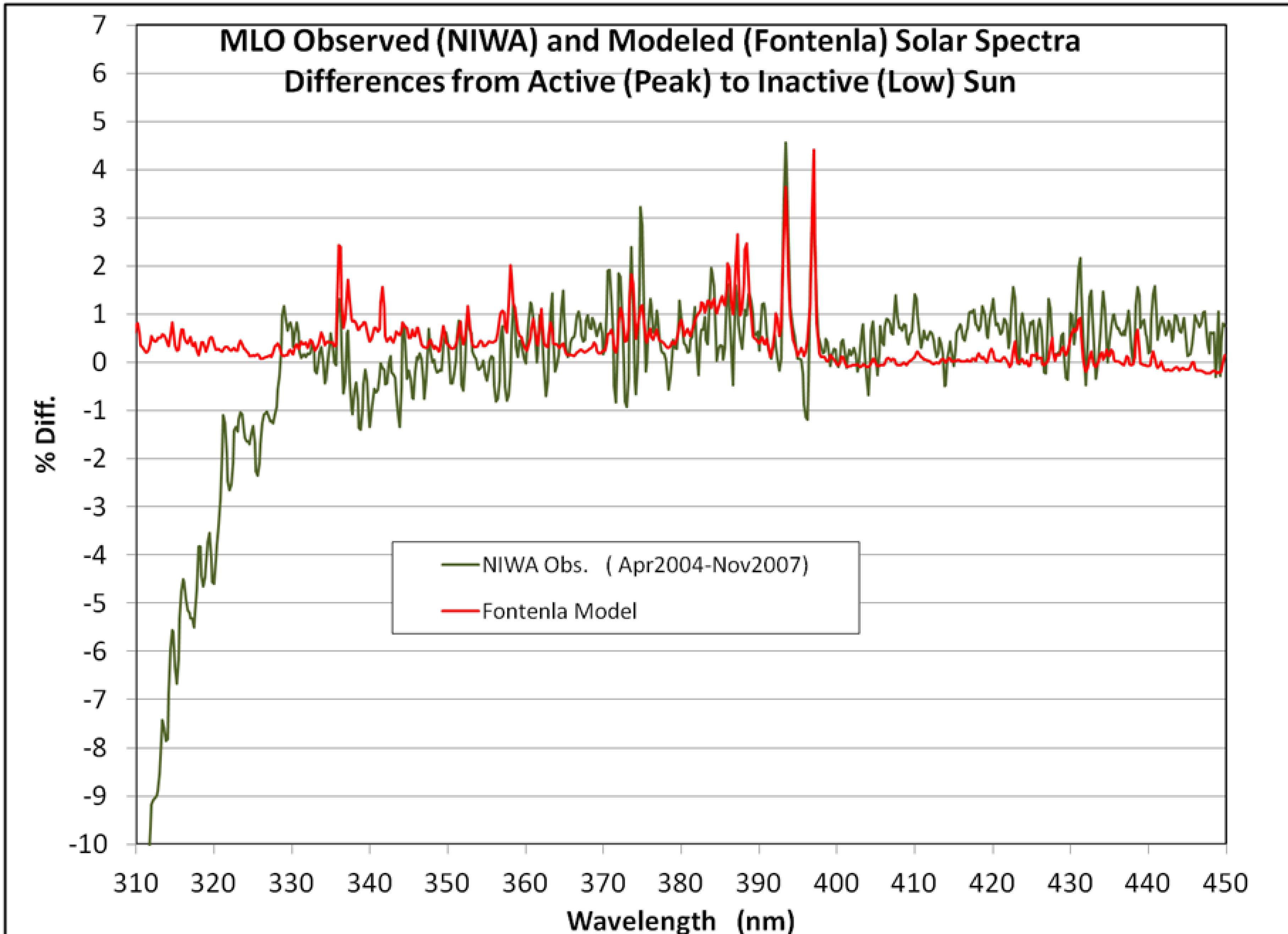
Spectral ratios (%) for nearby (+-10) days
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
Ratio (%)
305
325
345
365
385
405
425
445
Wavelength (nm)
2004 day1 - 2004 dayx
and
2007 day1 - 2007 dayx
MLO NIWA zen = 60deg.
delday2
delday3
delday4
delday5
delday6
delday7
delday8
delday9
delday10
deldayB2
deldayB3
deldayB4
deldayB5
deldayB6
deldayB7
deldayB8
deldayB9
deldayB10

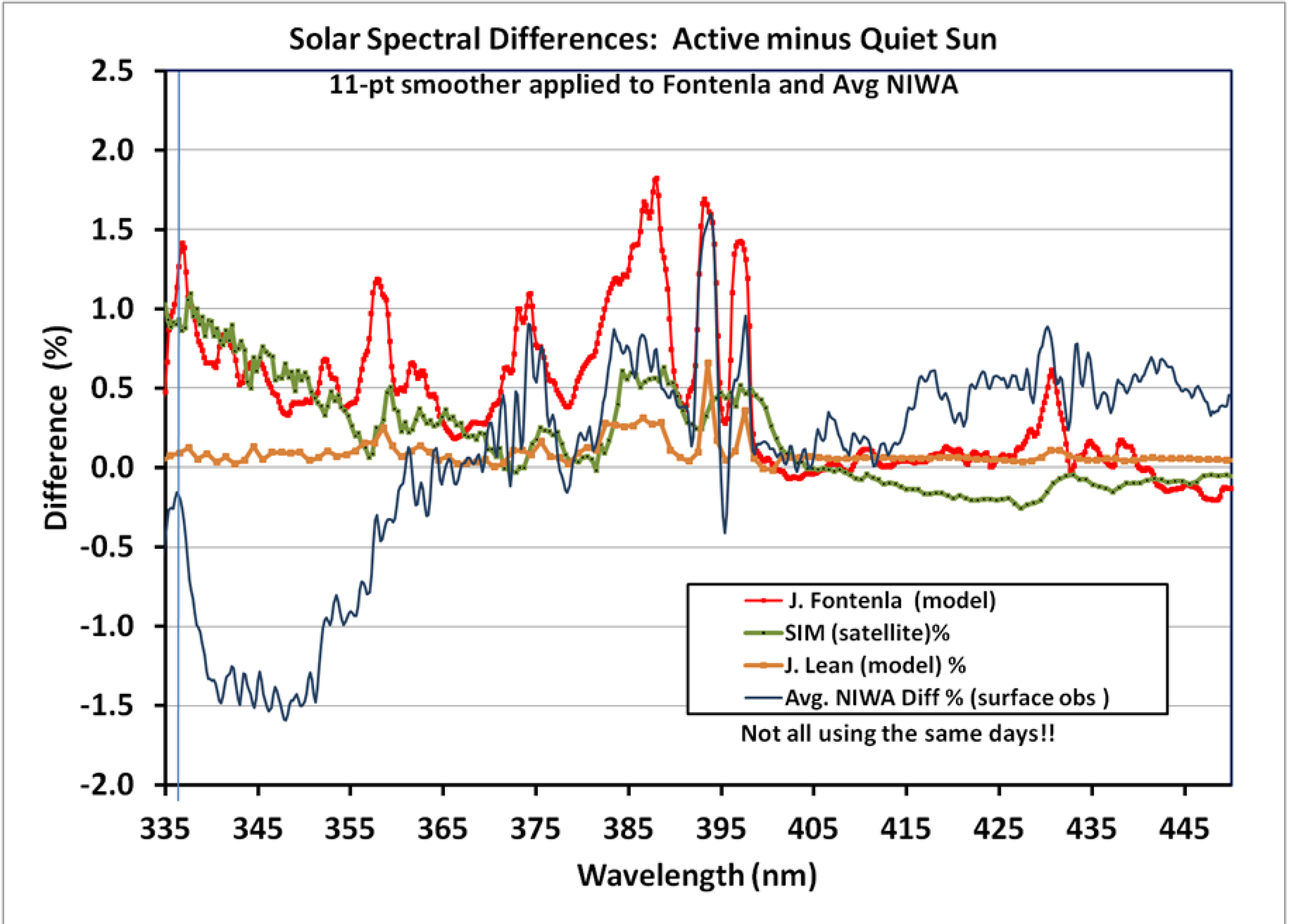
Modeled and Observed Changes in Spectral ETR Between an Active and Inactive Sun





Model from J. Fontenla et al. 2011
as used in MODTRAN5
(Peak day minus Low day ETR spectra)
Note: Not same dates as used by Haigh et al.


MLO Observed (NIWA) and Modeled (Fontenla) Solar Spectra
Differences from Active (Peak) to Inactive (Low) Sun
% Diff.
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
310
320
330
340
350
360
370
380
390
400
410
420
430
440
450
Wavelength (nm)
NIWA Obs. (Apr2004-Nov2007)
Fontenla Model



Solar Spectral Differences: Active minus Quiet Sun
11-pt smoother applied to Fontenla and Avg NIWA
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
Difference (%)
335
345
355
365
375
385
395
405
415
425
435
445
Wavelength (nm)
J. Fontenla (model)
SIM (satellite)%
J. Lean (model) %
Avg. NIWA Diff % (surface obs)
Not all using the same days!!