4.2.3 Error Budget

The original NRLTSI and NRLSSI values for modeled solar irradiance do not have accompanying error estimates. Error budgets for the total solar irradiance CDR (NRLTSI2 model) and the solar spectral irradiance CDR (NRSSI2 model) are time dependent; when the facular brightening achieves its minimum value and sunspot darkening contributions are zero, such as may occur during solar minimum conditions, the error budget reduces to that of the absolute uncertainty of the adopted irradiance of the quiet sun. But when facular brightening and sunspot darkening contributions are non-zero, which is typically the case, the estimation of these additional components produces additional uncertainties that increase the error budget.

Tables 5 and 6 provide initial uncertainty estimates typical of high solar activity conditions (30 October 2003) for total solar irradiance and solar spectral irradiance, respectively, arising from the first three sources of uncertainty identified in Section 4.2.2. Firstly, uncertainties in the absolute scale of the irradiance are those reported for the direct measurements. Secondly, uncertainties in the facular brightening and sunspot darkening indices input to the algorithm are specified as a conservative ±20%; the uncertainty in the mean sunspot darkening derived from independent stations (typically 2 to 4 per day) is of this order. Thirdly, uncertainties in the coefficients that transform the input indices to irradiance are obtained from the statistical output of the regression analysis used to construct the model that the algorithm uses. proxies of solar indices, which are not utilized in the algorithm but can be used to monitor the accuracy and stability of the input indices.

Uncertainties arising from the assumptions used to formulate the algorithm- the fourth source of uncertainty identified in Section 4.2.2- are more difficult to assess objectively and establish quantitatively. Future work in support of ongoing efforts to produce a robust solar irradiance climate data record will extend the initial error estimates for the NRLTSI2 and NRLSSI2 modeled solar irradiance given in Tables 5 and 6, including their time and wavelength dependencies. The future uncertainty estimates will also incorporate an understanding of the impacts of the assumptions in the algorithm’s theoretical basis and uncertainties in the input facular brightening and sunspot darkening values on the derived solar irradiance (itemized in Table 7). This future understanding will reflect previous peer-reviewed studies and statistical results from the operational production of the modeled solar irradiance.

**Total Solar Irradiance**

The total solar irradiance is determined (Section 3.4) as

and the uncertainty in this determination is estimated as

where

and

with the facular brightening F(t) specified by the GOME Mg II index and sunspot darkening as (Section 3.3.1)

**Solar Spectral Irradiance**

Solar spectral irradiance at wavelength λ is determined (Section 3.4) as

where

The coefficients dF and dS are

where and are obtained from multiple regression of the observed, detrended solar spectral irradiance time series with the detrended facular brightening and sunspot darkening indices, i.e.,

and bF, bS and and are the coefficients obtained from multiple regression of the solar spectral irradiance time series at wavelength λ (in 1 nm bins) using, respectively, direct and detrended observations.

The uncertainty in the solar spectral irradiance value is estimated as

where

with facular brightening F(t) specified by the GOME Mg II index.

Similarly,

with sunspot darkening as

**Table 5: Representative quantities and their uncertainties, used to estimate 1-σ relative uncertainties in total solar irradiance produced by the algorithm on 30th October 2003, when facular brightening and sunspot darkening were near their maximum values.**

|  |  |
| --- | --- |
| **Quantity and Uncertainty** | **Value** |
| a | 0.122 ± 0.005 |
| bF  MgII index scalar | 135.44 ± 1.14 |
| F(t)-FQ  MgII index change | 0.0151 ± 0.003 (20%) |
| bF×[F(t)-FQ]  facular TSI contribution | 2.045 ± 0.41 Wm-2 |
| bS  sunspot darkening scalar | -0.000535 ± 0.000005 |
| S(t)-SQ  sunspot darkening change | 10647 ± 2129 (20%) |
| BS×[S(t)-SQ]  sunspot TSI contribution | -5.70 ± 1.14 Wm-2 |
| T(t) - TQ  net TSI change relative to quiet sun | -3.53 ± (0.005 ÷ 0.41 ÷ 1.14)  ± 1.56 |
| TQ | 1360.45 ± 0.5 Wm-2 |
| T(t)  absolute value | 1356.92 ± 2 Wm-2 |

**Table 6: Representative quantities and their uncertainties, used to estimate 1-σ relative uncertainties in solar spectral irradiance produced by the algorithm on 30th October 2003, when facular brightening and sunspot darkening were near their maximum values.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Quantity and Uncertainty** | **Value**  **121.5 nm** | **Value**  **250.5 nm** | **Value**  **500.5 nm** | **Value**  **1000.5 nm** |
| cF + CS | -5×10-8±6×10-8 | 3×10-7±3×10-6 | 2×10-5±9×10-6 | -10×10-6±4×10-6 |
| bF | 0.872±0.012\* | 0.872±0.012\* | 135.44 ± 1.14† | 135.44 ± 1.14† |
|  | 0.837±0.021\* | 0.872±0.022\* | 102.96± 1.8† | 102.96±1.8† |
|  | 0.0044±0.0005 | 0.092±0.0016 | 0.120±0.007 | 0.036±0.002 |
| dF  Mg II index scalar |  |  |  |  |
| eF  Mg II index scalar |  |  |  |  |
| F(t)-FQ  MgII index change | 0.0151 ± 0.003 (20%) | 0.0151 ± 0.003 (20%) | 0.0151 ± 0.003 (20%) | 0.0151 ± 0.003 (20%) |
| facular SSI contribution | 8.16×10-5 ±  Wm-2 | 1.70×10-3 ± Wm-2 | 2.78×10-3 ±  Wm-2 | 8.43×10-4 ±  Wm-2 |
| bS | NA | NA | -0.000535 ± 0.000005 | -0.000535 ± 0.000005 |
|  | NA | NA | -0.000504 ± 0.000005 | -0.000504 ± 0.000005 |
|  | 4×10-10±10×10-11 | -3×10-8±3×10-9 | -9×10-7±2×10-8 | -1.8×10-7±5×10-9 |
| dS  sunspot index scalar |  |  |  |  |
| eS  sunspot index scalar |  |  |  |  |
| sunspot SSI contribution | 4.17×10-6 ±  Wm-2 | -3.41×10-4 ± Wm-2 | -0.0112 ±  Wm-2 | -0.021 ±  Wm-2 |
| I(λ,t) - IQ(λ)  net SSI change relative to quiet sun | -xxx ± x |  |  |  |
| IQ (λ) | 1.36×10-4 ±  Wm-2 | 0.0548 ±  Wm-2 | 1.909 ±  Wm-2 | 0.7422 ±  Wm-2 |
| I(λ,t)  absolute value | 2.22×10-4 ±  Wm-2 | 0.0561 ±  Wm-2 | 1.901 ±  Wm-2 | 0.7409 ±  Wm-2 |

\* rotation-to-cycle scaling determined from Sac Peak CaII K record for λ < 300 nm

† rotation-to-cycle scaling determined from TSI K record for λ > 300 nm