GMI Science Team Meeting
11-13 Oct 2006 NASA Goddard

Michael Prather
UC Irvine

►fractional cloud cover (in review JGR)

Jessica Neu, Prather, Penner

►CTM transport errors & 2x-to-convergence (?)

Wild, O., and M. J. Prather (2006), Global tropospheric ozone modeling: Quantifying errors due to grid resolution, J. Geophys. Res., 111, D11305.

►validation of met fields T & q

►fast-JX aerosol parameters (UMich)

►fractional cloud cover (submitted Sept 2006, JGR)

Global atmospheric chemistry: integrating over fractional cloud cover

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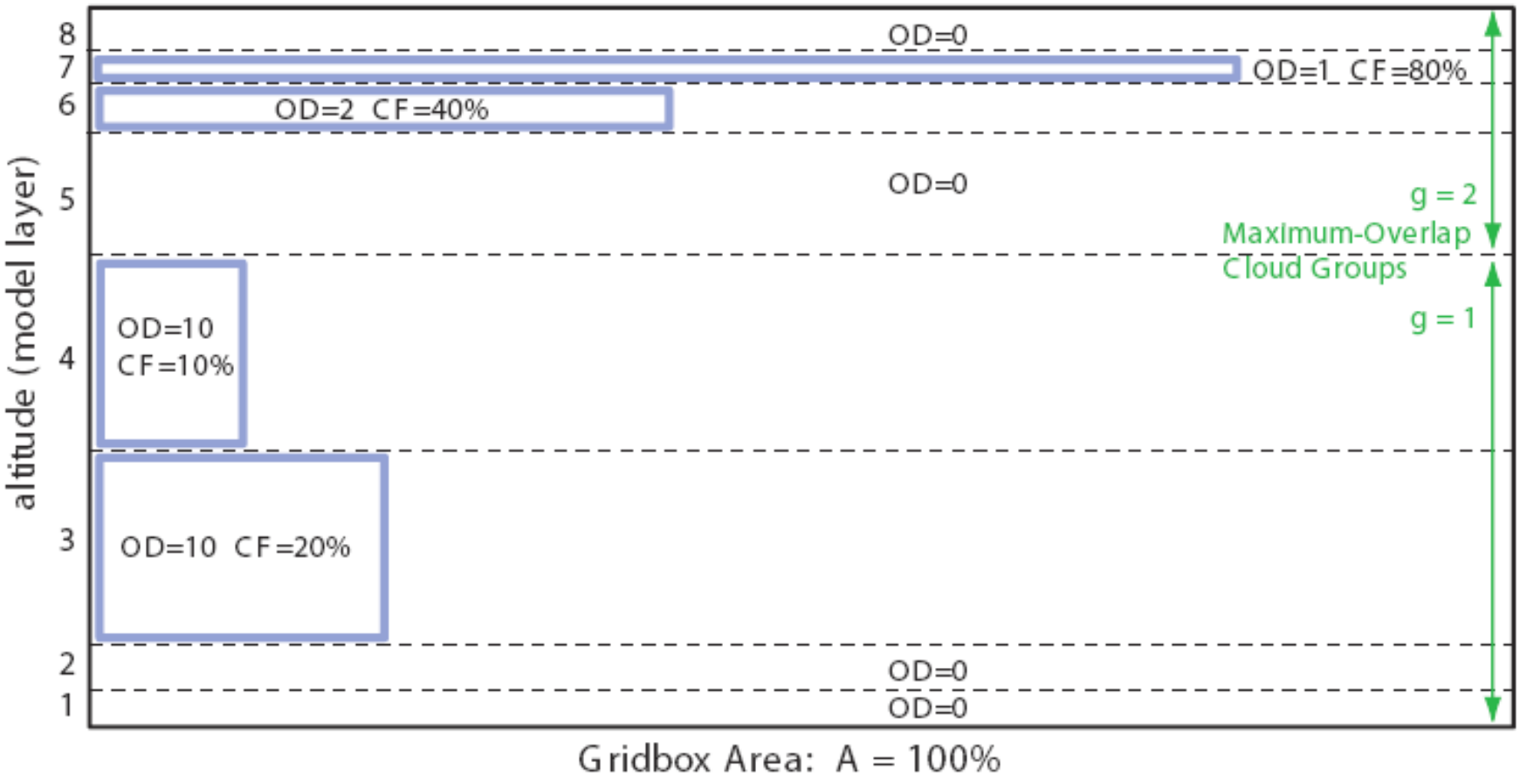
►fractional cloud cover (submitted Sept 2006, JGR)

Abstract. A new approach defined here allows for the averaging of photochemistry over complex cloud fields within a grid square and can be readily implemented in current global models. As diagnosed from observations or meteorological models, fractional cloud cover with many overlying cloud layers can generate hundreds to thousands of different cloud profiles per grid square. We define a quadrature-based method, applied here to the problem of averaging photolysis rates over this range of cloud patterns, which opens new opportunities for modeling in-cloud chemistry in global models. We select up to four representative cloud profiles, optimizing the selection and weighting of each to minimize the difference in photolysis rates when compared with the integration over the entire set of cloud distributions. To implement our algorithm, we adapt the UCI fast-JX photolysis code to the cloud statistics from the ECMWF forecast model at T42L40 resolution. For the tropics and midlatitudes, grid-square-averaged photolysis rates for O_3, NO_2, and NO_3 using four representative atmospheres differ by at most 3.3% rms from rates averaged over the hundreds or more cloudy atmospheres derived from a maximum-random overlap scheme. Further, bias errors in both the free troposphere and the boundary layer are less than 1%. Similar errors are shown to be 10-20% for current approximation methods. Errors in the quadrature method are less than the uncertainty in the choice of maximum-random overlap schemes. We apply the method to the averaging of photochemistry over different cloud profiles and explore possible extensions to heterogeneous cloud chemistry.

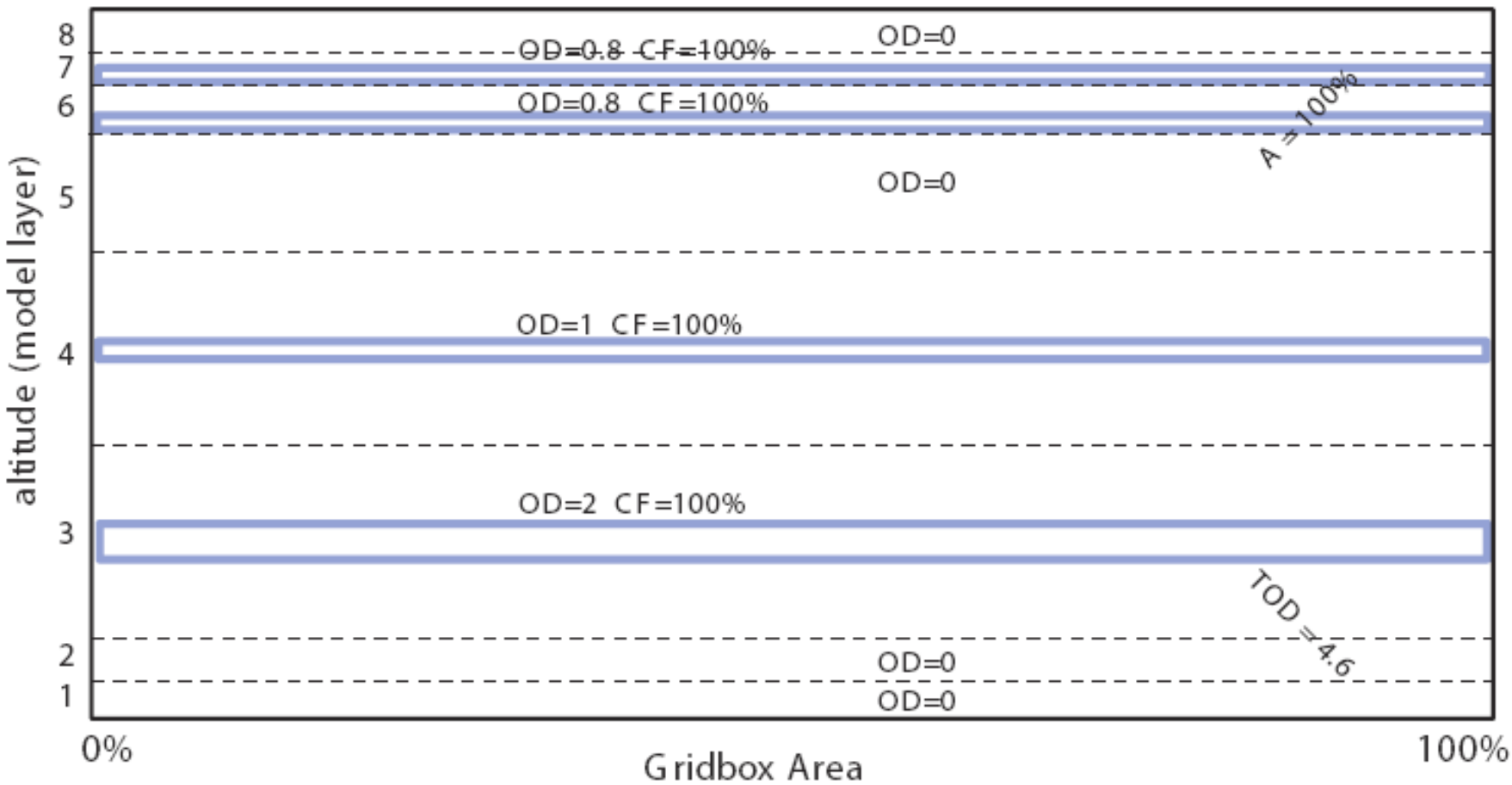
CF-paper Fig. 1

cloud fraction & OD from met fields:



cloud fraction & OD as treated in fast-JX now
= "linear approx"

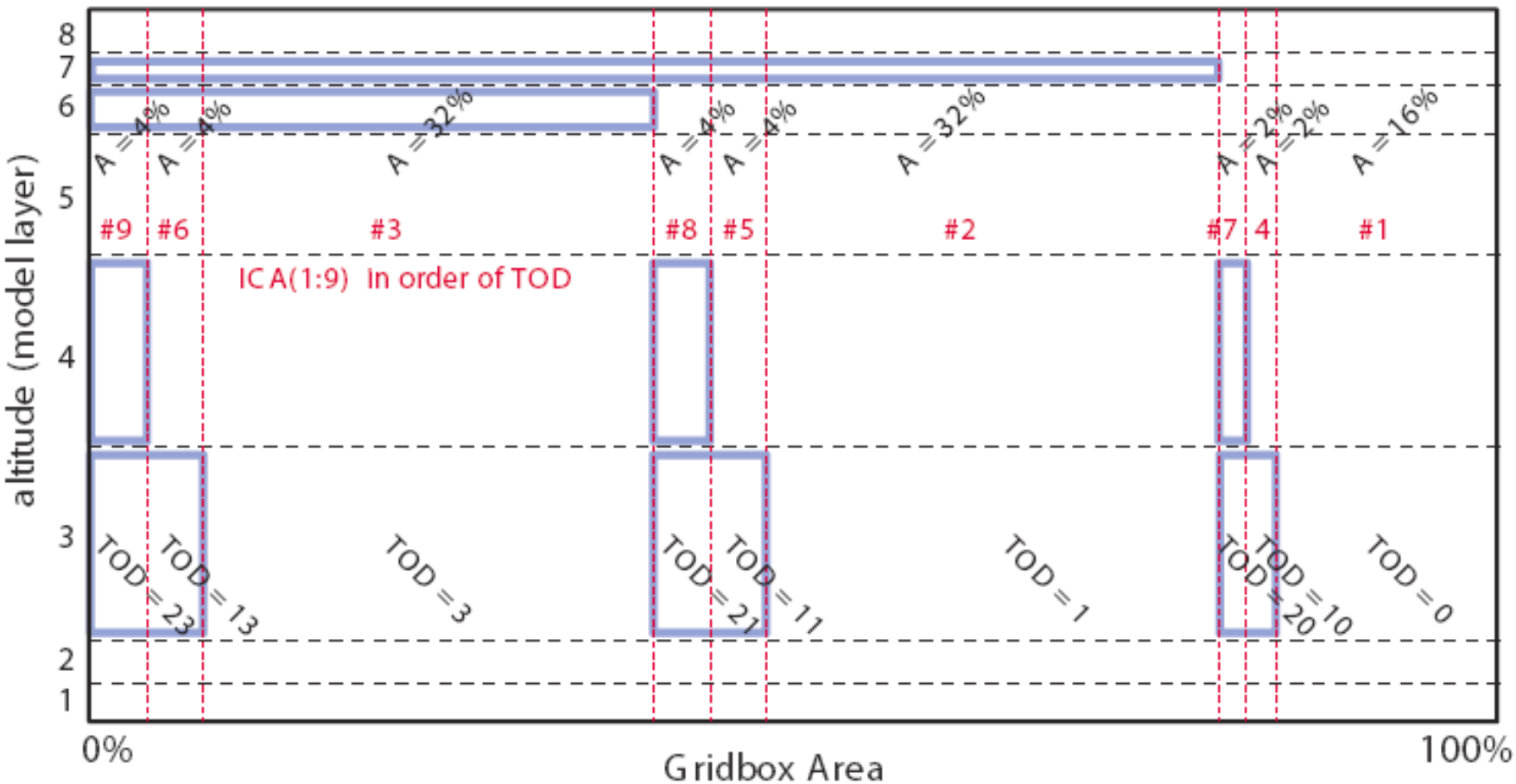
CF-paper Fig. 2



in a max-random w/ 0%-threshold overlap model

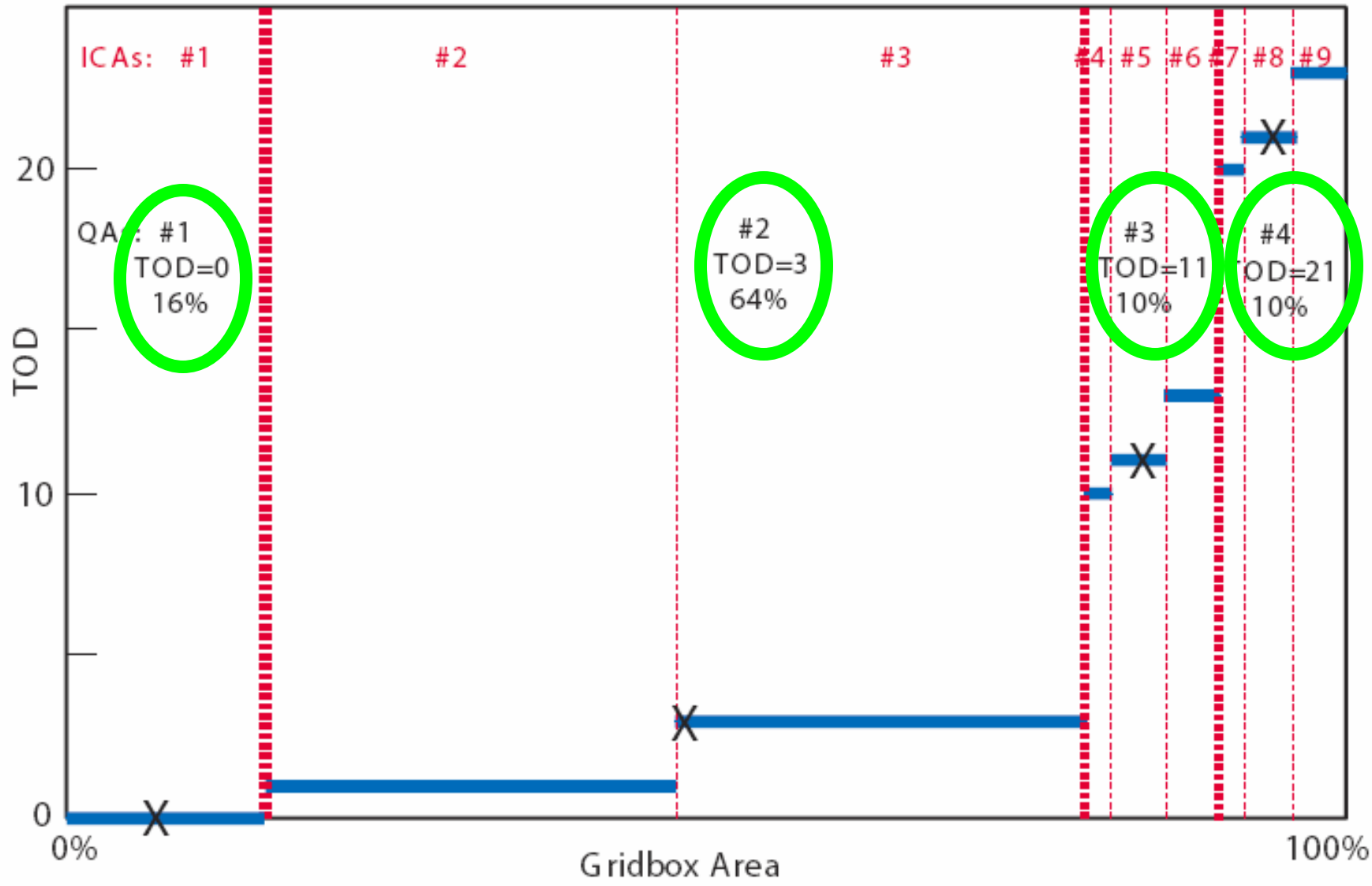
these clouds become 2 groups w/ max overlap

CF-paper Fig. 3



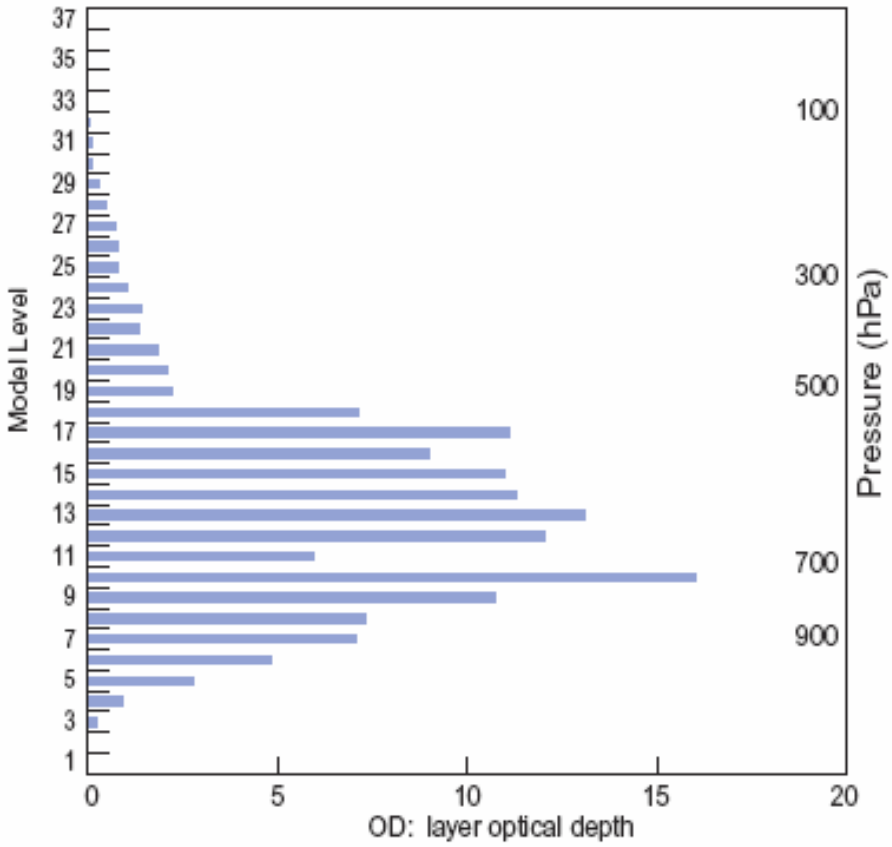
atmospheres (ICAs) sorted by Total OD and
the 4 quadrature atmospheres (X's) identified

CF-paper Fig. 4

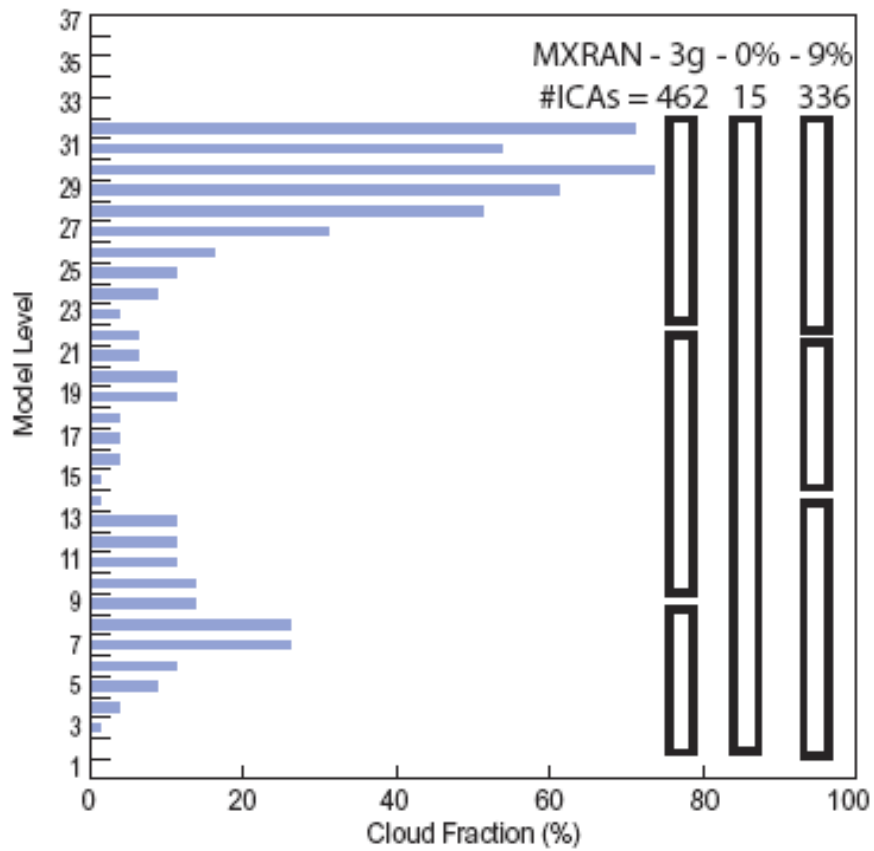


realistic: instantaneous tropical box in Oslo/EC T42 (5.6-8.4°N, 23.9-26.7°W) from the 1200-1500Z 15 Jan 2000.

CF = cloud fraction

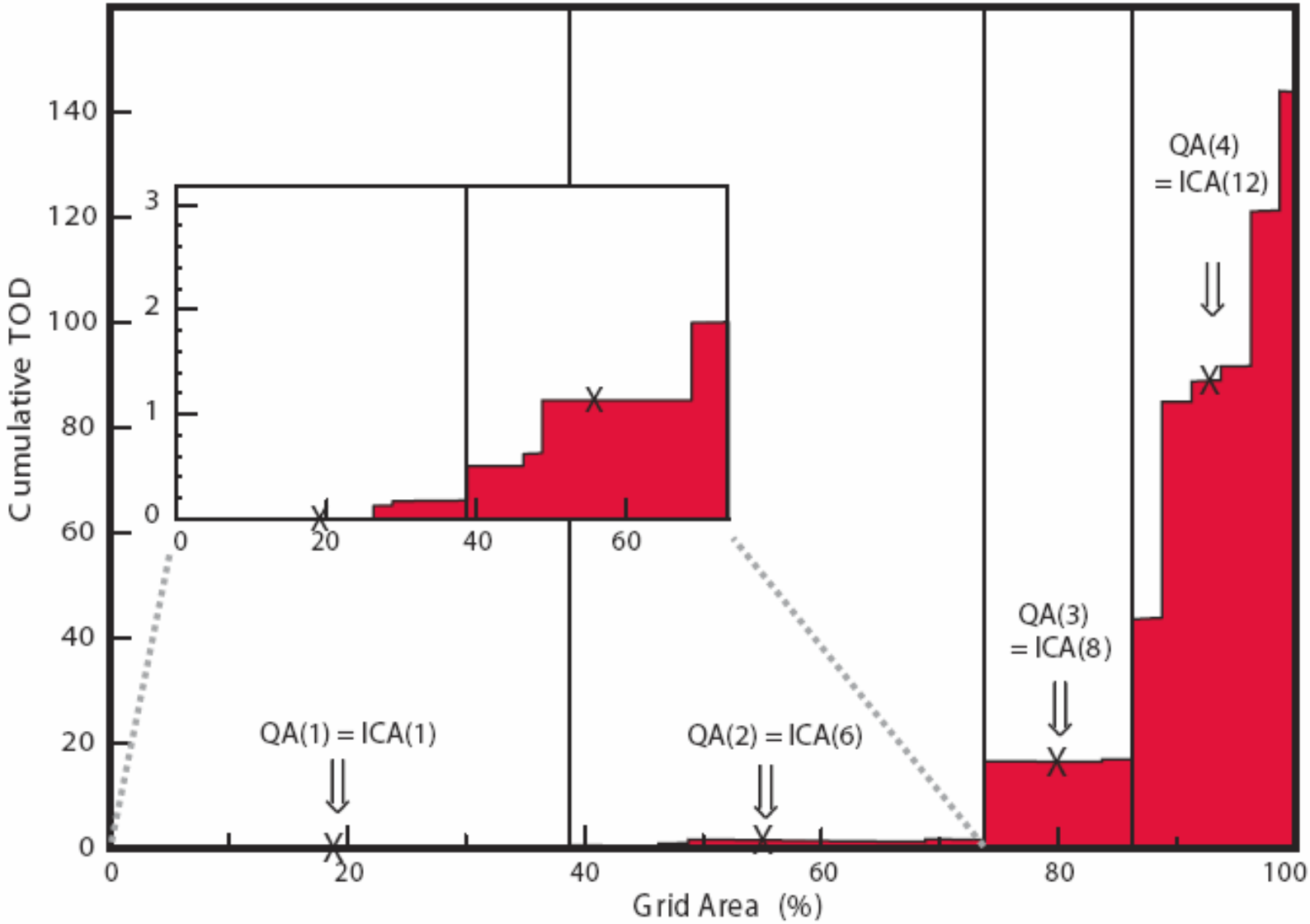


OD = cloud opt depth



CF-paper Fig. 7

assuming 0% threshold for separation = 2 groups = 15 ICAs, sort by TOD and generate the 4 QAs

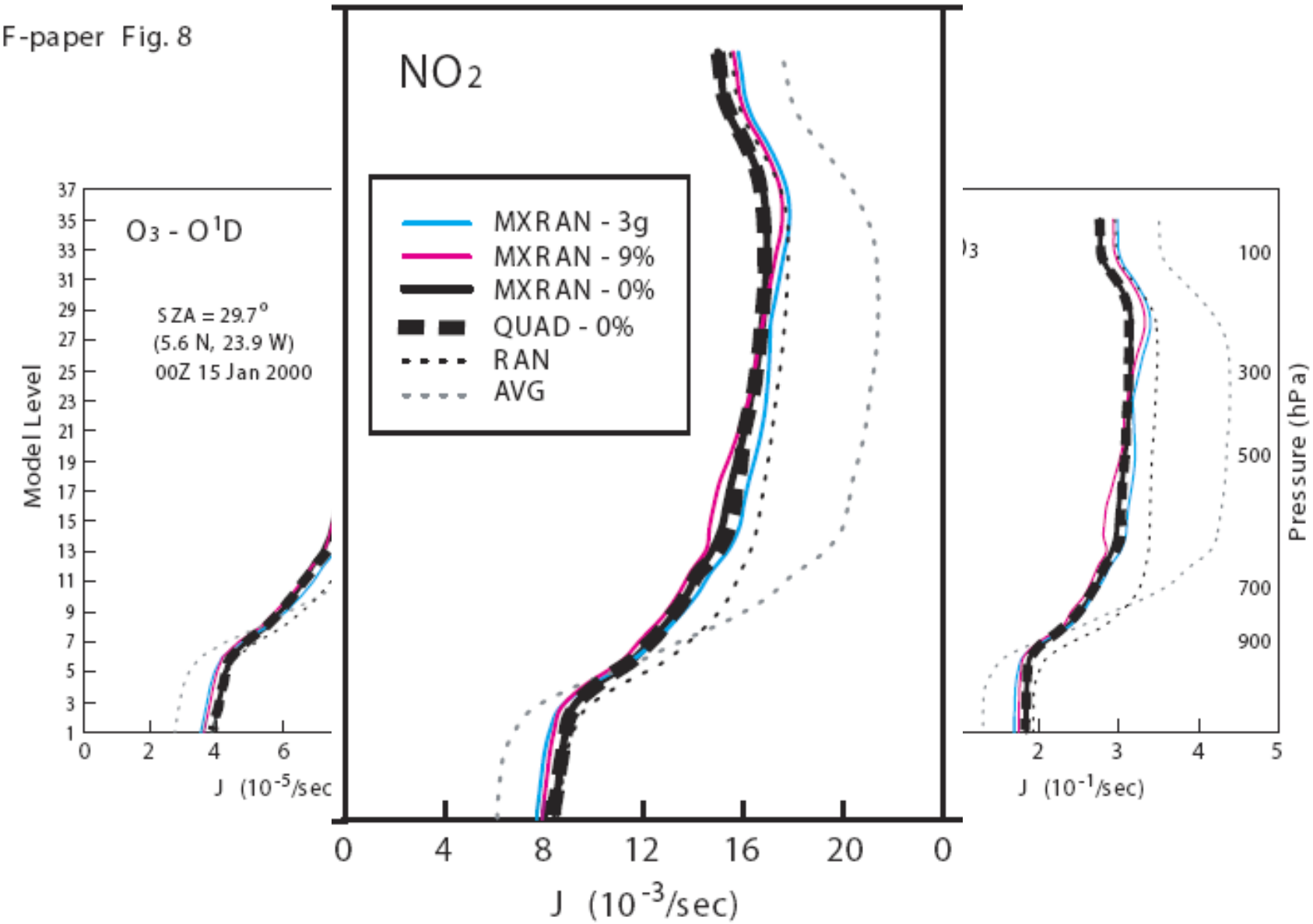


Calculate 3 key J values through the troposphere

$O_3 \rightarrow O(^1D)$	290-330 nm
NO_2	340-400 nm
NO_3	500-700 nm

truth#1	**0% threshold**	**15 ICAs**
truth#2	9% threshold	336 ICAs
truth#3	3 fixed groups	462 ICAs
approx:	LIN = linear avg (ODxCF)	1 ICA
approx:	RAN = max-ran ($ODxCF^{3/2}$)	1 ICA
quad#1:	from 0% threshold	4 ICAs
quad#2:	*from 9% threshold*	*4 ICAs*
quad#3	*from 3 fixed-grps*	*4 ICAs*

CF-paper Fig. 8



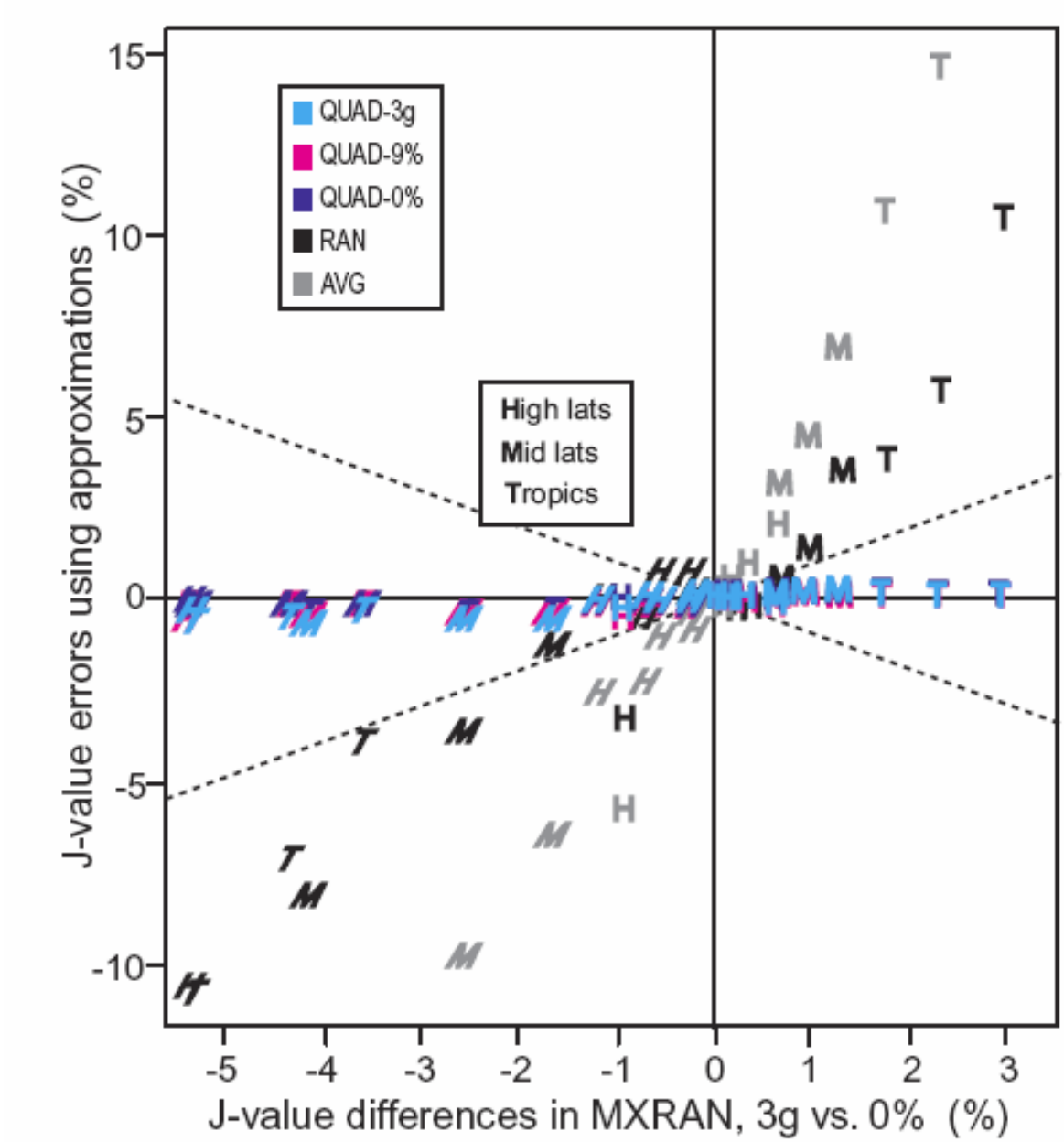
24-hr average J's: 15 Jan 2000, 00-24Z, 8 fields

RMS Error

		Group Diff 3g-0%	Group Diff 9%-0%	QUAD Err 3g	QUAD Err 9%	QUAD Err 0%	RAN Err	AVG Err
TROPICS	O_3-O^1D	2.6	0.9	3.2	2.3	1.5	5.6	13.7
	NO_2	3.1	1.1	3.1	2.2	1.5	7.0	16.8
	NO_3	3.7	1.4	3.3	2.4	1.6	11.3	22.4
MIDLATS	O_3-O^1D	1.1	0.2	2.4	1.6	1.4	2.2	5.0
	NO_2	1.6	0.3	2.6	1.8	1.6	3.3	6.9
	NO_3	2.3	0.4	3.3	2.4	2.1	6.4	10.9
N HIGH LATS	O_3-O^1D	0.2	0.0	0.9	0.7	0.6	0.5	0.6
	NO_2	0.4	0.1	1.8	1.4	1.2	0.9	1.5
	NO_3	3.2	0.5	7.8	6.7	6.2	9.2	12.6
S HIGH LATS	O_3-O^1D	0.2	0.0	0.7	0.5	0.4	0.6	0.8
	NO_2	0.4	0.1	0.8	0.5	0.5	0.6	1.3
	NO_3	0.8	0.1	1.1	0.8	0.7	1.3	2.5

24-hr average J's: 15 Jan 2000, 00-24Z, 8 fields

bias



24-hr average J's: 15 Jan 2000, 00-24Z, 8 fields

albedo errors

	UV-Vis Albedo (%)		Absolute Error (%)		
	MXRAN-3g	MXRAN-0%	QUAD 0%	RAN	AVG
TROPICS	**39**	**35**	**+0.0**	**+8.0**	**+18.8**
MIDLATS	**47**	**45**	**+0.1**	**+3.0**	**+8.2**
N HIGH LATS	**66**	**66**	**+0.2**	**+1.0**	**+2.2**
S HIGH LATS	**29**	**29**	**-0.1**	**-0.4**	**+1.6**

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D11305, doi:10.1029/2005JD006605, 2006

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►CTM transport errors & 2x-to-convergence

Global tropospheric ozone modeling: Quantifying errors due to grid resolution

Oliver Wild[1,2] and Michael J. Prather[3]

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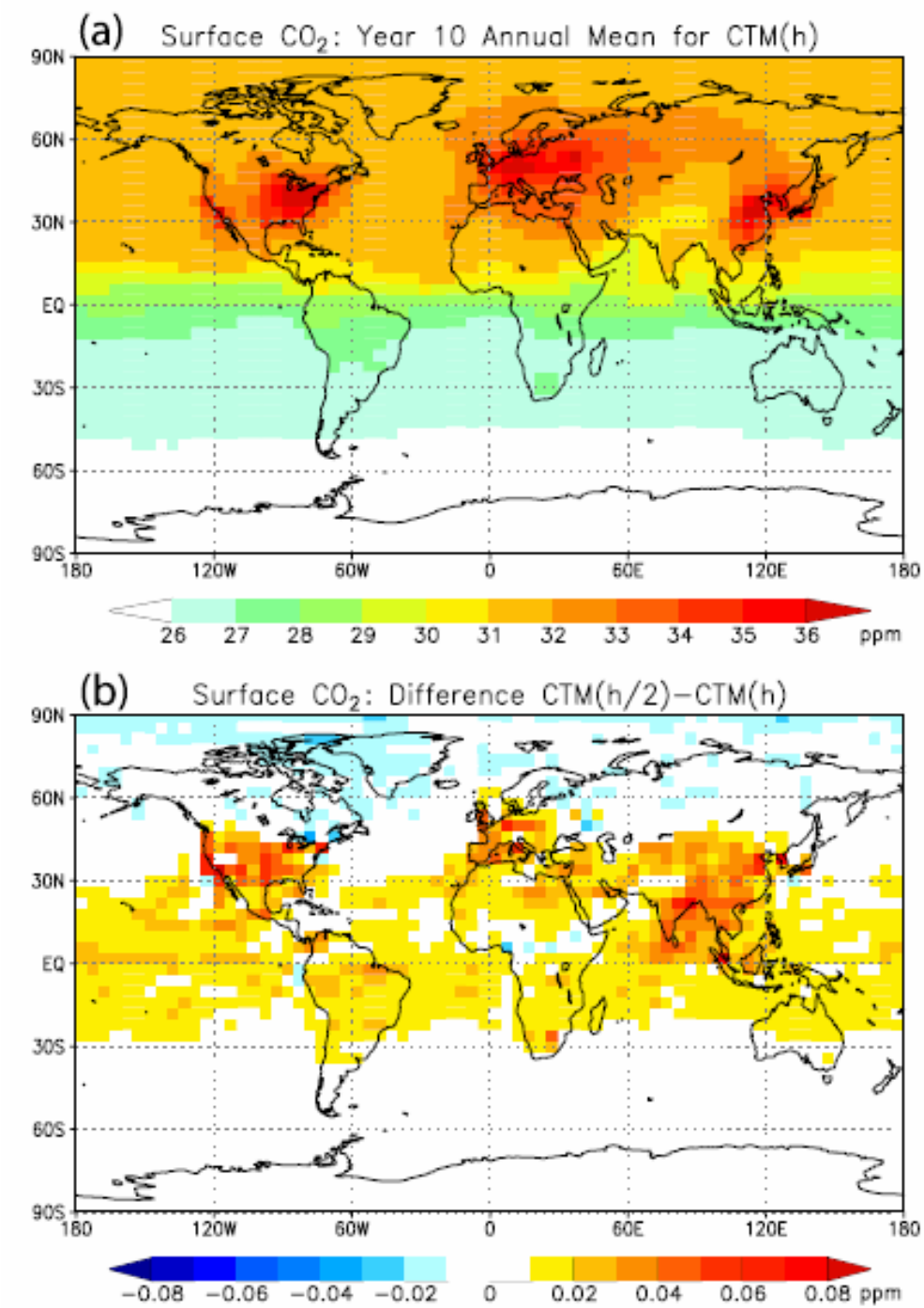
[1] Ozone production in global chemical models is dependent on model resolution because ozone chemistry is inherently nonlinear, the timescales for chemical production are short, and precursors are artificially distributed over the spatial scale of the model grid. In this study we examine the sensitivity of ozone, its precursors, and its production to resolution by running a global chemical transport model at four different resolutions between T21 (5.6° × 5.6°) and T106 (1.1° × 1.1°) and by quantifying the errors in regional and global budgets. The sensitivity to vertical mixing through the


(a)
Surface CO_2: Year 10 Annual Mean for CTM(h)
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
26
27
28
29
30
31
32
33
34
35
36
ppm
(b)
Surface CO_2: Difference CTM(h/2)−CTM(h)
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
−0.08
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08 ppm

ratio of successive corrections being the convergence factor, k.

$$C(h_0) = C(h) + (C(h/2) - C(h)) + (C(h/4) - C(h/2)) + (C(h/8) - C(h/4)) + \ldots$$

$$k = (C(h/4) - C(h/2))/(C(h/2) - C(h)) = (C(h/8) - C(h/4))/(C(h/4) - C(h/2)) < 1$$

$$C(h_0) = C(h) + (C(h/2) - \quad = C(h) + (C(h/2) -$$

[15] Thus all that is ne answer, and hence the nu doubled resolution simul particularly extensive con the value of k is a global r geometrically converging l lated k's.

$$k_{124} = (C(h/4) - C$$
$$k_{248} = (C(h/8) - C$$

[16] The CTM was reco of resolution. The original G1), was doubled to 144 × (G4), and 576 × 354 ×

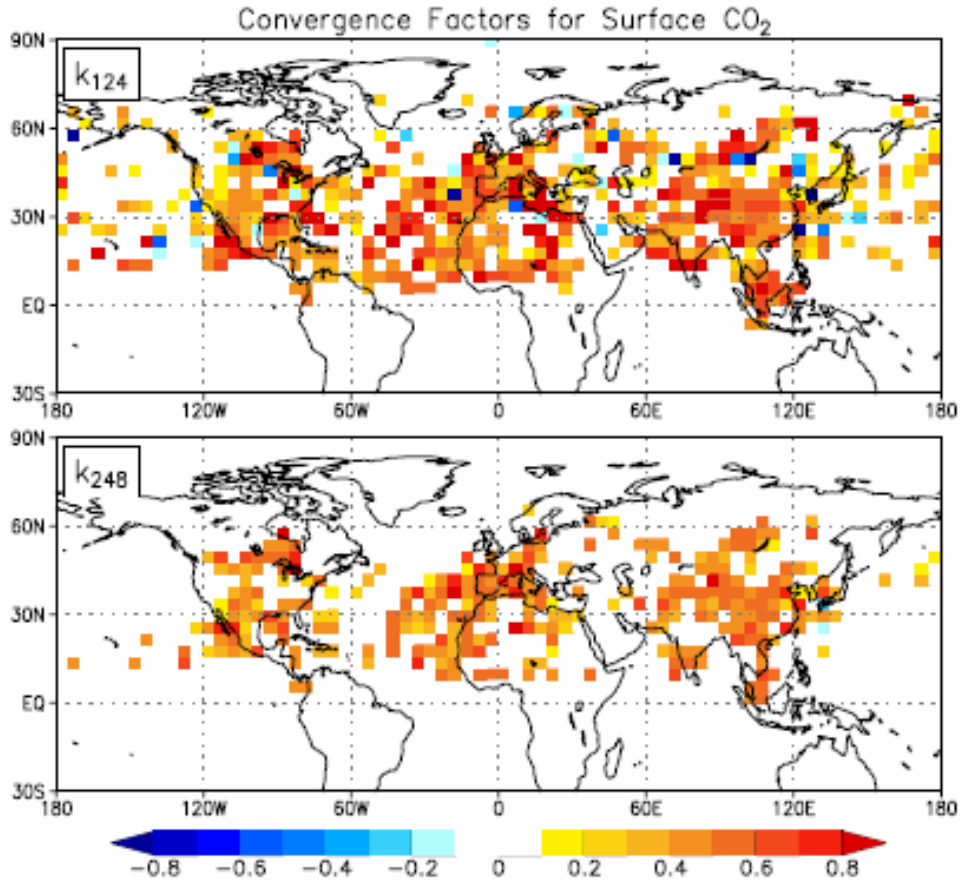


Figure 2. Convergence factors, k, for the 1–2–4 and 2–4–8 sequences of doubled resolution CTM

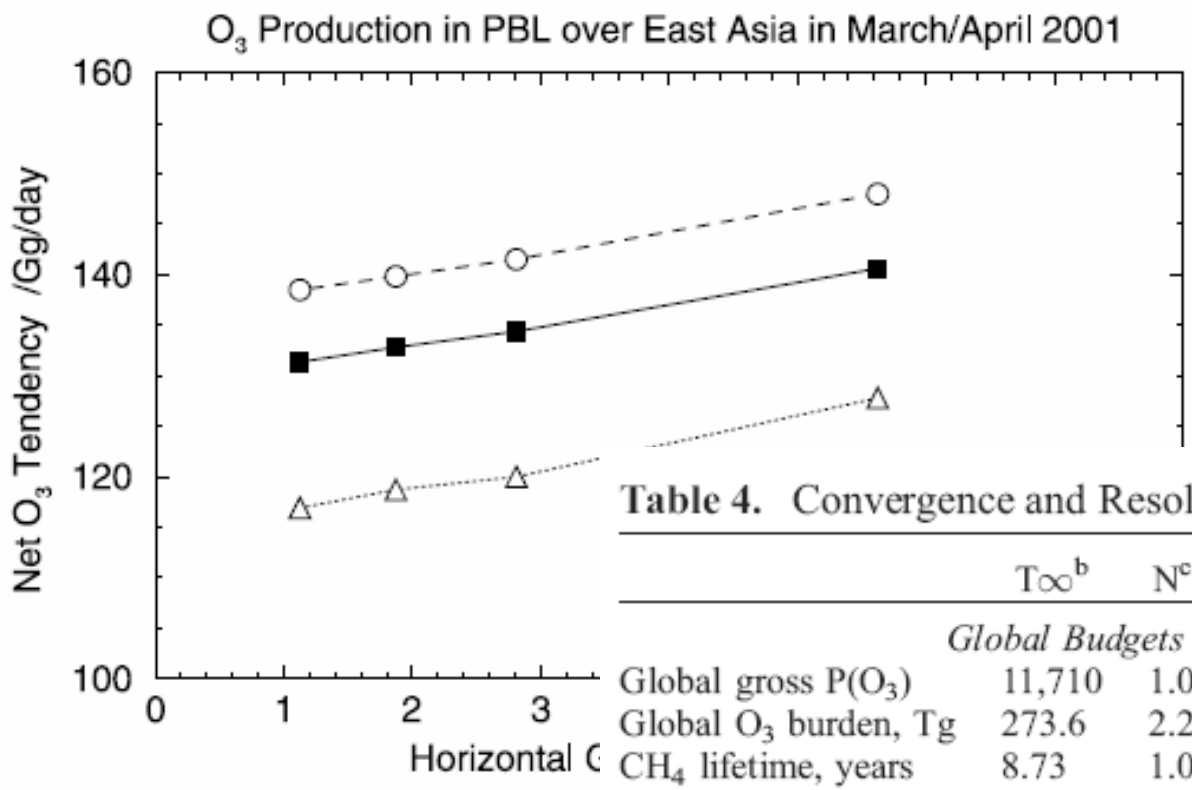


Table 4. Convergence and Resolution Errors in Oxidant Budgets[a]

	$T\infty$[b]	N[c]	ε_{21}[d]	ε_{42}	ε_{63}	ε_{106}
Global Budgets (From Table 2)						
Global gross $P(O_3)$	11,710	1.0	578	422	335	169
Global O_3 burden, Tg	273.6	2.2	20.2	10.0	4.1	1.3
CH_4 lifetime, years	8.73	1.0	−0.67	−0.41	−0.29	−0.16
Impacts of East Asian Emissions (From Table 3)						
Regional net $P(O_3)$	43.0	1.0	15.8	6.2	4.3	2.5
Regional gross $P(O_3)$	84.1	1.8	18.0	6.2	4.5	2.5
Regional O_3 burden	20.8	2.9	6.6	1.4	0.3	0.1
Global gross $P(O_3)$	210.4	2.3	20.6	12.8	5.0	1.5
Global O_3 burden	49.6	2.1	6.6	3.4	1.4	0.5

[a]Budgets in Gg/day and burdens in Gg unless stated.
[b]Corrected budget based on T42–T63–T106 convergence.
[c]Order N used in Richardson Extrapolation.
[d]Estimated error at each resolution, ε_{21} = T21-T∞.

10-yr runs for Trop. CO_2

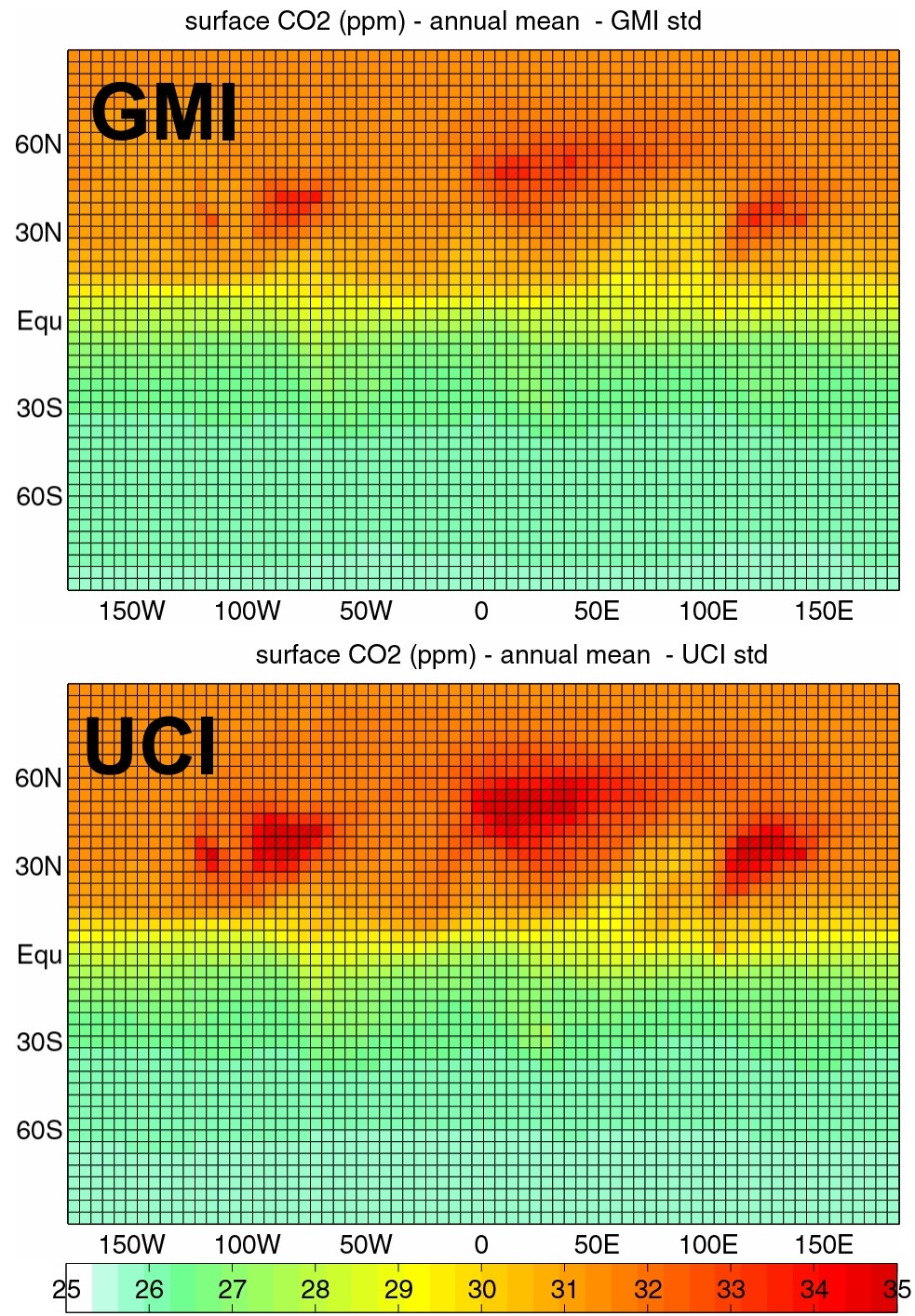
(circa 2004)

surface CO_2 mixing ratio

annual/monthly means from Yr 10

GMI appears more "diffusive"
UCI retains higher abundances
over source regions.

N.B. model 4x5 grid shown



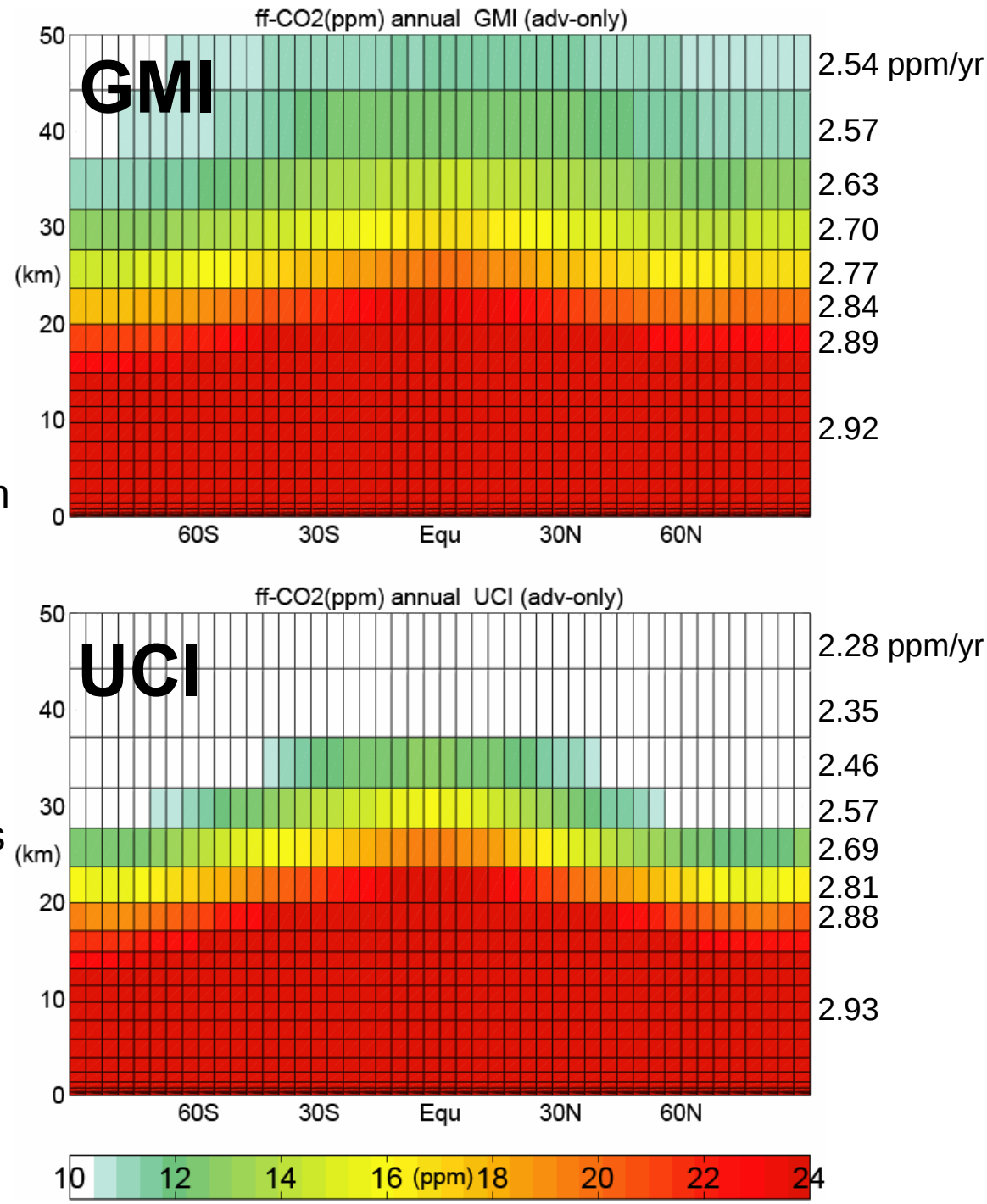
10-yr runs for Stratospheric CO_2

(circa 2004)

zonal mean CO_2 mixing ratio
annual average of Year 10
actual model grid shown.

approach to steady-state shown
as growth in Yr10

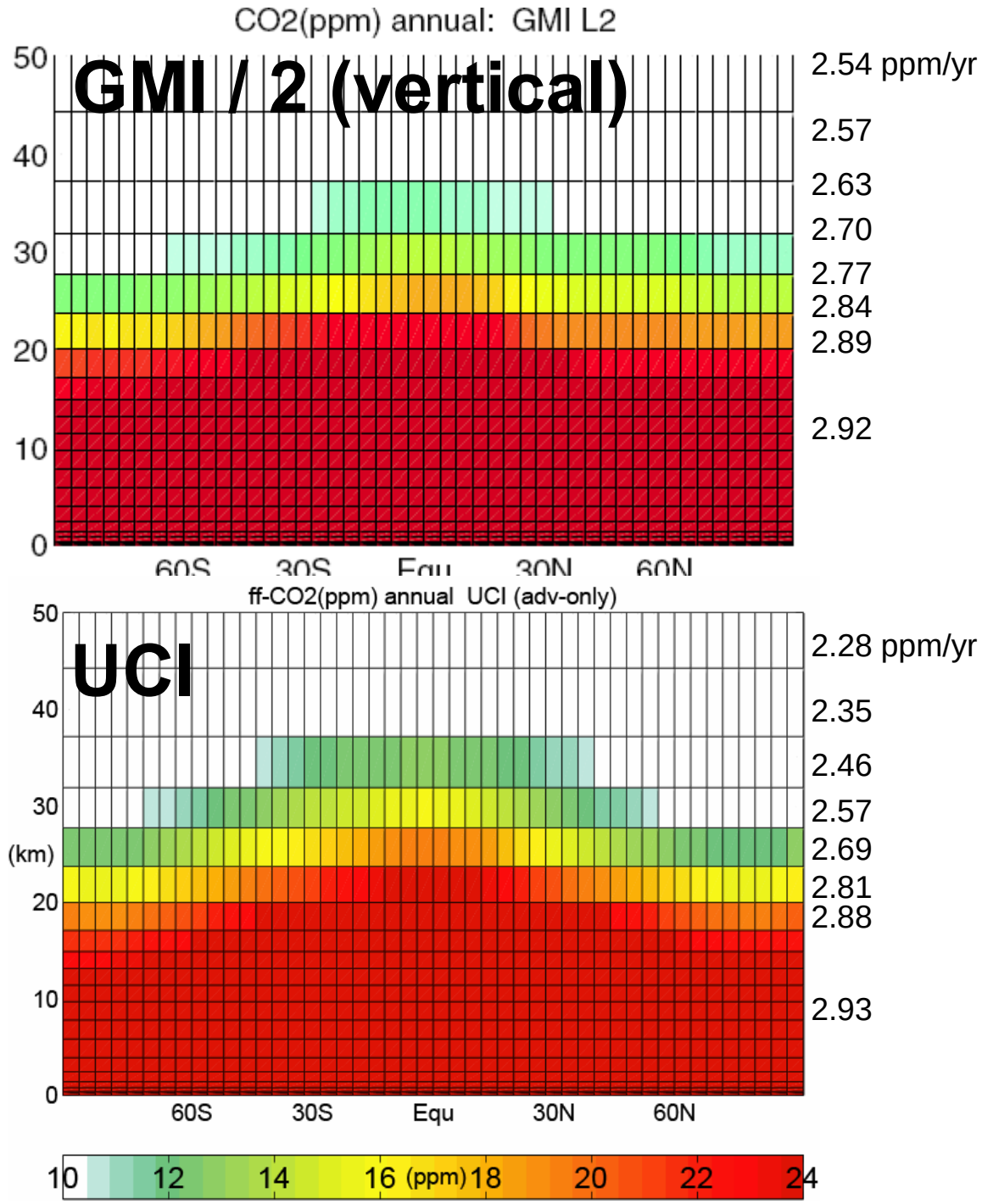
GMI vs. UCI (adv-only)
- GMI is more “diffusive”
- UCI is still 24% away from s-s



10-yr runs for Stratospheric CO_2

OCTOBER 2005 !!!

Vertical looks much better, but need Horizontal doubling, too much horizontal diffusion



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►validation of met fields T & q

Ozone, water vapor, and temperature in the upper tropical troposphere: Variations over a decade of MOZAIC measurements

Sarah E. Bortz,[1] Michael J. Prather,[1] Jean-Pierre Cammas,[2] Valérie Thouret,[2] and Herman Smit[3]

Received 19 July 2005; revised 16 September 2005; accepted 7 November 2005; published 3 March 2006.

Longitudinal Distribution
of MOZAIC cruise level data

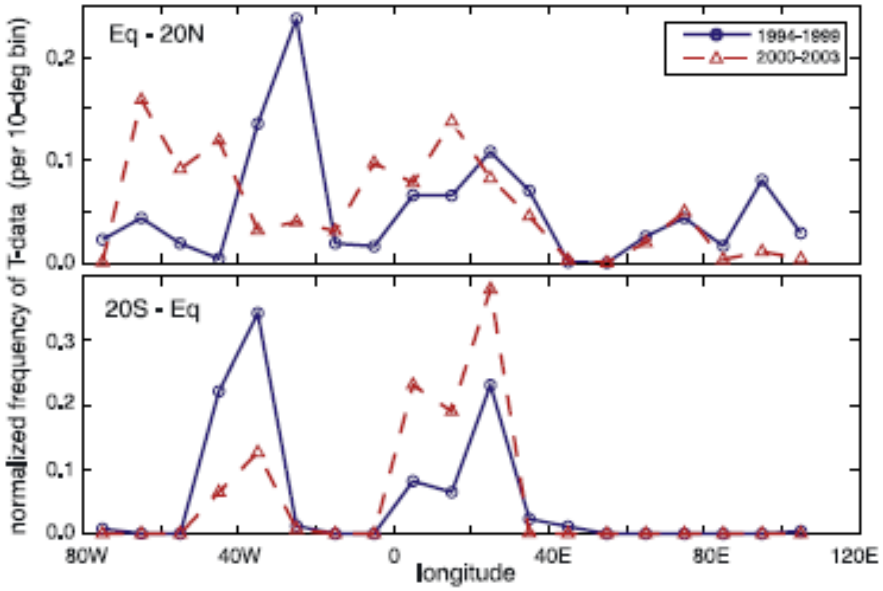


Figure 1. Normalized longitudinal distribution of MOZAIC temperature data at cruise levels in the North (upper panel, 0–20°N) and South Tropics (lower, 0–20°S) during 1994–1999 (solid, blue circles) and 2000–2003 (dashed, red triangles).

Upper Trop Ozone trend in tropics

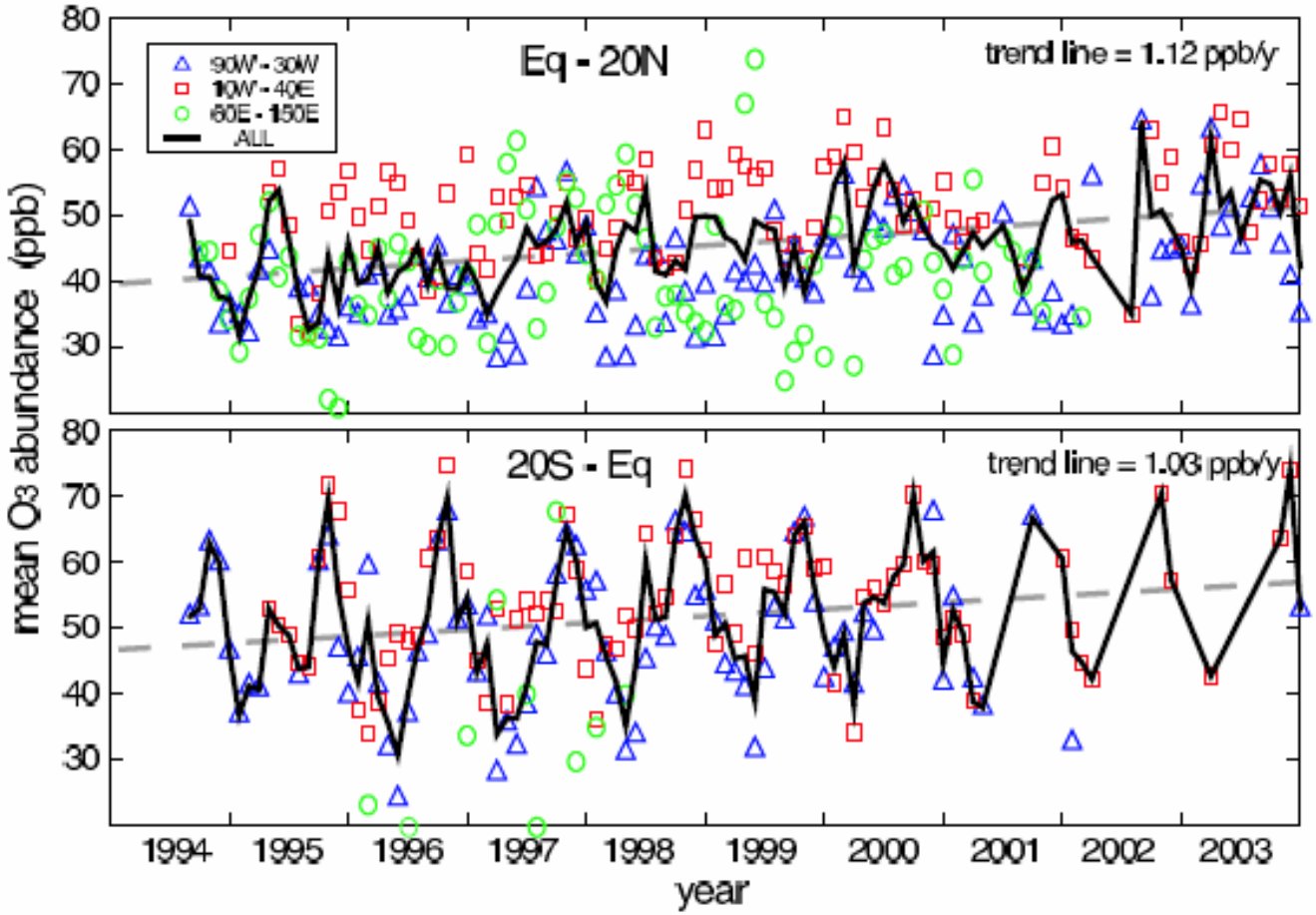
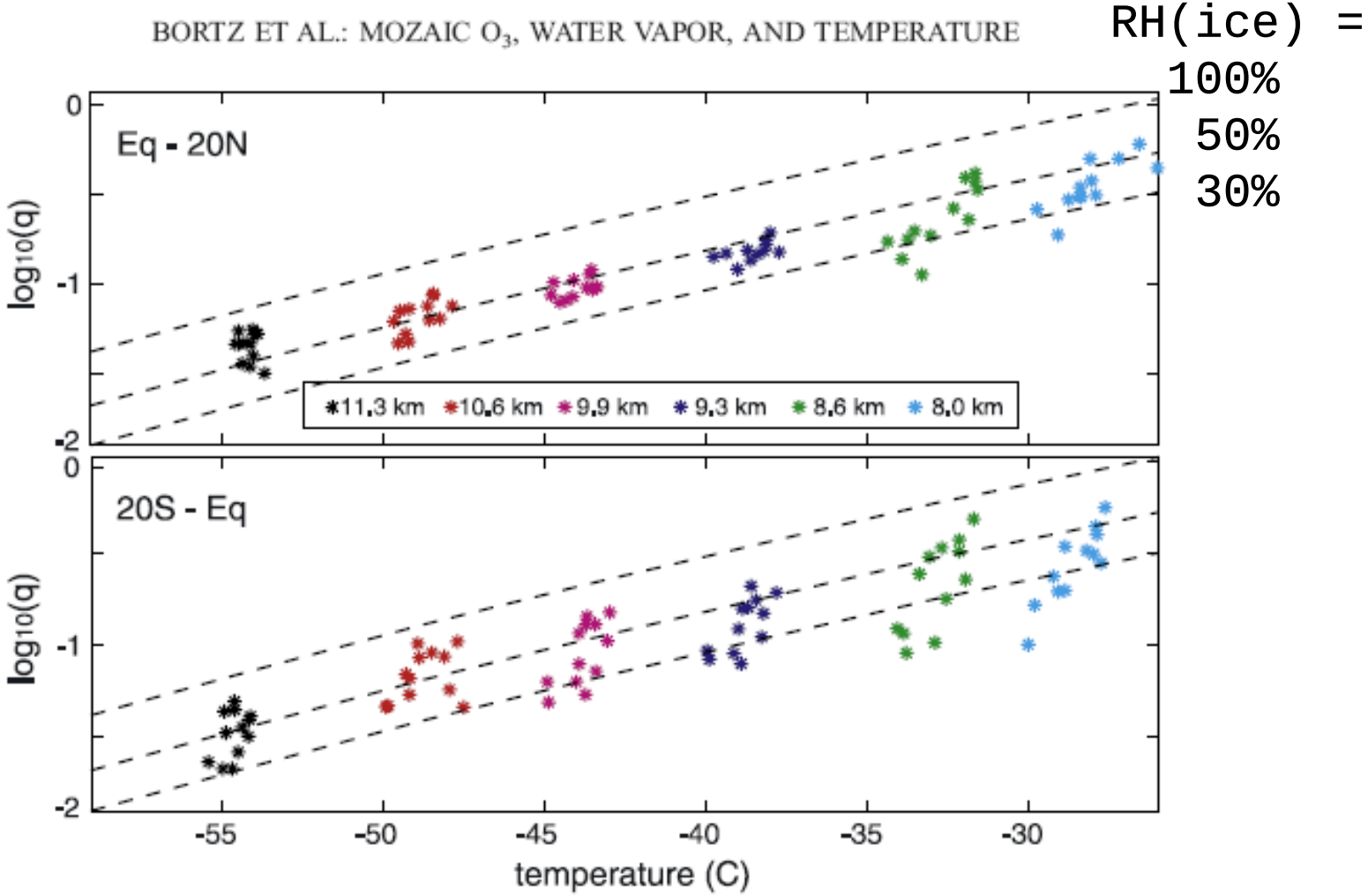


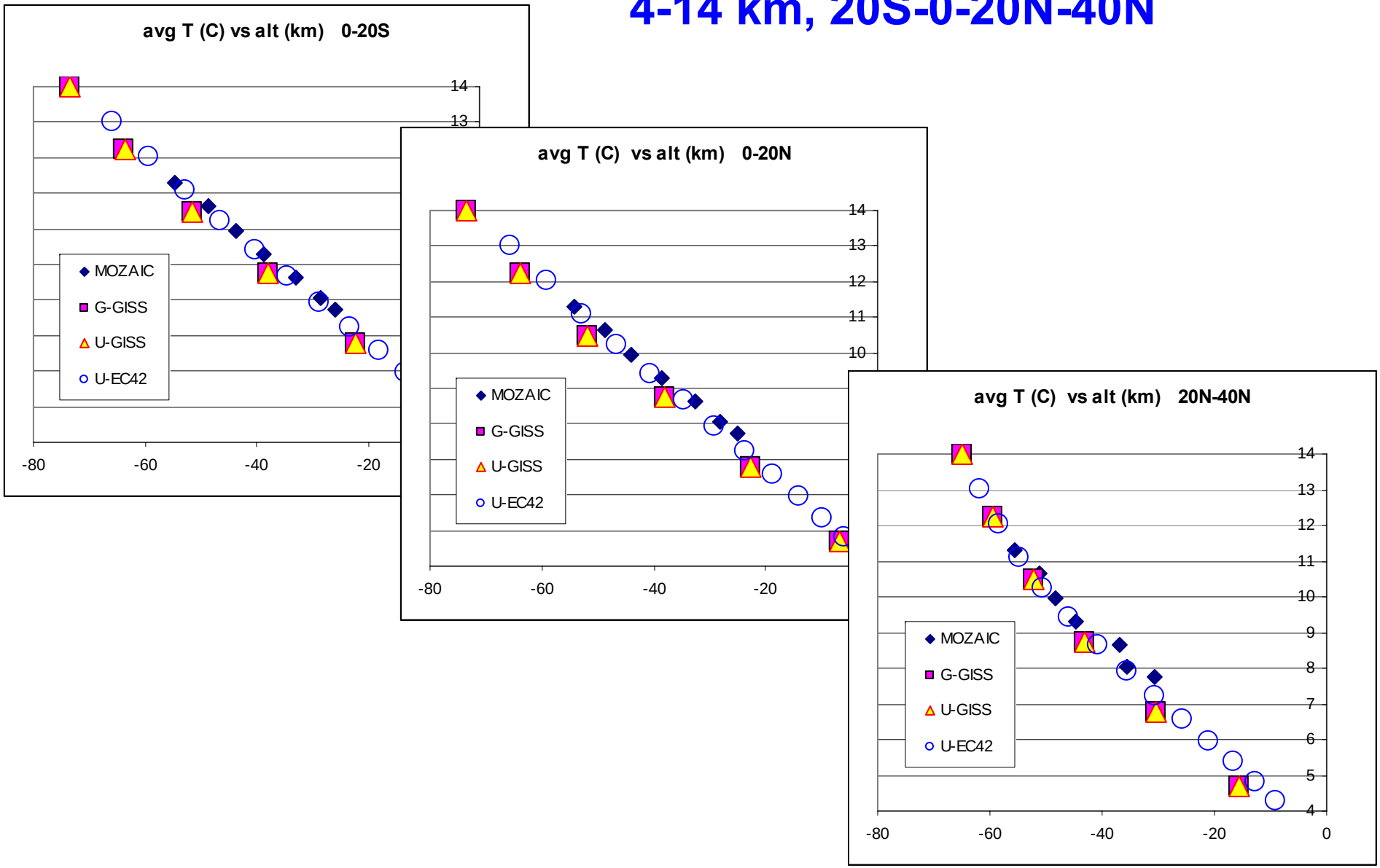
Figure 5. Monthly mean O_3 mole fraction (ppb) averaged over MOZAIC cruise levels for the perio

►validation of met fields T & q



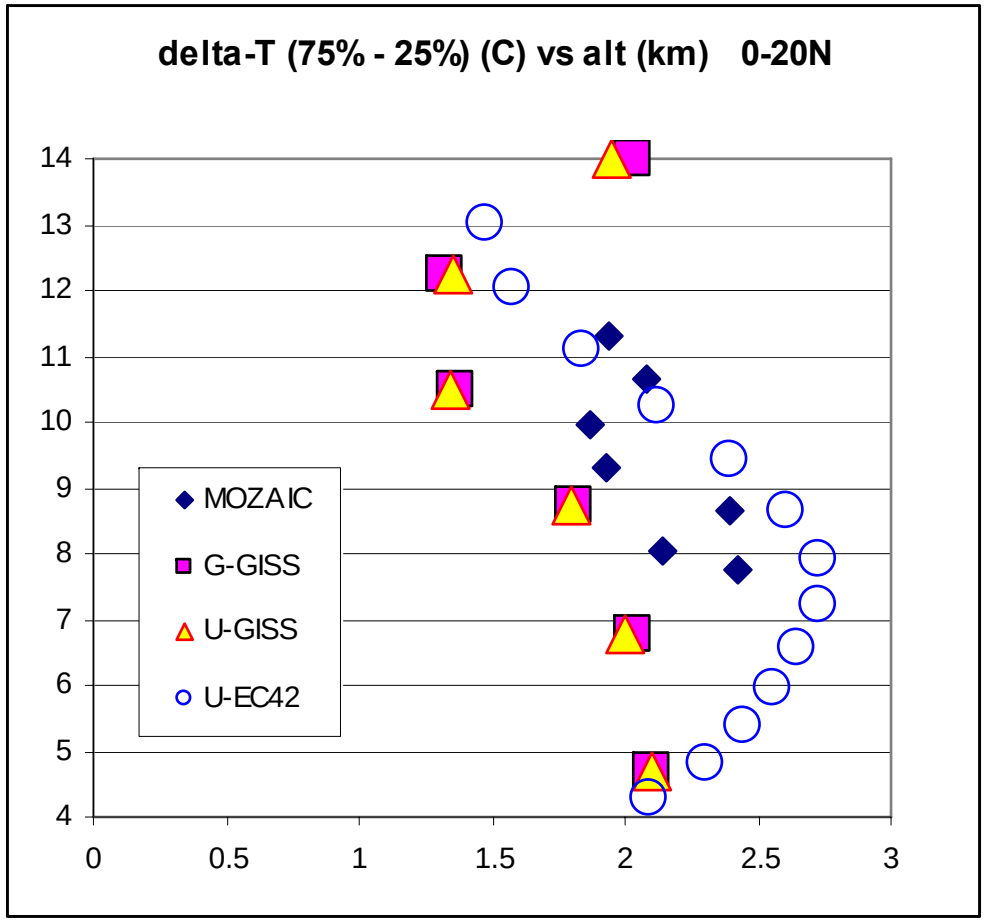
re 3. Mean seasonal cycle of $\log_{10}$(q, in g/kg) versus T (°C) at the upper six MOZAIC cruise levels

►validation of met fields T & q:
4-14 km, 20S-0-20N-40N



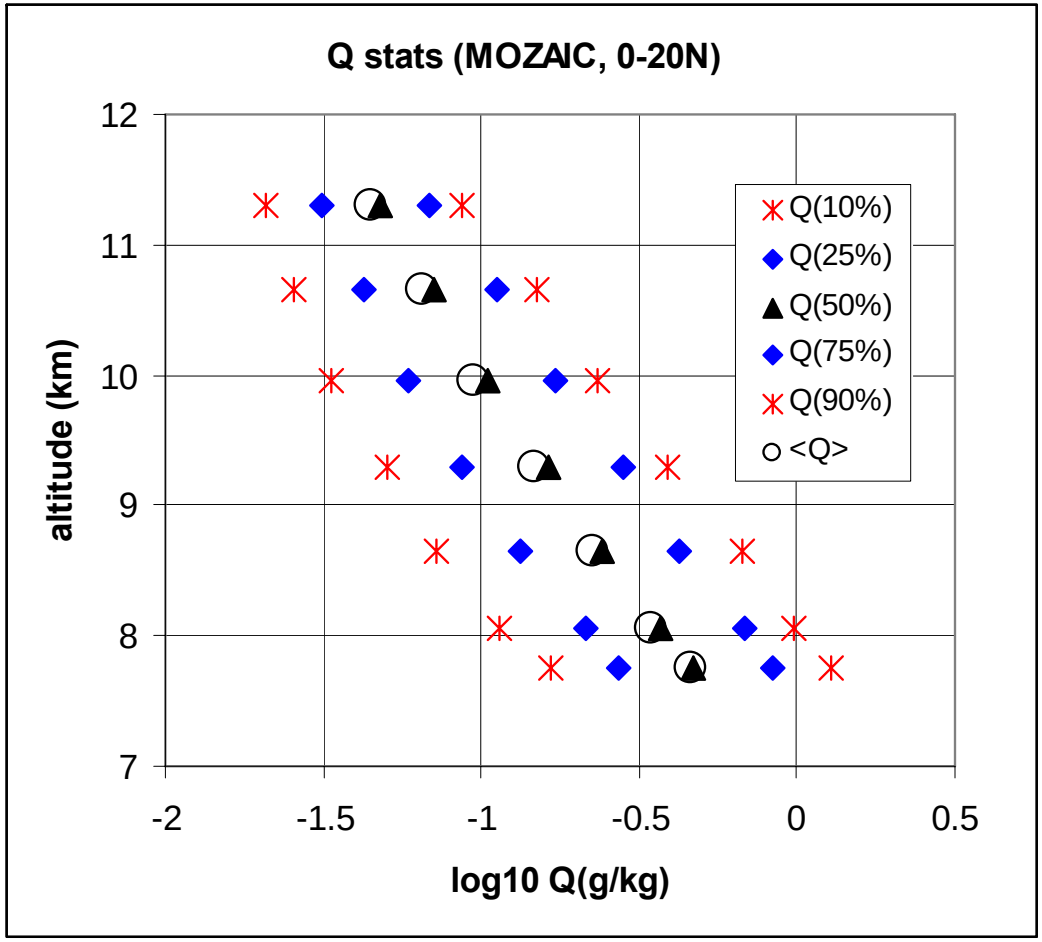
►validation of met fields T & q

look at stats: T(75%) – T(25%)



►validation of met fields T & q

q-stats from met fields corrupted.



►fast-JX aerosol parameters (UMich)

Minghuai Wang (minghuai@umich.edu)

Aerosol optical properties for sulfate, internal mixed fossil fuel aerosol, internal mixed biomass burning aerosol, dust, and sea salt

21 **1. sulfate**

so4_0_XX%.dat: aerosol opitcal properties for sulfate aerosol at relative humidity = XX% = {0, 5, 10, 15, …, 100%}

168 **2. internal mixed fossil fuel aerosol(sulfate, BC and OC):**

ffi0c.RHXX.r0YY.dat: aerosol opitcal properties for internal mixed fossil fuel aerosol at relative humidity = XX% and at BC fraction = YY%

336 **3. internal mixed biomass burning aerosol (BC and OC):**

bio0c.RHXX.r0YY.dat: aerosol opitcal properties for internal mixed biomass burning aerosol at relative humidity = XX% and at BC fraction=YY%

4 **4. mineral dust:**

dust_aop.r0.05to0.63.dat: size bin 1 (r: 0.05-0.63um)
dust_aop.r0.63to1.26.dat: size bin 2 (r: 0.63-1.25um)
dust_aop.r1.26to2.5.dat: size bin 3 (r: 1.26-2.5um)
dust_aop.r2.5to10.dat: size bin 4 (r: 2.5-10um)

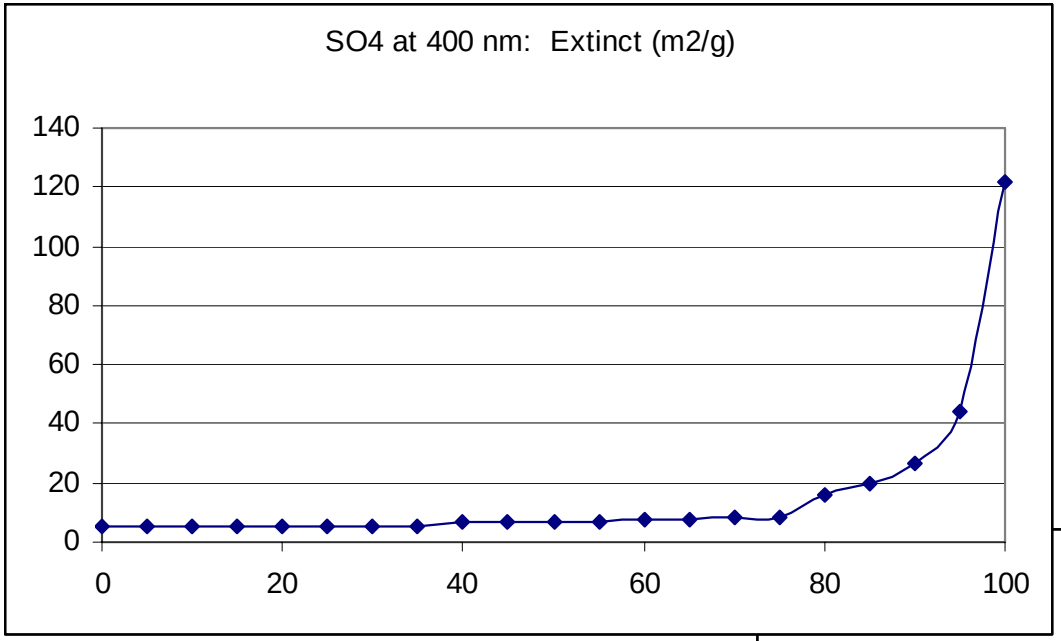
4 **5. sea salt:**

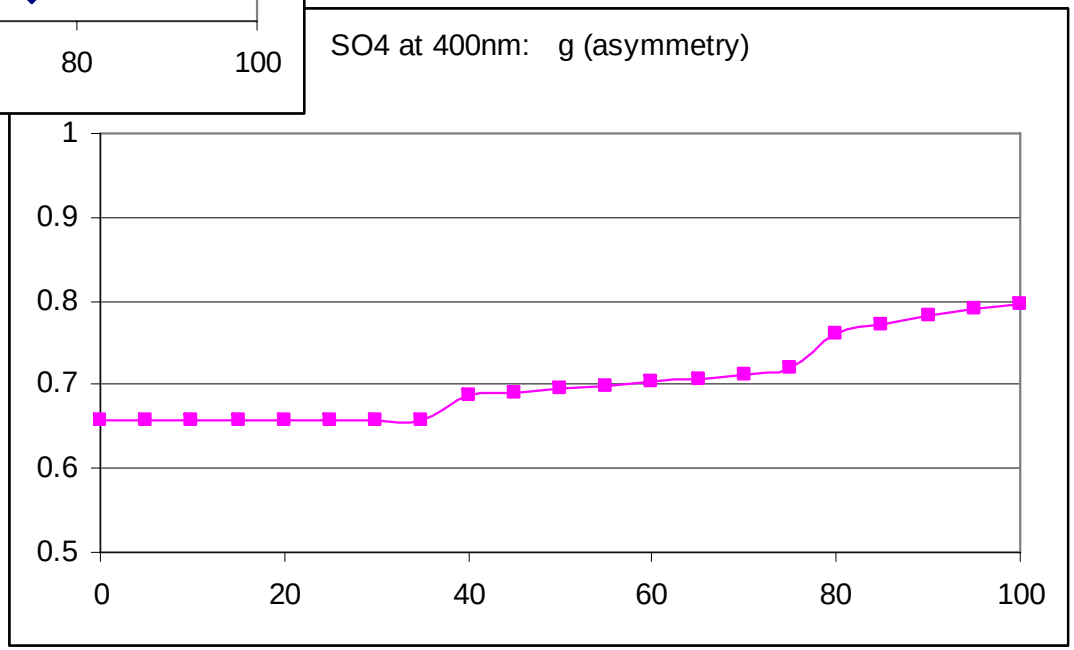
ss_aop.r0.05to0.63.dat: size bin 1 (r: 0.05-0.63um)
ss_aop.r0.63to1.26.dat: size bin 2 (r: 0.63-1.25um)
ss_aop.r1.26to2.50.dat: size bin 3 (r: 1.26-2.5um)
ss_aop.r2.50to10.dat: size bin 4 (r: 2.5-10um)

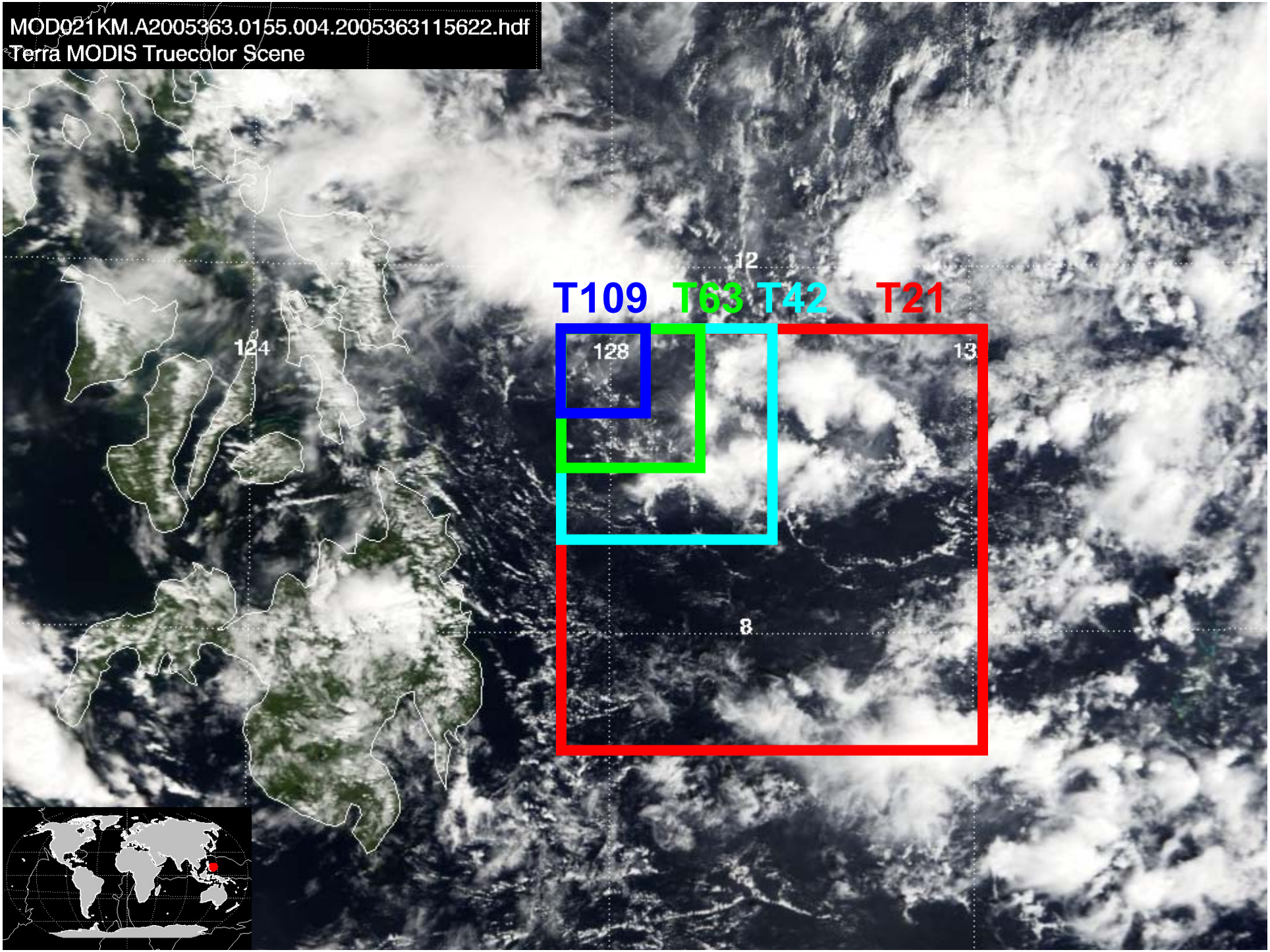
►fast-JX aerosol parameters (UMich)

```
 w    ?Q?    R-eff   SSA    Leg P - P0:P7
 so4_0_00%.dat
  300  6.8842  0.000  1.0000  1.000 2.015 2.256 2.122 1.833 1.505 1.195 0.926
  400  5.3066  0.000  1.0000  1.000 1.970 2.155 1.981 1.673 1.342 1.042 0.789
  600  3.0580  0.000  1.0000  1.000 1.853 1.909 1.651 1.311 0.990 0.723 0.515
 1000  1.0553  0.000  1.0000  1.000 1.622 1.462 1.106 0.769 0.508 0.325 0.203
 so4_0_05%.dat
  300  6.8842  0.000  1.0000  1.000 2.015 2.256 2.122 1.833 1.505 1.195 0.926
  400  5.3066  0.000  1.0000  1.000 1.970 2.155 1.981 1.673 1.342 1.042 0.789
  600  3.0580  0.000  1.0000  1.000 1.853 1.909 1.651 1.311 0.990 0.723 0.515
 1000  1.0553  0.000  1.0000  1.000 1.622 1.462 1.106 0.769 0.508 0.325 0.203
. . .
so4_0_60%.dat
  300  9.5158  0.000  1.0000  1.000 2.143 2.550 2.550 2.342 2.044 1.725 1.422
  400  7.4057  0.000  1.0000  1.000 2.108 2.469 2.429 2.195 1.885 1.566 1.269
  600  4.3582  0.000  1.0000  1.000 1.999 2.219 2.070 1.773 1.443 1.137 0.874
 1000  1.5950  0.000  1.0000  1.000 1.763 1.726 1.420 1.073 0.770 0.535 0.363
. . .
so4_0_95%.dat
  300 47.6711  0.000  1.0000  1.000 2.350 3.068 3.364 3.388 3.243 3.002 2.713
  400 43.7619  0.000  1.0000  1.000 2.376 3.136 3.477 3.540 3.427 3.207 2.931
  600 33.1890  0.000  1.0000  1.000 2.358 3.089 3.399 3.435 3.300 3.065 2.780
 1000 17.6353  0.000  1.0000  1.000 2.240 2.789 2.915 2.799 2.555 2.255 1.943
 so4_0_99%.dat
  300119.0841  0.000  1.0000  1.000 2.361 3.096 3.411 3.451 3.320 3.087 2.803
  400121.5463  0.000  1.0000  1.000 2.388 3.169 3.531 3.614 3.517 3.309 3.039
  600113.3539  0.000  1.0000  1.000 2.415 3.240 3.651 3.779 3.718 3.537 3.285
 1000 81.9287  0.000  1.0000  1.000 2.389 3.170 3.533 3.617 3.520 3.312 3.043
```

►fast-JX aerosol parameters (UMich)



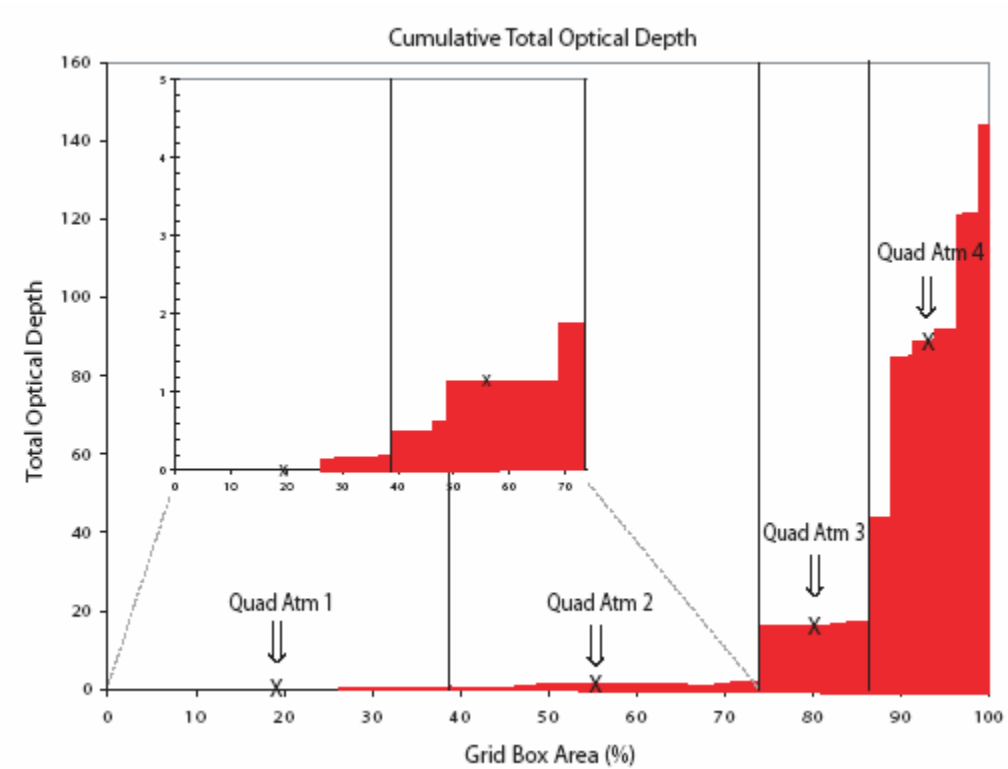


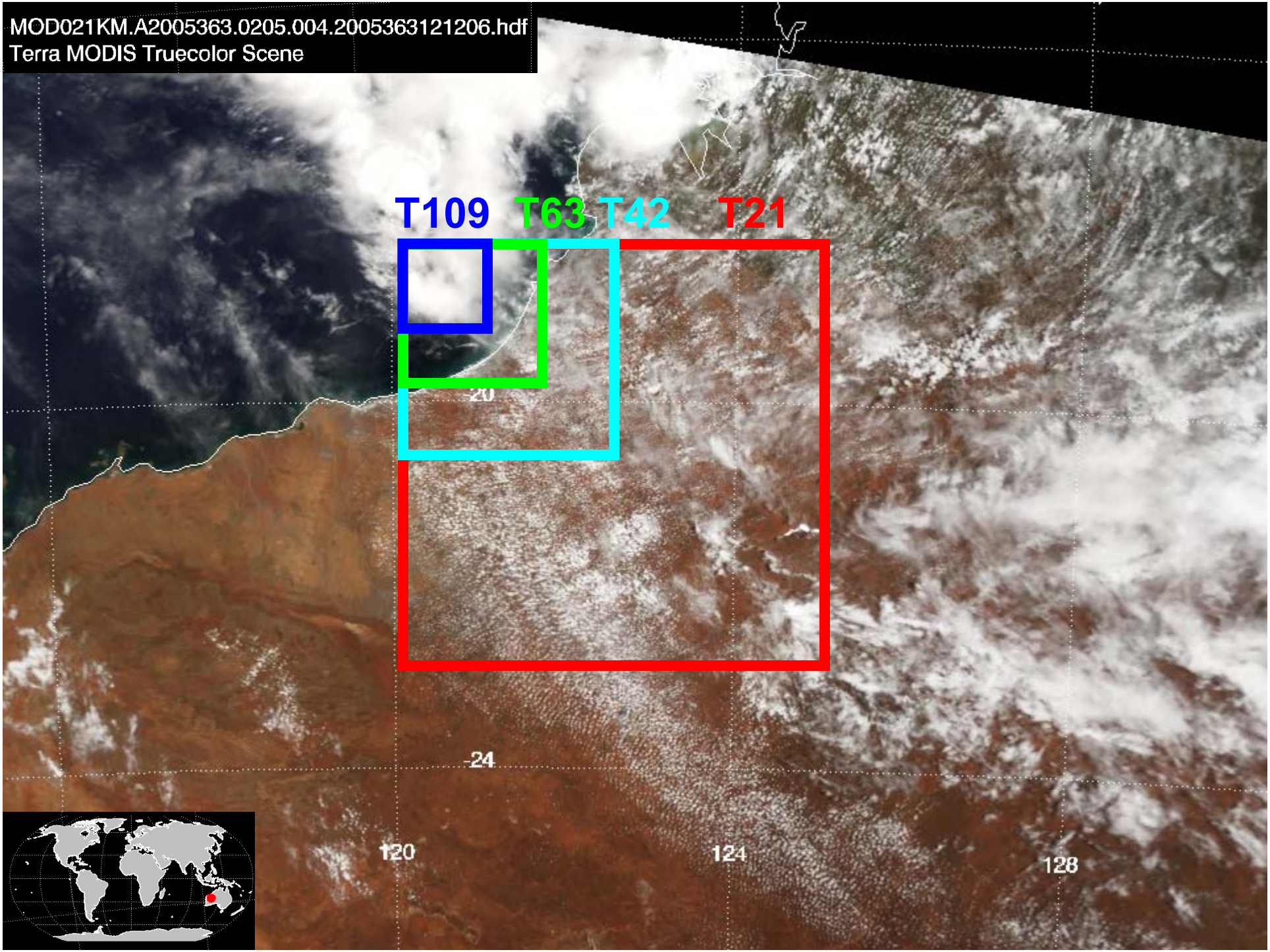

MOD021KM.A2005363.0155.004.2005363115622.hdf
Terra MODIS Truecolor Scene
T109
T63
T42
T21
12
124
128
13
8

Cloud Fraction and fast-JX – what is next ?

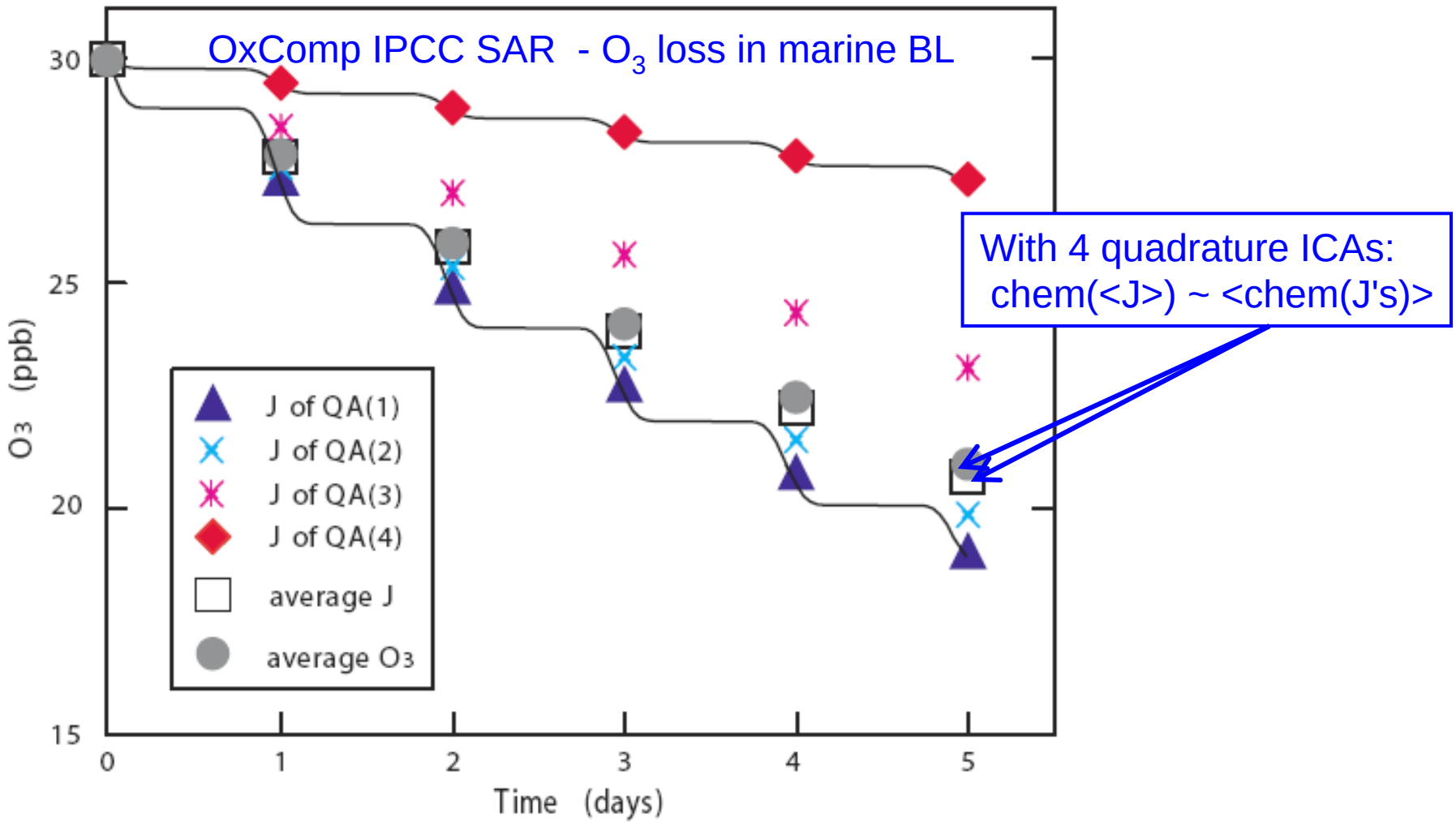
- ►**implement self-consistent J's and heating rates**
- ►**model validation of cloud cover**
- ►**cloud chemistry with quadrature**

Our distribution of Total Optical Depth generated from the fractional cloud cover *and* the assumptions about overlap should be testable ?



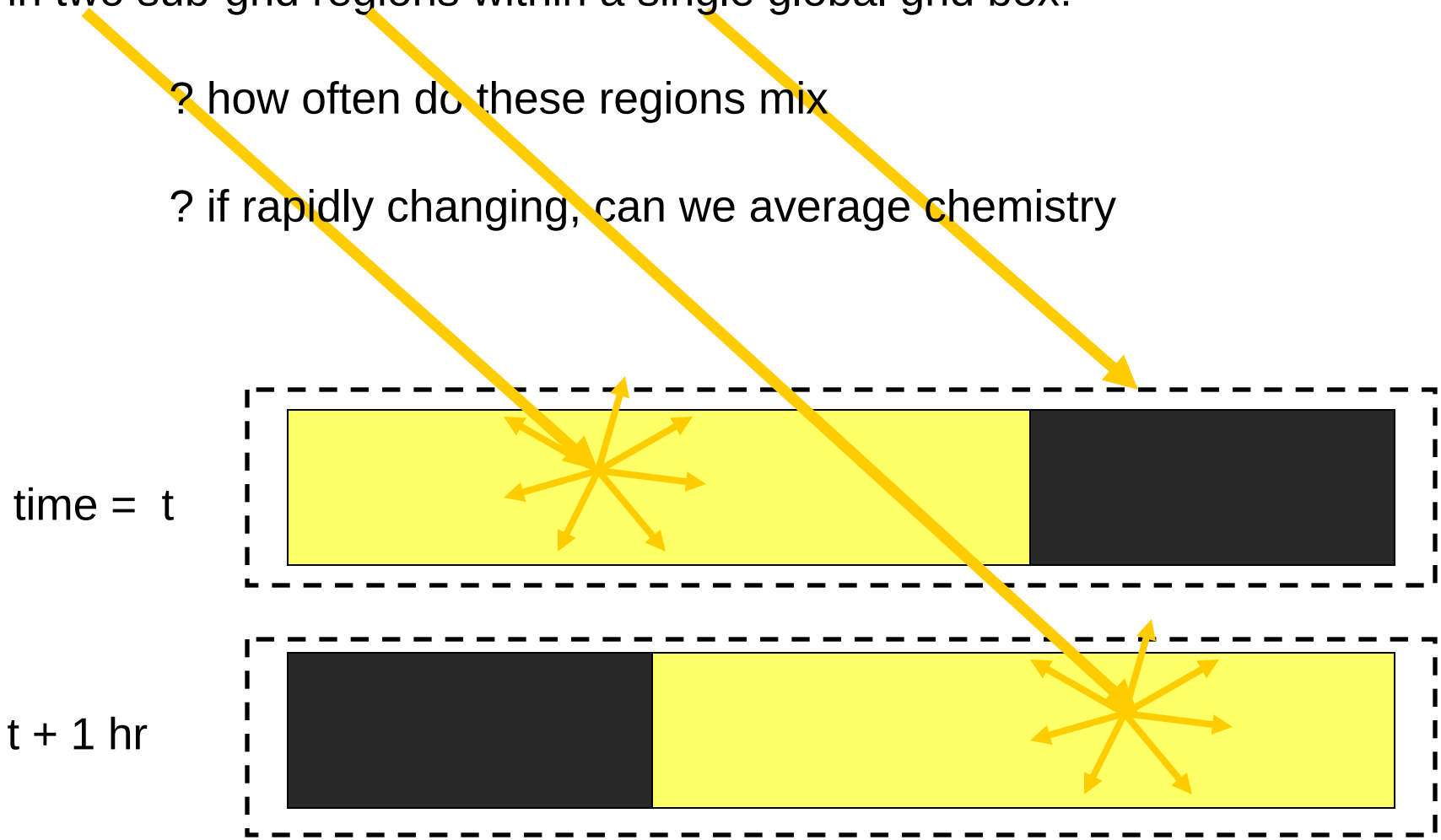

MOD021KM.A2005363.0205.004.2005363121206.hdf
Terra MODIS Truecolor Scene
T109
T63
T42
T21
-20
-24
120
124
128

? the chemistry of the average conditions (J's, cloud chem)
= the average of the chemistry for each ICA ?



Photochemistry in a real (3-D) world

There is no clear formalism for treating different non-linear chemistry in two sub-grid regions within a single global grid box:

? how often do these regions mix

? if rapidly changing, can we average chemistry