Update on Fast-J codes

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Part of this work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

- **Fast-J**: Calculates radiative transfer for single column with full scattering for a single column.
  - Currently uses grid-box averaged clouds. (not ideal)
  - Currently setup for Super-fast mechanism, but can be easily extended to other mechanisms.

- **Cloud-J**: Wraps around Fast-J, calling it multiple times to handle cloud overlap.
  - Good results with just 4 columns.

- **Solar-J**: Extends Fast-J to the additional wavelengths needed to replace solar heating from RRTMG.
  - Significantly improve on the acattering assumptions made by RRTMG.
  - Currently being tested at UCI.

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```
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
```

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
```

fast-J, an update

Full Fortran-90 implementation in CAM5 linked to aerosols

Philip Cameron-Smith & Michael Prather
CESM Chemistry-Climate WG
18 Feb 2015

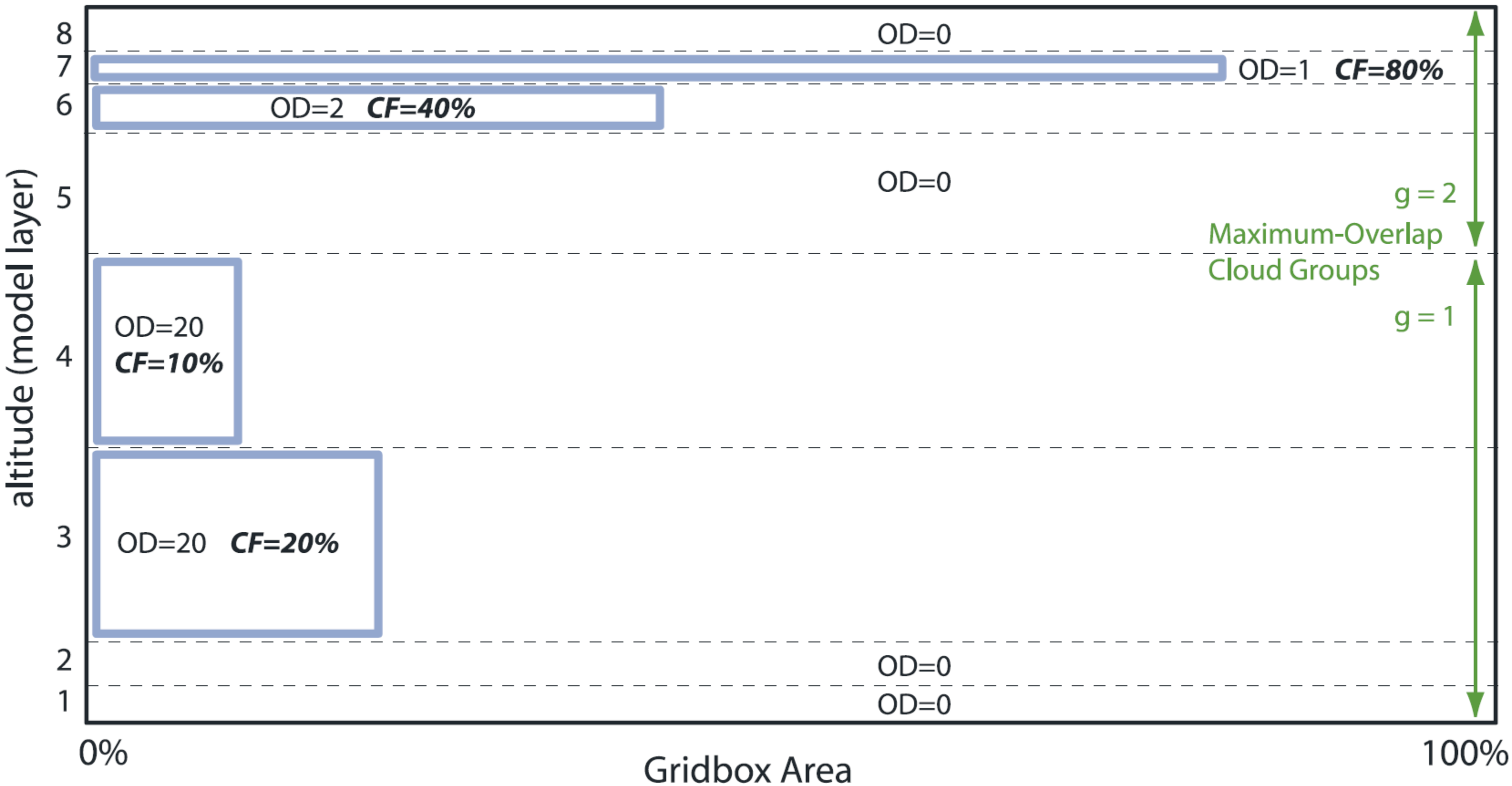
```
!------------------------------------------------------------------------------
!          UCI fast-JX  cloud-JX v-7.2b (12/2015)
!------------------------------------------------------------------------------
!
! !DESCRIPTION: decides what to do with cloud fraction,
!     including generate Independent Column Atmospheres (ICAs)for a max-ran
!     cloud overlap algorithm, and Quadrature Colm Atmos (QCAs).
!
      MODULE CLD_SUB_MOD

! USES:
      USE CMN_FJX_MOD

      USE FJX_SUB_MOD,  ONLY : EXITC, PHOTO_JX

      IMPLICIT NONE
!-----------------------------------------------------------------------
!
! !PUBLIC SUBROUTINES:
!
      PUBLIC  :: CLOUD_JX

      CONTAINS

      SUBROUTINE CLOUD_JX (U0,SZA,REFLB,SOLF,FG0,LPRTJ,PPP,ZZZ,TTT,  &
             DDD,RRR,OOO,    LWP,IWP,REFFL,REFFI,     CLDF,CWC,  &
             AERSP,NDXAER,L1U,ANU,VALJXX,NJXU,  &
             CLDFLAG,NRANDO,IRAN,L3RG,NICA,JCOUNT)

      implicit none

!  CLOUD_JX is fractional cloud cover driver for PHOTO_JX  (fast-JX v7.2)
!    calc J's for a single column atmosphere (aka Indep Colm Atmos or ICA)
!    needs P, T, O3, clds, aersls; adds top-of-atmos layer from climatology
!    needs day-fo-year for sun distance, SZA (not lat or long)
```

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



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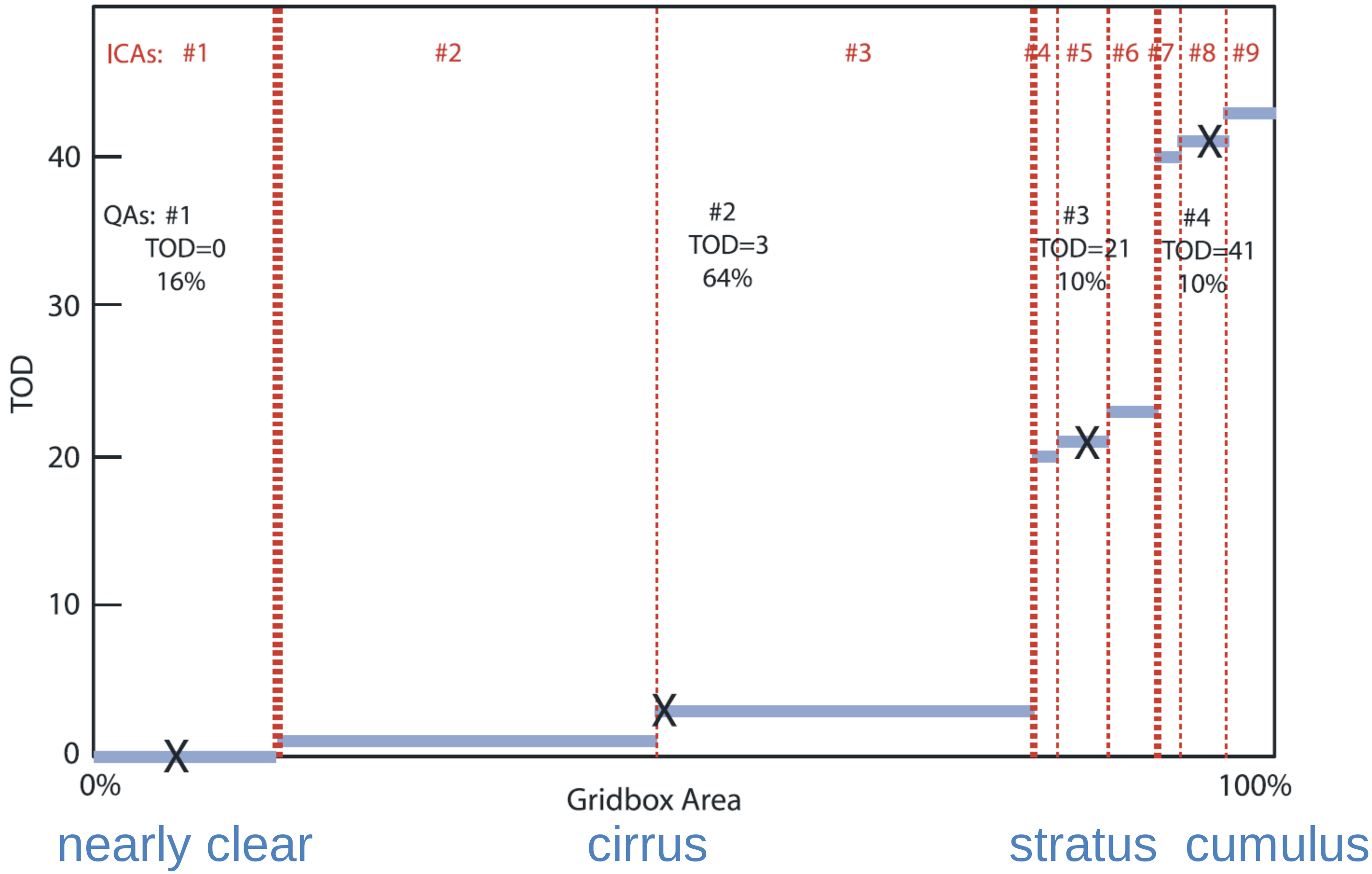
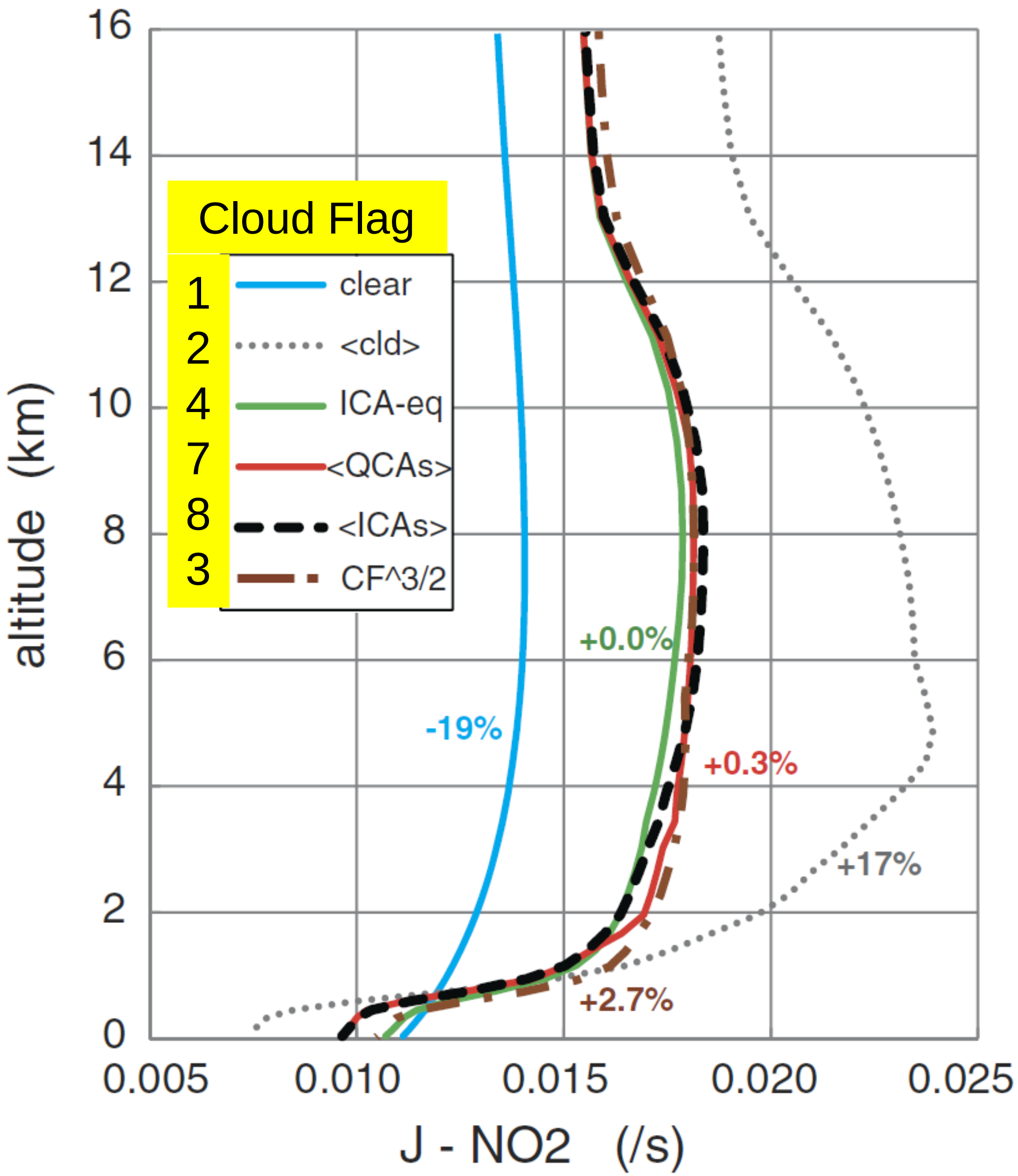
Cloud Quadrature picks representative ICAs from 4 cloudy types or just uses average clouds within each type





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.

- End of presentation.

cloud-J, what's new?

Full Fortran-90 version being tested in UCI CTM

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,NRAND0,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
```

cloud-J, what's new?

Full Fortran-90 version being tested in UCI CTM

for now, many options for approximating fractional clouds

```
!--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 clouds
!        CLDFLAG = 5  :  Random select NRANDO ICA's from all(Independent Column Atmos.)
!        CLDFLAG = 6  :  Use all (up to 4) quadrature cloud cover QCAs (mid-pts of bin)
!        CLDFLAG = 7  :  Use all (up to 4) QCAs (average clouds within each Q-bin)
!        CLDFLAG = 8  :  Calcluate J's for ALL ICAs (up to 20,000 per cell!)
!-----------------------------------------------------------------------
```

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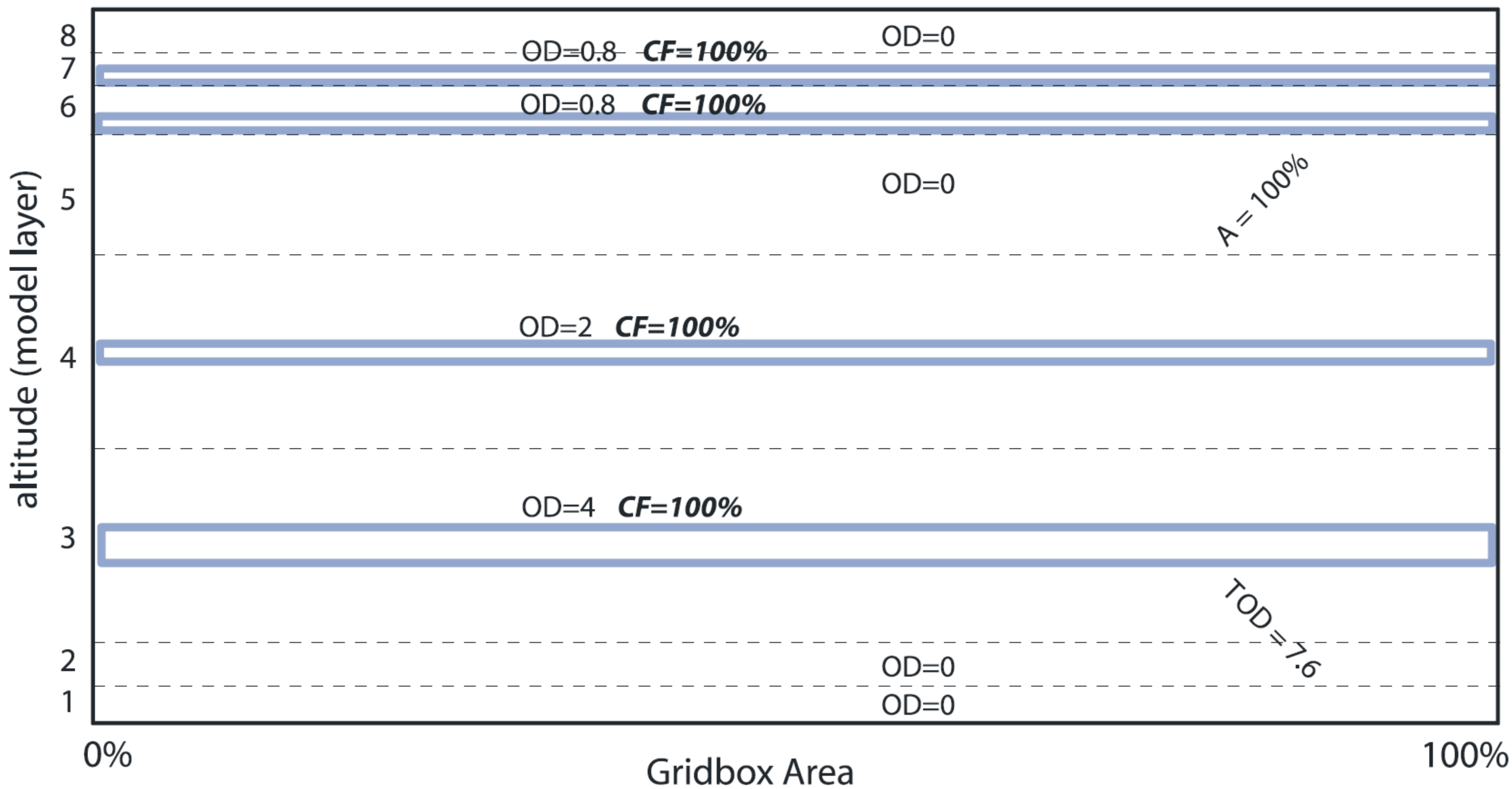
Averaged Cloud across grid box



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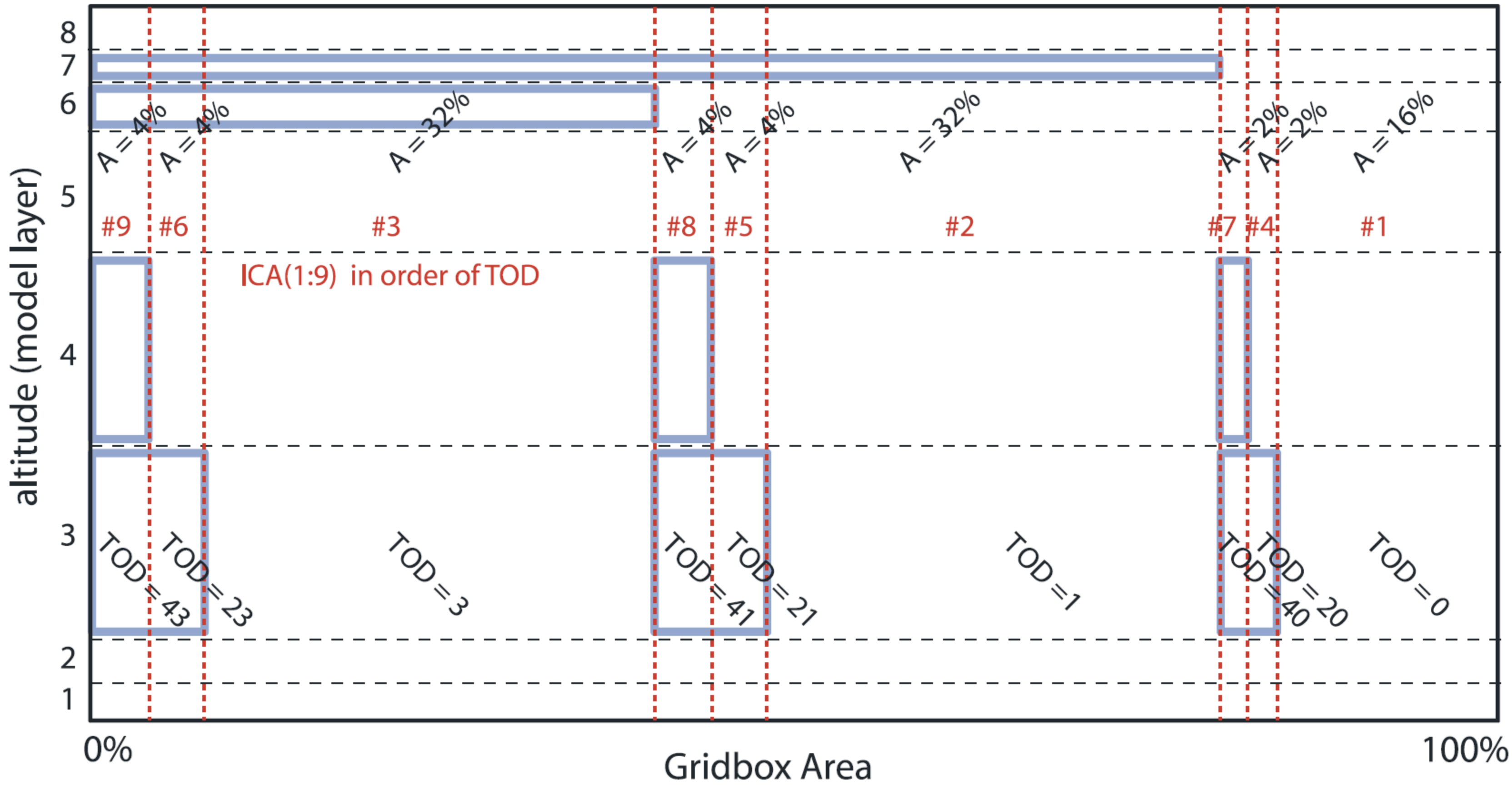
Max-Ran groups => Independent Column Atmospheres (ICAs) exact calculation of J's done over all ICAs



what's new? 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

First ***off-line*** tests of Solar-J vs RRTMG-SW are now underway.

A sample atmosphere for Solar-J

SZA = 13.6°

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

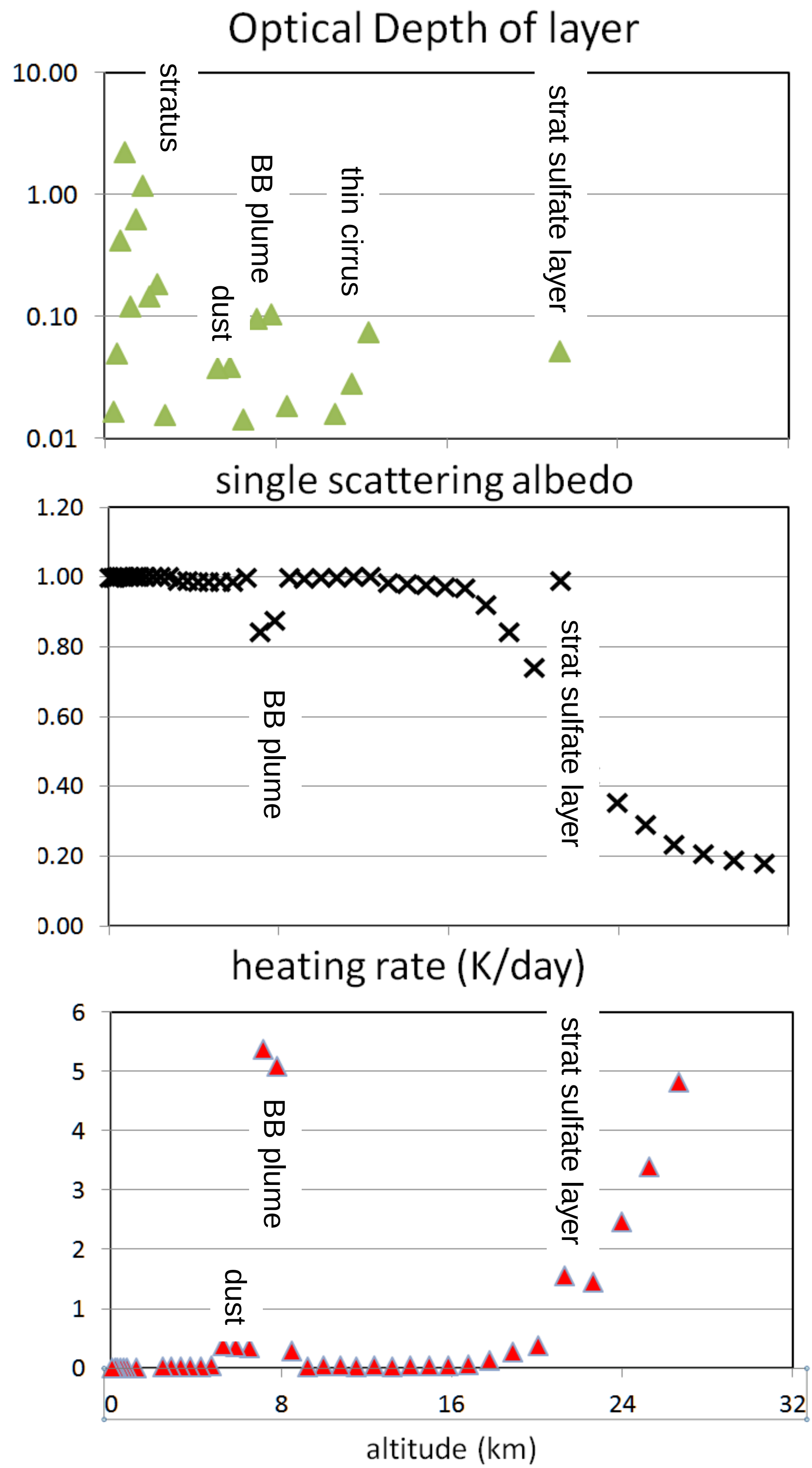
Solar flux (60% of solar energy < 850 nm)

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

** Note that with 2-stream RRTMG-SW, the OD would be rescaled from 5 to ~1 and the Direct PAR would be much greater.



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
BB plume
dust
strat sulfate layer
0
8
16
24
32
altitude (km)

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.