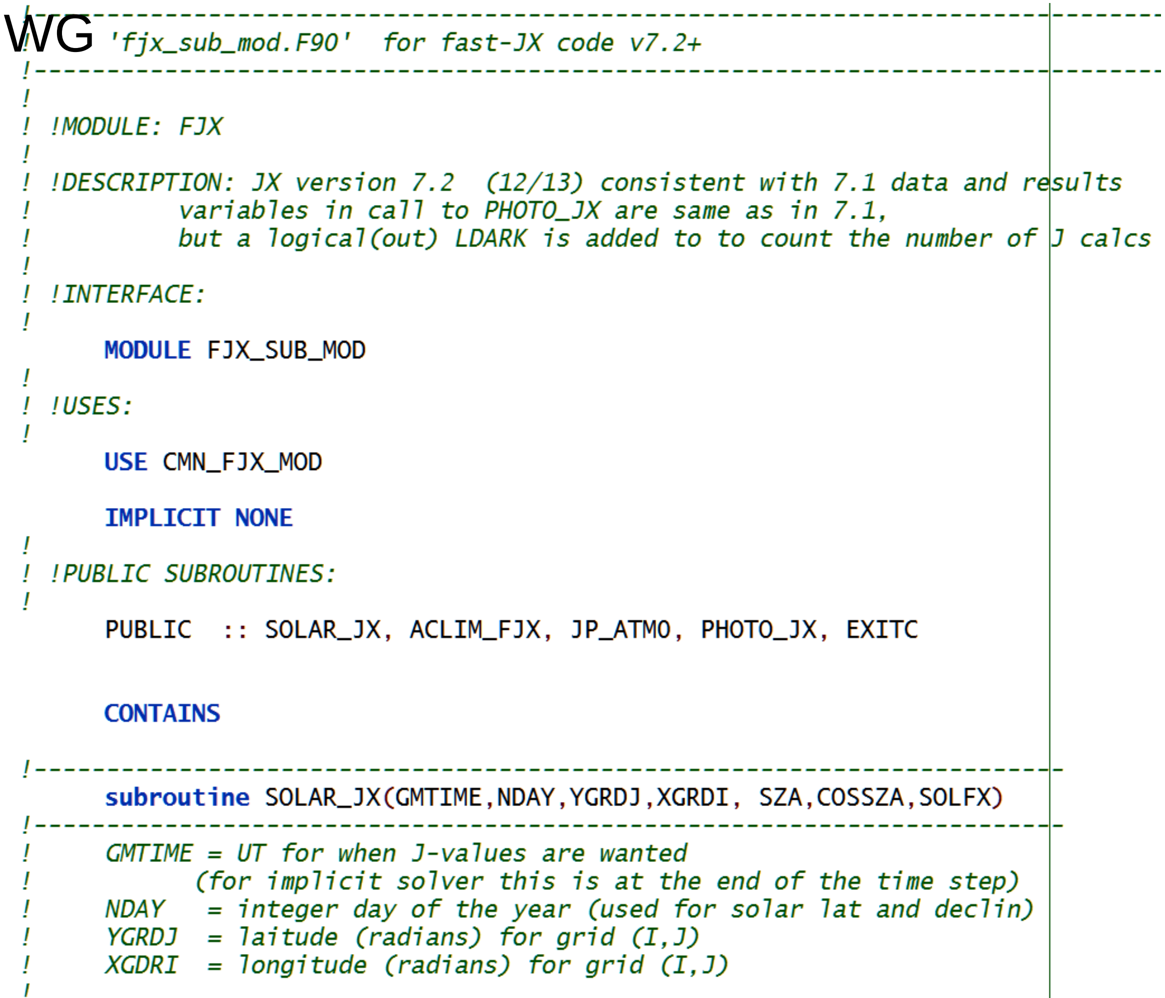
fast-J, an update

Full Fortran-90 implementation in CAM5

Linked to aerosols

Michael Prather & Philip Cameron-Smith
CESM Chemistry-Climate WG
10 Feb 2014



```
!------------------------------------------------------------------------------
!    'fjx_sub_mod.F90'  for fast-JX code v7.2+
!------------------------------------------------------------------------------
!
! !MODULE: FJX
!
! !DESCRIPTION: JX version 7.2  (12/13) consistent with 7.1 data and results
!          variables in call to PHOTO_JX are same as in 7.1,
!          but a logical(out) LDARK is added to to count the number of J calcs
!
! !INTERFACE:
!
      MODULE FJX_SUB_MOD
!
! !USES:
!
      USE CMN_FJX_MOD

      IMPLICIT NONE
!
! !PUBLIC SUBROUTINES:
!
      PUBLIC  :: SOLAR_JX, ACLIM_FJX, JP_ATM0, PHOTO_JX, EXITC


      CONTAINS

!-----------------------------------------------------------------------
      subroutine SOLAR_JX(GMTIME,NDAY,YGRDJ,XGRDI, SZA,COSSZA,SOLFX)
!-----------------------------------------------------------------------
!     GMTIME = UT for when J-values are wanted
!           (for implicit solver this is at the end of the time step)
!     NDAY   = integer day of the year (used for solar lat and declin)
!     YGRDJ  = laitude (radians) for grid (I,J)
!     XGDRI  = longitude (radians) for grid (I,J)
!
```

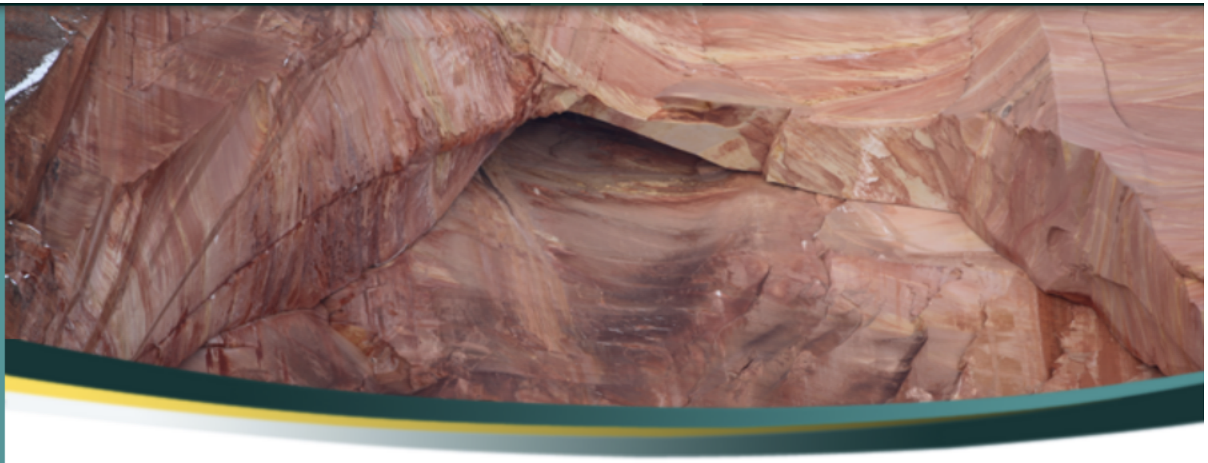
Research Group (1969)

(email)

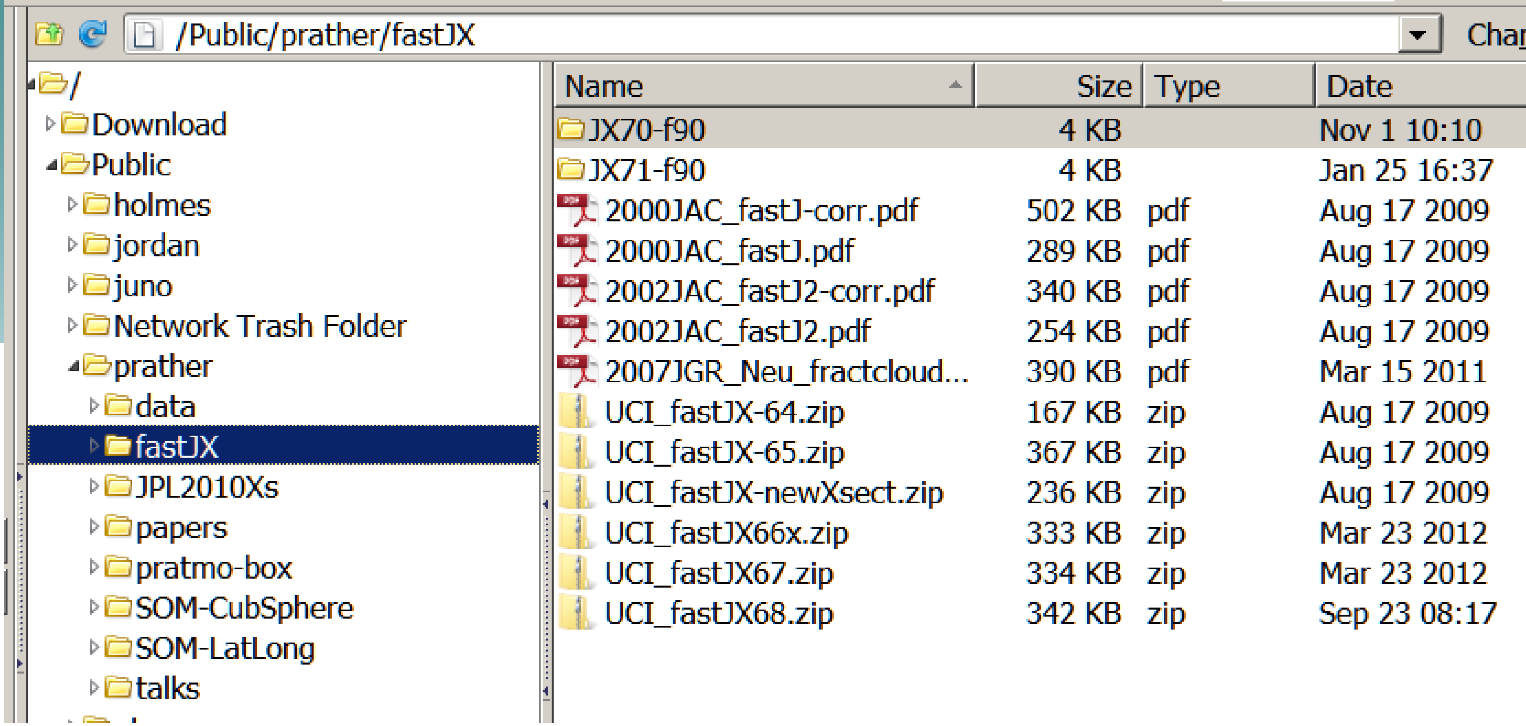
Software Releases

Fast JX
6.8 Jan 8 2013
Download (341.96 KB)

Environment Institute



Fast JX



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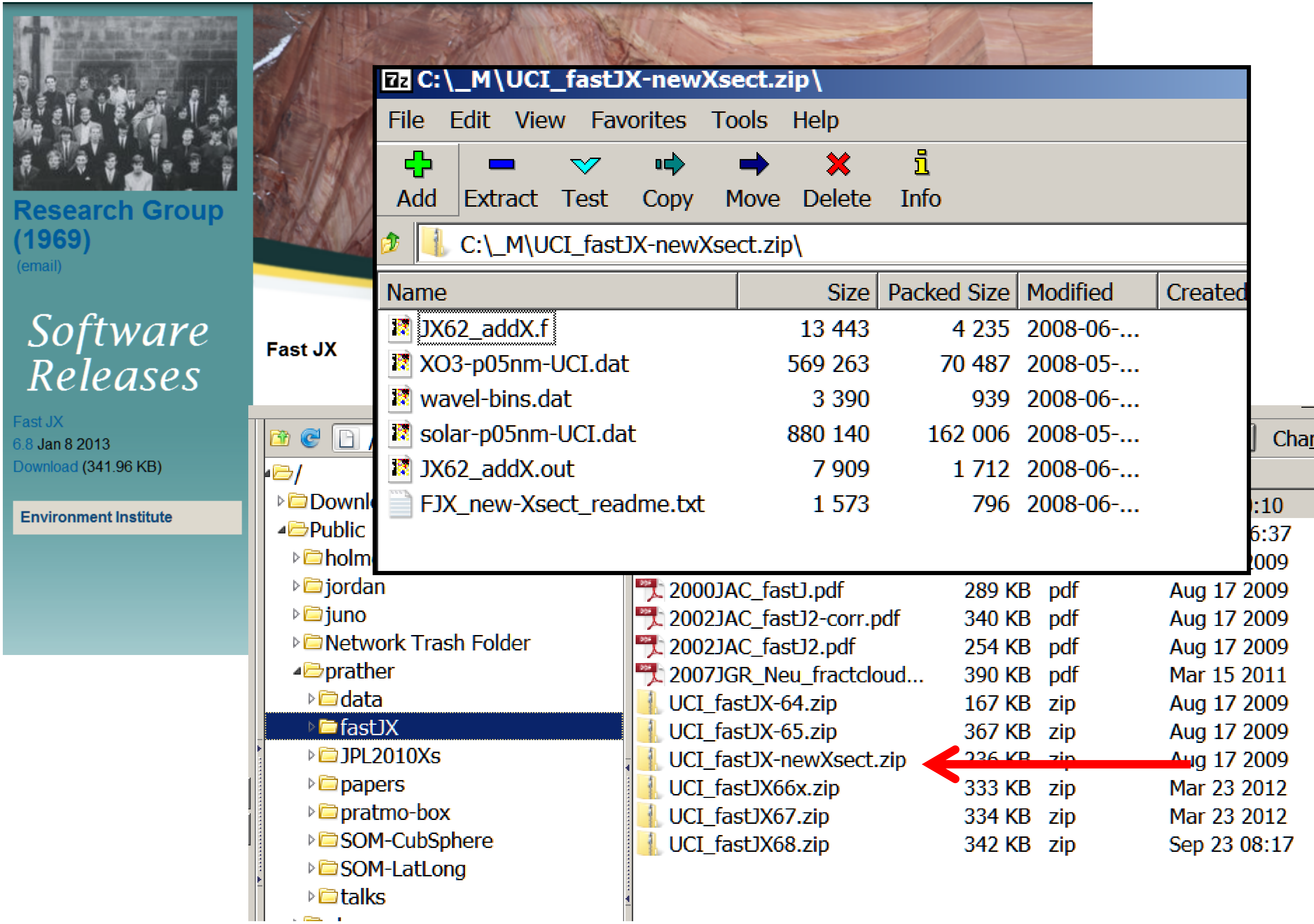
      - pratmo-box
      - SOM-CubSphere
      - SOM-LatLong
      - talks

Name	Size	Type	Date
JX70-f90	4 KB		Nov 1 10:10
JX71-f90	4 KB		Jan 25 16:37
2000JAC_fastJ-corr.pdf	502 KB	pdf	Aug 17 2009
2000JAC_fastJ.pdf	289 KB	pdf	Aug 17 2009
2002JAC_fastJ2-corr.pdf	340 KB	pdf	Aug 17 2009
2002JAC_fastJ2.pdf	254 KB	pdf	Aug 17 2009
2007JGR_Neu_fractcloud...	390 KB	pdf	Mar 15 2011
UCI_fastJX-64.zip	167 KB	zip	Aug 17 2009
UCI_fastJX-65.zip	367 KB	zip	Aug 17 2009
UCI_fastJX-newXsect.zip	236 KB	zip	Aug 17 2009
UCI_fastJX66x.zip	333 KB	zip	Mar 23 2012
UCI_fastJX67.zip	334 KB	zip	Mar 23 2012
UCI_fastJX68.zip	342 KB	zip	Sep 23 08:17



Research Group (1969)
(email)

Software Releases

Fast JX
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Download (341.96 KB)

Environment Institute

Fast JX

C:_M\UCI_fastJX-newXsect.zip\

C:_M\UCI_fastJX-newXsect.zip\

Name	Size	Packed Size	Modified	Created
JX62_addX.f	13 443	4 235	2008-06-...	
XO3-p05nm-UCI.dat	569 263	70 487	2008-05-...	
wavel-bins.dat	3 390	939	2008-06-...	
solar-p05nm-UCI.dat	880 140	162 006	2008-05-...	
JX62_addX.out	7 909	1 712	2008-06-...	
FJX_new-Xsect_readme.txt	1 573	796	2008-06-...	

- /
  - Downl
  - Public
    - holm
    - jordan
    - juno
    - Network Trash Folder
    - prather
      - data
      - fastJX
      - JPL2010Xs
      - papers
      - pratmo-box
      - SOM-CubSphere
      - SOM-LatLong
      - talks

2000JAC_fastJ.pdf	289 KB	pdf	Aug 17 2009
2002JAC_fastJ2-corr.pdf	340 KB	pdf	Aug 17 2009
2002JAC_fastJ2.pdf	254 KB	pdf	Aug 17 2009
2007JGR_Neu_fractcloud...	390 KB	pdf	Mar 15 2011
UCI_fastJX-64.zip	167 KB	zip	Aug 17 2009
UCI_fastJX-65.zip	367 KB	zip	Aug 17 2009
UCI_fastJX-newXsect.zip	236 KB	zip	Aug 17 2009
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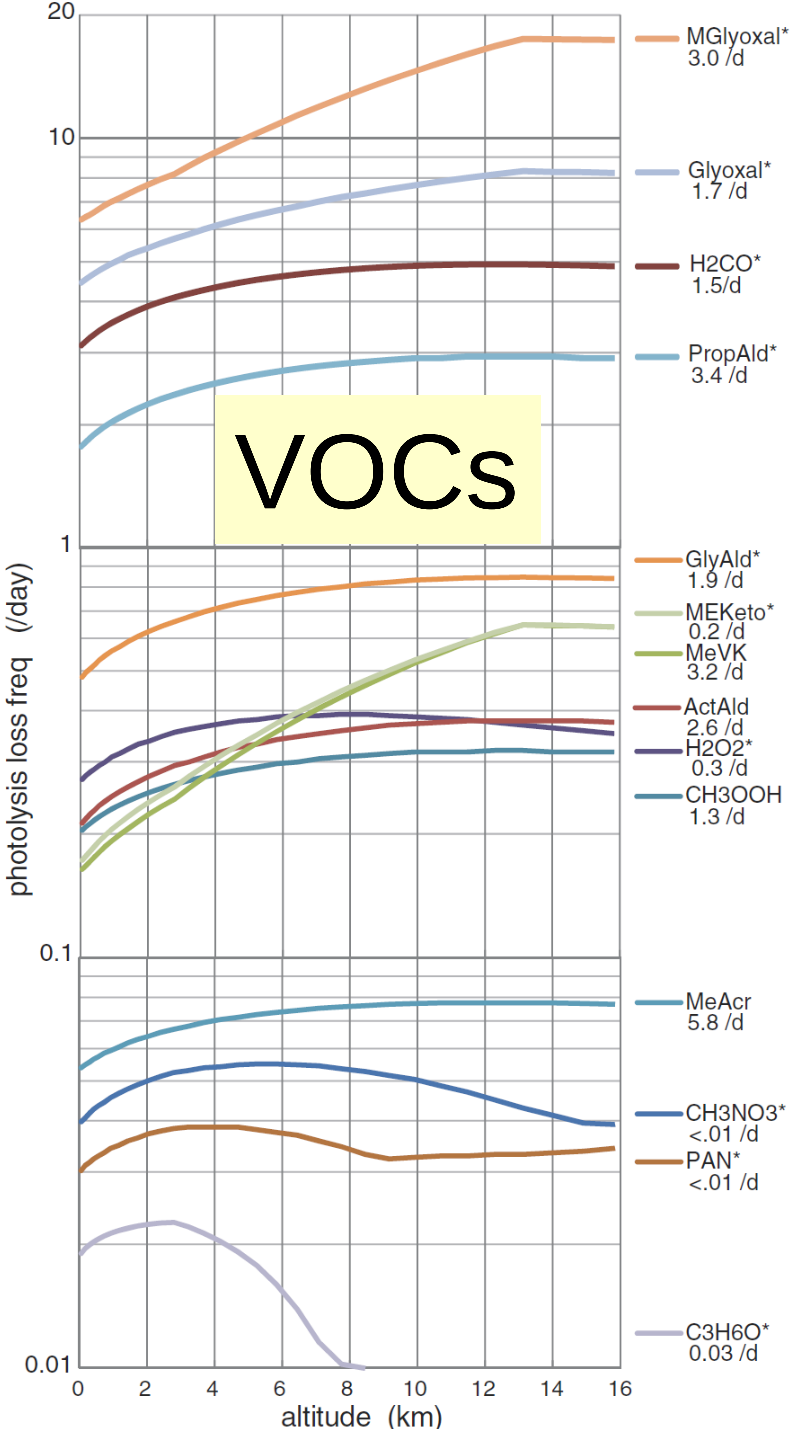
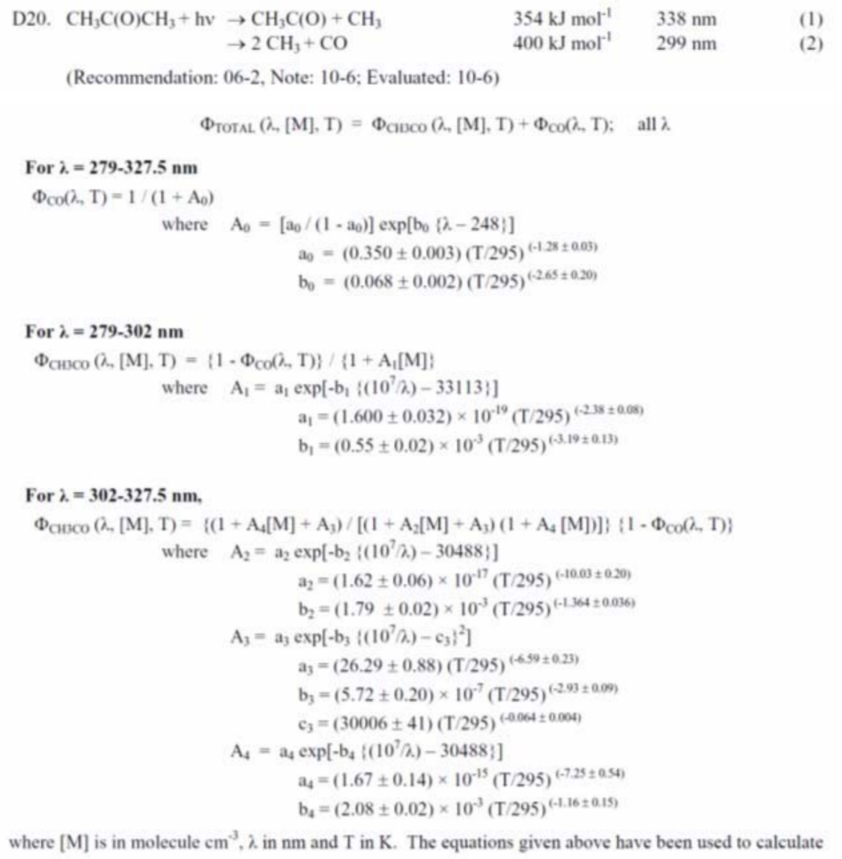


VOC and related species photolysis loss frequencies (/day) as a function of altitude (km). The complex structure with altitude is due to a combination of increasing uv-radiation with altitude and Stern-Volmer pressure dependences on quantum yields. We assume that the noon-time J's (tropical atmosphere, albedo = 0.10, SZA = 15°) apply for only 8 hours. Equivalent values for OH loss are shown with the species name in the legend and assume a noontime OH density of 6×10^{6} cm^{-3}. Asterisks denote species with photolysis loss larger than or comparable to OH loss.

VOC abbreviations are:
MGlyoxal = methyl glyoxal;
PropAld = propionaldehyde ;
GlyAld = glycol aldehyde;
MEKeto = methylethyl ketone;
MeVK = methylvinyl ketone;
ActAld = acetaldehyde;
MeAcr = methacrolein;
PAN = peroxyacetyl nitrate;
C3H6O = acetone.

JPL-2010 recommended quantum yields for acetone ($CH_3C(O)CH_3$) basically Blitz et al.

VOCs



D20. $CH_3C(O)CH_3 + h\nu \rightarrow CH_3C(O) + CH_3$ 354 kJ mol^{-1} 338 nm (1)

$\rightarrow 2\ CH_3 + CO$ 400 kJ mol^{-1} 299 nm (2)

(Recommendation: 06-2, Note: 10-6; Evaluated: 10-6)

$$\Phi_{TOTAL}(\lambda, [M], T) = \Phi_{CH3CO}(\lambda, [M], T) + \Phi_{CO}(\lambda, T); \quad \text{all } \lambda$$

For λ = 279-327.5 nm

$$\Phi_{CO}(\lambda, T) = 1 / (1 + A_0)$$

where $A_0 = [a_0 / (1 - a_0)] \exp[b_0 \{\lambda - 248\}]$

$a_0 = (0.350 \pm 0.003)\ (T/295)^{(-1.28 \pm 0.03)}$

$b_0 = (0.068 \pm 0.002)\ (T/295)^{(-2.65 \pm 0.20)}$

For λ = 279-302 nm

$$\Phi_{CH3CO}(\lambda, [M], T) = \{1 - \Phi_{CO}(\lambda, T)\} / \{1 + A_1[M]\}$$

where $A_1 = a_1 \exp[-b_1 \{(10^7/\lambda) - 33113\}]$

$a_1 = (1.600 \pm 0.032) \times 10^{-19}\ (T/295)^{(-2.38 \pm 0.08)}$

$b_1 = (0.55 \pm 0.02) \times 10^{-3}\ (T/295)^{(-3.19 \pm 0.13)}$

For λ = 302-327.5 nm,

$$\Phi_{CH3CO}(\lambda, [M], T) = \{(1 + A_4[M] + A_3) / [(1 + A_2[M] + A_3)(1 + A_4[M])]\} \{1 - \Phi_{CO}(\lambda, T)\}$$

where $A_2 = a_2 \exp[-b_2 \{(10^7/\lambda) - 30488\}]$

$a_2 = (1.62 \pm 0.06) \times 10^{-17}\ (T/295)^{(-10.03 \pm 0.20)}$

$b_2 = (1.79 \pm 0.02) \times 10^{-3}\ (T/295)^{(-1.364 \pm 0.036)}$

$A_3 = a_3 \exp[-b_3 \{(10^7/\lambda) - c_3\}^2]$

$a_3 = (26.29 \pm 0.88)\ (T/295)^{(-6.59 \pm 0.23)}$

$b_3 = (5.72 \pm 0.20) \times 10^{-7}\ (T/295)^{(-2.93 \pm 0.09)}$

$c_3 = (30006 \pm 41)\ (T/295)^{(-0.064 \pm 0.004)}$

$A_4 = a_4 \exp[-b_4 \{(10^7/\lambda) - 30488\}]$

$a_4 = (1.67 \pm 0.14) \times 10^{-15}\ (T/295)^{(-7.25 \pm 0.54)}$

$b_4 = (2.08 \pm 0.02) \times 10^{-3}\ (T/295)^{(-1.16 \pm 0.15)}$

where [M] is in molecule cm^{-3}, λ in nm and T in K. The equations given above have been used to calculate

VOC Stern–Volmer quantum yields
q (T, M, wavelength)
are very difficult to implement with any scheme using broad wavelength bins.

Interpolation tables for VOCs with pressure-dependent quantum yields			
Altitude (km)	Temperature (K)	Density (# cm^{-3})	Pressure (torr)
0	295	2.46×10^{19}	760
5	272	1.50×10^{19}	430
13	220	0.58×10^{19}	135

Fast-JX v6.8+

new: 1, 2, or 3 temperature interpolation points

```
fast-JX ver-6.8 standalone CTM code
UCI FJX v6.8 JPL10 (14Mar2011) + upto 3 T's or P'a - requires JX v6.8 (Sep2012)
     62      18
 x-sect:  1    O2            3   180.00   260.00   300.00
 x-sect:  2    O3            3   218.00   260.00   295.00
 x-sect:  3    O3(1D)        3   180.00   260.00   300.00
 x-sect:  4    NO       x    1   298.00
 x-sect:  5    H2COa         2   223.00   298.00
 x-sect:  6    H2COb         2   223.00   298.00
 x-sect:  7    H2O2          2   200.00   300.00
 x-sect:  8    CH3OOH        1   298.00
 x-sect:  9    NO2           3   200.00   234.00   294.00
 x-sect: 10    NO3           2   190.00   298.00
 x-sect: 11    N2O5          2   233.00   300.00
 x-sect: 12    HNO2          1   298.00
 x-sect: 13    HNO3          2   200.00   300.00
 x-sect: 14    HNO4          1   298.00
 x-sect: 15    ClNO3a   x    2   200.00   300.00
 x-sect: 16    ClNO3b   x    2   200.00   300.00
 x-sect: 17    Cl2      x    2   200.00   300.00
 x-sect: 18    HOCl     x    1   298.00
 x-sect: 19    OClO     x    1   204.00
 x-sect: 20    Cl2O2    x    1   190.00
 x-sect: 21    ClO      x    1   298.00
 x-sect: 22    BrO      x    1   298.00
 x-sect: 23    BrNO3    x    2   200.00   300.00
 x-sect: 24    HOBr     x    1   298.00
 x-sect: 25    BrCl     x    2   200.00   300.00
 x-sect: 26    N2O      x    2   200.00   300.00
 x-sect: 27    CFCl3    x    2   220.00   300.00
 x-sect: 28    CF2Cl2   x    2   220.00   300.00
 x-sect: 29    F113     x    2   210.00   300.00
 x-sect: 30    F114     x    2   210.00   300.00
 x-sect: 31    F115     x    1   298.00
 x-sect: 32    CCl4     x    2   200.00   300.00
 x-sect: 33    CH3Cl    x    2   200.00   300.00
 x-sect: 34    MeCCl3   x    2   200.00   300.00
 x-sect: 35    CH2Cl2   x    2   200.00   300.00
 x-sect: 36    CHF2Cl   x    2   200.00   300.00
 x-sect: 37    F123     x    2   210.00   295.00
 x-sect: 38    F141b    x    2   200.00   300.00
 x-sect: 39    F142b    x    2   210.00   298.00
 x-sect: 40    CH3Br    x    2   200.00   300.00
 x-sect: 41    H1211    x    2   200.00   300.00
 x-sect: 42    H1301    x    2   200.00   300.00
 x-sect: 43    H2402    x    2   200.00   300.00
 x-sect: 44    CH2Br2        2   210.00   298.00
 x-sect: 45    CHBr3         2   210.00   300.00
 x-sect: 46    CH3I          2   243.00   300.00
 x-sect: 47    CF3I          2   243.00   300.00
 x-sect: 48    OCS           2   200.00   300.00
 x-sect: 49    PAN           2   250.00   298.00
 x-sect: 50    CH3NO3        2   200.00   300.00
 x-sect: 51    ActAld        1   298.00
 x-sect: 52    MeVK     p    3   177.00   566.00   999.00
 x-sect: 53    MeAcr         1   298.00
 x-sect: 54    GlyAld        1   298.00
 x-sect: 55    MEKeto   p    2   177.00   999.00
 x-sect: 56    PrAld         1   298.00
 x-sect: 57    MGlyxl   p    3   177.00   566.00   999.00
 x-sect: 58    Glyxla   p    2   177.00   999.00
 x-sect: 59    Glyxlb   p    2   177.00   999.00
 x-sect: 60    Glyxlc   p    2   177.00   999.00
 x-sect: 61    Acet-a   p    3   177.00   566.00   999.00
 x-sect: 62    Acet-b   p    2   400.00   999.00
```

```
fast-JX ver-6.8 standalone CTM code
UCI FJX v6.8 JPL10 (14Mar2011) + upto 3 T's or P'a - requires JX v6.8 (Sep2012)
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 x-sect:  3     O3(1D)            3   180.00   260.00   300.00
 x-sect:  4     NO       x    1   298.00
 x-sect:  5     H2COa             2   223.00   298.00
 x-sect:  6     H2COb             2   223.00   298.00
 x-sect:  7     H2O2              2   200.00   300.00
 x-sect:  8     CH3OOH            1   298.00
 x-sect:  9     NO2               3   200.00   234.00   294.00
 x-sect: 10     NO3               2   190.00   298.00
 x-sect: 11     N2O5              2   233.00   300.00
 x-sect: 12     HNO2              1   298.00
 x-sect: 13     HNO3              2   200.00   300.00
 x-sect: 14     HNO4              1   298.00
 x-sect: 15     ClNO3a   x    2   200.00   300.00
 x-sect: 16     ClNO3b   x    2   200.00   300.00
 x-sect: 17     Cl2      x    2   200.00   300.00
 x-sect: 18     HOCl     x    1   298.00
 x-sect: 19     OClO     x    1   204.00
 x-sect: 20     Cl2O2    x    1   190.00
 x-sect: 21     ClO      x    1   298.00
 x-sect: 22     BrO      x    1   298.00
 x-sect: 23     BrNO3    x    2   200.00   300.00
 x-sect: 24     HOBr     x    1   298.00
 x-sect: 25     BrCl     x    2   200.00   300.00
 x-sect: 26     N2O      x    2   200.00   300.00
 x-sect: 27     CFCl3    x    2   220.00   300.00
 x-sect: 28     CF2Cl2   x    2   220.00   300.00
 x-sect: 29     F113     x    2   210.00   300.00
 x-sect: 30     F114     x    2   210.00   300.00
 x-sect: 31     F115     x    1   298.00
 x-sect: 32     CCl4     x    2   200.00   300.00
 x-sect: 33     CH3Cl    x    2   200.00   300.00
 x-sect: 34     MeCCl3   x    2   200.00   300.00
 x-sect: 35     CH2Cl2   x    2   200.00   300.00
 x-sect: 36     CHF2Cl   x    2   200.00   300.00
 x-sect: 37     F123     x    2   210.00   295.00
 x-sect: 38     F141b    x    2   200.00   300.00
 x-sect: 39     F142b    x    2   210.00   298.00
 x-sect: 40     CH3Br    x    2   200.00   300.00
 x-sect: 41     H1211    x    2   200.00   300.00
 x-sect: 42     H1301    x    2   200.00   300.00
 x-sect: 43     H2402    x    2   200.00   300.00
```

New JPL-2010 VOC X-sections

```
x-sect: 44     CH2Br2            2   210.00   298.00
x-sect: 45     CHBr3             2   210.00   300.00
x-sect: 46     CH3I              2   243.00   300.00
x-sect: 47     CF3I              2   243.00   300.00
                                                  300.00
                                                  298.00
x-sect: 50     CH3NO3            2   200.00   300.00
x-sect: 51     ActAld            1   298.00
x-sect: 52     MeVK      p    3   177.00   566.00   999.00
x-sect: 53     MeAcr             1   298.00
x-sect: 54     GlyAld            1   298.00
x-sect: 55     MEKeto    p    2   177.00   999.00
x-sect: 56     PrAld             1   298.00
x-sect: 57     MGlyxl    p    3   177.00   566.00   999.00
x-sect: 58     Glyxla    p    2   177.00   999.00
x-sect: 59     Glyxlb    p    2   177.00   999.00
x-sect: 60     Glyxlc    p    2   177.00   999.00
x-sect: 61     Acet-a    p    3   177.00   566.00   999.00
x-sect: 62     Acet-b    p    2   400.00   999.00
```

```
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UCI FJX v6.8 JPL10 (14Mar2011) + upto 3 T's or P'a - requires JX v6.8 (Sep2012)
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 x-sect:  3    O3(1D)        3   180.00   260.00   300.00
 x-sect:  4    NO       x    1   298.00
 x-sect:  5    H2COa         2   223.00   298.00
 x-sect:  6    H2COb         2   223.00   298.00
 x-sect:  7    H2O2          2   200.00   300.00
 x-sect:  8    CH3OOH        1   298.00
 x-sect:  9    NO2           3   200.00   234.00   294.00
 x-sect: 10    NO3           2   190.00   298.00
 x-sect: 11    N2O5          2   233.00   300.00
 x-sect: 12    HNO2          1   298.00
 x-sect: 13    HNO3          2   200.00   300.00
 x-sect: 14    HNO4          1   298.00
 x-sect: 15    ClNO3a   x    2   200.00   300.00
 x-sect: 16    ClNO3b   x    2   200.00   300.00
 x-sect: 17    Cl2      x    2   200.00   300.00
 x-sect: 18    HOCl     x    1   298.00
 x-sect: 19    OClO     x    1   204.00
 x-sect: 20    Cl2O2    x    1   190.00
 x-sect: 21    ClO      x    1   298.00
 x-sect: 22    BrO      x    1   298.00
 x-sect: 23    BrNO3    x    2   200.00   300.00
 x-sect: 24    HOBr     x    1   298.00
 x-sect: 25    BrCl     x    2   200.00   300.00
 x-sect: 26    N2O      x    2   200.00   300.00
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```

```
 x-sect: 44    CH2Br2        2   210.00   298.00
 x-sect: 45    CHBr3         2   210.00   300.00
 x-sect: 46    CH3I          2   243.00   300.00
```

new VOC Stern–Volmer implementation:
3 pressure-levels with standard T(p) profile.

```
 x-sect: 52    MeVK     p    3   177.00   566.00   999.00
 x-sect: 53    MeAcr         1   298.00
 x-sect: 54    GlyAld        1   298.00
 x-sect: 55    MEKeto   p    2   177.00   999.00
 x-sect: 56    PrAld         1   298.00
 x-sect: 57    MGlyxl   p    3   177.00   566.00   999.00
 x-sect: 58    Glyxla   p    2   177.00   999.00
 x-sect: 59    Glyxlb   p    2   177.00   999.00
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 x-sect: 61    Acet-a   p    3   177.00   566.00   999.00
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 x-sect:  3    O3(1D)        3   180.00   260.00   300.00
 x-sect:  4    NO       x    1   298.00
 x-sect:  5    H2COa         2   223.00   298.00
 x-sect:  6    H2COb         2   223.00   298.00
 x-sect:  7    H2O2          2   200.00   300.00
 x-sect:  8    CH3OOH        1   298.00
 x-sect:  9    NO2           3   200.00   234.00   294.00
 x-sect: 10    NO3           2   190.00   298.00
 x-sect: 11    N2O5          2   233.00   300.00
 x-sect: 12    HNO2          1   298.00
 x-sect: 13    HNO3          2   200.00   300.00
 x-sect: 14    HNO4          1   298.00
 x-sect: 15    ClNO3a   x    2   200.00   300.00
 x-sect: 16    ClNO3b   x    2   200.00   300.00
 x-sect: 17    Cl2      x    2   200.00   300.00
 x-sect: 18    HOCl     x    1   298.00
 x-sect: 19    OClO     x    1   204.00
 x-sect: 20    Cl2O2    x    1   190.00
 x-sect: 21    ClO      x    1   298.00
 x-sect: 22    BrO      x    1   298.00
 x-sect: 23    BrNO3    x    2   200.00   300.00
 x-sect: 24    HOBr     x    1   298.00
 x-sect: 25    BrCl     x    2   200.00   300.00
 x-sect: 26    N2O      x    2   200.00   300.00
 x-sect: 27    CFCl3    x    2   220.00   300.00
 x-sect: 28    CF2Cl2   x    2   220.00   300.00
 x-sect: 29    F113     x    2   210.00   300.00
 x-sect: 30    F114     x    2   210.00   300.00
 x-sect: 31    F115     x    1   298.00
 x-sect: 32    CCl4     x    2   200.00   300.00
 x-sect: 33    CH3Cl    x    2   200.00   300.00
 x-sect: 34    MeCCl3   x    2   200.00   300.00
 x-sect: 35    CH2Cl2   x    2   200.00   300.00
 x-sect: 36    CHF2Cl   x    2   200.00   300.00
 x-sect: 37    F123     x    2   210.00   295.00
 x-sect: 38    F141b    x    2   200.00   300.00
 x-sect: 39    F142b    x    2   210.00   298.00
 x-sect: 40    CH3Br    x    2   200.00   300.00
 x-sect: 41    H1211    x    2   200.00   300.00
 x-sect: 42    H1301    x    2   200.00   300.00
 x-sect: 43    H2402    x    2   200.00   300.00
```

Fast-JX v7.0b

F90 CAM5 implementation

Fast-JX v7.1

F90 WACCM (<200 nm)

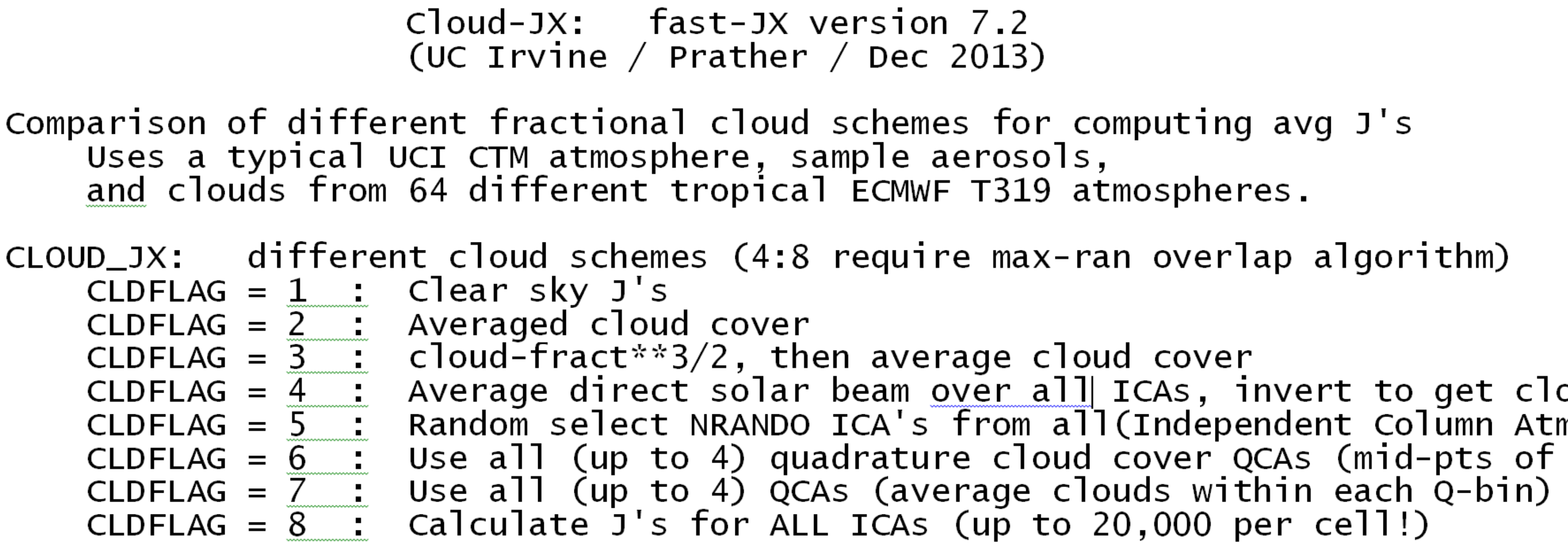
Fast-JX v7.2

F90 cloud-J for UCI CTM

```
x-sect: 44    CH2Br2        2   210.00   298.00
x-sect: 45    CHBr3         2   210.00   300.00
x-sect: 46    CH3I          2   243.00   300.00
x-sect: 47    CF3I          2   243.00   300.00
x-sect: 48    OCS           2   200.00   300.00
x-sect: 49    PAN           2   250.00   298.00
x-sect: 50    CH3NO3        2   200.00   300.00
x-sect: 51    ActAld        1   298.00
x-sect: 52    MeVK     p    3   177.00   566.00   999.00
x-sect: 53    MeAcr         1   298.00
x-sect: 54    GlyAld        1   298.00
x-sect: 55    MEKeto   p    2   177.00   999.00
x-sect: 56    PrAld         1   298.00
x-sect: 57    MGlyxl   p    3   177.00   566.00   999.00
x-sect: 58    Glyxla   p    2   177.00   999.00
x-sect: 59    Glyxlb   p    2   177.00   999.00
x-sect: 60    Glyxlc   p    2   177.00   999.00
x-sect: 61    Acet-a   p    3   177.00   566.00   999.00
x-sect: 62    Acet-b   p    2   400.00   999.00
```

cloud-J, what’s new?

Full Fortran-90 version being tested in UCI CTM

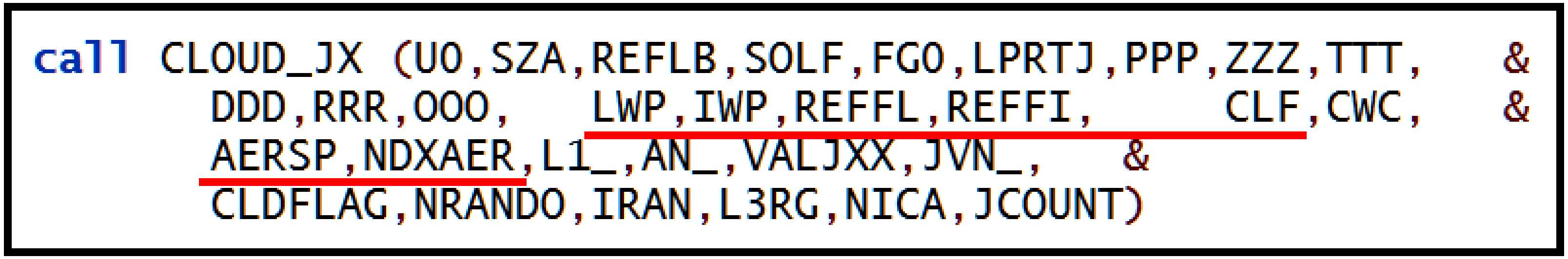


```
                    Cloud-JX:   fast-JX version 7.2
                    (UC Irvine / Prather / Dec 2013)

Comparison of different fractional cloud schemes for computing avg J's
    Uses a typical UCI CTM atmosphere, sample aerosols,
    and clouds from 64 different tropical ECMWF T319 atmospheres.

CLOUD_JX:   different cloud schemes (4:8 require max-ran overlap algorithm)
    CLDFLAG = 1  :  Clear sky J's
    CLDFLAG = 2  :  Averaged cloud cover
    CLDFLAG = 3  :  cloud-fract**3/2, then average cloud cover
    CLDFLAG = 4  :  Average direct solar beam over all ICAs, invert to get clo
    CLDFLAG = 5  :  Random select NRANDO ICA's from all(Independent Column Atm
    CLDFLAG = 6  :  Use all (up to 4) quadrature cloud cover QCAs (mid-pts of
    CLDFLAG = 7  :  Use all (up to 4) QCAs (average clouds within each Q-bin)
    CLDFLAG = 8  :  Calculate J's for ALL ICAs (up to 20,000 per cell!)
```

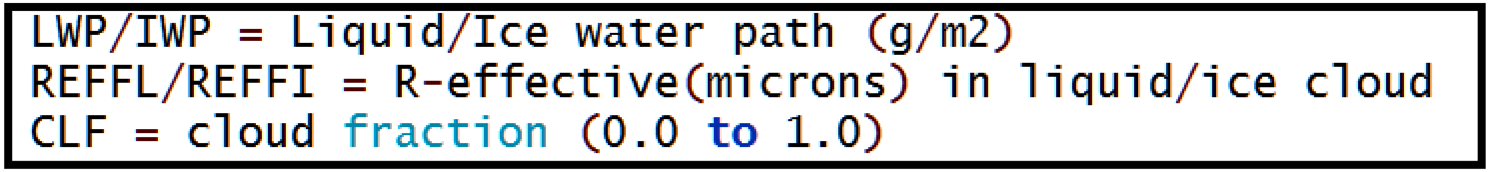
cloud-J, what's new?

Full Fortran-90 version being tested in UCI CTM

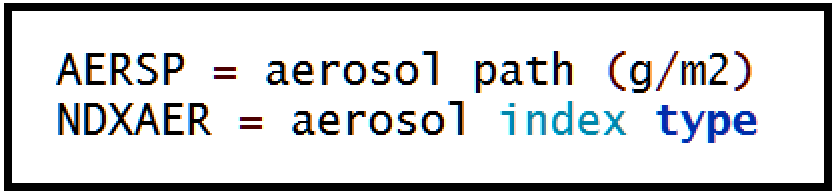
limited data passed to CLOUD_JX and thence to PHOTO_JX



```
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)
```



```
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)
```



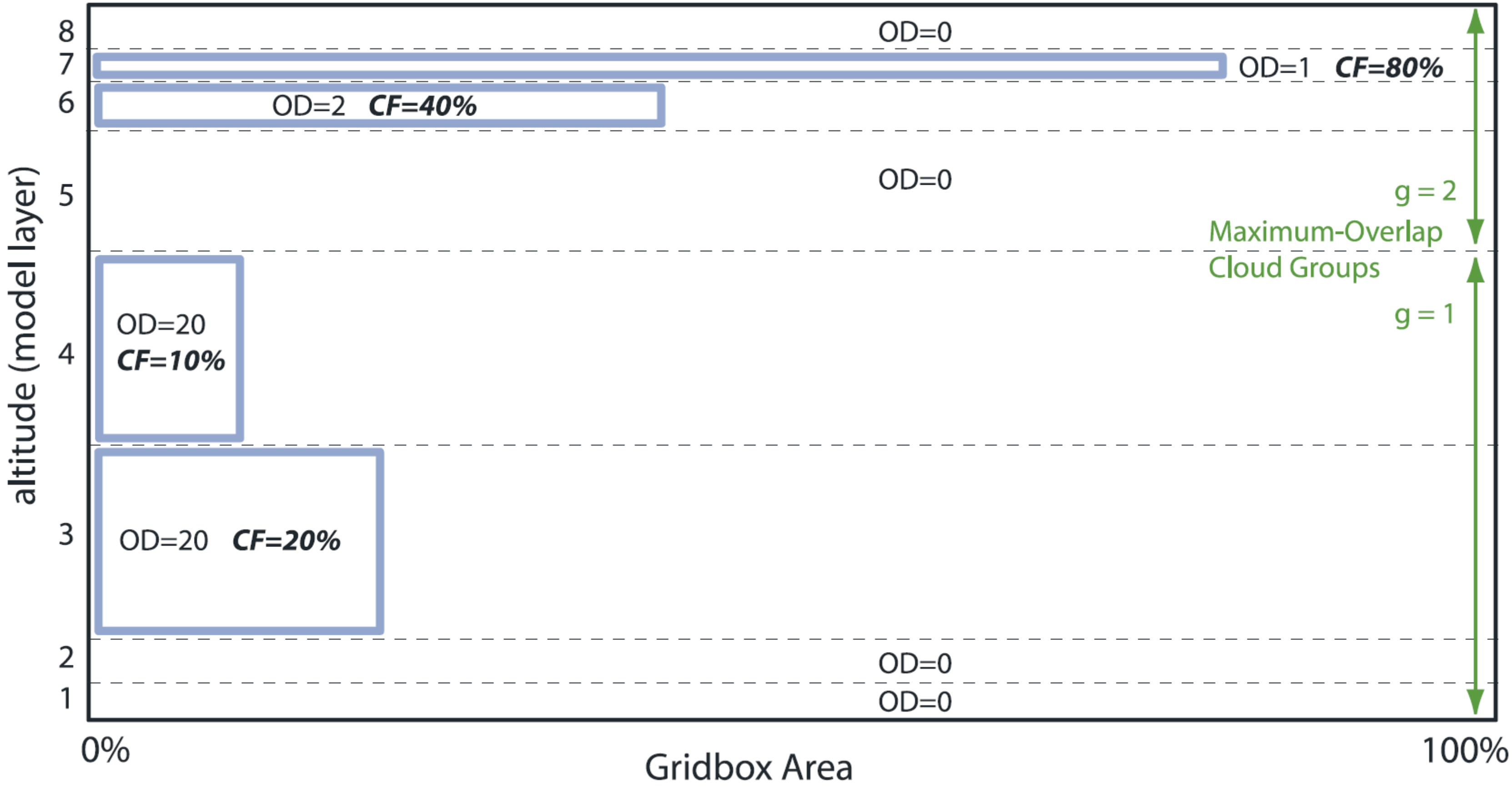
```
AERSP = aerosol path (g/m2)
NDXAER = aerosol index type
```

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D11306, doi:10.1029/2006JD008007, 2007

Global atmospheric chemistry: Integrating over fractional cloud cover

Jessica L. Neu,[1] Michael J. Prather,[1] and Joyce E. Penner[2]

In-Cloud properties (OD) and Cloud Fraction specified

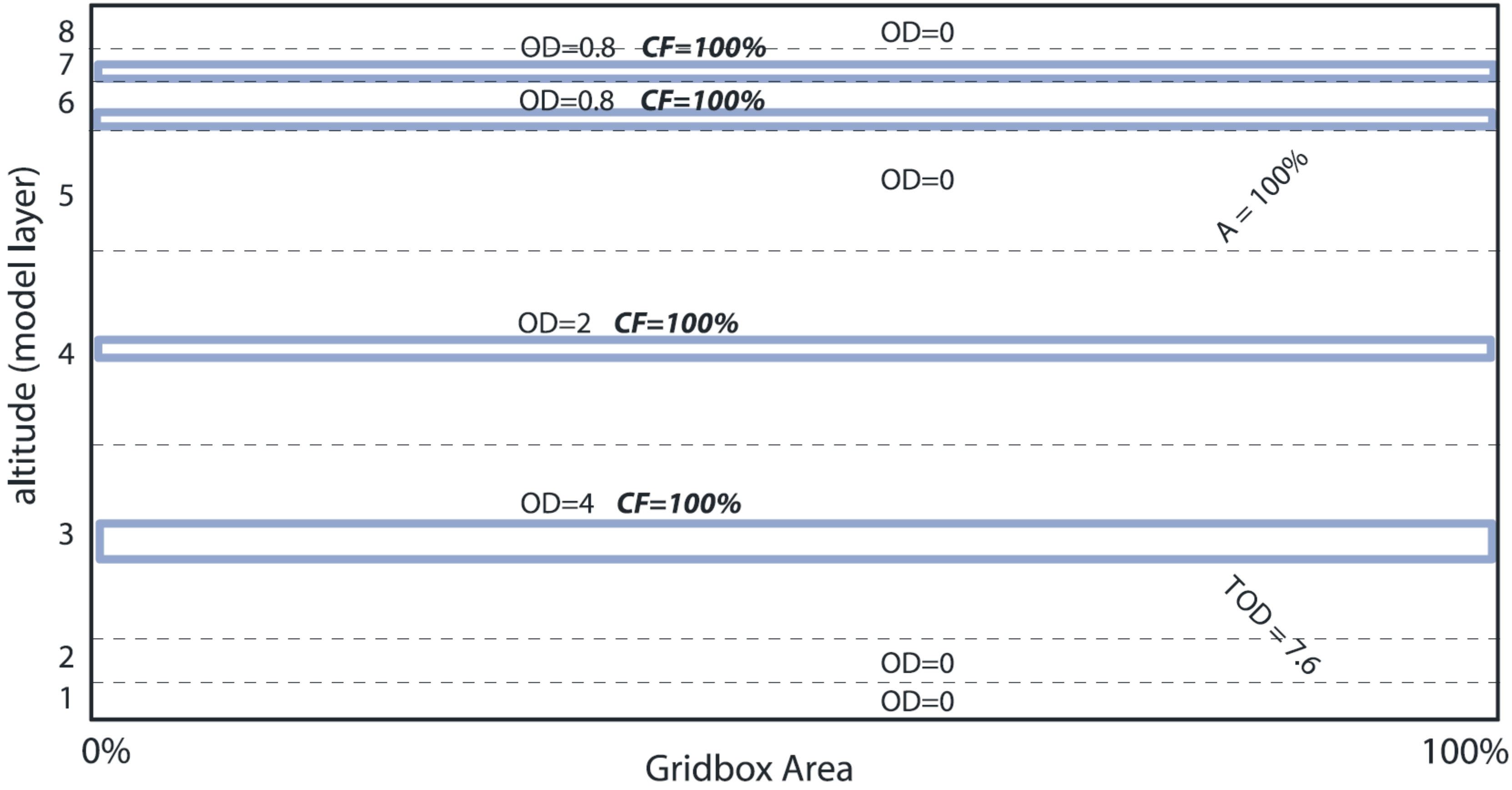


JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D11306, doi:10.1029/2006JD008007, 2007

Global atmospheric chemistry: Integrating over fractional cloud cover

Jessica L. Neu,[1] Michael J. Prather,[1] and Joyce E. Penner[2]

Averaged Cloud across grid box

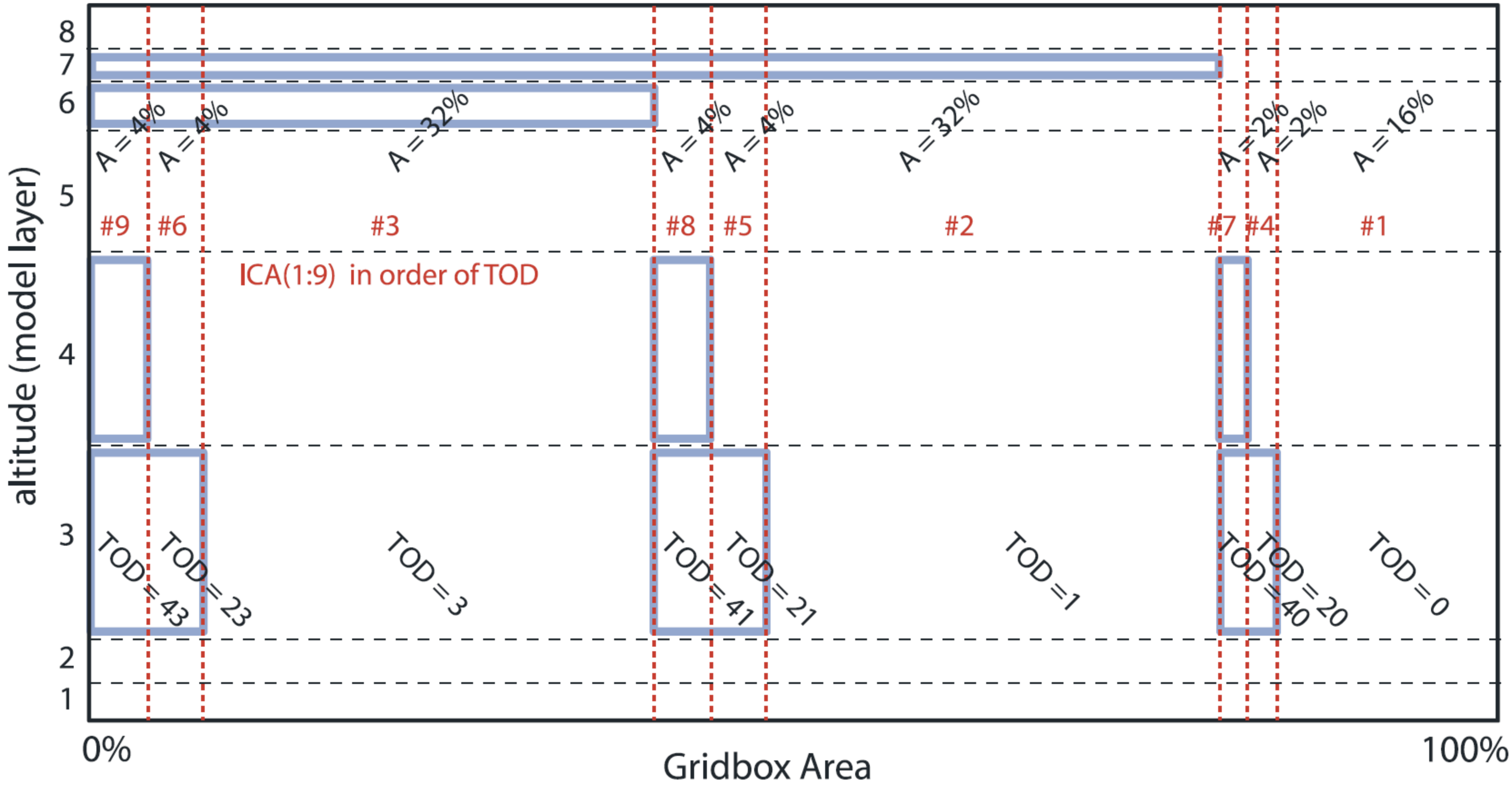


JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D11306, doi:10.1029/2006JD008007, 2007

Global atmospheric chemistry: Integrating over fractional cloud cover

Jessica L. Neu,[1] Michael J. Prather,[1] and Joyce E. Penner[2]

Max-Ran groups => Independent Column Atmospheres (ICAs)

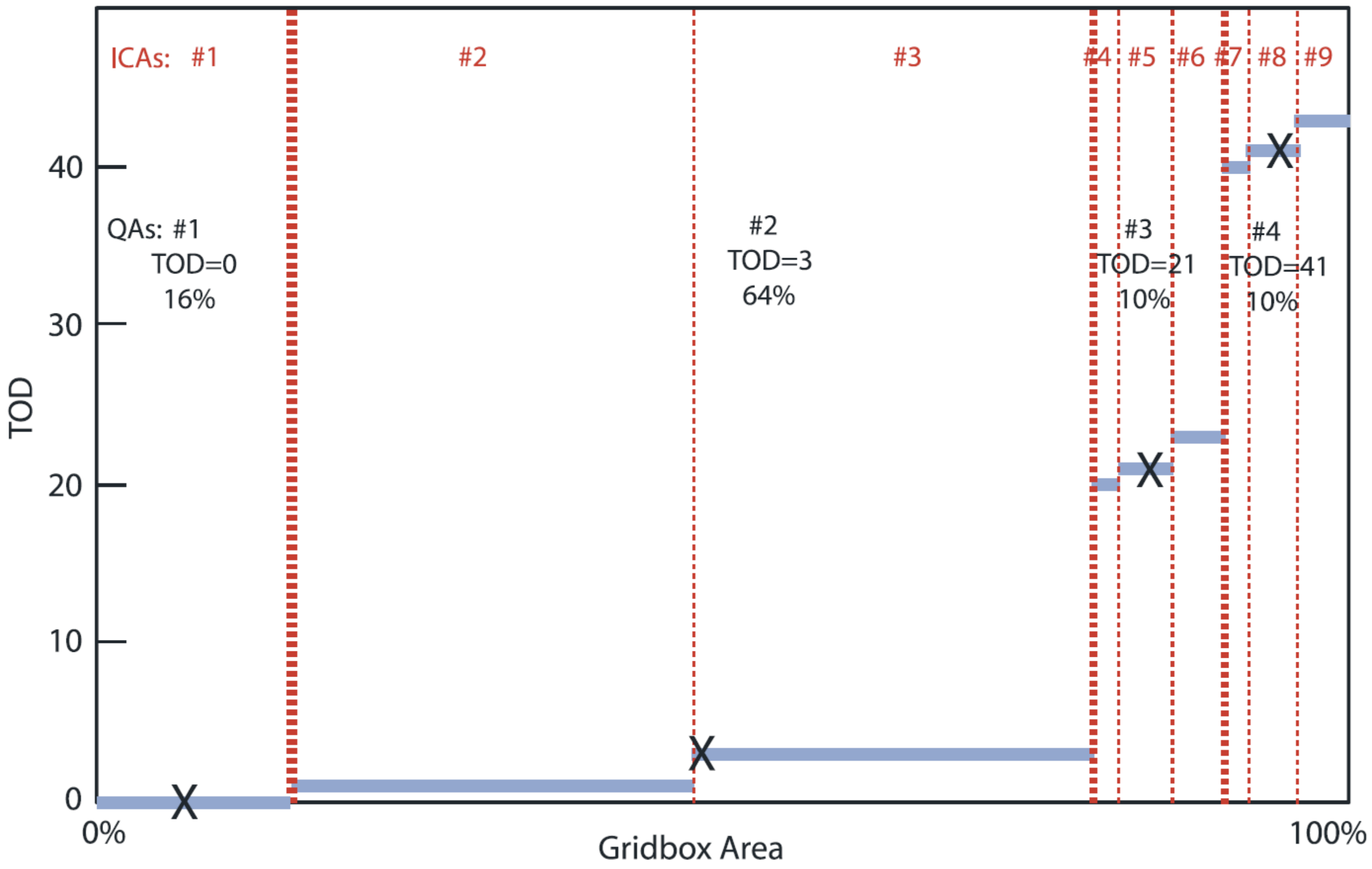


JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D11306, doi:10.1029/2006JD008007, 2007

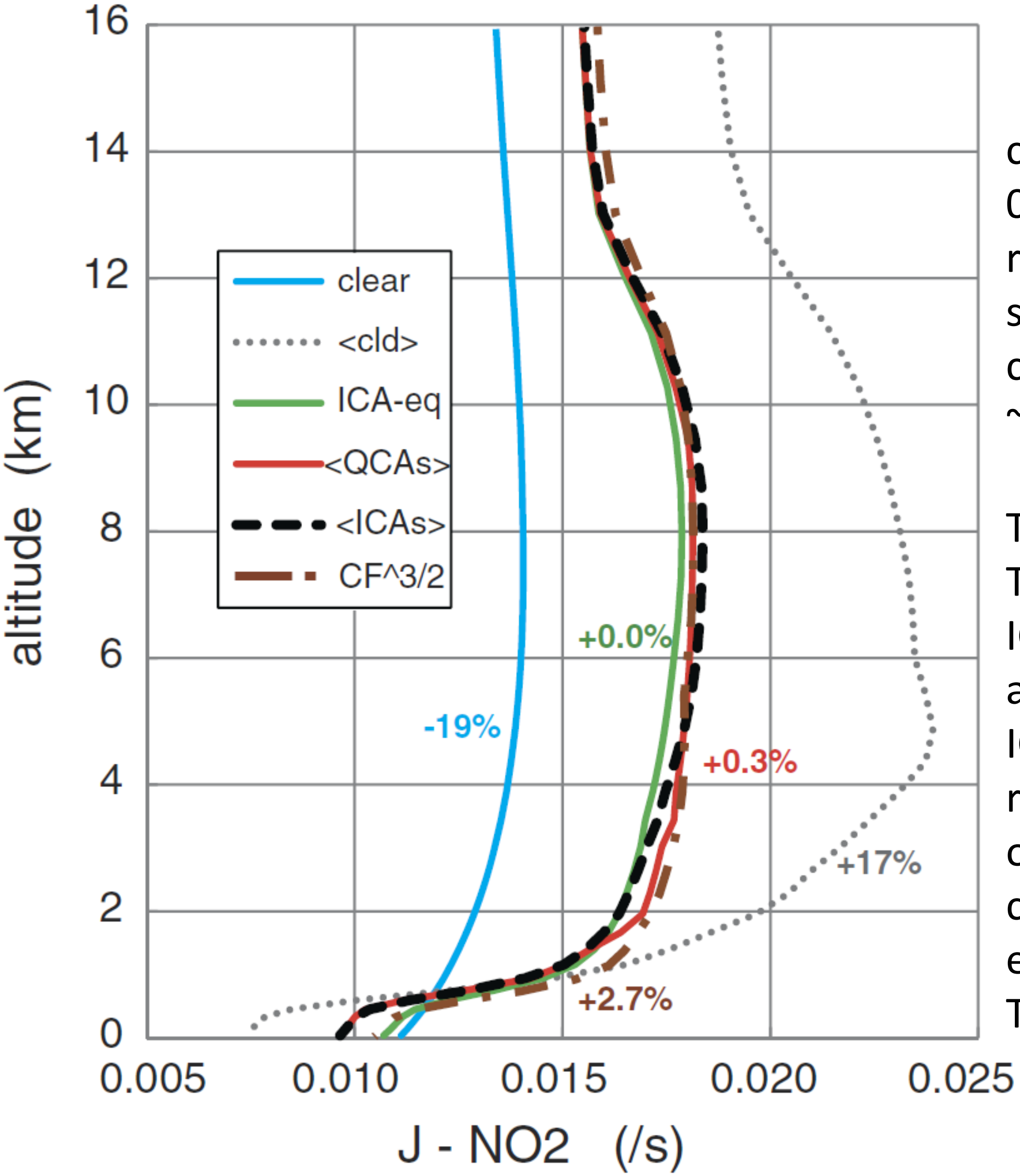
Global atmospheric chemistry: Integrating over fractional cloud cover

Jessica L. Neu,[1] Michael J. Prather,[1] and Joyce E. Penner[2]

Cloud Quadrature picks 4 cloudy types



nearly clear cirrus stratus cumulus



J-values for NO_2

calculated for a single grid box (0000-0300H 1 Jan 2005, T42, J=32&I=4) with a range of clouds from cumulus (1-9 km, small cloud fraction, OD ~20 per layer) to cirrus (11-14 km, large cloud fraction, OD ~ 0.4).

The max-ran overlap model has 10 ICAs. The true answer is the average over the ICAs (<ICAs>). The 4-point quadrature atmospheres (<QCAs>) and the single ICA-equivalent atmosphere give similar result with pressure-weighted bias errors of <1%, but the clear sky and averaged cloud cover (<cld>) have large mean bias errors of -19% and +17%, respectively. The pseudo-random approximation pRAN ($CF^{3/2}$) has +2.7% bias.

RMS error (%) L=1

		J(O1D)	*J(NO2)*	*J(NO3a)*	*J(HNO3)*
clearsky	640	27.	24.	23.	26.
avgcloud	640	18.	15.	15.	16.
cldf^3/2	640	6.	8.	12.	6.
ICA-beam	**640**	**3.**	**6.**	**10.**	**3.**
ICAs-ran	3200	10.	10.	10.	10.
QCAs-mid	1852	5.	5.	6.	5.
QCAs-avg	**1852**	**2.**	**2.**	**2.**	**2.**
all ICAs	11294				

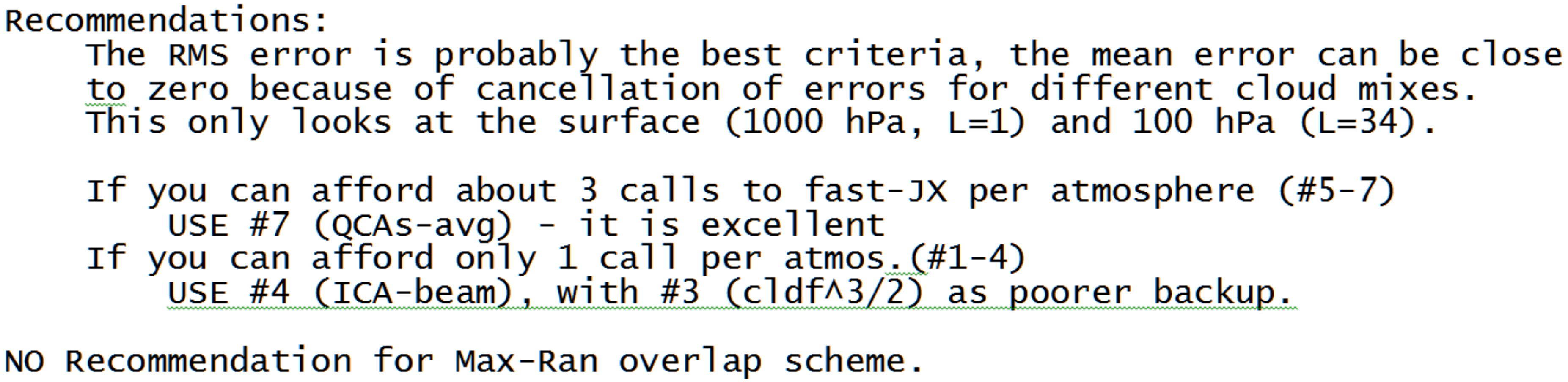
RMS error (%) L=34

		J(O1D)	J(NO2)	J(NO3a)	J(HNO3)
clearsky	640	7.	14.	21.	7.
avgcloud	640	4.	8.	13.	4.
cldf^3/2	640	1.	2.	3.	1.
ICA-beam	**640**	**1.**	**2.**	**3.**	**1.**
ICAs-ran	3200	3.	6.	8.	3.
QCAs-mid	1852	1.	2.	3.	1.
QCAs-avg	**1852**	**0.**	**0.**	**1.**	**0.**
all ICAs	11294				

RMS error (%)		p-avg			
		J(O1D)	J(NO2)	J(NO3a)	J(HNO3)
clearsky	640	8.	14.	19.	9.
avgcloud	640	6.	10.	14.	7.
cldf^3/2	640	2.	3.	5.	2.
ICA-beam	**640**	**2.**	**4.**	**6.**	**3.**
ICAs-ran	3200	4.	6.	8.	4.
QCAs-mid	1852	2.	3.	3.	3.
QCAs-avg	**1852**	**1.**	**1.**	**2.**	**1.**
all ICAs	11294				

cloud-J, what's new?

Full Fortran-90 version being tested in UCI CTM



Recommendations:

The RMS error is probably the best criteria, the mean error can be close to zero because of cancellation of errors for different cloud mixes.
This only looks at the surface (1000 hPa, L=1) and 100 hPa (L=34).

If you can afford about 3 calls to fast-JX per atmosphere (#5-7)
USE #7 (QCAs-avg) - it is excellent
If you can afford only 1 call per atmos.(#1-4)
USE #4 (ICA-beam), with #3 (cldf^3/2) as poorer backup.

NO Recommendation for Max-Ran overlap scheme.

A sample atmosphere for fast-J

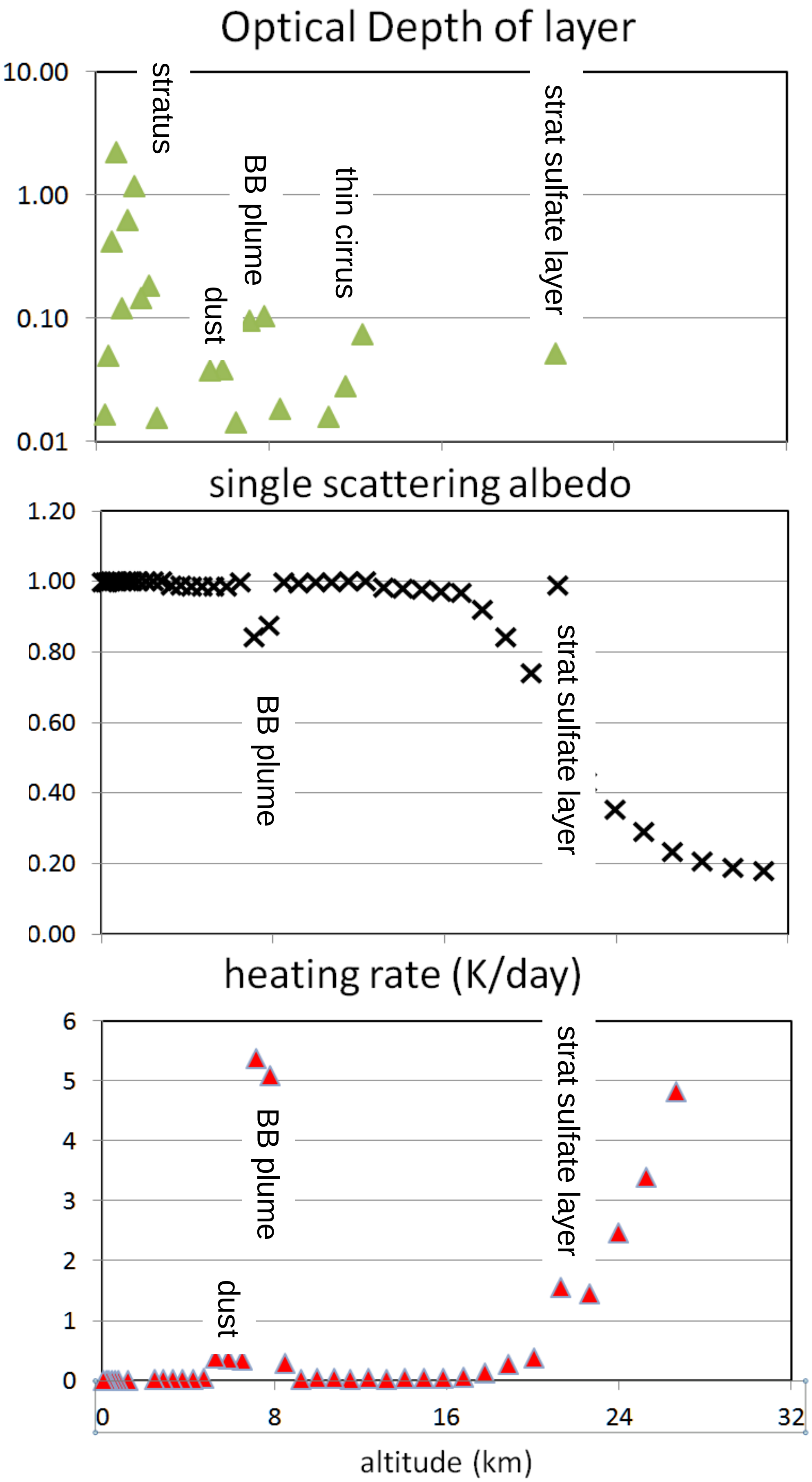
SZA = 13.6°

Aerosol + Cloud OD: 5.50
Biomass Burning plume: 0.20
Dust layer: 0.08

Solar flux (60% of solar energy < 850 nm)

Incoming: 805 W/m^2
Reflected diffuse: 298 W/m^2
Absorbed in atmosphere: 87 W/m^2
Absorbed at surface: 420 W/m^2

Photosynthetic (PAR)
Direct: 0.3 µE/m^2/s
Diffuse: 1265 µE/m^2/s


Optical Depth of layer
10.00
1.00
0.10
0.01
stratus
dust
BB plume
thin cirrus
strat sulfate layer
single scattering albedo
1.20
1.00
0.80
0.60
0.40
0.20
0.00
BB plume
strat sulfate layer
heating rate (K/day)
6
5
4
3
2
1
0
dust
BB plume
strat sulfate layer
0
8
16
24
32
altitude (km)

Why cloud-J instead of RRTMG-SW?

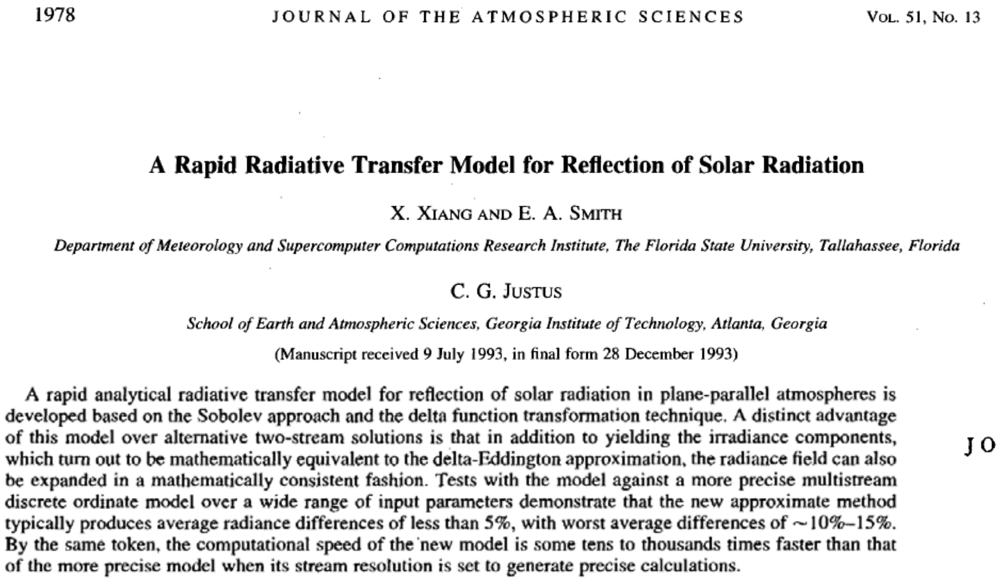
RRTM-SW is a full DISORT (16-stream) scattering code
(too expensive for GCM work)

RRTMG-SW is an 2-stream, delta-Eddington, Henyey-Greenstein approx
(that is implemented in CAM5)

Fast-JX is a full Feautrier (8-stream) scattering code (OK w/160-stream)
(that is now implemented in CAM5)

Why cloud-J instead of RRTMG-SW?

2-stream delta-Eddington is OK – right?



1978 JOURNAL OF THE ATMOSPHERIC SCIENCES VOL. 51, NO. 13

A Rapid Radiative Transfer Model for Reflection of Solar Radiation

X. XIANG AND E. A. SMITH

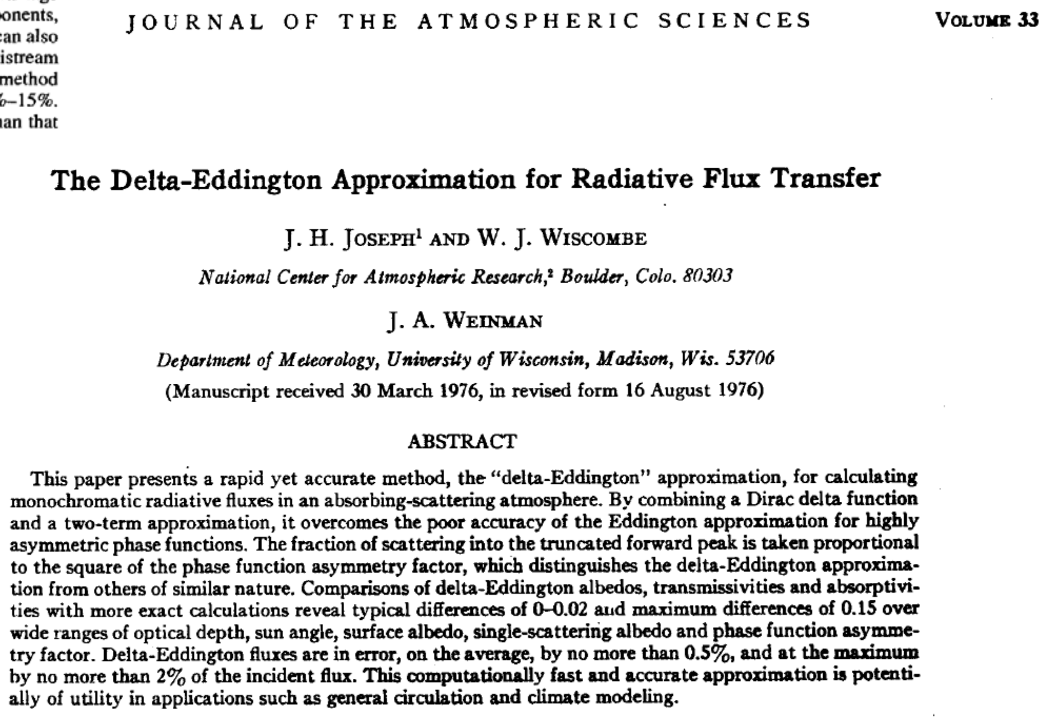
Department of Meteorology and Supercomputer Computations Research Institute, The Florida State University, Tallahassee, Florida

C. G. JUSTUS

School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia

(Manuscript received 9 July 1993, in final form 28 December 1993)

A rapid analytical radiative transfer model for reflection of solar radiation in plane-parallel atmospheres is developed based on the Sobolev approach and the delta function transformation technique. A distinct advantage of this model over alternative two-stream solutions is that in addition to yielding the irradiance components, which turn out to be mathematically equivalent to the delta-Eddington approximation, the radiance field can also be expanded in a mathematically consistent fashion. Tests with the model against a more precise multistream discrete ordinate model over a wide range of input parameters demonstrate that the new approximate method typically produces average radiance differences of less than 5%, with worst average differences of ~10%–15%. By the same token, the computational speed of the new model is some tens to thousands times faster than that of the more precise model when its stream resolution is set to generate precise calculations.



JOURNAL OF THE ATMOSPHERIC SCIENCES VOLUME 33

The Delta-Eddington Approximation for Radiative Flux Transfer

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J. A. WEINMAN

Department of Meteorology, University of Wisconsin, Madison, Wis. 53706

(Manuscript received 30 March 1976, in revised form 16 August 1976)

ABSTRACT

This paper presents a rapid yet accurate method, the "delta-Eddington" approximation, for calculating monochromatic radiative fluxes in an absorbing-scattering atmosphere. By combining a Dirac delta function and a two-term approximation, it overcomes the poor accuracy of the Eddington approximation for highly asymmetric phase functions. The fraction of scattering into the truncated forward peak is taken proportional to the square of the phase function asymmetry factor, which distinguishes the delta-Eddington approximation from others of similar nature. Comparisons of delta-Eddington albedos, transmissivities and absorptivities with more exact calculations reveal typical differences of 0–0.02 and maximum differences of 0.15 over wide ranges of optical depth, sun angle, surface albedo, single-scattering albedo and phase function asymmetry factor. Delta-Eddington fluxes are in error, on the average, by no more than 0.5%, and at the maximum by no more than 2% of the incident flux. This computationally fast and accurate approximation is potentially of utility in applications such as general circulation and climate modeling.

Why cloud-J instead of RRTMG-SW?

1978 JOURNAL OF THE ATMOSPHERIC SCIENCES Vol. 51, No. 13

A Rapid Radiative Transfer Model for Reflection of Solar Radiation

X. Xiang and E. A. Smith

Department of Meteorology and Supercomputer Computations Research Institute, The Florida State University, Tallahassee, Florida

C. G. Justus

School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia

(Manuscript received 9 July 1993, in final form 28 December 1993)

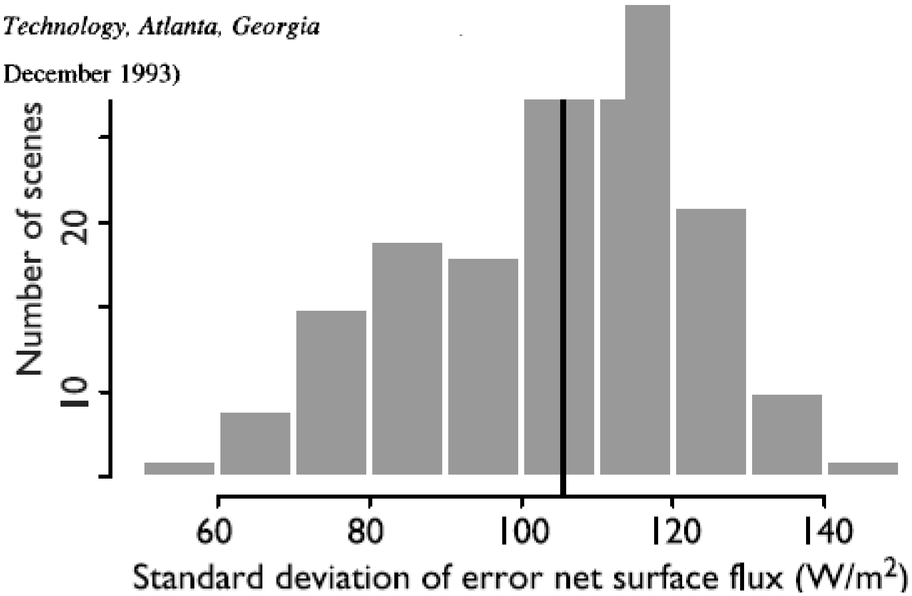
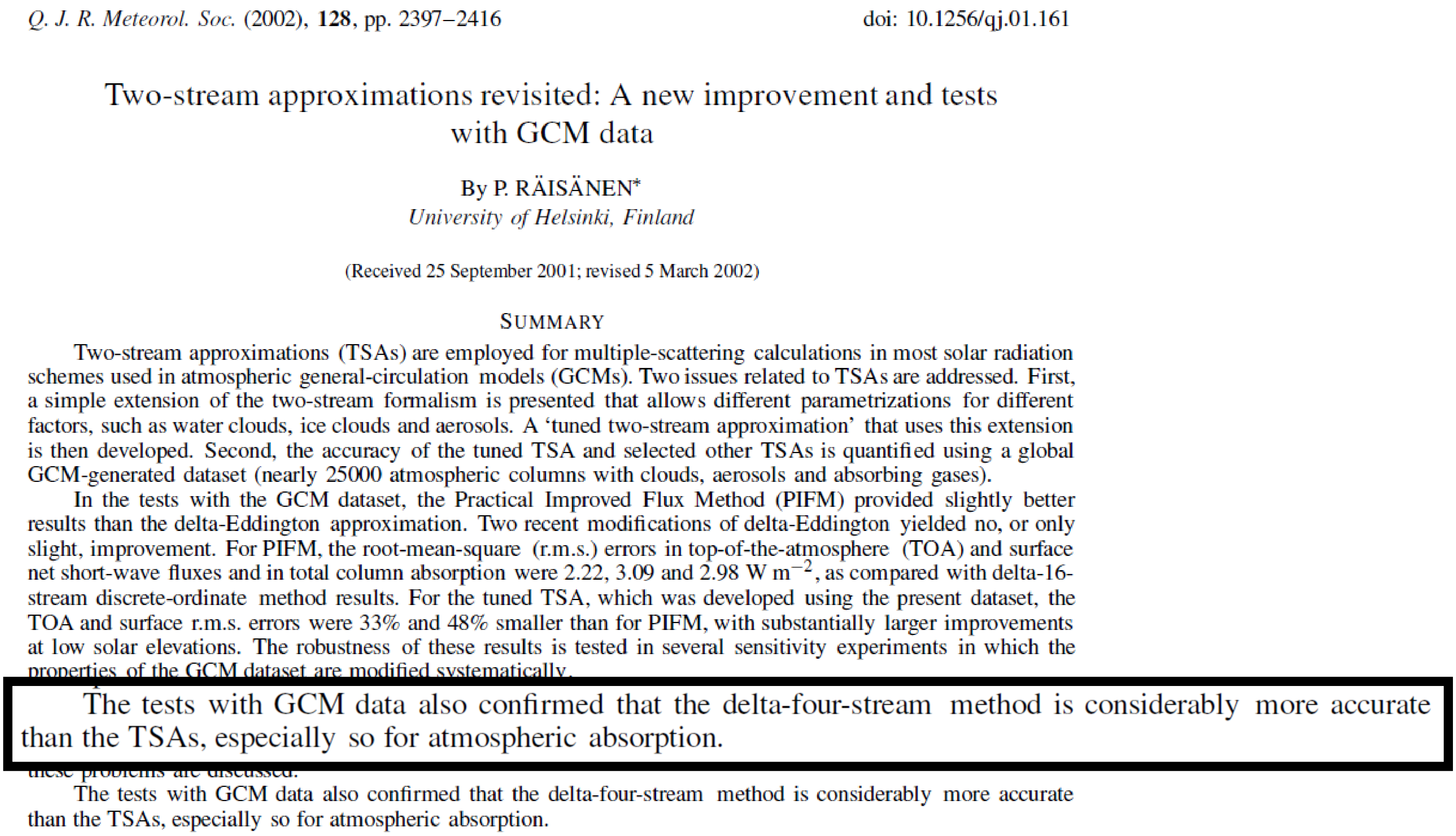


Figure 1. Errors introduced by the Monte Carlo integration of the independent column approximation (McICA) in calculations of (top) surface fluxes and (bottom) heating rates. For each of 120 cloud fields over the life of a tropical

Why cloud-J instead of RRTMG-SW?



Q. J. R. Meteorol. Soc. (2002), **128**, pp. 2397–2416 doi: 10.1256/qj.01.161

Two-stream approximations revisited: A new improvement and tests with GCM data

By P. RÄISÄNEN*
University of Helsinki, Finland

(Received 25 September 2001; revised 5 March 2002)

SUMMARY

Two-stream approximations (TSAs) are employed for multiple-scattering calculations in most solar radiation schemes used in atmospheric general-circulation models (GCMs). Two issues related to TSAs are addressed. First, a simple extension of the two-stream formalism is presented that allows different parametrizations for different factors, such as water clouds, ice clouds and aerosols. A 'tuned two-stream approximation' that uses this extension is then developed. Second, the accuracy of the tuned TSA and selected other TSAs is quantified using a global GCM-generated dataset (nearly 25000 atmospheric columns with clouds, aerosols and absorbing gases).

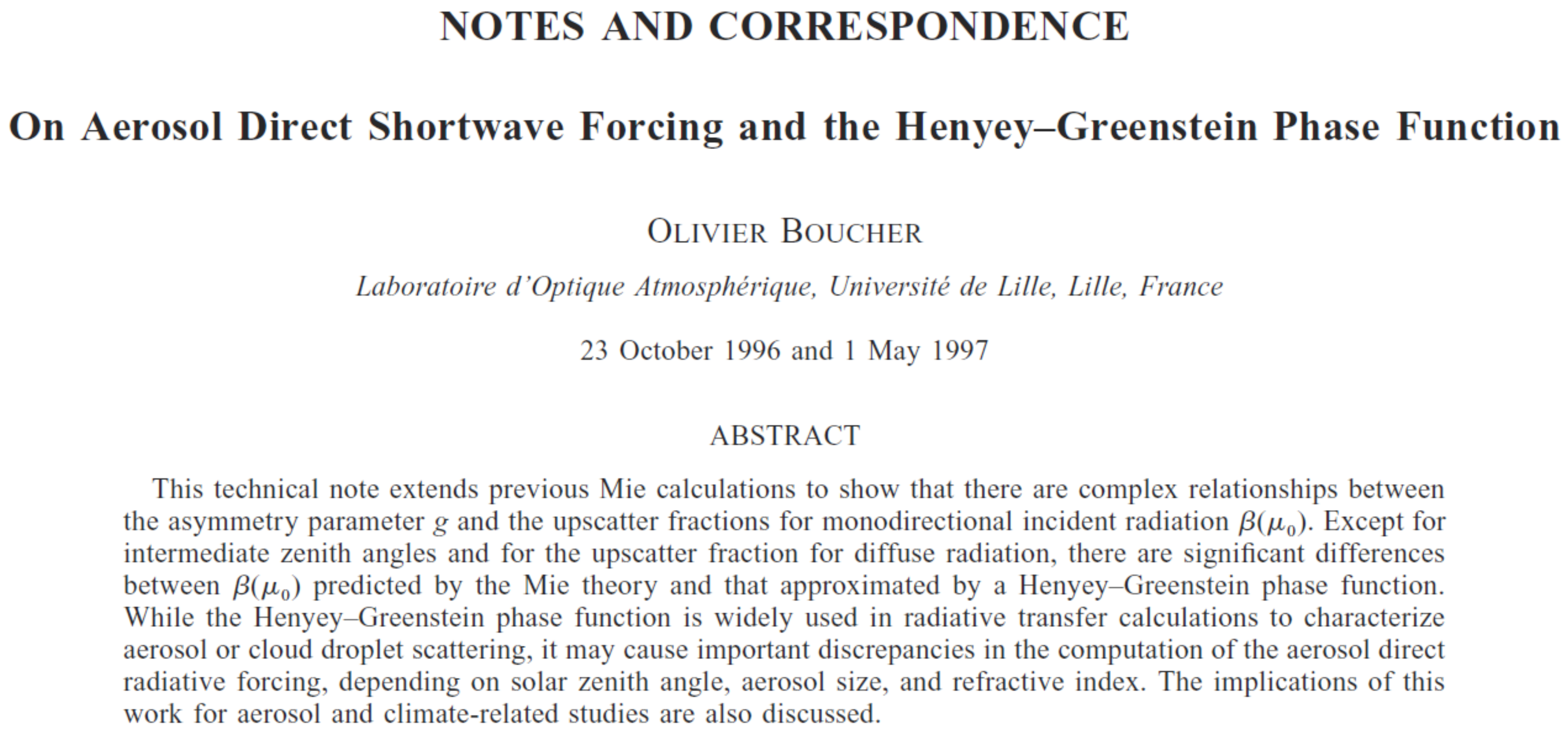
In the tests with the GCM dataset, the Practical Improved Flux Method (PIFM) provided slightly better results than the delta-Eddington approximation. Two recent modifications of delta-Eddington yielded no, or only slight, improvement. For PIFM, the root-mean-square (r.m.s.) errors in top-of-the-atmosphere (TOA) and surface net short-wave fluxes and in total column absorption were 2.22, 3.09 and 2.98 W m^{-2}, as compared with delta-16-stream discrete-ordinate method results. For the tuned TSA, which was developed using the present dataset, the TOA and surface r.m.s. errors were 33% and 48% smaller than for PIFM, with substantially larger improvements at low solar elevations. The robustness of these results is tested in several sensitivity experiments in which the properties of the GCM dataset are modified systematically.

The tests with GCM data also confirmed that the delta-four-stream method is considerably more accurate than the TSAs, especially so for atmospheric absorption.

these problems are discussed.

The tests with GCM data also confirmed that the delta-four-stream method is considerably more accurate than the TSAs, especially so for atmospheric absorption.

Why cloud-J instead of RRTMG-SW?



NOTES AND CORRESPONDENCE

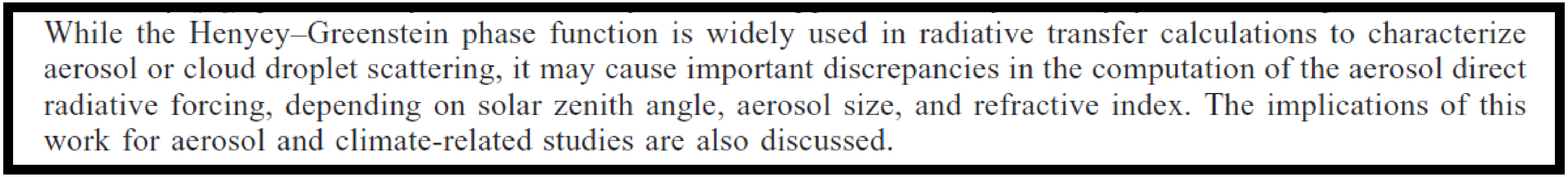
On Aerosol Direct Shortwave Forcing and the Henyey–Greenstein Phase Function

OLIVIER BOUCHER
Laboratoire d'Optique Atmosphérique, Université de Lille, Lille, France

23 October 1996 and 1 May 1997

ABSTRACT

This technical note extends previous Mie calculations to show that there are complex relationships between the asymmetry parameter g and the upscatter fractions for monodirectional incident radiation $\beta(\mu_0)$. Except for intermediate zenith angles and for the upscatter fraction for diffuse radiation, there are significant differences between $\beta(\mu_0)$ predicted by the Mie theory and that approximated by a Henyey–Greenstein phase function. While the Henyey–Greenstein phase function is widely used in radiative transfer calculations to characterize aerosol or cloud droplet scattering, it may cause important discrepancies in the computation of the aerosol direct radiative forcing, depending on solar zenith angle, aerosol size, and refractive index. The implications of this work for aerosol and climate-related studies are also discussed.



While the Henyey–Greenstein phase function is widely used in radiative transfer calculations to characterize aerosol or cloud droplet scattering, it may cause important discrepancies in the computation of the aerosol direct radiative forcing, depending on solar zenith angle, aerosol size, and refractive index. The implications of this work for aerosol and climate-related studies are also discussed.

fast-J solar bins

Wavelength (nm)	Solar (W/m^2)	PAR (µE)
187	0.01	
191	0.02	
193	0.02	
196	0.01	
202	0.08	
208	0.04	
211	0.09	
214	0.11	
261	4.84	
267	2.97	
277	2.23	
295	3.97	
303	5.03	
310	3.23	
316	5.59	
333	22.98	3
380	80.45	125
412-850	696.40	2026

RRTM-SW solar bins

Wavelength range (nm)		Solar (W/m^2)
200	*263*	3.12
263	*345*	50.15
345	*441*	129.5
441	*625*	347.2
625	*778*	218.1
778	***1242***	**345.7**
1242	***1299***	**24.29**
1299	***1626***	**102.9**
1626	***1942***	**55.63**
1942	***2151***	**22.43**
2151	***2500***	**23.73**
2500	***3077***	**20.36**
3077	***3846***	**12.11**
3846	***12195***	**12.79**

Fast-J would need to add 9 bins at most