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Photolysis and Clouds in CESM-CAM: fast-JX & cloud-JX

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UCIrvine

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Fast-JX: RT in a perfect world (plane-parallel, pseudo-spherical)

High-res solar fluxes (10 cm^{-1}) convolved with X-sections
Accurately weighted X-sections and Q-yields
Optimization of wavelength bins
Highly accurate cloud-aerosol scattering (160 angles, no δ-scaling)
Optimized Feautrier code (pre-DISORT)

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Ambiguous correlations of clouds – many different “answers”
3-D RT may be needed

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Cloud-JX: Approximation of RT in an imperfect world

Ambiguous correlations of clouds – many different “answers”
3-D RT may be needed

Cloud-Scav: How sausage is made

Deal with ambiguous overlapping of precipitation
Uncertainties in ice-gas interactions (surface, buried, bulk)
. . .

Research Group (1969)

(email)

Software Releases

Fast JX

Fast JX

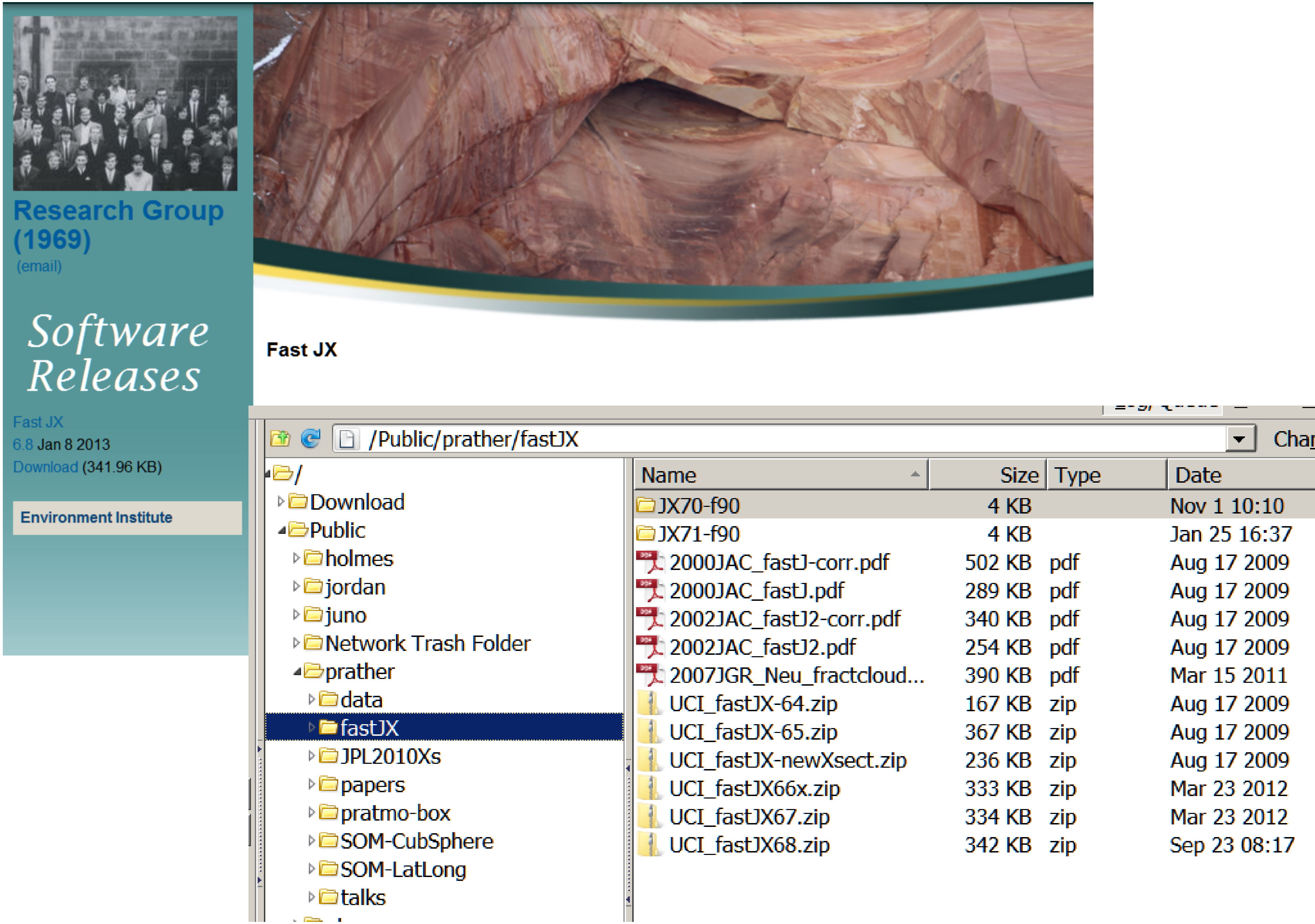
Fast-JX code now replaces Fast-J & Fast-J2

Fast JX

CURRENT v6.8

Fast-JX code now replaces Fast-J & Fast-J2

- current version Fast-JX 6.8 has updated cross-sections (and new interpolation) but keeps to same test-code structure
- >>>new version 7.0+ is being tested and will provide an isolated .f90 version as well as fractional-cloud algorithms<<<
- combined stratosphere & troposphere J-values (0-60 km)
- rapid, quadrature-based, flexible photolysis codes
- accurate plane-parallel treatment of all aerosol and cloud scattering
- pseudo-spherical attenuation of incident sunlight, include flux deposition in layers (heating)
- cross-sections for many species, updated to JPL-2010 (& IUPAC for VOCs)
- program to generate new fast-JX cross-sections for v6+ (see link below)
- fractional cloud cover algorithm with fast-J (see preprint below)



Research Group (1969)
(email)

Software Releases

Fast JX
6.8 Jan 8 2013
Download (341.96 KB)

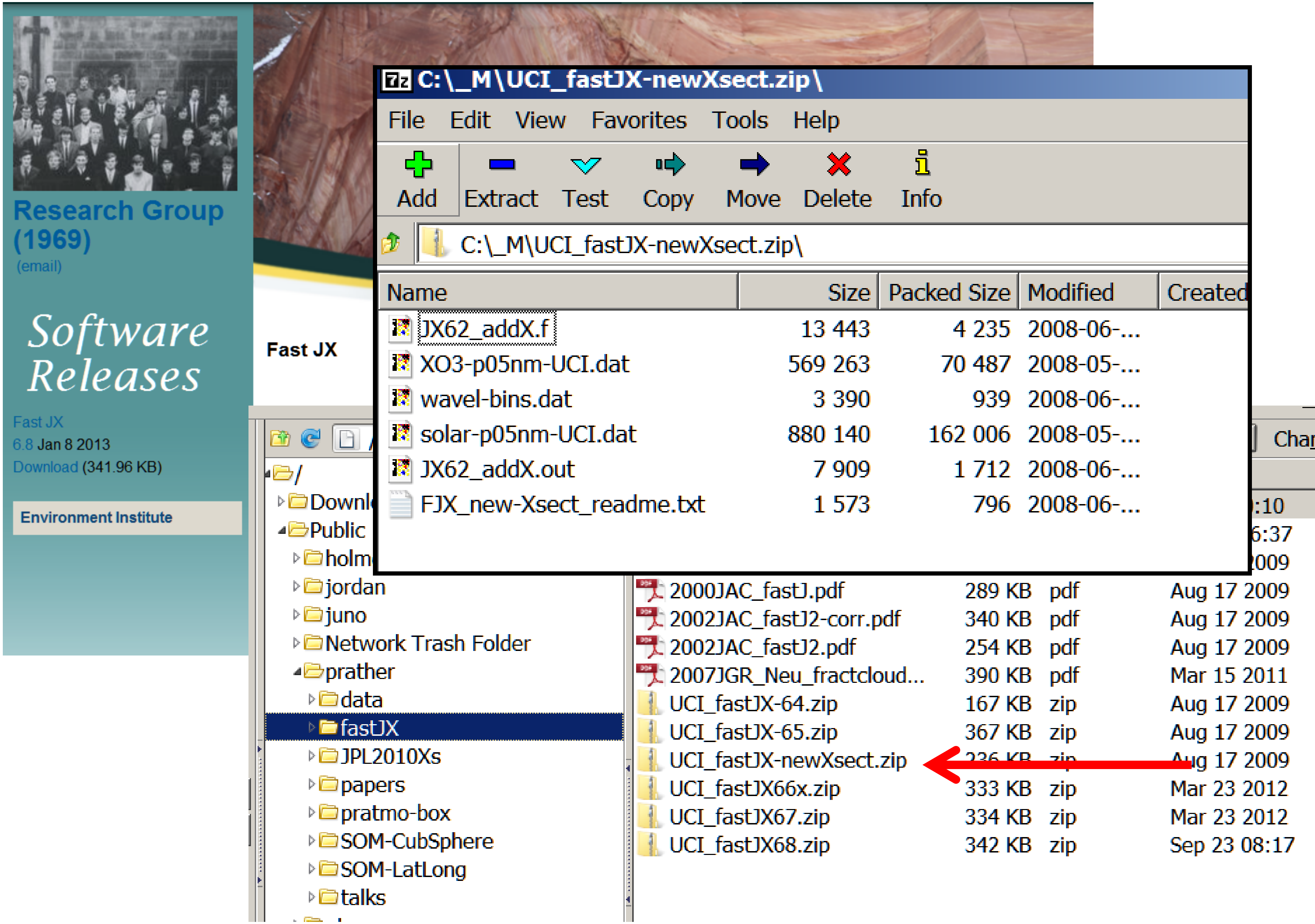
Environment Institute

Fast JX

/Public/prather/fastJX

- /
  - Download
  - Public
    - holmes
    - jordan
    - juno
    - Network Trash Folder
    - prather
      - data
      - fastJX
      - JPL2010Xs
      - papers
      - 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

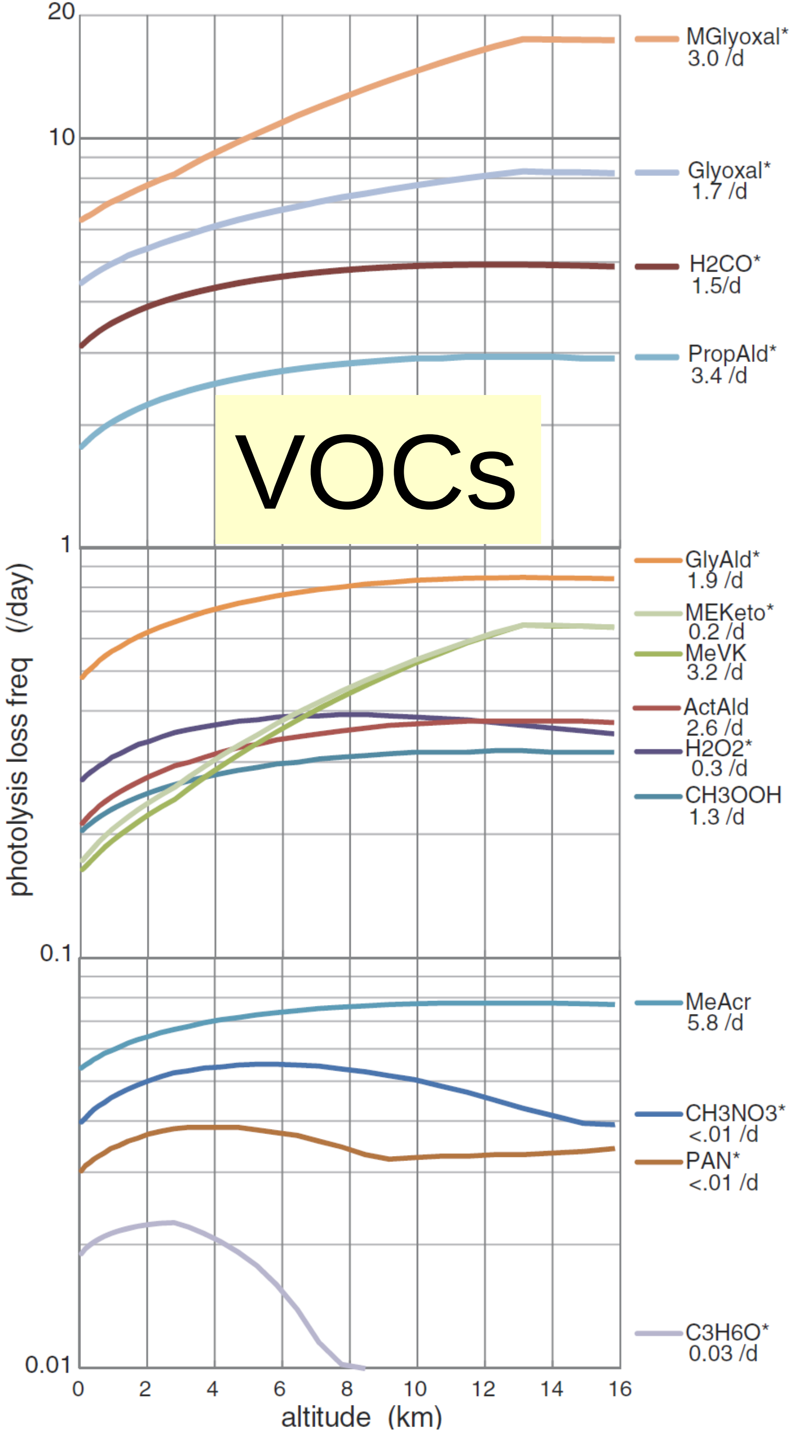


C:_M\UCI_fastJX-newXsect.zip\

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

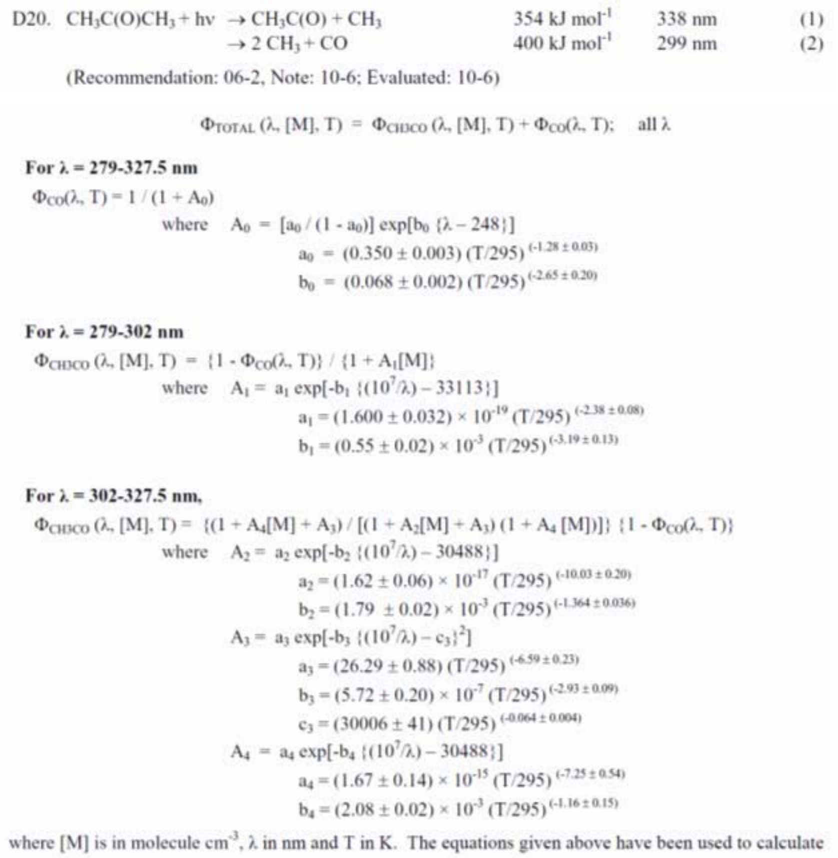
2000JAC_fastJ.pdf	289 KB	pdf	Aug 17 2009
2002JAC_fastJ2-corr.pdf	340 KB	pdf	Aug 17 2009
2002JAC_fastJ2.pdf	254 KB	pdf	Aug 17 2009
2007JGR_Neu_fractcloud...	390 KB	pdf	Mar 15 2011
UCI_fastJX-64.zip	167 KB	zip	Aug 17 2009
UCI_fastJX-65.zip	367 KB	zip	Aug 17 2009
UCI_fastJX-newXsect.zip	236 KB	zip	Aug 17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



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.



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)

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

For λ = 279-327.5 nm

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

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

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

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,

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

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

VOCs

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+

```
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
```

new: 1, 2, or 3 temperature interpolation points

```
 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
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 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
                                      0   300.00
                                      0   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
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 x-sect:  4    NO       x    1   298.00
 x-sect:  5    H2COa         2   223.00   298.00
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 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
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 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
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 x-sect: 34    MeCCl3   x    2   200.00   300.00
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 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
```

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
 x-sect: 62    Acet-b   p    2   400.00   999.00
```
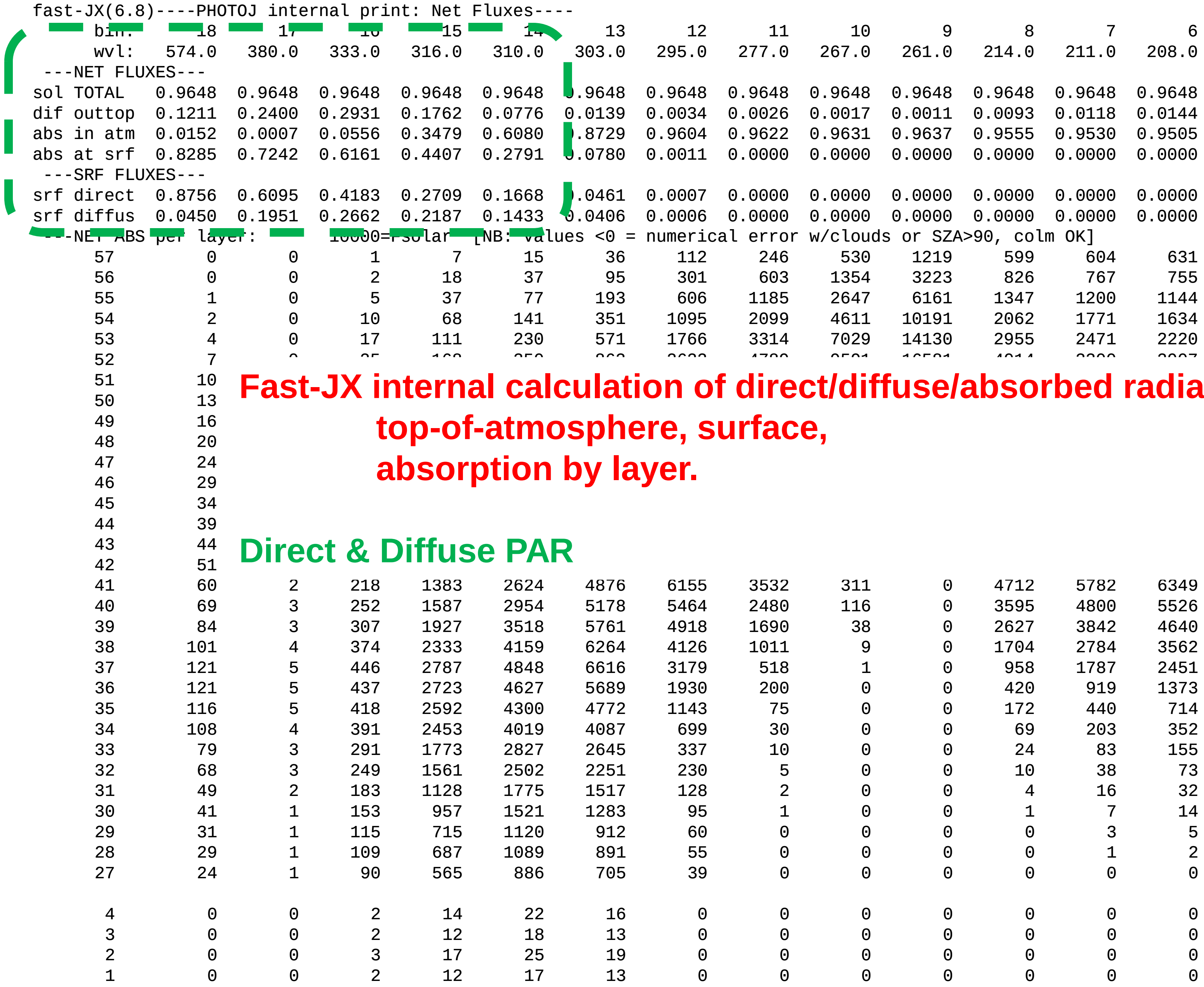
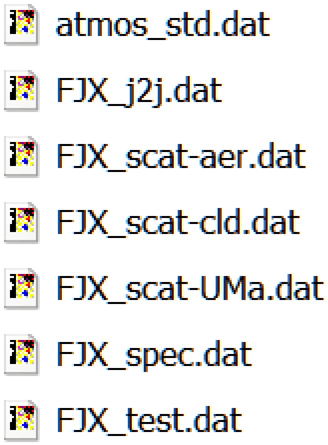



```
fast-JX(6.8)----PHOTOJ internal print: Net Fluxes----
      bin:      18      17      16      15      14      13      12      11      10       9       8       7       6
      wvl:   574.0   380.0   333.0   316.0   310.0   303.0   295.0   277.0   267.0   261.0   214.0   211.0   208.0
 ---NET FLUXES---
sol TOTAL   0.9648  0.9648  0.9648  0.9648  0.9648  0.9648  0.9648  0.9648  0.9648  0.9648  0.9648  0.9648  0.9648
dif outtop  0.1211  0.2400  0.2931  0.1762  0.0776  0.0139  0.0034  0.0026  0.0017  0.0011  0.0093  0.0118  0.0144
abs in atm  0.0152  0.0007  0.0556  0.3479  0.6080  0.8729  0.9604  0.9622  0.9631  0.9637  0.9555  0.9530  0.9505
abs at srf  0.8285  0.7242  0.6161  0.4407  0.2791  0.0780  0.0011  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
 ---SRF FLUXES---
srf direct  0.8756  0.6095  0.4183  0.2709  0.1668  0.0461  0.0007  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
srf diffus  0.0450  0.1951  0.2662  0.2187  0.1433  0.0406  0.0006  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
 ---NET ABS per layer:       10000=Fsolar  [NB: values <0 = numerical error w/clouds or SZA>90, colm OK]
      57         0       0       1       7      15      36     112     246     530    1219     599     604     631
      56         0       0       2      18      37      95     301     603    1354    3223     826     767     755
      55         1       0       5      37      77     193     606    1185    2647    6161    1347    1200    1144
      54         2       0      10      68     141     351    1095    2099    4611   10191    2062    1771    1634
      53         4       0      17     111     230     571    1766    3314    7029   14130    2955    2471    2220
      52         7
      51        10
      50        13
      49        16
      48        20
      47        24
      46        29
      45        34
      44        39
      43        44
      42        51
      41        60       2     218    1383    2624    4876    6155    3532     311       0    4712    5782    6349
      40        69       3     252    1587    2954    5178    5464    2480     116       0    3595    4800    5526
      39        84       3     307    1927    3518    5761    4918    1690      38       0    2627    3842    4640
      38       101       4     374    2333    4159    6264    4126    1011       9       0    1704    2784    3562
      37       121       5     446    2787    4848    6616    3179     518       1       0     958    1787    2451
      36       121       5     437    2723    4627    5689    1930     200       0       0     420     919    1373
      35       116       5     418    2592    4300    4772    1143      75       0       0     172     440     714
      34       108       4     391    2453    4019    4087     699      30       0       0      69     203     352
      33        79       3     291    1773    2827    2645     337      10       0       0      24      83     155
      32        68       3     249    1561    2502    2251     230       5       0       0      10      38      73
      31        49       2     183    1128    1775    1517     128       2       0       0       4      16      32
      30        41       1     153     957    1521    1283      95       1       0       0       1       7      14
      29        31       1     115     715    1120     912      60       0       0       0       0       3       5
      28        29       1     109     687    1089     891      55       0       0       0       0       1       2
      27        24       1      90     565     886     705      39       0       0       0       0       0       0

       4         0       0       2      14      22      16       0       0       0       0       0       0       0
       3         0       0       2      12      18      13       0       0       0       0       0       0       0
       2         0       0       3      17      25      19       0       0       0       0       0       0       0
       1         0       0       2      12      17      13       0       0       0       0       0       0       0
```

Fast-JX internal calculation of direct/diffuse/absorbed radiation:
top-of-atmosphere, surface,
absorption by layer.

Direct & Diffuse PAR

* fast-JX v6.8+ data tables



Std atmospheres	atmos_std.dat
J-to-J translation #	FJX_j2j.dat
Aerosol scattering #	FJX_scat-aer.dat
Cloud scattering	FJX_scat-cld.dat
UM Aerosol scattering	FJX_scat-UMa.dat
X-sections & solar flux	FJX_spec.dat
test input for standalone	FJX_test.dat

 # User defined tables, specific to the chemistry.

New fast-JX v.7+ .f90 modules for CAM5

fully tested in UCI CTM, now being implemented in CAM5 (LLNL)

JX71-f90

New modularized fast-JX.f90 versions,
not compatible with v.6.8 standalone, but traceable/close.

Fast-JX now does a single (independent) column atmosphere (ICA)
In the ICA, clouds are assumed to be 100% fractional coverage,
Values fed to fast-JX (module PHOTO_JX) are now only:

- SolarZenithAngle, cos(SZA), surf. albedo, solar distance factor
- pressure, altitude at level edges
- molecules air /cm^2, molecules O_3 /cm^2 at each level
- temperature, relative humidity at levels
- LiquidWaterPath (g/m^2), R_{eff}(Liquid) (microns) at levels
- IceWaterPath (g/m^2), R_{eff}(Ice) (microns) at levels
- Aerosol Path (g/m^2), Aerosol-Index (key to fast-JX tables*)

Fast-JX uses path and R_{eff} to derive 600 nm OD, then picks nearest
or appropriate scattering table for cloud from R_{eff}(L) or T(Ice).
Now includes both ice and liquid scattering in same layer.

A J-to-J translator is part of initialization calling sequence.

Cloud-Scav: How sausage is made

Deal with ambiguous overlapping of precipitation

Uncertainties in ice-gas interactions (surface, buried, bulk)

. . .

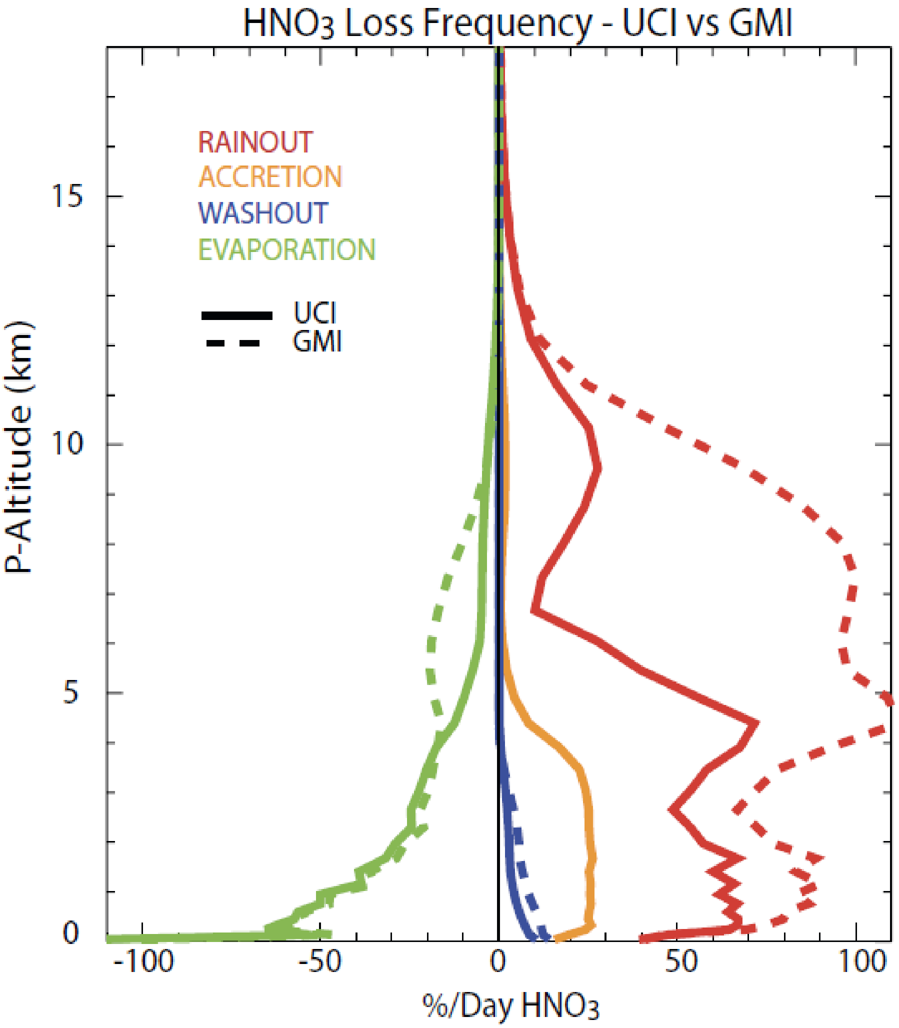
Atmos. Chem. Phys., 12, 3289–3310, 2012
www.atmos-chem-phys.net/12/3289/2012/
doi:10.5194/acp-12-3289-2012

Atmospheric Chemistry and Physics

Toward a more physical representation of precipitation scavenging in global chemistry models: cloud overlap and ice physics and their impact on tropospheric ozone

J. L. Neu[1,*] **and M. J. Prather**[1]

[1] Department of Earth System Science, University of California,
[*] now at: Jet Propulsion Laboratory, Pasadena, California, USA



Atmos. Chem. Phys., 12, 3289–3310, 2012
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doi:10.5194/acp-12-3289-2012

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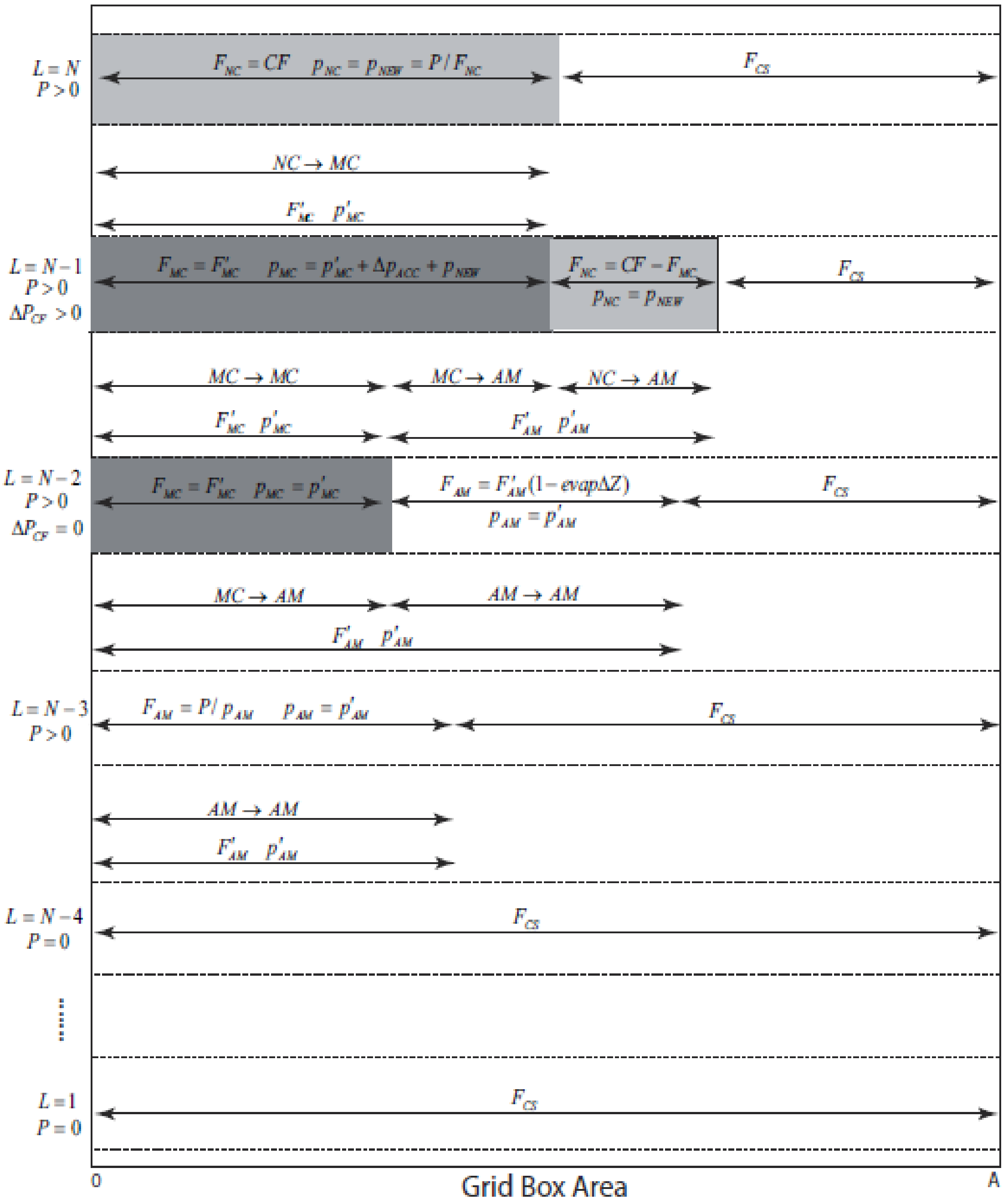


Fig. A1. Schematic of an idealized grid box with N levels, indicated by the horizontal dotted lines. The space between the levels is for

Cloud-JX: Approximation of RT in an imperfect world

Ambiguous correlations of clouds – many different “answers”

3-D RT may be needed

New fast-JX v.7+ .f90 modules for CAM5
fully tested in UCI CTM, now being implemented in CAM5 (LLNL)

JX72-f90 = cloud-JX

New fast-JX v.72+ .f90 modules for CAM5 for fractional cloud cover
now being tested in UCI CTM, soon to be implemented in CAM5 (LLNL)

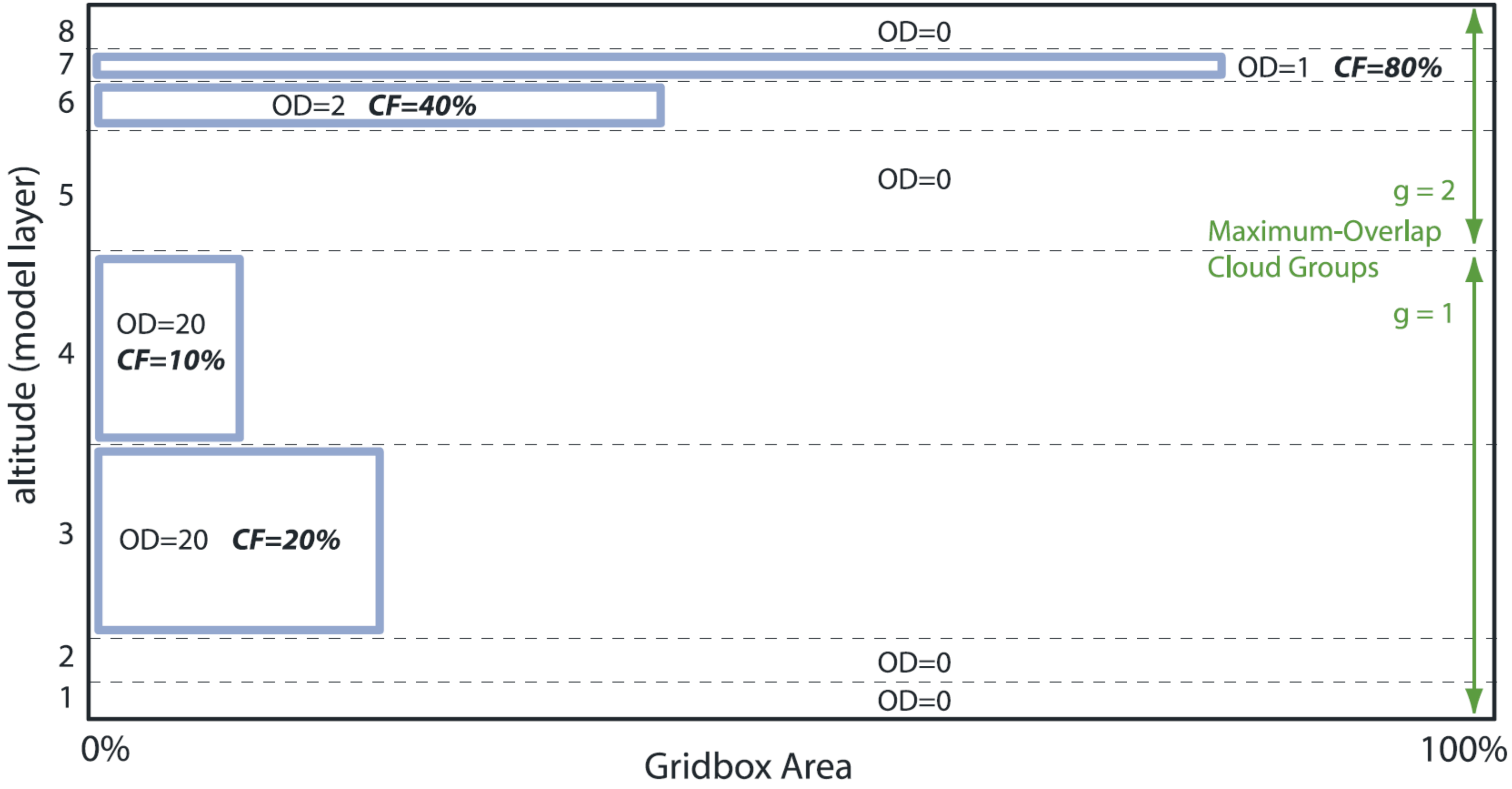
Cloud-JX
uses the JX71-f90 module to calculate J values,
takes data on cloud properties and cloud fraction from met fields
user-selected cloud overlap and approximation (see below)

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

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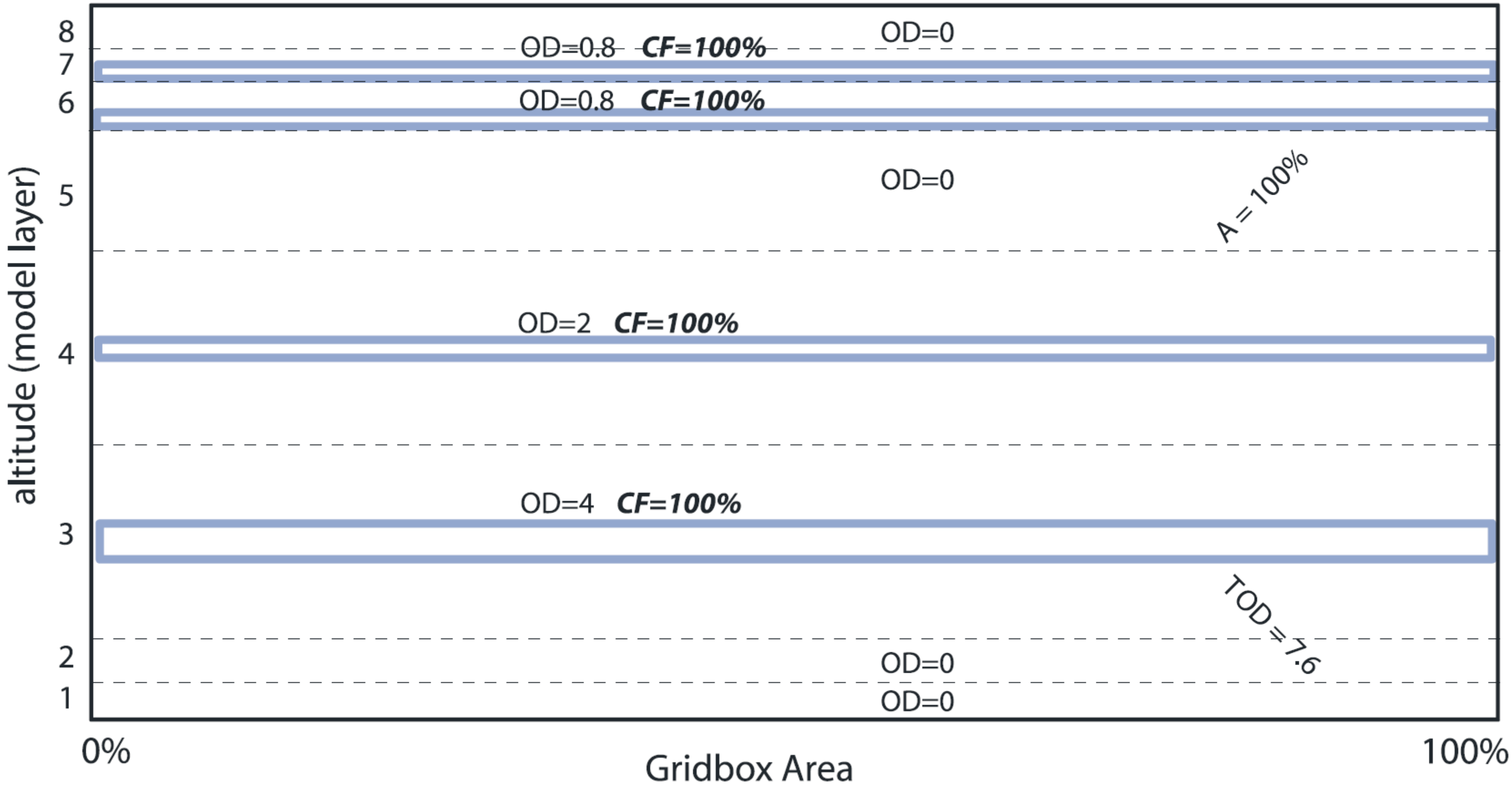
Averaged Cloud across grid box

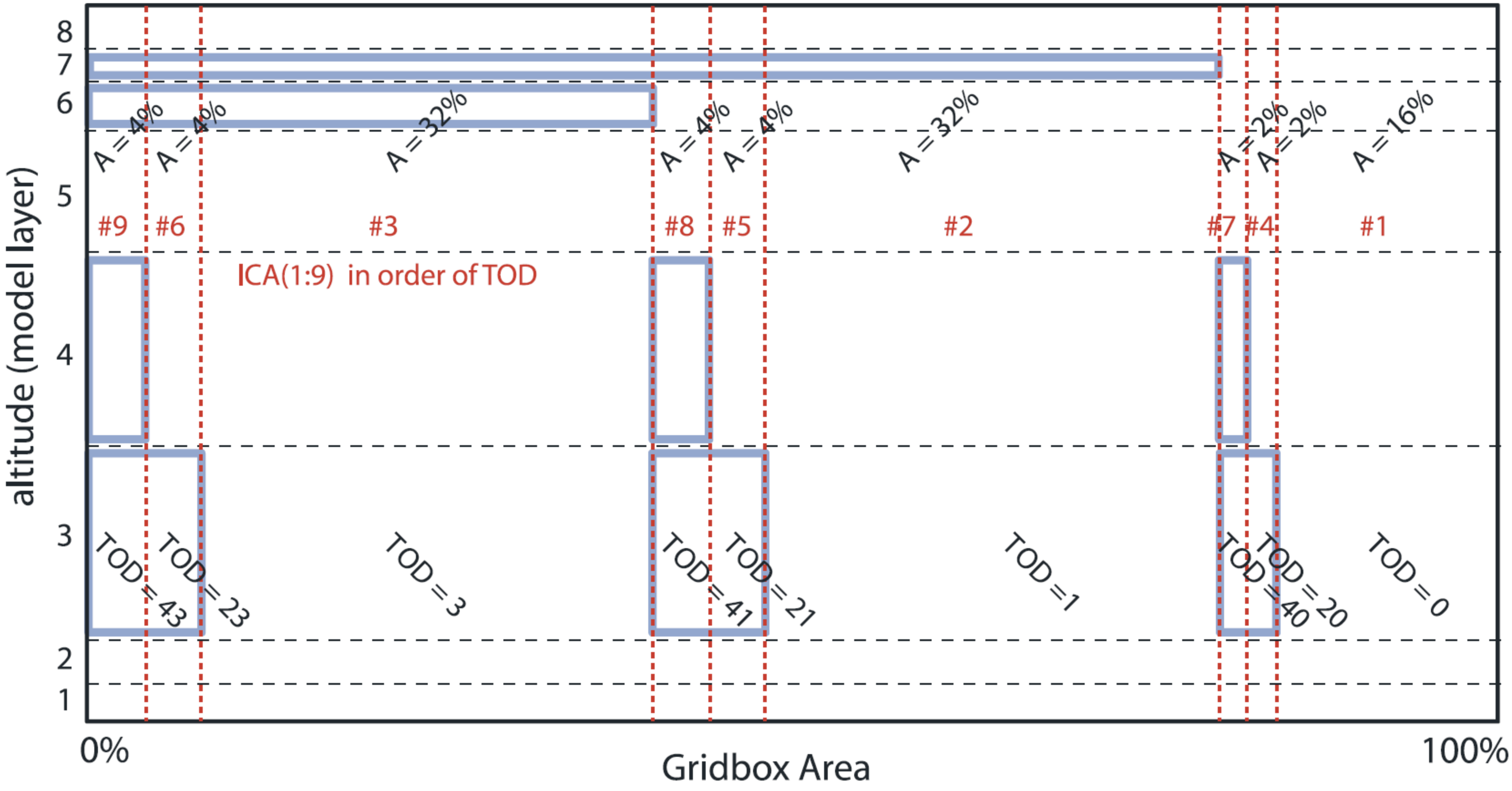


JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D11306, doi:10.1029/2006JD008007, 2007

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)



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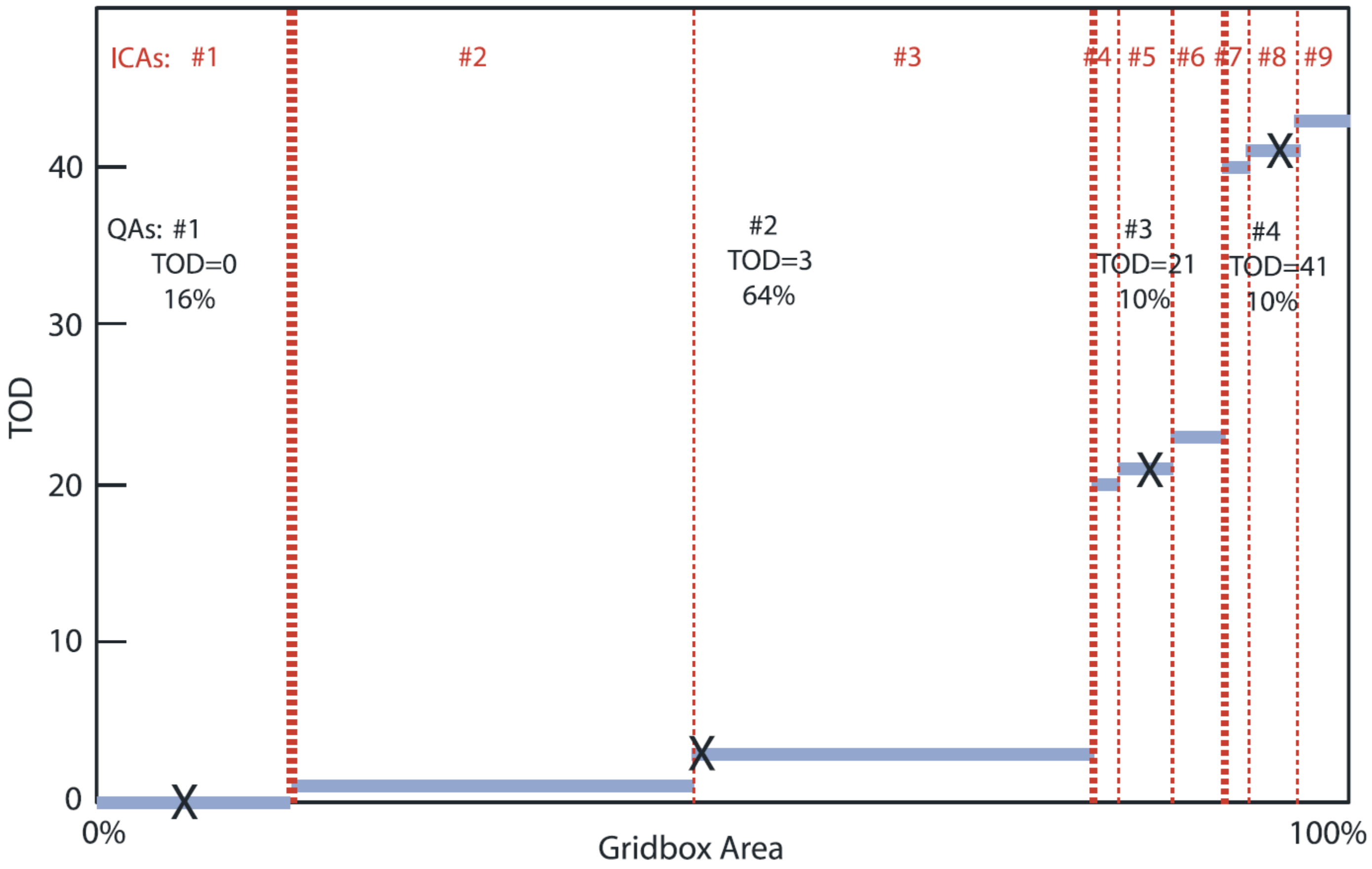
Global atmospheric chemistry: Integrating over fractional cloud cover

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

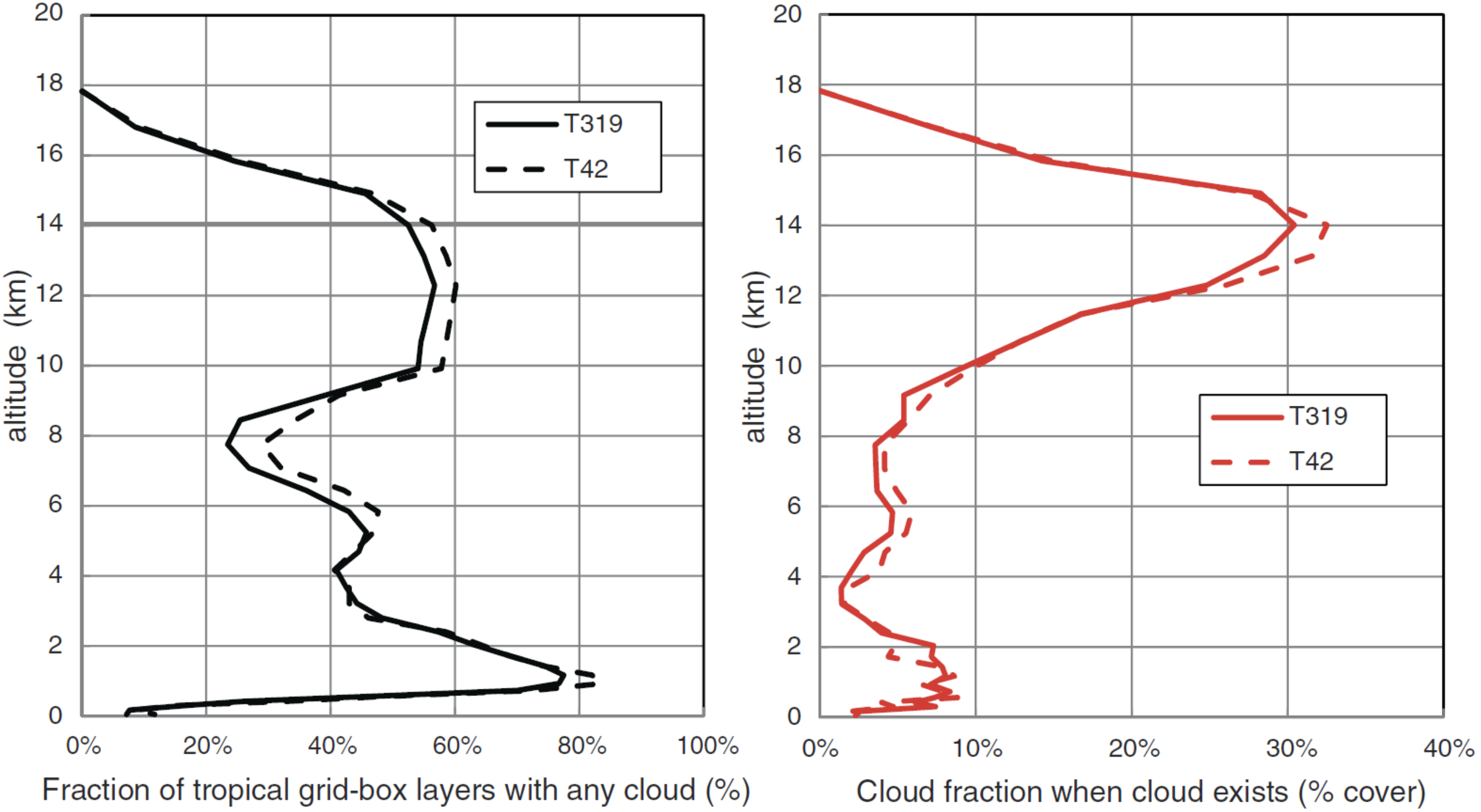
Cloud Quadrature picks 4 cloudy types



nearly clear cirrus stratus cumulus

Fraction of layers with any cloud fraction >0.1%

Average cloud fraction in layers with clouds.



Results are taken from a single met field on 1 Jan 2005 and the tropical belt just south of the equator for T319 (640 grid boxes) and T42 (128 boxes).

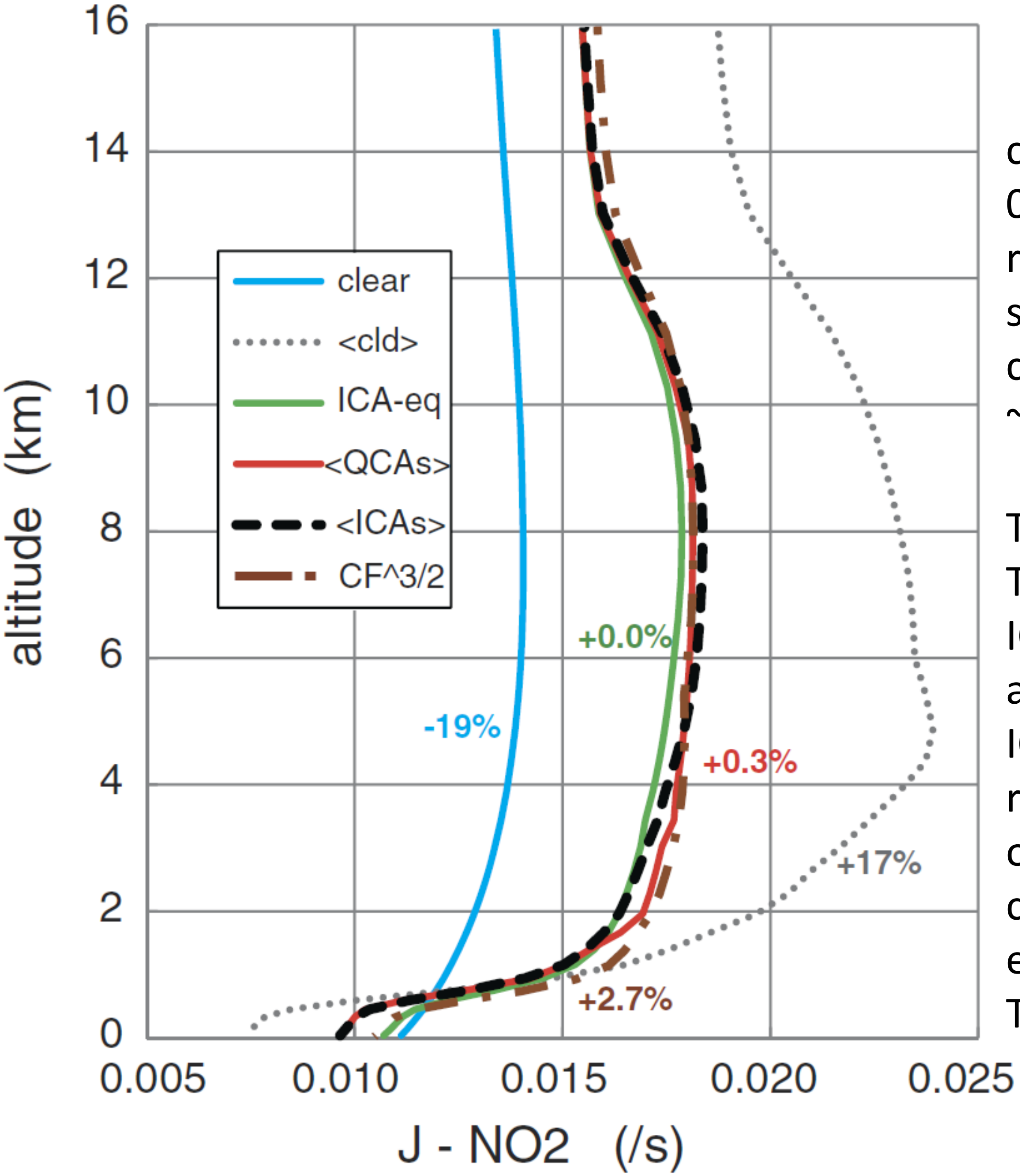
J values for max-ran overlapping clouds using different approximations

J approx.	calls/box	method
$\langle ICAs\rangle^0_{T42}$	**27.2**	**Max-Ran break at CF=0, average of all ICAs, T42L60 (128 boxes)**
$\langle QCAs\rangle^0_{T42}$	2.8	Cloud Quadrature, MaxRan:0, T42 fields
$ICA\text{-}eq^0_{T42}$	1	Equivalent direct beam = <ICAs>, MaxRan:0, inverted cloud-OD, T42
$pRAN^0_{T42}$	1	pseudo-random, MaxRan:0, Cloud-OD = $CF^{3/2}$ x in-cloud-OD, T42
$\langle cld\rangle^0_{T42}$	1	Average cloud, MaxRan:0, Cloud-OD = CF x in-cloud-OD, T42
$clear^0_{T42}$	1	Clear sky, no clouds, T42 fields
$\langle ICAs\rangle^0_{T319}$	**27.0**	**Max-Ran break at CF=0, average of all ICAs, T319L60 (640 boxes)**
$\langle QCAs\rangle^0_{T319}$	2.8	Cloud Quadrature, MaxRan:0, T319 fields
$\langle ICAs\rangle^3_{T42}$	**58.1**	**Max-Ran 3 groups, break at 1km & ice-cloud, T42 fields**
$\langle QCAs\rangle^3_{T42}$	2.8	Cloud Quadrature, MaxRan:3, T42 fields
$ICA\text{-}eq^3_{T42}$	1	Equivalent direct beam = <ICAs>, MaxRan:3, inverted cloud-OD, T42
$\langle cld\rangle^3_{T42}$	1	Average cloud (Cloud-OD = CF x incloud-OD, MaxRan:3, T42 fields
$clear^3_{T42}$	1	Clear sky, no clouds, T42 fields

Notes: J values are calculated using fast-JX with a single standard tropical atmosphere for temperature and ozone, surface albedo of 0.10, and solar zenith angle of 14.6°. Both bias and rms errors are in natural log units (e.g., $\ln(J/J_{<ICAs>})$) and labeled as %, and all are pressure-weighted across all CTM layers from 1000 to 100 hPa. J-values are calculated for

the true ICA average (<ICAs>),
clear sky, averaged-cloud (<cld>),
quadrature column atmospheres (<QCAs>),
the ICA-equivalent atmosphere (ICA-eq), and
the Briegleb pseudo-random (pRAN = $<cld*cf^{3/2}>$).

Each test case ($^{0}{}_{T42}$, $^{0}{}_{T319}$, $^{3}{}_{T42}$) has its own set if ICAs and "true answer"(<ICAs>). Cloud distributions and overlaps are taken from the cloud fractions, liquid/ice water paths for an equatorial belt of 128 different T42 grid boxes. One approximation (<QCAs>) is also shown for an equatorial belt of 640 T319 grid boxes. The ICAs are defined by a max-ran overlap scheme with random overlap groups separated by any clear layer (denoted by ^{0}) or with 3 fixed groups (denoted by ^{3}, with breaks at L=8-9 (~ 1 km) and at the first ice water cloud). ICA-eq averages the attenuation of the direct solar beam over ICAs using the solar zenith angle and the effective isotropic optical depth (OD) of the clouds in each layer. Isotropic OD is calculated as cloud OD x (1 – g), where the asymmetry factor is calculated as $g^* = 1.10 \times P_1 / 3$, where P1 is the first term in the Legendre expansion of the scattering phase function and supplied by the fast-JX data tables. The ICA-eq atmosphere specifies cloud OD in each layer consistent with the averaged direct beam.*



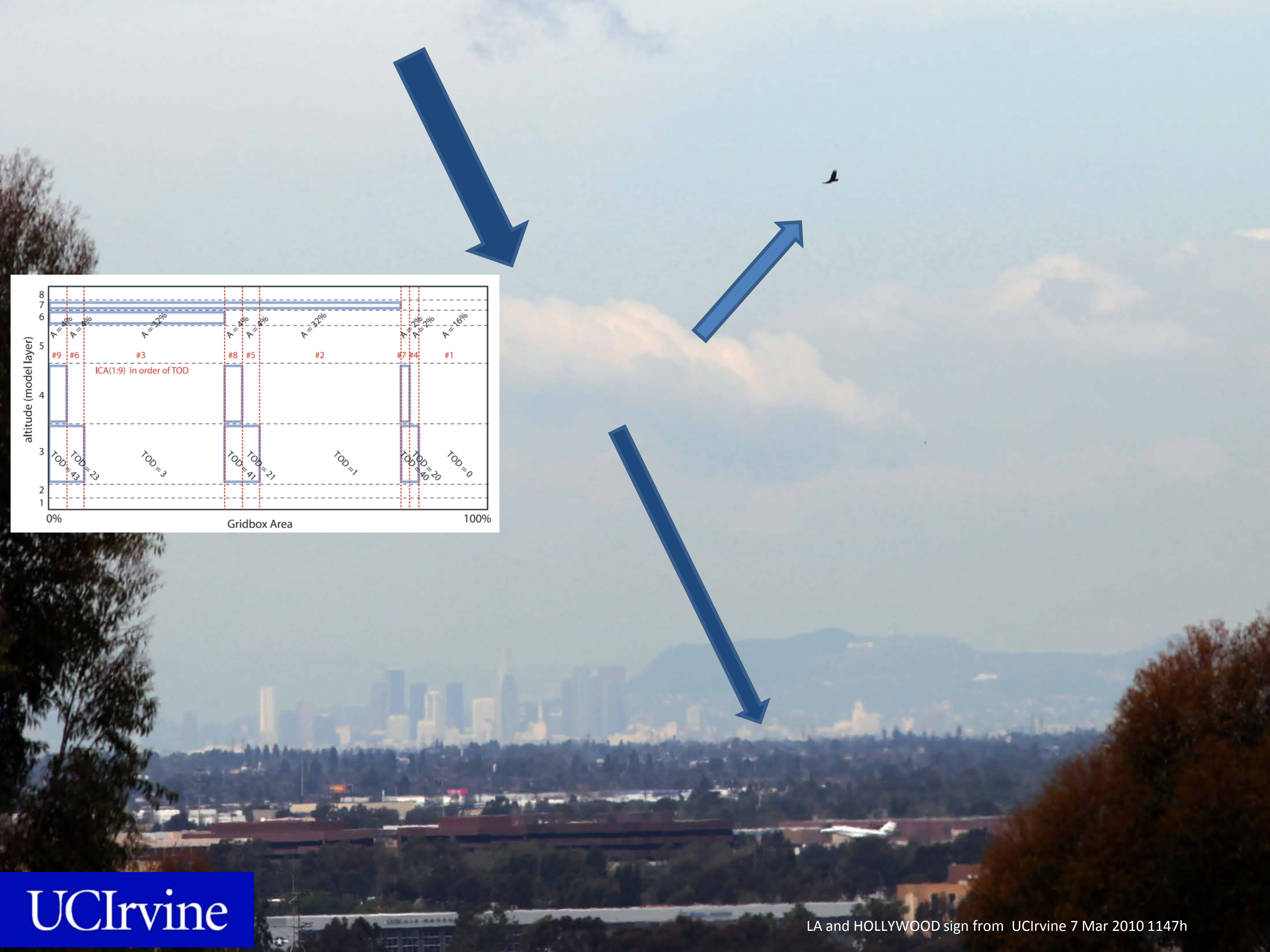
J-values for NO_2

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.

Errors in average J values for max-ran overlapping clouds using different approximations

		BIAS error				RMS error			
J approx.	calls/box	J-O$_3$(^{1}D)	J-NO$_2$	J-NO$_3$	J-HNO$_3$	J-O$_3$(^{1}D)	J-NO$_2$	J-NO$_3$	J-HNO$_3$
<ICAs>$^0_{T42}$	**27.2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
<QCAs>$^0_{T42}$	2.8	+0.2%	+0.6%	+1.0%	+0.7%	2%	2%	3%	3%
ICA-eq$^0_{T42}$	1**	+1.1%	+1.2%	+2.6%	+1.9%	2%	4%	6%	5%
pRAN$^0_{T42}$	1	+1.4%	+1.4%	+2.6%	+2.0%	4%	5%	8%	6%
<cld>$^0_{T42}$	1	+5.3%	+8.7%	+12%	+9.5%	9%	12%	16%	13%
clear$^0_{T42}$	1	-5.2%	-10%	-14%	-10%	10%	13%	17%	14%
<ICAs>$^0_{T319}$	**27.0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
<QCAs>$^0_{T319}$	2.8	+0.2%	+0.4%	+0.8%	+0.5%	2%	2%	3%	2%
<ICAs>$^3_{T42}$	**58.1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
<QCAs>$^3_{T42}$	2.8	+0.6%	+1.4%	+2.1%	1.6%	3%	4%	5%	4%
ICA-eq$^3_{T42}$	1**	+1.5%	+1.9%	+3.6%	+2.6%	3%	4%	7%	5%
<cld>$^3_{T42}$	1	+4.4%	+7.5%	+11%	+8.3%	8%	10%	14%	11%
clear$^3_{T42}$	1	-6.1%	-11%	-15%	-12%	11%	15%	18%	15%



LA and HOLLYWOOD sign from UCIrvine 7 Mar 2010 1147h