**Answer to Referee #1**

We thank the Referee for raising a number of important points. We have addressed all the points raised by him/her and have marked blue the relevant corrections in the current version of the paper that have been applied to comply with his/her comments, as well as with those by Referee #2. Besides, quotations were added for the following papers:

1) Bolduc, C., Charbonneau, P., Dumoulin, V., Bourqui, M. S., and Crouch, A. D.: A Fast Model for the reconstruction of Spectral Solar Irradiance in the Near- and Mid-Ultraviolet, Solar Phys., 279, 383–409, doi:10.1007/s11207-012-0019-4, 2012.

2) Cahalan, R., Pilewskie, P., and Woods, T.: Free flyer Total and Spectral Solar Irradiance Sensor (TSIS) and climate services missions, in: EGU General Assembly Conference Abstracts, edited by Abbasi, A. and Giesen, N., vol. 14 of EGU General Assembly Conference Abstracts, p. 1886, 2012.

3) Crouch, A. D., Charbonneau, P., Beaubien, G., and Paquin-Ricard, D.: A Model for the Total Solar Irradiance Based on Active Region Decay, Astrophys. J., 677, 723–741, doi:10.1086/527433, 2008.

4) Fontenla, J. M., Avrett, E., Thuillier, G., and Harder, J.: Semiempirical Models of the Solar Atmosphere. I. The quiet- and active sun photosphere at moderate resolution, Astrophys. J. Lett., 639, 441–458, doi:10.1086/499345, 2006.

5) Haberreiter, M., Krivova, N. A., Schmutz, W., and Wenzler, T.: Reconstruction of solar UV irradiance back to 1974, Advances in Space Research, 35, 365–369, doi:10.1051/0004-6361:200809503, 2005.

6) Haberreiter, M., Schmutz, W., and Hubeny, I.: NLTE model calculations for the solar atmosphere with an iterative treatment of opacity distribution functions, Astron. Astrophys., 492, 833–840, doi:10.1051/0004-6361:200809503, 2008.

7) Hubeny, I. and Lanz, T.: Non-LTE line-blanketed model atmospheres of hot stars. 1: Hybrid complete linearization/accelerated lambda iteration method, ApJ, 439, 875-904, doi: 10.1086/175226, 1995.

8) Marsh, D. R., Mills, M. J., Kinnison, D. E., Lamarque, J. F., Calvo, N., and Polvani, L.: Climate change from 1850 to 2005 simulated in CESM1 (WACCM), submitted to J. Clim., 2012.

9) Meehl, G., Arblaster, J., Matthes, K., Sassi, F., and van Loon, H.: Amplifying the Pacific climate system response to a small 11 year solar cycle forcing, Science, 325, 1114–1118, doi:10.1126/science.1172872, 2009.

10) Shapiro, A. V., Rozanov, E. V., Shapiro, A. I., Egorova, T. A., Harderi, J., Weber, M., Smith, A. K., Schmutz, W., and Peter, T.: The role of the solar irradiance variability in the evolution of the middle atmosphere during 2004-2009, J. Geophys. Res.(Atmospheres), under revision, 2012b.

11) Solanki, S. K., Krivova, N. A., and Haigh, J. D.: Solar Activity and Climate, Annual Review of Astronomy and Astrophysics, 51, null, doi:10.1146/annurev-astro-082812-141007, 2013.

12) Topka, K. P., Tarbell, T. D., and Title, A. M.: Properties of the smallest solar magnetic elements. I - Facular contrast near sun center, Astrophys. J., 396, 351–363, doi:10.1086/171721, 1992.

13) Wang, H., Spirock, T., Goode, P., Lee, C., Zirin, H., and Kosonocky, W.: Contrast of faculae at 1.6 Microns, Astrophys. J., 495, 957–964, doi:10.1086/305311, 1998.

14) Wehrli, C., Schmutz, W., and Shapiro, A.: Correlation of Spectral Solar Irradiance with solar activity as measured by SPM/VIRGO, submitted to Astron. Astrophys., 2012.

15) Willson, R. C.: The ACRIMSAT/ACRIM III experiment: extending the precision, long-term total solar irradiance climate database, Earth Observer, 13, 14–17, 2001.

The following references were removed:

1) Kunze, M., Godolt, M., Heimann-Reinus, A., Langematz, U., Grenfell, J. L., and Rauer, H.: Investigating the early Earth faint young Sun problem with a general circulation model, Planet. Space Sci., submitted, 2012.

2) Willson, R. C. and Helizon, R. S.: EOS/ACRIM III instrumentation, in: Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, vol. 3750 of Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, edited by: Barnes, W. L., Proc. SPIE Vol. 3750, 233–242, Earth Observing Systems IV, Society of Photo-Optical Instrumentation Engineers (SPIE), Bellingham WA, USA, 233–242, 1999.

From here below we discuss the main “specific comments” of the Referee. Referee’s comments and our answers are marked in the following red and black, respectively. The comments that were not answered extensively below have been directly modified in the paper and marked in either blue or italic. Revisions applied to account for comments and suggestions by G. Kopp, J. Fontenla, and M. Haberreiter, which were also mentioned by the Referees, have been marked red in the current version of the paper.

SPECIFIC COMMENTS

1. p. 24559, lines 10-12: While an abstract is intended to be a general summary of the entire paper, it would be helpful to clearly state here that the SORCE measurements during 2004-2009 are the key topic of discussion.

We agree with the Referee. As written in our reply to the comments by Referee #2 and A. Robock, we have revised the abstract to summarize the contents of the paper and to emphasize the main conclusions. The revised abstract states:

“The lack of long and reliable time series of solar spectral irradiance (SSI) measurements makes an accurate quantification of solar contributions to recent climate change difficult. Whereas earlier SSI observations and the models provided a qualitatively consistent picture of the SSI variability, recent measurements by the SORCE satellite suggest a significantly stronger variability in the ultraviolet (UV) spectral range and changes in the visible and near-infrared (NIR) bands in anti-phase with the solar cycle. A number of recent chemistry-climate model (CCM) simulations have shown that this might have significant implications on the Earth’s atmosphere. Motivated by these results, we summarize here our current knowledge of SSI variability and its impact on Earth’s climate.
We present a detailed overview of existing SSI measurements and provide thorough comparison of models available to date. SSI changes influence the Earth’s atmosphere, both directly, through changes in shortwave (SW) heating and therefore, temperature and ozone distributions in the stratosphere, and indirectly, through dynamical feedbacks. We investigate these direct and indirect effects using several state-of-the art CCM simulations forced with measured and modeled SSI changes. A unique asset of this study is the use of a common comprehensive approach for an issue that is usually addressed separately by different communities.
We show that the SORCE measurements are difficult to reconcile with earlier observations and with SSI models. Of the five SSI models discussed here, specifically NRLSSI, SATIRE-S, COSI,

SRPM, and OAR, only one shows a behaviour of the UV and visible irradiance qualitatively resembling that of the recent SORCE measurements. However, the integral of the SSI computed with this model over the entire spectral range does not reproduce the measured cyclical changes of the total solar irradiance, which is an essential requisite for realistic evaluations of solar effects on the Earth's climate in CCMs.
We show that within the range provided by the recent SSI observations and semiempirical models discussed here, the NRLSSI model and SORCE observations can be considered as the lower and upper limits in the magnitude of the SSI solar cycle variation.
The results of the CCM simulations, forced with the SSI solar cycle variations estimated from the NRLSSI model and from SORCE measurements, show that the direct solar response in the stratosphere is larger for the SORCE than for the NRLSSI data. Correspondingly, larger UV forcing also leads to a larger surface response.
Finally, we discuss the reliability of the available data and we propose additional coordinated work, first to built composite SSI datasets out of scattered observations and to refine current SSI models, and second, to run coordinated CCM experiments."

2. p. 24560, lines 4-6: Is the 8% value referring to temperature change? Some other parameter?

That sentence was indeed improperly formulated. We have revised it from:

"According to the 4th assessment report of the Intergovernmental Panel on Climate Change, about 8% of recent global climate change may be attributed to solar variability (Solomon et al., 2007)."

to:

"According to the 4th assessment report of the Intergovernmental Panel on Climate Change, solar variability represents about 8% of recent total net radiative anthropogenic forcing (Solomon et al., 2007)."

3. p. 24560, lines 18-19: Short-term decreases of TSI due to large sunspots can actually be 2-3 times larger than this.

The following sentence has been added:

"Changes 2-3 times larger than this (cf. cyclic modulation) are observed on time scales of few days. "

4. p. 24561, lines 4-6: Does this percentage correspond to the 120-350 nm wavelength range given in line 1?

We have specified that it applies "shortward of 400 nm'." The sentence was changed from:

"Therefore, although the UV radiation represents less than 8% of the TSI (Krivova et al., 2006), its variability may have a significant impact on climate."

to:

"Hence, although the UV radiation shortward of 400 nm represents less than 8% of the TSI, its variability may have a significant impact on climate."

5. p. 24564, lines 18-19: See previous comment #3 regarding the term "conspicuous".

The adjectives "conspicuous" and "pronounced" have been replaced by the adjective "noticeable". The revised sentence states:

"Most noticeable is the ≈0.1% modulation of TSI in phase with the 11-yr solar cycle."

6. p. 24564, lines 25-26: Although spectrally resolved visible and near-IR solar cycle variations may be of the same “order” as TSI variations, the large amount of solar flux at these wavelengths means that the difference between 0.1% and 0.5% still has important terrestrial consequences. Measurements capable of determining this difference over a solar cycle are not available yet.

The paragraph has been revised from:

“In contrast, the visible and IR bands have the largest contribution to the TSI and directly heat Earth’s surface and lower atmosphere. Their impact on the Earth’s climate is expected to be small unless it involves amplification mechanisms (e.g. the “bottom-up” mechanism, van Loon et al., 2007, see also Sect. 4.1).”

to:

“In contrast, the visible and IR bands, which have the largest contribution to the TSI, small variations over the solar cycle, and no absorption in the atmosphere but in some well-defined IR bands, directly heat the Earth’s surface and the lower atmosphere. The large amount of solar flux at the visible and IR bands implies that small flux differences may induce important terrestrial consequences. The impact of the variability of these bands on the Earth’s climate is expected to be small, although it may involve amplification mechanisms (e.g. the “bottom-up” mechanism, van Loon et al., 2007).

7. p. 24565, lines 20-24: Of these instruments, only SIM claims to have a full end to- end calibration. The ISS SOLSPEC principal investigator reported at the February 2012 workshop (p. 24570, lines 5-9; see “The Earth Observer”, vol. 24, July-August 2012, p. 17-20) that the deuterium lamps intended to monitor long-term instrument calibration are experiencing operational problems, so that determining solar variations for Cycle 24 may be difficult.

We would like to point out that during the SORCE meeting an alternative method for in-flight instrument aging monitoring was also reported. The method, which was considered at the time of the communication, is based on the use of the lines provided by an Ar hollow cathod lamp.

8. p. 24566, lines 19-21: Reference solar irradiance measurements can also be used for long-term calibration, as noted on the previous page for SBUV instruments.

We have revised the text accordingly. The paragraph was changed from:

“The second option is to use stable external calibration targets like selected stars, as is done for UARS/SOLSTICE and SORCE/SOLSTICE (McClintock et al., 2005).”

to:

“The second option is to use reference data, e.g. solar irradiance measurements for long-term calibrations, as reported for the NOAA SBUV instruments, periodic recalibrations using sounding rockets, or stable external calibration targets like selected stars, as done for UARS/SOLSTICE and SORCE/SOLSTICE (McClintock et al., 2005).”

9. p. 24567, line 3: The purpose of “recent” should be clarified here. The next section (2.2.1) addresses SCIAMACHY measurements that began in 2002, but there is no discussion of UARS SUSIM data that were also in progress at that time and extend through July 2005.

We have revised the sentence so to specify that we summarize “newly available data obtained during the last decade”. The new sentence states:

“In the following subsections a brief summary of newly available SSI observations obtained during the last decade is given.”

10. p. 24567, lines 18-21: The SCIAMACHY data set is not a true long-term irradiance product, but is essentially a semi-empirical model (like NRLSSI) with a different set of scaling coefficients. Its spectral coverage is valuable for comparisons with SORCE SIM data, but it does not provide any additional validation of the time dependence of those measurements.

We agree with the Referee. We have revised the text accordingly. The sentence has been changed from:

“In order to provide estimates for solar cycle variability from SCIAMACHY measurements (230 nm–2.4 μm) without the need for a detailed degradation correction, the SCIAMACHY proxy model was developed by fitting solar proxy time series to observed SCIAMACHY measurements over several 27-day solar rotation periods (Pagaran et al., 2009).”

to:

“In order to provide estimates for solar cycle variability from SCIAMACHY measurements (230 nm–2.4 μm) without the need for a detailed degradation correction, a proxy model (hereafter referred to as SCIAMACHY proxy model) was developed by fitting solar proxy time series to observed SCIAMACHY measurements over several 27-day solar rotation periods (Pagaran et al., 2009).”

11. p. 24569, lines 18-19: The SIM measurements are claimed to have extremely good long-term stability (0.5-1.0% at 200-300 nm, 0.2-0.05% at 310-400 nm), as discussed in Merkel et al. (2011). They do not discuss an increase in uncertainty with time.

We have revised the sentences in the whole section accordingly the issue raised by the Referee. Changes are marked blue.

12. p. 24569, lines 19-21: It should be pointed out that the SIM UV data (below 308 nm), which represent an important part of this paper, are not part of the SORCE public Level 3 data product.

The following sentences have been added to the section:

“It is worth mentioning that the SORCE public Level 3 data include the SOLSTICE data up to 308 nm and SIM data above 308 nm. However, the SIM spectra do extend down to about 200 nm. The SORCE data used in our study to estimate the atmospheric response to SSI solar cycle variations are specified in Table 3. "

13. p. 24570, lines 13-27: The work of Woods (2012) is only a conference presentation, not a published (or even submitted) paper. It should not be treated at the same level as other publications. The term “plausible” for this work implies a problem with the current long-term corrections that has not been acknowledged publicly by either the SIM or SOLSTICE teams. This discussion also applies to the overview statement on p. 24564, lines 3-5.

We thank the Referee for raising this issue. We have revised the whole paper and specifically text in section 2 accordingly. We have also added a few details on the method. The paragraph now states:

“These discrepancies with prior cycle observations and with SSI models have inspired new analyses and collaborations aimed at a better understanding of the potential sources of instrument degradation that might have affected SORCE instruments and previous instruments as well. The studies have been concentrated on SSI instrument observations, capabilities, and estimated spectral irradiance uncertainties, methods of correcting for degradation, and refinement of estimated uncertainties. It has been understood that all detectors and optics suffer some degradation in space, largely due to exposure to solar light, and also due to hydrocarbon contamination that dominates below 400 nm. Accordingly, new models of degradation based on total dose, rather than just exposure time, are being developed for the SORCE and other instruments. Revised data sets are expected out in 2013. Besides, degradation trends have also been analyzed by considering the expected invariance of SSI over the solar cycle minimum. The latter method has been developed by Woods (2012) and applied to data during last solar cycle minimum (2008–2009) to estimate possible degradation trends for SORCE/SIM and SORCE/SOLSTICE. It consists of identifying near-identical solar activity levels on both sides of the minimum to derive corrections for instrument degradation. This analysis showed good agreement of the variability from moderate solar activity level to minimum level from various measurements and models, from 120 nm to 300 nm for solar cycles 21 through 24. However, as the method has about 30% uncertainty in variability due to the assumptions about selecting times of similar irradiance levels, the results may not be as accurate as those derived from analyses based on instrument degradation alone. The analysis by Woods (2012) reduces the variability of the integrated UV irradiance from 200 nm to 400 nm, relative to the measured TSI change, to 110% 338 (Fig. 2) from the 190% change reported by Harder et al. (2009). Nevertheless, to be compatible with the observed TSI changes even this lower amplitude of the UV variation over the solar cycle still requires compensation from out-of-phase trends at other wavelengths, in particular above ≈ 400 nm. Other analyses of solar cycle variability suggests that the UV variability in the 200 nm to 400 nm range is about 60% of the measured TSI change (Krivova et al., 2006; Pagaran 344 et al., 2009; Morrill et al., 2011b)."

14. p. 24571, lines 1-11: This paragraph seems to be a "looking ahead" statement that adds nothing to the analysis of current SORCE data. It could be combined with similar text on p. 24607 in the Conclusion.

The contents of the paragraph have been moved to the discussion section 3.4.

15. p. 24572, lines 8-11: The Thuillier et al. (2012) paper does not show any comparisons of time series with SORCE data. See item #7 for further comments.

We agree with the Referee. However, we would like to point out that the paper by Thuillier et al. (2012) describes a method to reconstruct the past SSI using the Mg II index and neutron monitor data for post 1978 period, and $^{10}$Be isotope concentration prior to 1978 . Section 2.4 and Fig. 6 of the paper by Thuillier et al. (2012) show the performance of the method by comparing method results with measurements by SORCE and SOLAR.

16. p. 24572, lines 19-22: DeLand and Cebula (2008) did attempt to address the differences in absolute calibration between instruments by normalizing each data set to a single reference spectrum.

We agree with the Referee. However, for time intervals in which there were no such reference spectra, the adjustments had to be made differently. This shows up in the composite data set by DeLand and Cebula as discontinuities when moving from one data set to the other.

17. p. 24573, lines 4-7: The level of consistency between SSI and solar proxies is in fact a key point. If we truly "know" that SSI behavior is completely consistent with proxy behavior, then one could argue that further SSI measurements are not needed.

We thank the Referee for having raised this issue. The sentences describing the method in the submitted version sound indeed ambiguous. The point is that all known solar proxies (so far) remain in fully phase with each other (up to a constant phase shift) regardless of the solar cycle. This is a strong, albeit not sufficiently, indication that different spectral bands are likely to remain in phase as well. The question whether the phase coherence between the SSI and the proxies holds, is a somewhat different one. This has now been reformulated in the text.

18. p. 24573, lines 25-28: The agreement in phase between different data sets is forced by the use of the Mg II index as a common reference. However, the derived amplitudes for Cycle 23 shown in this figure differ by a factor of 3. Which result should a user believe?

We would like to emphasize that the use of the MgII index as a reference is just there to fix the phase reference (one could have chosen any proxy here) for helping in comparing the different cycles but has no impact whatsoever on the way the SSI is extrapolated back- and forward in time. So, no single proxy is used to extrapolate the SSI, unlike what has often been done so far. This is an important point, which has now been more clearly formulated in the text.

19. p. 24575, lines 18-29: There was substantial work done to address the differences in TSI measurements prior to 2010, as discussed in the following paragraph and the comment by G. Kopp. I would rephrase this paragraph to say that the PREMOS data "support" the results of the ground-based work, and move it to follow the paragraph on p. 24576, lines 1-20.

The text has been revised accordingly. Revisions are marked red in the current version. The paragraph was changes as follows:

"The PREMOS experiment on the French satellite PICARD, which was launched in July 2010, has contributed to the understanding of the instrument offsets, by confirming the lower TSI value initially reported by the SORCE/TIM (Kopp et al., 2005)….omissis… The new experiments and the work carried out by the international community, which included realization of new facilities, ground-based tests, and collaborations aimed at identifying, quantifying, and verifying the causes of the discrepancy between the TIM and older TSI instruments, have ultimately led to the understanding of the instrument offsets. In particular…"

20. p. 24577, lines 4-5: As discussed in item #13, this is not a published result, and it should be noted that the SIM team has not publicly acknowledged this statement as a basis for revising their data.

See reply to comment #13.

21. p. 24577, lines 12-13: Previous SSI measurements in the UV (e.g. SME, SBUV/2, UARS SUSIM, UARS SOLSTICE) do quote long-term uncertainties for their data, as summarized in Table 1 of DeLand and Cebula (2012) and references therein. The limited lifetime of individual instruments does preclude definite statements about multidecadal variations at this time.

The following sentence was added in section 2.1:

"Table 1 of DeLand and Cebula (2012) summarizes the measurement uncertainties for these instruments."

22. p. 24585, lines 5-10: An examination of the Fontenla et al. (2011) paper found a brief discussion of temperature vs. pressure derivative (their paragraph 60) where the extended wavelength coverage of SORCE SIM is apparently useful. The comment by J. Fontenla contains more discussion of this statement.

We have revised the contents of the whole subsection in reply to comments by J. Fontenla and in line with the replies we posted in the forum. We have also added the sentence that follows in sect. 1:

"Variability out-of-phase with solar activity is indeed predicted by some SSI models in the NIR, but with a significantly lower magnitude than found by SORCE/SIM. Details are provided in the following. The inverse variability observed by SIM in a wide integrated band in the visible was, however, unexpected. It can be interpreted as a result of effects induced by the evolution of surface magnetism in the solar atmosphere (e.g. Harder et al., 2009). However, other observations and analyses of existing long-term SSI data show results in contrast with those derived from SORCE/SIM (Wehrli et al., 2012)."

We liked better no to add details of the mechanisms, which we believe would be understood only by expert readers in the field. We added the quotation of the Harder et al. paper, where, to our knowledge, the discussion of the temperature vs. pressure derivative effects was posted first.

23. p. 24586, lines 17-19: It is not clear from this discussion why the use of UARS SOLSTICE data as described here should lead to lower variability as calculated by NRLSSI. DeLand et al. (2004) discusses comparisons between UARS SUSIM and UARS SOLSTICE at mid-UV wavelengths, but that paper does not address how well the observed rotational modulation values for cycle 22 agree. The UARS SOLSTICE data were forced to have no long-term change at wavelengths longer than 300 nm, but the predominant contribution to the NRLSSI variations at these wavelengths comes from the sunspot darkening term.

The whole sentence has been revised as follows:

"Compared to the SATIRE and COSI models (described below), the NRLSSI model shows lower variations on solar-cycle and longer time scales between 250 and 400 nm (Figs. 2 and 7). This is mainly because the regression coefficients are derived from rotational variability only."

24. p. 24588, lines 21-22: Is this statement consistent with the time series shown in Harder et al. (2009) and the conclusions given there?

The sentence has been revised as follows:

"At the same time, wavelength−integrated SORCE/SIM data show different trends (only about 60% of the TIM changes are reproduced over the SORCE/SIM life time), though the uncertainties in the integrated SORCE/SIM data are quite large (see Ball et al., 2011)."

25. p. 24593, lines 6-7: The Harder et al. (2010) paper only discusses the absolute calibration of SORCE SIM, and does not address its long-term stability. The values quoted in Merkel et al. (2011) (and listed here in item #11) represent uncertainties considerably less than 1%/year if applied over the SIM lifetime. If these values are accepted, then the SIM results do not overlap with the model calculations.

We would like to draw the Referee attention on that the 1% stability quoted in this section refers to SOLSTICE, not SIM. And it is true that in the 220-240 nm spectral region SIM is less stable that SOLSTICE.

26. p. 24593, lines 16-18: As discussed in item #23, it is not clear why UARS SOLSTICE should be considered to have a "low response" to solar variability for wavelengths longer than 220 nm.

The sentence has been revised as follows:

"As a consequence of the low response of UARS/SOLSTICE to long-term variability above 300 nm and the use of rotational variability to estimate the regression coefficients, it is likely that NRLSSI underestimates the changes in this range (Lean, 2012, personal communication), and can thus be considered as the lower limit."

27. p. 24598, lines 18-28: It should be made clear that this discussion is taken from a submitted paper that has not been published.

We have changed the text accordingly. An update is presented from the work of Oberlander et al.

28. p. 24600, lines 21-24: Because the solar cycle signal used for the HadGEM3 simulations is a factor of 3 larger than the signal from 2004 to 2007 as determined from solar proxies, there is a question as to whether the model responses will in fact scale linearly with this change in forcing.

We thank the Referee for having raised this issue. The whole section has been revised to account for this comment and those raised by Referee #2.

Table 3 has been added and the text of the whole section revised in order to clarify the solar cycle forcing used by all models, and especially HadGEM3 and GEOSCCM. Spectral forcings in both model's simulations are scaled and we are clarifying this in the text. Also, an addition is made in the text on the relatively short period that the models and the observations are used to infer the solar cycle.

29. p. 24608, lines 3-5: Please modify this statement in line with previous comments in items #13 and #20.

See reply to comment #13.