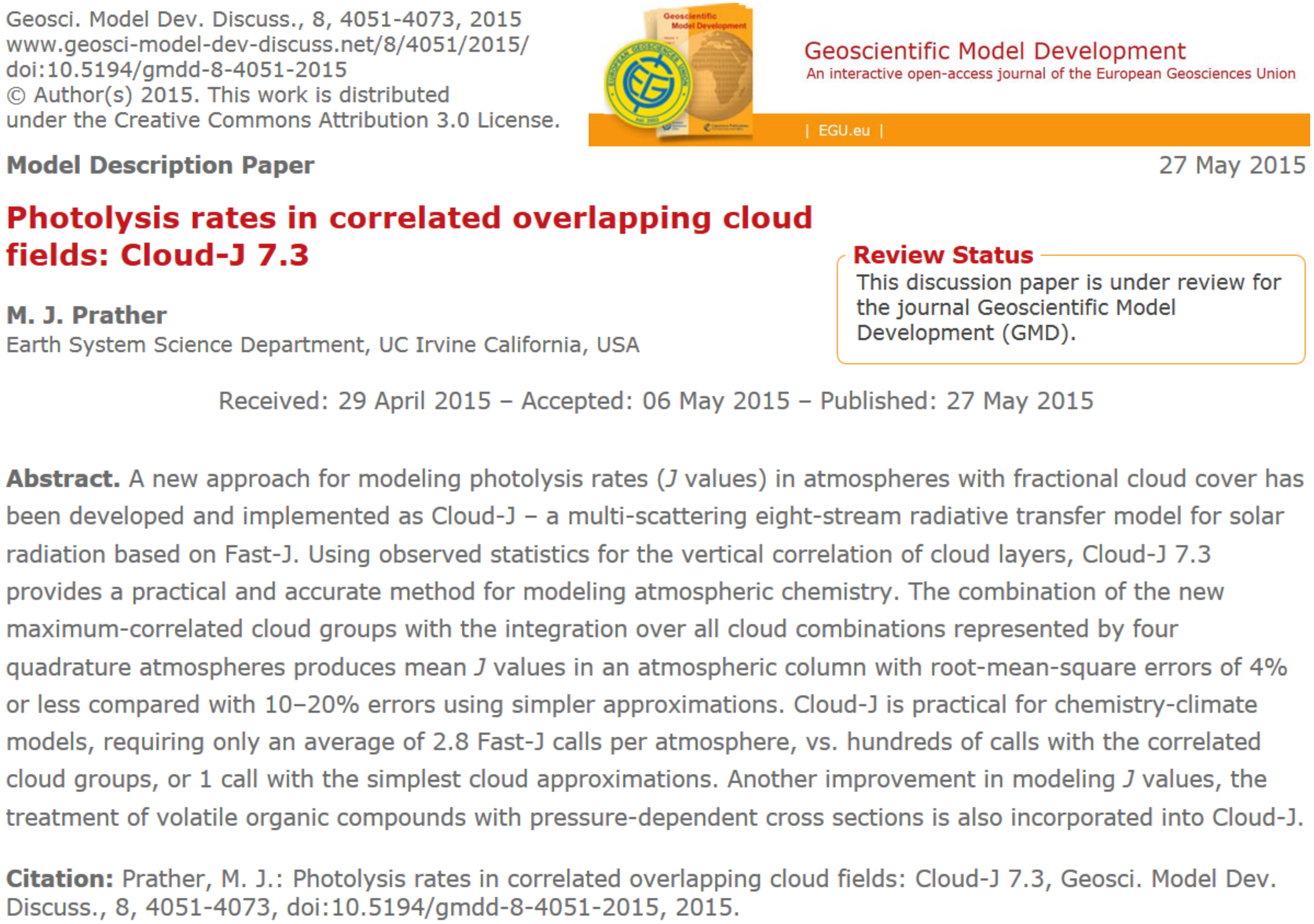
Fast-J & Cloud-J -- an update

Michael Prather, Juno Hsu, Alex Nicolau, Alex Veidenbaum (UC Irvine)
Philip Cameron-Smith (LLNL) & Michael Prather

CESM Chemistry-Climate WG, June 2015, Breckenridge



Geosci. Model Dev. Discuss., 8, 4051-4073, 2015
www.geosci-model-dev-discuss.net/8/4051/2015/
doi:10.5194/gmdd-8-4051-2015

Geoscientific Model Development
An interactive open-access journal of the European Geosciences Union
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Model Description Paper

27 May 2015

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

Review Status
This discussion paper is under review for the journal Geoscientific Model Development (GMD).

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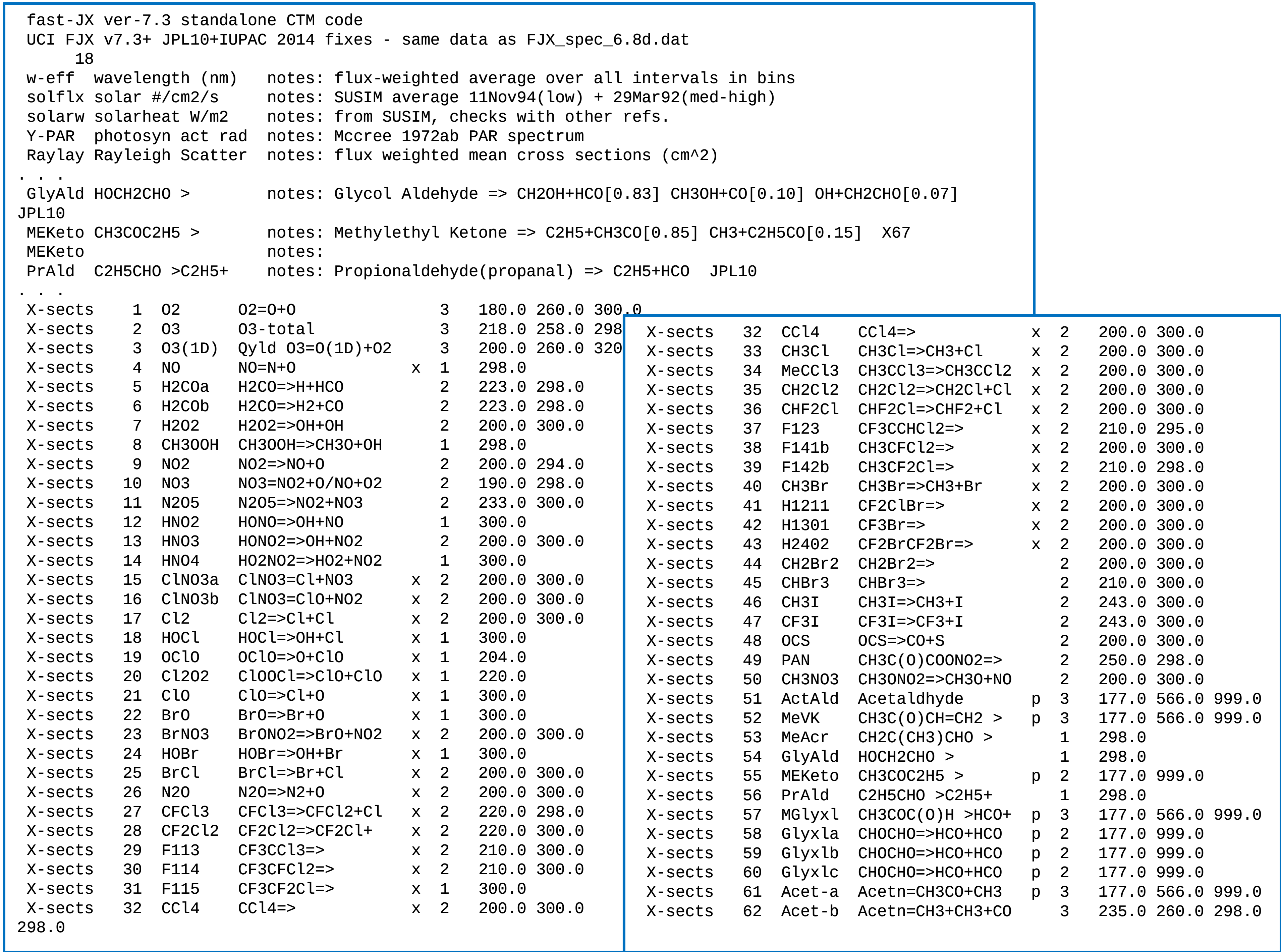
Earth System Science Department, UC Irvine California, USA

Received: 29 April 2015 – Accepted: 06 May 2015 – Published: 27 May 2015

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.

Citation: Prather, M. J.: Photolysis rates in correlated overlapping cloud fields: Cloud-J 7.3, Geosci. Model Dev. Discuss., 8, 4051-4073, doi:10.5194/gmdd-8-4051-2015, 2015.



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 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
 solflx solar #/cm2/s     notes: SUSIM average 11Nov94(low) + 29Mar92(med-high)
 solarw solarheat 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+HCO[0.83] CH3OH+CO[0.10] OH+CH2CHO[0.07]
JPL10
 MEKeto CH3COC2H5 >       notes: Methylethyl Ketone => C2H5+CH3CO[0.85] CH3+C2H5CO[0.15]  X67
 MEKeto                   notes:
 PrAld  C2H5CHO >C2H5+    notes: Propionaldehyde(propanal) => C2H5+HCO  JPL10
. . .
 X-sects    1  O2      O2=O+O                3   180.0 260.0 300.0
 X-sects    2  O3      O3-total              3   218.0 258.0 298
 X-sects    3  O3(1D)  Qyld O3=O(1D)+O2      3   200.0 260.0 320
 X-sects    4  NO      NO=N+O             x  1   298.0
 X-sects    5  H2COa   H2CO=>H+HCO           2   223.0 298.0
 X-sects    6  H2COb   H2CO=>H2+CO           2   223.0 298.0
 X-sects    7  H2O2    H2O2=>OH+OH           2   200.0 300.0
 X-sects    8  CH3OOH  CH3OOH=>CH3O+OH       1   298.0
 X-sects    9  NO2     NO2=>NO+O             2   200.0 294.0
 X-sects   10  NO3     NO3=NO2+O/NO+O2       2   190.0 298.0
 X-sects   11  N2O5    N2O5=>NO2+NO3         2   233.0 300.0
 X-sects   12  HNO2    HONO=>OH+NO           1   300.0
 X-sects   13  HNO3    HONO2=>OH+NO2         2   200.0 300.0
 X-sects   14  HNO4    HO2NO2=>HO2+NO2       1   300.0
 X-sects   15  ClNO3a  ClNO3=Cl+NO3       x  2   200.0 300.0
 X-sects   16  ClNO3b  ClNO3=ClO+NO2      x  2   200.0 300.0
 X-sects   17  Cl2     Cl2=>Cl+Cl         x  2   200.0 300.0
 X-sects   18  HOCl    HOCl=>OH+Cl        x  1   300.0
 X-sects   19  OClO    OClO=>O+ClO        x  1   204.0
 X-sects   20  Cl2O2   ClOOCl=>ClO+ClO    x  1   220.0
 X-sects   21  ClO     ClO=>Cl+O          x  1   300.0
 X-sects   22  BrO     BrO=>Br+O          x  1   300.0
 X-sects   23  BrNO3   BrONO2=>BrO+NO2    x  2   200.0 300.0
 X-sects   24  HOBr    HOBr=>OH+Br        x  1   300.0
 X-sects   25  BrCl    BrCl=>Br+Cl        x  2   200.0 300.0
 X-sects   26  N2O     N2O=>N2+O          x  2   200.0 300.0
 X-sects   27  CFCl3   CFCl3=>CFCl2+Cl    x  2   220.0 298.0
 X-sects   28  CF2Cl2  CF2Cl2=>CF2Cl+     x  2   220.0 300.0
 X-sects   29  F113    CF3CCl3=>          x  2   210.0 300.0
 X-sects   30  F114    CF3CFCl2=>         x  2   210.0 300.0
 X-sects   31  F115    CF3CF2Cl=>         x  1   300.0
 X-sects   32  CCl4    CCl4=>             x  2   200.0 300.0
298.0
```

```
 X-sects   32  CCl4    CCl4=>             x  2   200.0 300.0
 X-sects   33  CH3Cl   CH3Cl=>CH3+Cl      x  2   200.0 300.0
 X-sects   34  MeCCl3  CH3CCl3=>CH3CCl2   x  2   200.0 300.0
 X-sects   35  CH2Cl2  CH2Cl2=>CH2Cl+Cl   x  2   200.0 300.0
 X-sects   36  CHF2Cl  CHF2Cl=>CHF2+Cl    x  2   200.0 300.0
 X-sects   37  F123    CF3CCHCl2=>        x  2   210.0 295.0
 X-sects   38  F141b   CH3CFCl2=>         x  2   200.0 300.0
 X-sects   39  F142b   CH3CF2Cl=>         x  2   210.0 298.0
 X-sects   40  CH3Br   CH3Br=>CH3+Br      x  2   200.0 300.0
 X-sects   41  H1211   CF2ClBr=>          x  2   200.0 300.0
 X-sects   42  H1301   CF3Br=>            x  2   200.0 300.0
 X-sects   43  H2402   CF2BrCF2Br=>       x  2   200.0 300.0
 X-sects   44  CH2Br2  CH2Br2=>              2   200.0 300.0
 X-sects   45  CHBr3   CHBr3=>               2   210.0 300.0
 X-sects   46  CH3I    CH3I=>CH3+I           2   243.0 300.0
 X-sects   47  CF3I    CF3I=>CF3+I           2   243.0 300.0
 X-sects   48  OCS     OCS=>CO+S             2   200.0 300.0
 X-sects   49  PAN     CH3C(O)COONO2=>       2   250.0 298.0
 X-sects   50  CH3NO3  CH3ONO2=>CH3O+NO      2   200.0 300.0
 X-sects   51  ActAld  Acetaldhyde        p  3   177.0 566.0 999.0
 X-sects   52  MeVK    CH3C(O)CH=CH2 >    p  3   177.0 566.0 999.0
 X-sects   53  MeAcr   CH2C(CH3)CHO >        1   298.0
 X-sects   54  GlyAld  HOCH2CHO >            1   298.0
 X-sects   55  MEKeto  CH3COC2H5 >        p  2   177.0 999.0
 X-sects   56  PrAld   C2H5CHO >C2H5+        1   298.0
 X-sects   57  MGlyxl  CH3COC(O)H >HCO+   p  3   177.0 566.0 999.0
 X-sects   58  Glyxla  CHOCHO=>HCO+HCO    p  2   177.0 999.0
 X-sects   59  Glyxlb  CHOCHO=>HCO+HCO    p  2   177.0 999.0
 X-sects   60  Glyxlc  CHOCHO=>HCO+HCO    p  2   177.0 999.0
 X-sects   61  Acet-a  Acetn=CH3CO+CH3    p  3   177.0 566.0 999.0
 X-sects   62  Acet-b  Acetn=CH3+CH3+CO      3   235.0 260.0 298.0
```

```
 fast-JX ver-7.3 standalone CTM code
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 solarw solarheat W/m2     notes: from SU
 Y-PAR  photosyn act rad   notes: Mccree
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. . .
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 X-sects    1  O2       O2=O+O
 X-sects    2  O3       O3-total
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 X-sects   13  HNO3     HONO2=>OH+NO2
 X-sects   14  HNO4     HO2NO2=>HO2+NO2
 X-sects   15  ClNO3a   ClNO3=Cl+NO3
 X-sects   16  ClNO3b   ClNO3=ClO+NO2
 X-sects   17  Cl2      Cl2=>Cl+Cl
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 X-sects   26  N2O      N2O=>N2+O
 X-sects   27  CFCl3    CFCl3=>CFCl2+Cl
 X-sects   28  CF2Cl2   CF2Cl2=>CF2Cl+      x  2    220.0 300.0
 X-sects   29  F113     CF3CCl3=>           x  2    210.0 300.0
 X-sects   30  F114     CF3CFCl2=>          x  2    210.0 300.0
 X-sects   31  F115     CF3CF2Cl=>          x  1    300.0
 X-sects   32  CCl4     CCl4=>              x  2    200.0 300.0
298.0
```

```
 X-sects   58  Glyxla   CHOCHO=>HCO+HCO   p  2    177.0 999.0
 X-sects   59  Glyxlb   CHOCHO=>HCO+HCO   p  2    177.0 999.0
 X-sects   60  Glyxlc   CHOCHO=>HCO+HCO   p  2    177.0 999.0
 X-sects   61  Acet-a   Acetn=CH3CO+CH3   p  3    177.0 566.0 999.0
 X-sects   62  Acet-b   Acetn=CH3+CH3+CO     3    235.0 260.0 298.0
```

Fast-JX v6.8d

Last F77 heritage version of Fast-J

Fast-JX v7.0d

F90 CAM5

Fast-JX v7.1c

F90 WACCM (allows WACCM-J <200 nm)

Fast-JX 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 FJX bins, clouds & molecules to 5 µm

Cloud-J v7.3 is really new and presents a breakthrough in Scale Independence

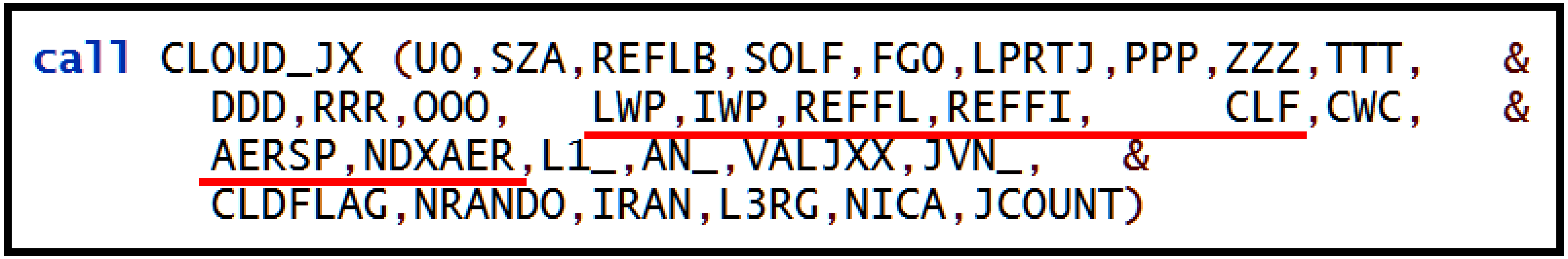
A problem with deterministic cloud overlap algorithms using correlation lengths is that they fail the scale-independence test in that the number of atmospheres to be averaged over ***grows as*** $\boldsymbol{2^{NL}}$, where NL is the number of layers.

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 6½ MAX groups (the ½ 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 5×10^6, 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}.

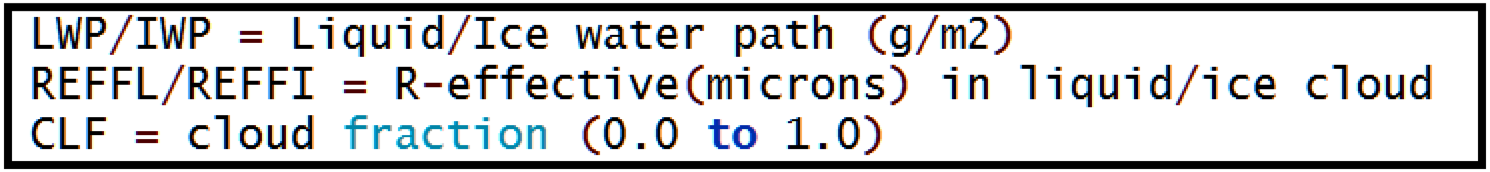
Cloud-J

limited data passed to CLOUD_JX (only interface to rest of model)



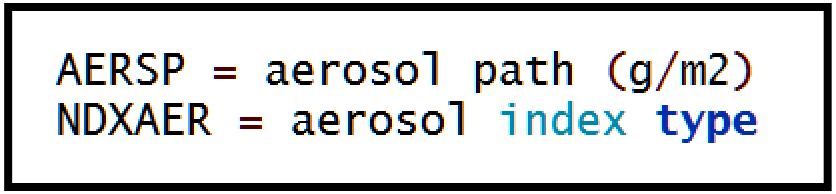
```
call CLOUD_JX (U0,SZA,REFLB,SOLF,FG0,LPRTJ,PPP,ZZZ,TTT,    &
       DDD,RRR,OOO,    LWP,IWP,REFFL,REFFI,       CLF,CWC,    &
       AERSP,NDXAER,L1_,AN_,VALJXX,JVN_,    &
       CLDFLAG,NRANDO,IRAN,L3RG,NICA,JCOUNT)
```

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:

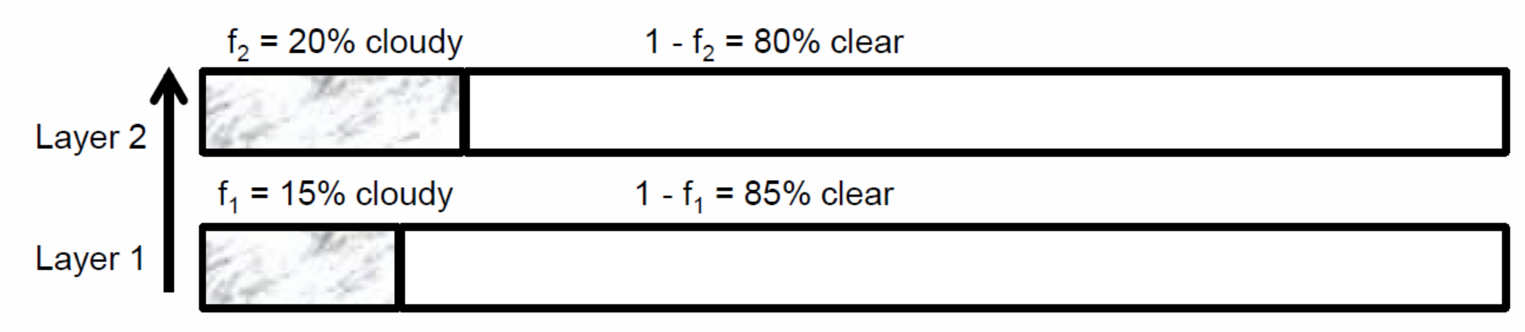
1st *0 – 1.5 km* 2nd *1.5 – 3.5 km* 3rd *3.5 – 6 km*
4th *6 – 9 km* 5th *9 – 13 km* 6th *>13 km*
a 7th MAX group is split from the top group, if cirrus shields present.

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 (~1/e) between MAX groups is set

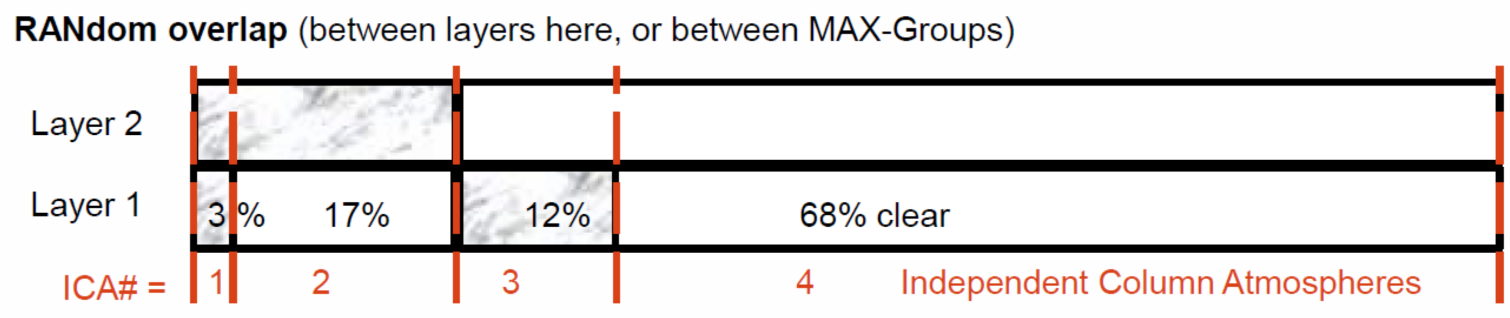
Cloud overlap algorithms:



Layer 2: cloudy fraction = f^{L2} = 20% clear fraction = 1 – f^{L2} = 80%

Layer 1: cloudy fraction = f^{L1} = 15% clear fraction = 1 – f^{L1} = 85%

Random overlap (RAN)



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

$$w^{L1}(\#1) = f^{L1} \tag{1}$$

$$w^{L1}(\#2) = 1 - f^{L1} \tag{2}$$

$$w^{L2}(\#1) = w^{L2}(\#2) = f^{L2} \tag{3}$$

$$W^{L1-L2}(\#1) = w^{L1}(\#1)w^{L2}(\#1) = f^{L1}f^{L2} = 0.15 \times 0.20 = 3\% \text{ (from Fig. 1)} \tag{4}$$

$$W^{L1-L2}(\#2) = w^{L1}(\#2)w^{L2}(\#2) = (1 - f^{L1})f^{L2} = 0.85 \times 0.20 = 17\% \tag{5}$$

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

$$w^{L1}(\#3) = f^{L1} \quad \text{and} \quad w^{L2}(\#3) = 1 - f^{L2} \tag{6}$$

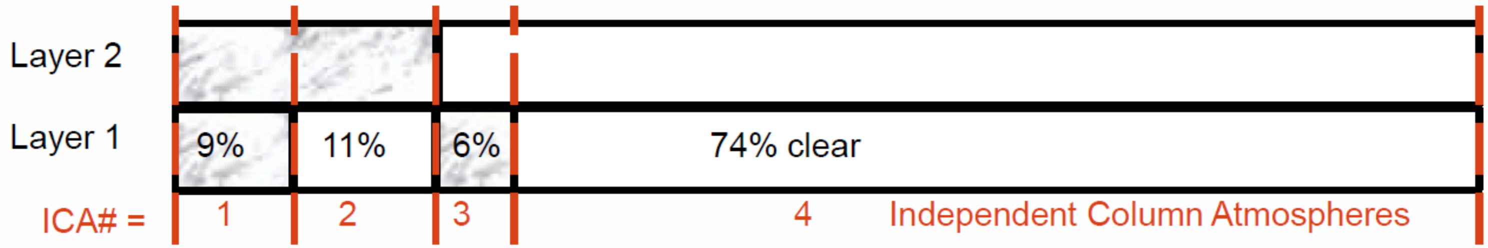
$$w^{L1}(\#4) = 1 - f^{L1} \quad \text{and} \quad w^{L2}(\#4) = 1 - f^{L2}. \tag{7}$$

$$W^{L1-L2}(\#3) = w^{L1}(\#3)w^{L2}(\#3) = f^{L1}(1 - f^{L2}) = 0.15 \times 0.80 = 12\% \text{ (Fig. 1)} \tag{8}$$

$$W^{L1-L2}(\#4) = w^{L1}(\#4)w^{L2}(\#4) = (1 - f^{L1})(1 - f^{L2}) = 0.85 \times 0.80 = 68\% \tag{9}$$

Correlated overlap (COR)

CORrelated overlap, with cc = ½ (between layers here, or between MAX-Groups)



$$\boxed{g = 1 + \mathrm{cc}(1/f^{\mathrm{L2}} - 1), \text{ subject to } g \le 1/f^{\mathrm{L1}} \text{ and } g \le 1/f^{\mathrm{L2}} \qquad (10)}$$

$$w^{\mathrm{L1}}(\#1) = gf^{\mathrm{L1}} = 3 \times 0.15 = 45\% \qquad (11)$$

$$w^{\mathrm{L1}}(\#2) = 1 - gf^{\mathrm{L1}} = 1 - 0.45 = 55\% \qquad (12)$$

$$w^{\mathrm{L1}}(\#3) = f^{\mathrm{L1}}(1 - gf^{\mathrm{L2}})/(1 - f^{\mathrm{L2}}) = 0.15 \times (1 - 3 \times 0.20)/0.80 = 7.5\% \qquad (13)$$

$$w^{\mathrm{L1}}(\#4) = 1 - w^{\mathrm{L1}}(\#3) = 1 - 0.075 = 92.5\% \qquad (14)$$

$$w^{\mathrm{L2}}(\#1) = w^{\mathrm{L2}}(\#2) = f^{\mathrm{L2}} \qquad (15)$$

$$w^{\mathrm{L2}}(\#3) = w^{\mathrm{L2}}(\#4) = (1 - f^{\mathrm{L2}}). \qquad (16)$$

ICAs #1 has more L1 cloudy fraction below L2 cloud (9%) than in RAN (3%)

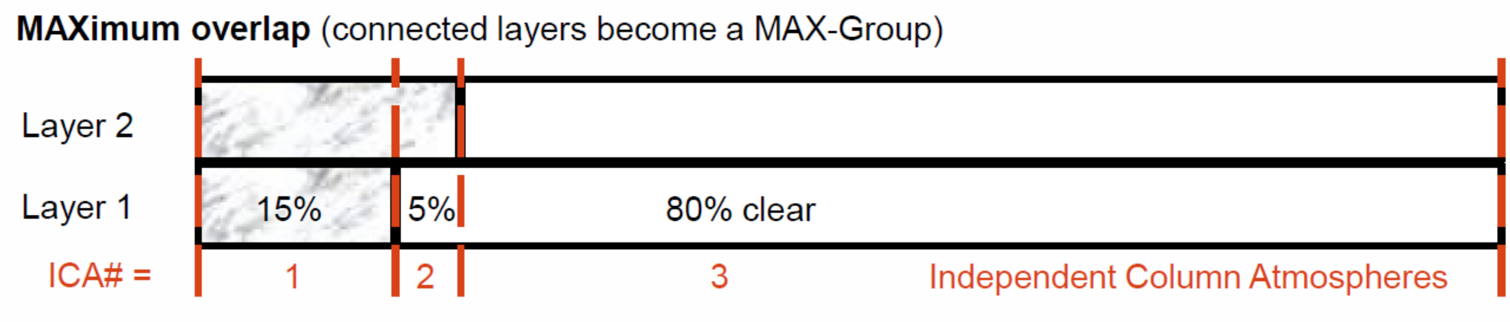
$$W^{\mathrm{L1-L2}}(\#1) = w^{\mathrm{L1}}(\#1)w^{\mathrm{L2}}(\#1) = gf^{\mathrm{L1}}f^{\mathrm{L2}} = 3 \times 0.15 \times 0.20 = 9\% \qquad (17)$$

$$W^{\mathrm{L1-L2}}(\#2) = w^{\mathrm{L1}}(\#2)w^{\mathrm{L2}}(\#2) = (1 - gf^{\mathrm{L1}})f^{\mathrm{L2}} = 0.55 \times 0.20 = 11\% \qquad (18)$$

$$W^{\mathrm{L1-L2}}(\#3) = w^{\mathrm{L1}}(\#3)w^{\mathrm{L2}}(\#3) = f^{\mathrm{L1}}(1 - gf^{\mathrm{L2}}) = 0.15 \times 0.40 = 6\% \qquad (19)$$

$$W^{\mathrm{L1-L2}}(\#4) = w^{\mathrm{L1}}(\#4)w^{\mathrm{L2}}(\#4) = 1 - f^{\mathrm{L2}} - f^{\mathrm{L1}}(1 - gf^{\mathrm{L2}}) = 1 - 0.20 - 0.06 = 74\% \qquad (20)$$

Maximal overlap (MAX)



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

There are only 3 ICAs

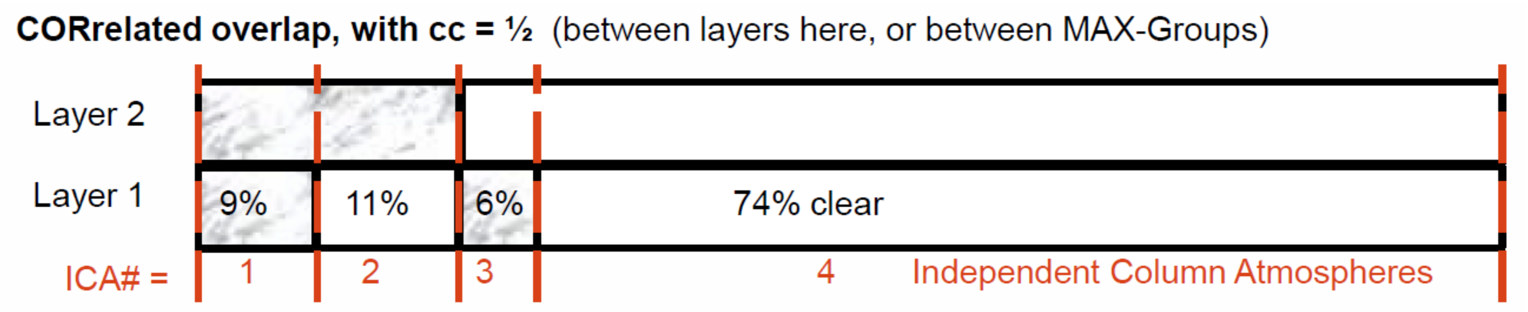
A MAX group corresponds to set of (N1+1) ICAs:

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

$$F = \sum f_i \leq 1$$

$f^{G1}_{J1=1:N1}$ totaling F^{G1} and a clear-sky with fraction $1 - F^{G1}$

Maximal groups with correlated overlap (MAX-COR)



For 2 MAX-COR groups (G1 & G2), each with a number of ICAs (N1+1 & N2+1), the numbering scheme is:

$$(1,1),(2,1),(3,1),\ldots(\mathrm{N1}+1,1),(1,2),(2,2),(3,2),\ldots(\mathrm{N1}+1,\mathrm{N2}+1) \tag{21}$$

$$\mathrm{J1} = (\mathrm{M}-1) \bmod (\mathrm{N1}+1)+1 \tag{22}$$

$$\mathrm{J2} = \text{integer}\,((\mathrm{M}-1)/(\mathrm{N1}+1)) \bmod (\mathrm{N2}+1)+1 \tag{23}$$

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

$$g = 1 + \mathrm{cc}\,(1/F^{\mathrm{G2}} - 1), \text{ subject to } g \le 1/F^{\mathrm{G1}} \text{ and } g \le 1/F^{\mathrm{G2}} \tag{24}$$

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

$$w^{\mathrm{G1}}(\mathrm{cloudy}^{\mathrm{G1}},\ \mathrm{cloudy}^{\mathrm{G2}}) = g f^{\mathrm{G1}}_{\mathrm{J1}} \tag{25}$$

$$w^{\mathrm{G1}}(\mathrm{clear}^{\mathrm{G1}},\ \mathrm{cloudy}^{\mathrm{G2}}) = 1 - \sum(\text{over cloudy G1}) g f^{\mathrm{G1}}_{\mathrm{J1}} = 1 - gF^{\mathrm{G1}} \tag{26}$$

$$w^{\mathrm{G1}}(\mathrm{cloudy}^{\mathrm{G1}},\ \mathrm{clear}^{\mathrm{G2}}) = f^{\mathrm{G1}}_{\mathrm{J1}}(1 - gF^{\mathrm{G2}})/(1 - F^{\mathrm{G2}}) \tag{27}$$

$$w^{\mathrm{G1}}(\mathrm{clear}^{\mathrm{G1}},\ \mathrm{clear}^{\mathrm{G2}}) = 1 - F^{\mathrm{G1}}(1 - gF^{\mathrm{G2}})/(1 - F^{\mathrm{G2}}) \tag{28}$$

Comparisons of # ICAs generated by: G6 = new MAX-COR model
G3 = fixed 3-level MAX-RAN model
G0 = MAX-RAN with breaks at every ***f*** = 0

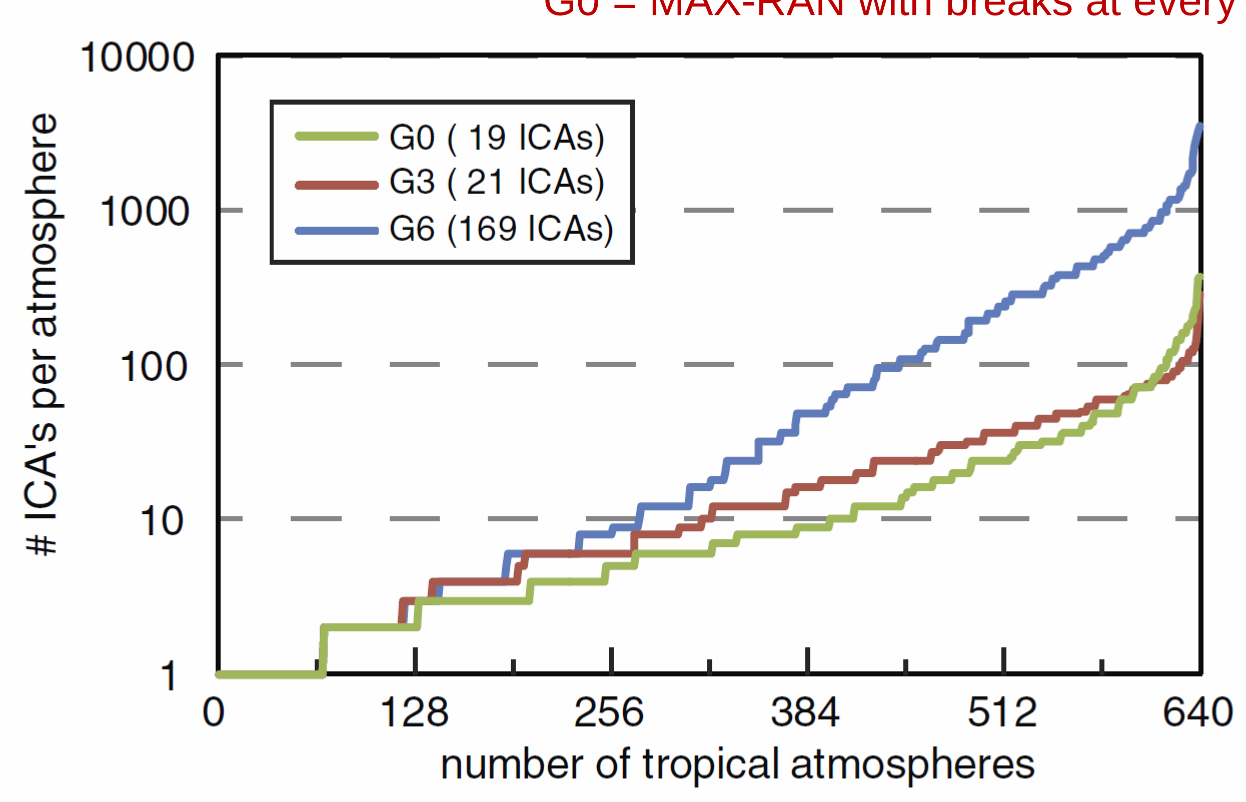


Figure. Number of Independent Column Atmospheres (ICAs) generated by three different cloud overlap models (G0, G3, G6) from 640 different tropical fractionally cloudy atmospheres (FCAs) and sorted in order of increasing ICA number.

The different correlation coefficients used in the G6 model do not change the number of ICAs, only their weightings. The average number of ICAs per FCA is given in the legend.

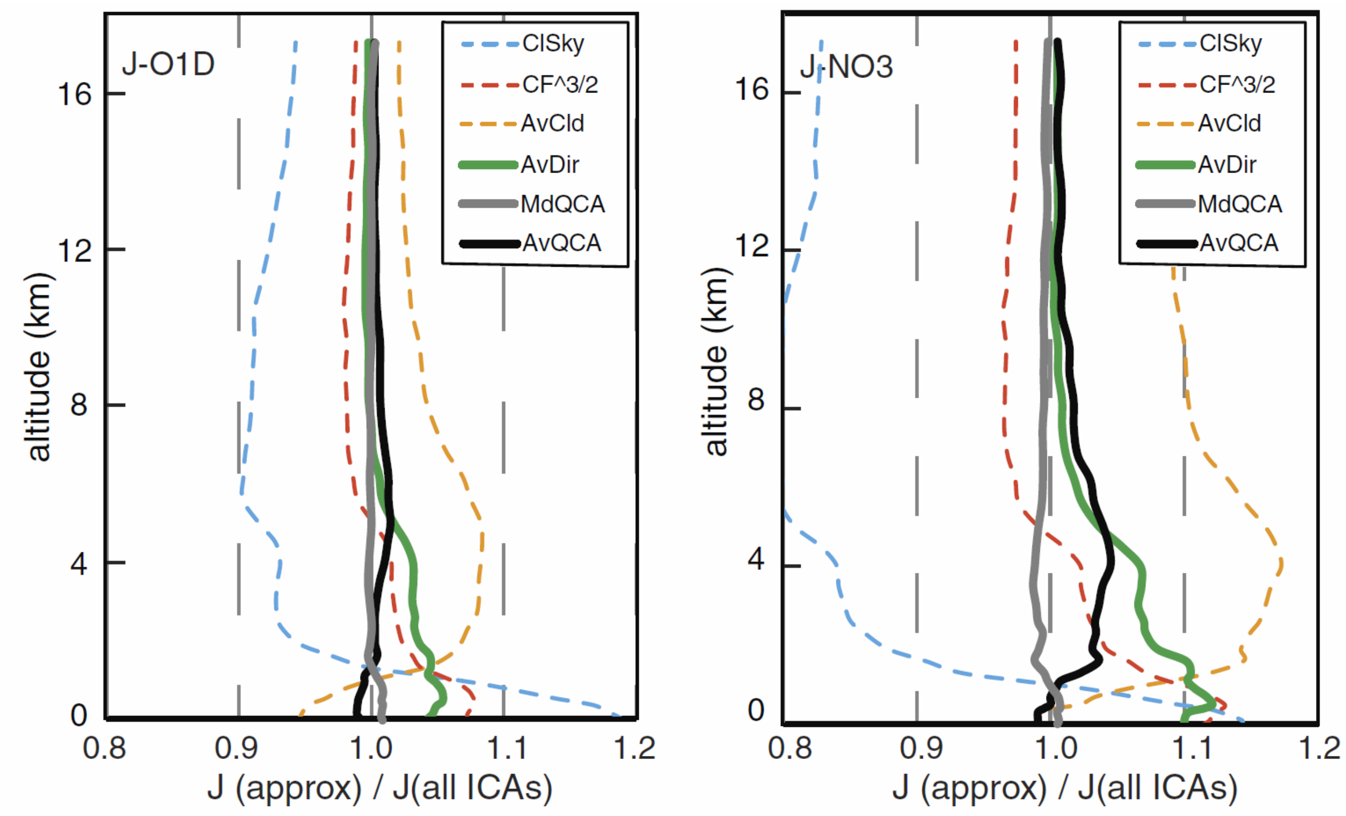
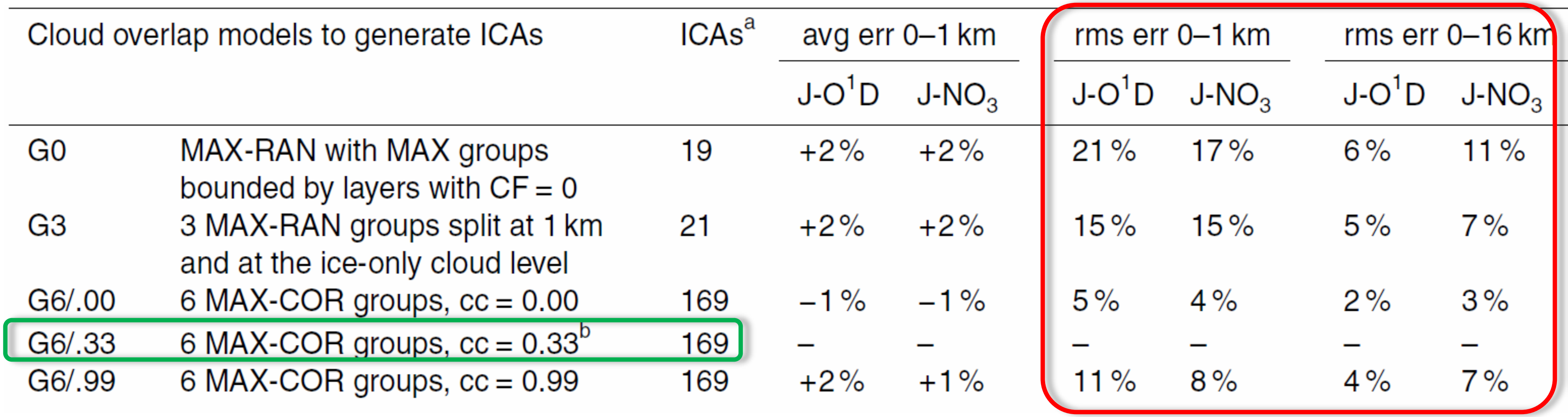


Figure. J-value mean error (640 tropical T319L60 atmospheres) for various approximations used to average over all ICAs (total here = 108125). Reference model in G6 w/cc=0.33.

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), Avereage QCA and Average Direct Beam (both Prather 2015).

J-O1D: $O_3+hv = O(^1D)+O_2$ (~6 x10^{-5} s^{-1}).
J-NO3: $NO_3+hv = NO+O_2$ or NO_2+O (~0.3 s^{-1}).

Table 1. J-value average and root-mean-square error for cloud overlap model (all ICAs)



Cloud overlap models to generate ICAs		ICAs[a]	avg err 0–1 km		rms err 0–1 km		rms err 0–16 km	
			J-O^{1}D	J-NO$_3$	J-O^{1}D	J-NO$_3$	J-O^{1}D	J-NO$_3$
G0	MAX-RAN with MAX groups bounded by layers with CF = 0	19	+2 %	+2 %	21 %	17 %	6 %	11 %
G3	3 MAX-RAN groups split at 1 km and at the ice-only cloud level	21	+2 %	+2 %	15 %	15 %	5 %	7 %
G6/.00	6 MAX-COR groups, cc = 0.00	169	−1 %	−1 %	5 %	4 %	2 %	3 %
G6/.33	6 MAX-COR groups, cc = 0.33[b]	169	–	–	–	–	–	–
G6/.99	6 MAX-COR groups, cc = 0.99	169	+2 %	+1 %	11 %	8 %	4 %	7 %

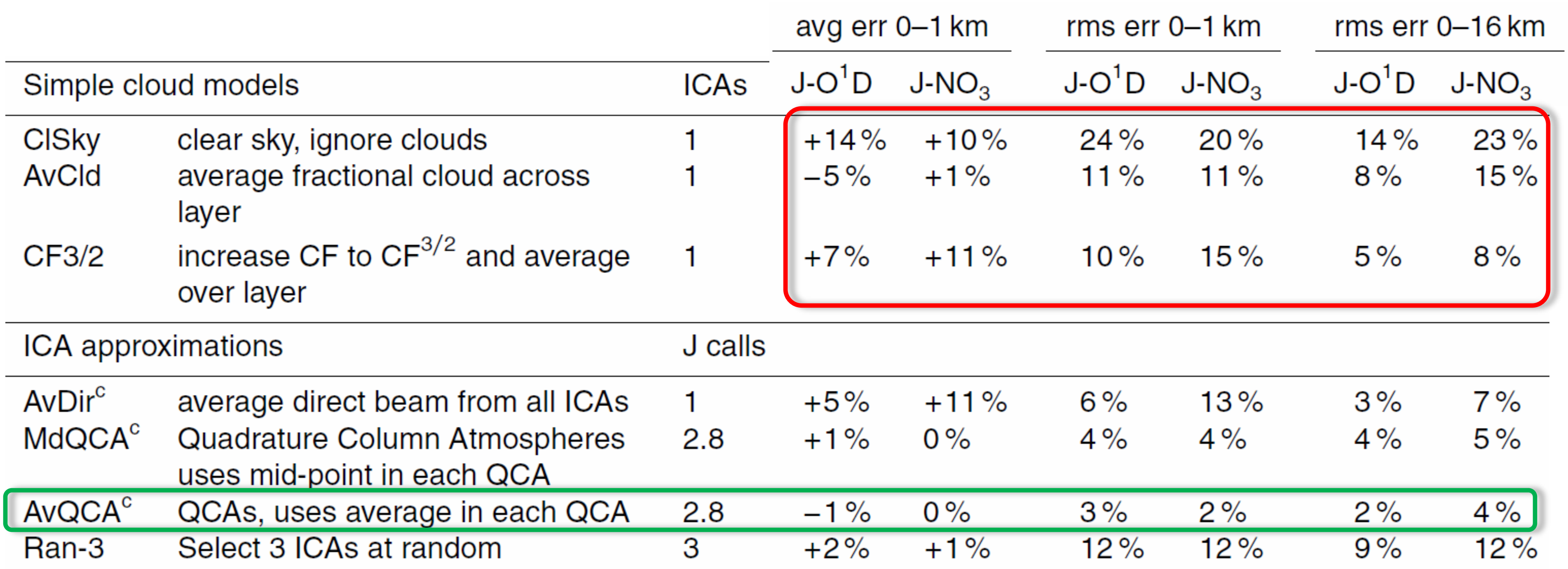
All models are OK for large-scale averages
(e.g., 640 atmospheres and 108,125 ICAs).

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



			avg err 0–1 km		rms err 0–1 km		rms err 0–16 km	
Simple cloud models		ICAs	J-O^{1}D	J-NO$_3$	J-O^{1}D	J-NO$_3$	J-O^{1}D	J-NO$_3$
ClSky	clear sky, ignore clouds	1	+14 %	+10 %	24 %	20 %	14 %	23 %
AvCld	average fractional cloud across layer	1	−5 %	+1 %	11 %	11 %	8 %	15 %
CF3/2	increase CF to CF$^{3/2}$ and average over layer	1	+7 %	+11 %	10 %	15 %	5 %	8 %
ICA approximations		J calls						
AvDir[c]	average direct beam from all ICAs	1	+5 %	+11 %	6 %	13 %	3 %	7 %
MdQCA[c]	Quadrature Column Atmospheres uses mid-point in each QCA	2.8	+1 %	0 %	4 %	4 %	4 %	5 %
AvQCA[c]	QCAs, uses average in each QCA	2.8	−1 %	0 %	3 %	2 %	2 %	4 %
Ran-3	Select 3 ICAs at random	3	+2 %	+1 %	12 %	12 %	9 %	12 %

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 QCAs) is poor choice for rms error.

PREVIEW: Solar-J

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.

PREVIEW: Solar-J

fast-J solar bins

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

RRTM-SW solar bins

#	Wavelength range (nm)		Solar (W/m^2)
28	200	263	3.12
27	263	345	50.15
26	345	441	129.5
25	**441**	**625**	347.2
24	**625**	**778**	218.1
23	**778**	**1242**	**345.7**
22	**1242**	**1299**	**24.29**
21	**1299**	**1626**	**102.9**
20	**1626**	**1942**	**55.63**
19	**1942**	**2151**	**22.43**
18	**2151**	**2500**	**23.73**
17	**2500**	**3077**	**20.36**
16	**3077**	**3846**	**12.11**
29	**3846**	**12195**	**12.79**

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.

Preview: Solar-J

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: