Fast-J & Cloud-J -- an update

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Photolysis rates in correlated overlapping cloud fields: Cloud-J 7.3

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Abstract. A new approach for modeling photolysis rates (J values) in atmospheres with fractional cloud cover has been developed and implemented as Cloud-J – a multi-scattering eight-stream radiative transfer model for solar radiation based on Fast-J. Using observed statistics for the vertical correlation of cloud layers, Cloud-J 7.3 provides a practical and accurate method for modeling atmospheric chemistry. The combination of the new maximum-correlated cloud groups with the integration over all cloud combinations represented by four quadrature atmospheres produces mean J values in an atmospheric column with root-mean-square errors of 4% or less compared with 10–20% errors using simpler approximations. Cloud-J is practical for chemistry-climate models, requiring only an average of 2.8 Fast-J calls per atmosphere, vs. hundreds of calls with the correlated cloud groups, or 1 call with the simplest cloud approximations. Another improvement in modeling J values, the treatment of volatile organic compounds with pressure-dependent cross sections is also incorporated into Cloud-J.

fast-JX ver-7.3 standalone CTM code
UCI FJX v7.3+ JPL10+ IUPAC 2014 fixes - same data as FJX_spec_6.8d.dat

18

w-eff  wavelength (nm) notes: flux-weighted average over all intervals in bins
solar #/cm2/s notes: SUSIM average 11Nov94(low) + 29Mar92(med-high)
solar heat W/m2 notes: from SUSIM, checks with other refs.
Y-PAR photosyn act rad notes: Mccree 1972ab PAR spectrum
Raylay Rayleigh Scatter notes: flux weighted mean cross sections (cm^2)

... GlyAld HOCH2CHO =>
notes: Glycol Aldehyde => CH2OH+HC(O)[0.83] CH3OH+CO[0.10] OH+CH2CHO[0.07]
JPL10
MEKeto CH3COC2H5 >
notes: Methyl ethyl Ketone => C2H5+CH3CO[0.85] CH3+C2H5CO[0.15] X67
MEKeto

PrAld C2H5CHO => C2H5+    notes: Propionaldehyde (propanal) => C2H5+HCO
JPL10

... X-sects

X-sects 1 O2 O2=>O+O 1 298.0 300.0
X-sects 2 O3 O3-total 3 180.0 260.0 300.0
X-sects 3 NO NO=>N+O 1 298.0
X-sects 4 H2CO H2CO=>H+HCO 2 298.0 300.0
X-sects 5 H2O H2O2=>H2+CO 2 298.0 300.0
X-sects 6 CH3OCH3 CH3OCH3=>CH3+OH 1 298.0
X-sects 7 N2O N2O=>N2+O 2 298.0 300.0
X-sects 8 H2O2 H2O2=>OH+OH 2 298.0 300.0
X-sects 9 CH3OOH CH3OOH=>CH3+OH 1 298.0
X-sects 10 NO NO=N+O 1 298.0
X-sects 11 H2COa H2CO=>H+HCO 2 223.0 298.0
X-sects 12 H2COb H2CO=>H2+CO 2 223.0 298.0
X-sects 13 H2O2 H2O2=>H+HOH 2 200.0 300.0
X-sects 14 CH3OCH3 CH3OCH3=>CH3+OH 1 298.0
X-sects 15 CH3OH CH3OH=>CH3+OH 1 298.0
X-sects 16 CH3OCH2CH3 CH3OCH2CH3=>CH3+CH2OH 1 298.0
X-sects 17 CH2=CH2 CH2=CH2=>CH2+CH2 2 200.0 300.0
X-sects 18 CH2=CHCH3 CH2=CHCH3=>CH2+CH3 2 200.0 300.0
X-sects 19 CH3CH2=CH2 CH3CH2=CH2=>CH3+CH2=CH2 2 200.0 300.0
X-sects 20 CH3(1D) CH3(1D) => CH3+ 2 200.0 300.0
X-sects 21 CH2=CH=CH2 CH2=CH=CH2 => CH2+CH=CH2 2 200.0 300.0
X-sects 22 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 23 CH2=CHCHO CH2=CHCHO => CH2+CHO 2 200.0 300.0
X-sects 24 CH3CHO CH3CHO => CH3+CHO 1 298.0
X-sects 25 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 26 CH3CH3 CH3CH3 => CH3+CH3 2 200.0 300.0
X-sects 27 CH3CH2CH3 CH3CH2CH3 => CH3+CH2CH3 2 200.0 300.0
X-sects 28 CH3CH2CH2CH3 CH3CH2CH2CH3 => CH3+CH2CH2CH3 2 200.0 300.0
X-sects 29 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 30 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 31 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 32 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 33 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 34 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 35 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 36 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 37 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 38 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
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X-sects 41 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 42 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
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X-sects 46 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 47 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 48 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 49 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 50 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 51 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 52 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 53 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 54 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 55 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 56 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 57 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 58 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 59 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 60 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 61 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0
X-sects 62 CH2=CH2 CH2=CH2 => CH2+CH2 2 200.0 300.0

...
Fast-J X v6.8d  
Last F77 heritage version of Fast-J

Fast-J X v7.0d  
F90 CAM5

Fast-J X v7.1c  
F90 WACCM (allows WACCM-J <200 nm)

Fast-J X v7.2  
Cloud-J for UCI CTM (Neu 2007 MAX-RAN)

Cloud-J v7.3  
New correlated cloud overlap (Prather 2015)

Solar-J v7.3  
Extend FJ X bins, clouds & molecules to 5 μm
Cloud-J v7.3 is really new and presents a breakthrough in Scale Independence

A problem with deterministic cloud overlap algorithms using correlation lengths is that they fail the scale-independence test in that the number of atmospheres to be averaged over grows as $2^{NL}$, where NL is the number of layers.

Cloud-J eliminates this problem with two quantizations that bring the number of cloud combinations to a fixed maximum, independent of NL:

1) Group the cloudy layers within one correlation length into one maximum overlap group (new to Prather 2015), creating $6\frac{1}{2}$ MAX groups (the $\frac{1}{2}$ includes the cirrus shield separation). Clouds close together are MAX overlapped.

2) Quantize the fractional cloud cover in any to the nearest 10th percentile (0%, 10%, 20%, ... 100%), ensuring that no matter how many layers are in each MAX group, there are at most 10 different ICAs (from Neu 2007)

3) Assume that each MAX group is correlated with the one above at a level corresponding to about one e-fold (algorithm new to Prather 2015)

4) The maximum # of ICAs to characterize is less than $5\times10^6$, independent of NL. With coding in Cloud-J, this computational time is inconsequential. The # of ICAs for NL=40 and a straightforward correlation algorithm is as large as $10^{12}$. 
Cloud-J

limited data passed to CLOUD_J X (only interface to rest of model)

call CLOUD_JX (U0, SZA, REFLB, SOLF, FG0, LPRTJ, PPP, ZZZ, TTT, &
DDD, RRR, OOO, _LWP, _IWP, REFFL, REFFI, _CLF, CWC, &
AERSP, NDXAER, _L1_, _AN_, VALJXX, JVN_, &
CLDFLAG, NRANDO, IRAN, L3RG, NICA, JCOUNT)

Only needs from CAM are profiles of 5 cloud quantities

LWP/IWP = Liquid/Ice water path (g/m2)
REFFL/REFFI = R-effective (microns) in liquid/ice cloud
CLF = cloud fraction (0.0 to 1.0)

and profiles of aerosol quantities

AERSP = aerosol path (g/m2)
NDXAER = aerosol index type
Photolysis rates in correlated overlapping cloud fields: Cloud-J 7.3

A new approach for modeling the observed vertical correlation of fractional cloud layers is presented.

The vertical correlation length $L$ (km) is based on observations:

1.5 km near surface \(-\) to \(-\) 3 km in upper troposphere.

For practicality, 6 maximally overlapped (MAX) groups are based on $L$:

1\(^{st}\) 0 – 1.5 km  
2\(^{nd}\) 1.5 – 3.5 km  
3\(^{rd}\) 3.5 – 6 km  
4\(^{th}\) 6 – 9 km  
5\(^{th}\) 9 – 13 km  
6\(^{th}\) >13 km  

A 7\(^{th}\) MAX group is split from the top group, if cirrus shields present.

A new algorithm for correlated overlap of the MAX groups is presented:

MAX-COR has limits of

MAX-RAN for zero correlation ($cc=0$)

one MAX group for full correlation ($cc=1$)

Correlation coefficient = 0.33 ($\sim1/e$) between MAX groups is set
Cloud overlap algorithms:

Layer 2: cloudy fraction = $f_{L2} = 20\%$  \hspace{1cm}  clear fraction = $1 - f_{L2} = 80\%$

Layer 1: cloudy fraction = $f_{L1} = 15\%$  \hspace{1cm}  clear fraction = $1 - f_{L1} = 85\%$
**Random overlap (RAN)**

<table>
<thead>
<tr>
<th>Layer 2</th>
<th>Layer 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3%</td>
</tr>
<tr>
<td>ICA#</td>
<td>1</td>
</tr>
</tbody>
</table>

Independent Column Atmospheres

**ICAs #1 and #2 fall beneath cloudy fraction in Layer 2:**

\[
\begin{align*}
W^{L1}(#1) &= f^{L1} \\
W^{L1}(#2) &= 1 - f^{L1} \\
W^{L2}(#1) &= W^{L2}(#2) = f^{L2}
\end{align*}
\]

\[
W^{L1-L2}(#1) = W^{L1}(#1)W^{L2}(#1) = f^{L1}f^{L2} = 0.15 \times 0.20 = 3\% \text{ (from Fig. 1)}
\]

**ICAs #3 and #4 fall beneath clear fraction in Layer 2:**

\[
\begin{align*}
W^{L1}(#3) &= f^{L1} \quad \text{and} \quad W^{L2}(#3) = 1 - f^{L2} \\
W^{L1}(#4) &= 1 - f^{L1} \quad \text{and} \quad W^{L2}(#4) = 1 - f^{L2}
\end{align*}
\]

\[
\begin{align*}
W^{L1-L2}(#3) &= W^{L1}(#3)W^{L2}(#3) = f^{L1}(1 - f^{L2}) = 0.15 \times 0.80 = 12\% \text{ (Fig. 1)}
\end{align*}
\]

\[
\begin{align*}
W^{L1-L2}(#4) &= W^{L1}(#4)W^{L2}(#4) = (1 - f^{L1})(1 - f^{L2}) = 0.85 \times 0.80 = 68\%
\end{align*}
\]
ICAs #1 has more L1 cloudy fraction below L2 cloud (9%) than in RAN (3%)

\[ g = 1 + \text{cc}(1/f^{L2} - 1), \text{ subject to } g \leq 1/f^{L1} \text{ and } g \leq 1/f^{L2} \]  

(10)

\[ w^{L1}(\#1) = gf^{L1} = 3 \times 0.15 = 45\% \]  

(11)

\[ w^{L1}(\#2) = 1 - gf^{L1} = 1 - 0.45 = 55\% \]  

(12)

\[ w^{L1}(\#3) = f^{L1}(1 - gf^{L2})/(1 - f^{L2}) = 0.15 \times (1 - 3 \times 0.20)/0.80 = 7.5\% \]  

(13)

\[ w^{L1}(\#4) = 1 - w^{L1}(\#3) = 1 - 0.075 = 92.5\% \]  

(14)

\[ w^{L2}(\#1) = w^{L2}(\#2) = f^{L2} \]  

(15)

\[ w^{L2}(\#3) = w^{L2}(\#4) = (1 - f^{L2}). \]  

(16)

ICA#s L1 has more L1 cloudy fraction below L2 cloud (9%) than in RAN (3%)

\[ W^{L1-L2}(\#1) = w^{L1}(\#1)w^{L2}(\#1) = gf^{L1}f^{L2} = 3 \times 0.15 \times 0.20 = 9\% \]  

(17)

\[ W^{L1-L2}(\#2) = w^{L1}(\#2)w^{L2}(\#2) = (1 - gf^{L1})f^{L2} = 0.55 \times 0.20 = 11\% \]  

(18)

\[ W^{L1-L2}(\#3) = w^{L1}(\#3)w^{L2}(\#3) = f^{L1}(1 - gf^{L2}) = 0.15 \times 0.40 = 6\% \]  

(19)

\[ W^{L1-L2}(\#4) = w^{L1}(\#4)w^{L2}(\#4) = 1 - f^{L2} - f^{L1}(1 - gf^{L2}) = 1 - 0.20 - 0.06 = 74\% \]  

(20)
ICAs #1 has more L1 cloudy fraction below L2 cloud (15%) than in COR (9%).

There are only 3 ICAs.

A MAX group corresponds to set of (N1+1) ICAs:

fractions \( f_1, f_2, f_3, \ldots \) and their weights \( w_1, w_2, w_3, \ldots \)

\[
F = \sum f_i \leq 1
\]

\( f_{j_1=1:N1} \) totaling \( F^{G1} \) and a clear-sky with fraction \( 1 - F^{G1} \)
For 2 MAX-COR groups (G1 & G2), each with a number of ICAs (N1+1 & N2+1), the numbering scheme is:

\[(1, 1), (2, 1), (3, 1), \ldots (N1 + 1, 1), (1, 2), (2, 2), (3, 2), \ldots (N1 + 1, N2 + 1)\]  \hspace{1cm} (21)

\[J1 = (M - 1) \mod (N1 + 1) + 1\]  \hspace{1cm} (22)

\[J2 = \text{integer} \left(\frac{(M - 1)}{(N1 + 1)}\right) \mod (N2 + 1) + 1\]  \hspace{1cm} (23)

The correlation enhancement factor \(g\) is based on the sum of cloudy fractions in each group

\[g = 1 + cc \left(\frac{1}{F^{G2}} - 1\right), \text{ subject to } g \leq \frac{1}{F^{G1}} \text{ and } g \leq \frac{1}{F^{G2}}\]  \hspace{1cm} (24)

The weights for each level depend on the cloudy-clear combinations:

\[w^{G1}(\text{cloudy}^{G1}, \text{cloudy}^{G2}) = gf^{G1}_{J1}\]  \hspace{1cm} (25)

\[w^{G1}(\text{clear}^{G1}, \text{cloudy}^{G2}) = 1 - \sum (\text{over cloudy G1})gf^{G1}_{J1} = 1 - gF^{G1}\]  \hspace{1cm} (26)

\[w^{G1}(\text{cloudy}^{G1}, \text{clear}^{G2}) = f^{G1}_{J1}(1 - gF^{G2})/(1 - F^{G2})\]  \hspace{1cm} (27)

\[w^{G1}(\text{clear}^{G1}, \text{clear}^{G2}) = 1 - F^{G1}(1 - gF^{G2})/(1 - F^{G2})\]  \hspace{1cm} (28)
Comparisons of #ICAs generated by:

- $G_6$ = new MAX-COR model
- $G_3$ = fixed 3-level MAX-RAN model
- $G_0$ = MAX-RAN with breaks at every $f = 0$

**Figure.** Number of Independent Column Atmospheres (ICAs) generated by three different cloud overlap models ($G_0$, $G_3$, $G_6$) from 640 different tropical fractionally cloudy atmospheres (FCAs) and sorted in order of increasing ICA number.

The different correlation coefficients used in the $G_6$ model do not change the number of ICAs, only their weightings. The average number of ICAs per FCA is given in the legend.
Figure. $J$-value mean error (640 tropical T319L60 atmospheres) for various approximations used to average over all ICAs (total here = 108125). Reference model in G6 w/cc=0.33.

Three simple cloud methods (ClearSky, CldFr to 3/2 power, AvgCloud) do not use cloud-overlap model.

Three approximations for the ICAs are Median Quad Colm Atmos (Neu 2007), Average QCA and Average Direct Beam (both Prather 2015).

\[ J - O1D: \quad O_3 + hv = O(1D) + O_2 (~6 \times 10^{-5} \text{ s}^{-1}). \]
\[ J - NO3: \quad NO_3 + hv = NO + O_2 \text{ or } NO_2 + O (~0.3 \text{ s}^{-1}). \]
### Table 1. J-value average and root-mean-square error for cloud overlap model (all ICAs)

<table>
<thead>
<tr>
<th>Cloud overlap models to generate ICAs</th>
<th>ICAs(^a)</th>
<th>avg err 0–1 km</th>
<th>rms err 0–1 km</th>
<th>rms err 0–16 km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>J-O(^1)D</td>
<td>J-NO(_3)</td>
<td>J-O(^1)D</td>
</tr>
<tr>
<td>G0 MAX-RAN with MAX groups</td>
<td>19</td>
<td>+2%</td>
<td>21%</td>
<td>6%</td>
</tr>
<tr>
<td>bounded by layers with CF = 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G3 3 MAX-RAN groups split at 1 km</td>
<td>21</td>
<td>+2%</td>
<td>15%</td>
<td>5%</td>
</tr>
<tr>
<td>and at the ice-only cloud level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G6/.00 6 MAX-COR groups, cc = 0.00</td>
<td>169</td>
<td>−1%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>G6/.33 6 MAX-COR groups, cc = 0.33(^b)</td>
<td>169</td>
<td>+2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G6/.99 6 MAX-COR groups, cc = 0.99</td>
<td>169</td>
<td>+1%</td>
<td>11%</td>
<td>4%</td>
</tr>
</tbody>
</table>

All models are OK for large-scale averages (e.g., 640 atmospheres and 108,125 ICAs).

RMS errors are large for the small number MAX-RAN groups (G0, G3, with G6/.99 ~ 1 MAX group).

RMS errors for 6 MAX-COR with cc = 0.00 (effectively MAX-RAN) are OK.

**Recognizing the correlation across the 6 MAX-COR groups makes a difference!**
Table 2. J-value average and root-mean-square error for approximating all ICAs

<table>
<thead>
<tr>
<th>Simple cloud models</th>
<th>ICAs</th>
<th>avg err 0–1 km</th>
<th>rms err 0–1 km</th>
<th>rms err 0–16 km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>J-O1D</td>
<td>J-NO3</td>
<td>J-O1D</td>
</tr>
<tr>
<td>CISky</td>
<td>1</td>
<td>+14%</td>
<td>+10%</td>
<td>24%</td>
</tr>
<tr>
<td>AvClD</td>
<td>1</td>
<td>-5%</td>
<td>+1%</td>
<td>11%</td>
</tr>
<tr>
<td>CF3/2</td>
<td>1</td>
<td>+7%</td>
<td>+11%</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICA approximations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>J calls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AvDir^c</td>
<td>1</td>
<td>+5%</td>
<td>+11%</td>
<td>6%</td>
</tr>
<tr>
<td>MdQCA^c</td>
<td>2.8</td>
<td>+1%</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>AvQCA^c</td>
<td>2.8</td>
<td>-1%</td>
<td>0%</td>
<td>3%</td>
</tr>
<tr>
<td>Ran-3</td>
<td>3</td>
<td>+2%</td>
<td>+1%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Simple cloud models all have large errors.

Either QCA models are best.

Averaging the direct beam over all ICAs did not work as well as expected.

Picking random ICAs (instead of the QCA) is poor choice for rms error.
Solar-J is Cloud-J extended beyond 800 nm with RRTMG-SW bands and thus will do solar heating.

Solar-J includes direct and diffuse PAR (with 4-angle diffuse field).

Solar-J is funded by DOE BER and will be implemented as a drop-in replacement for Cloud-J, including cloud overlap and ice/liquid water absorption.

First off-line tests of Solar-J vs RRTMG-SW are now underway.
### Fast-J Solar Bins

<table>
<thead>
<tr>
<th>#</th>
<th>Wavelength (nm)</th>
<th>Solar (W/m²)</th>
<th>PAR (µE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>187</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>191</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>193</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>196</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>202</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>208</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>211</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>214</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>261</td>
<td>4.84</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>267</td>
<td>2.97</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>277</td>
<td>2.23</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>295</td>
<td>3.97</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>303</td>
<td>5.03</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>310</td>
<td>3.23</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>316</td>
<td>5.59</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>333</td>
<td>22.98</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>380</td>
<td>80.45</td>
<td>125</td>
</tr>
<tr>
<td>18</td>
<td>412-850</td>
<td>696.40</td>
<td>2026</td>
</tr>
</tbody>
</table>

### RRTM-SW Solar Bins

<table>
<thead>
<tr>
<th>Wavelength range (nm)</th>
<th>Solar (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>180-200</td>
<td>3.12</td>
</tr>
<tr>
<td>200-263</td>
<td>50.15</td>
</tr>
<tr>
<td>263-345</td>
<td>129.5</td>
</tr>
<tr>
<td>345-441</td>
<td>347.2</td>
</tr>
<tr>
<td>441-625</td>
<td>218.1</td>
</tr>
<tr>
<td>625-778</td>
<td>345.7</td>
</tr>
<tr>
<td>778-1242</td>
<td>24.29</td>
</tr>
<tr>
<td>1242-1299</td>
<td>102.9</td>
</tr>
<tr>
<td>1299-1626</td>
<td>55.63</td>
</tr>
<tr>
<td>1626-1942</td>
<td>22.43</td>
</tr>
<tr>
<td>1942-2151</td>
<td>23.73</td>
</tr>
<tr>
<td>2151-2500</td>
<td>20.36</td>
</tr>
<tr>
<td>2500-3077</td>
<td>12.11</td>
</tr>
<tr>
<td>3077-3846</td>
<td>12.79</td>
</tr>
<tr>
<td>3846-12195</td>
<td></td>
</tr>
</tbody>
</table>

Fast-J would need to add 9 super-bins which amounts to ~40 added calculations.

Overlap bin 18 vs 24-25 (14 bins) will become Fast-J bins 18a,b,c,d,e.
Juno Hsu has completed the first cut and adding RRTMG-SW to the Fast-J short-wavelength bins. The key overlap region is the last Fast-J bin #18 (442 – 778 nm) which overlaps 2 RRTM bins. 

Fast-J now runs with the RRTM absorption longward of 442 nm.

Clear sky, high-sun comparison shown here: