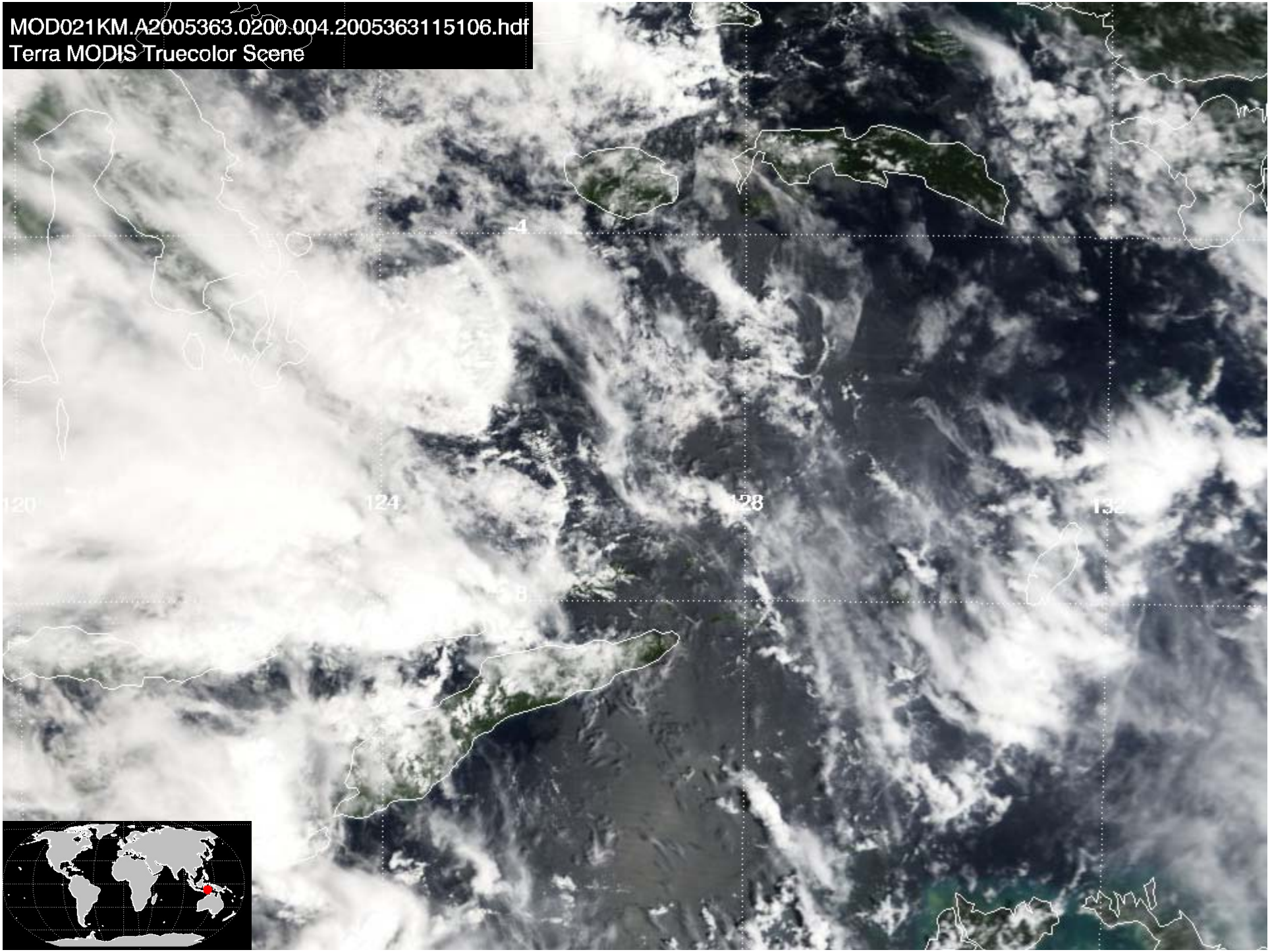

MOD021KM.A2005363.0200.004.2005363115106.hdf
Terra MODIS Truecolor Scene
4
120
124
128
8

GMI Science Team Meeting
11-13 Jan 2006 Georgia Tech

Michael Prather
U.S. Department of State, 2201 C St NW

~~► new STE O_3 diagnostics w/ Linoz (*JGR 2005*)~~

~~► incorporating fractional cloud cover in CTMs~~

~~► model validation of cloud cover (?)~~

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

GMI Science Team Meeting
11-13 Jan 2006 Georgia Tech

Michael Prather
UC Irvine

►new STE O_3 diagnostics w/ Linoz (*JGR 2005*)
Juno Hsu, Prather & Oliver Wild

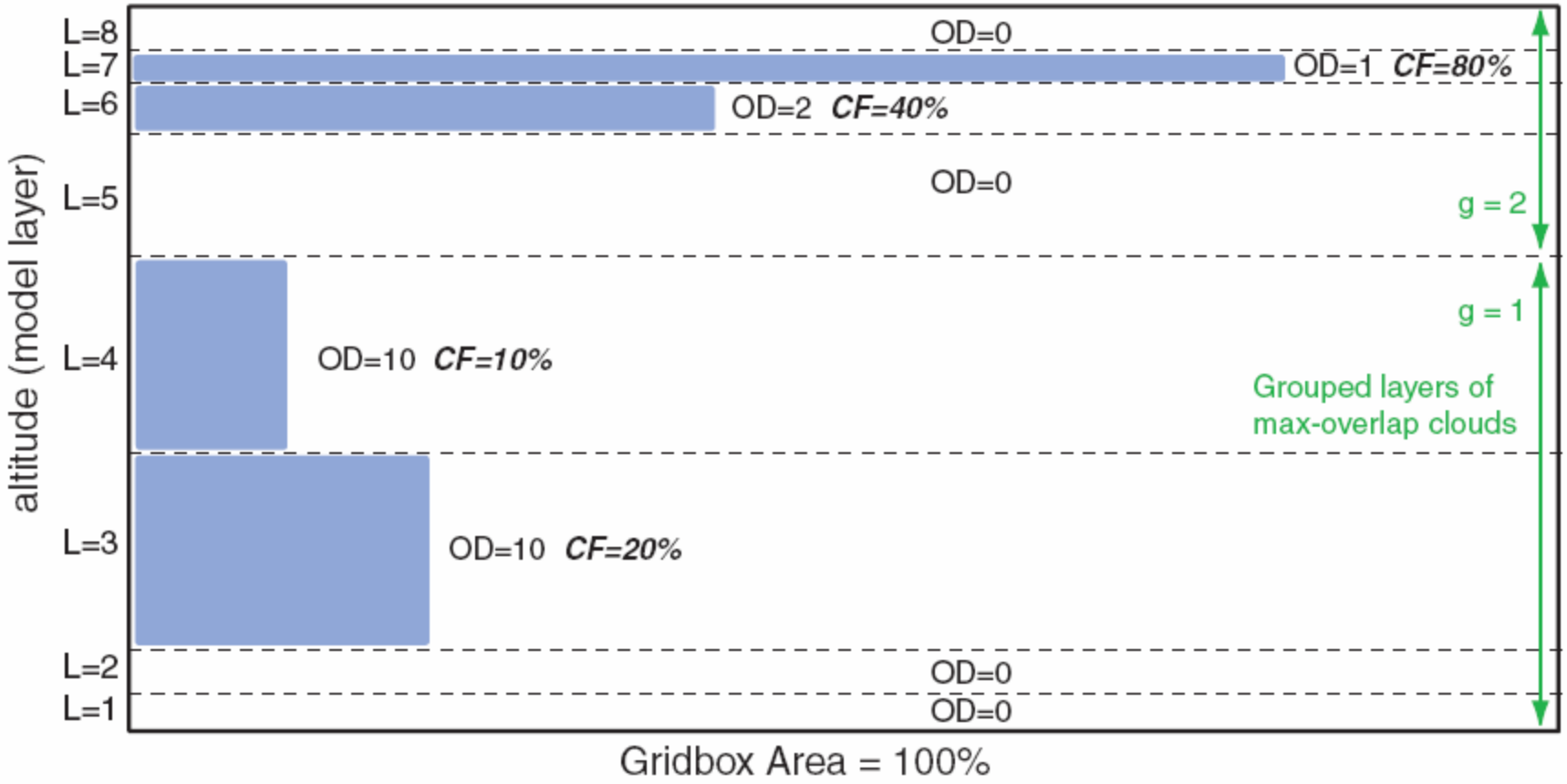
►incorporating fractional cloud cover in CTMs (done! 'in prep')
Jessica Neu, Prather & Joyce Penner

►model validation of cloud cover (?)

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

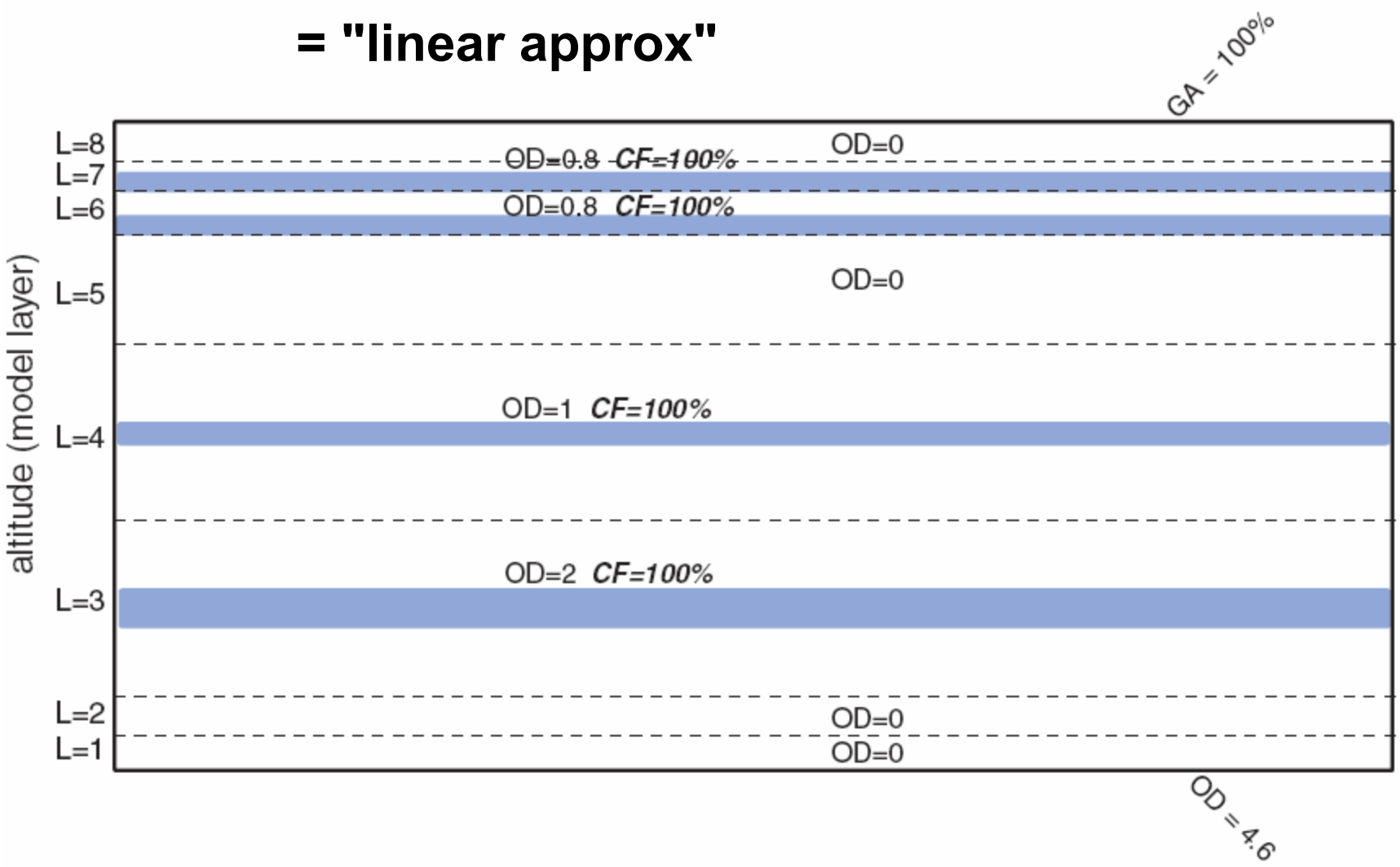
►fractional cloud cover

cloud fraction & OD from met fields:



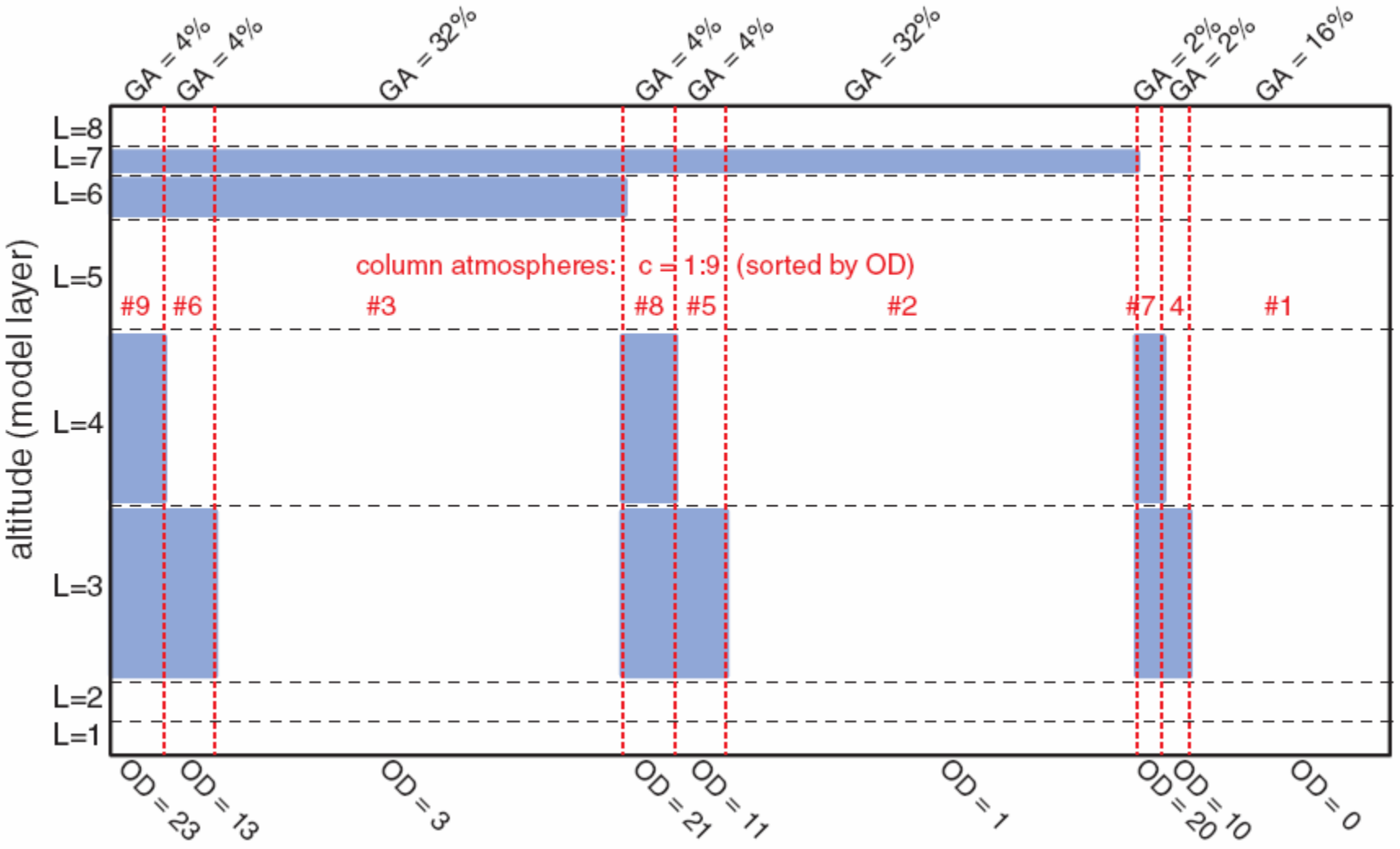
►fractional cloud cover

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

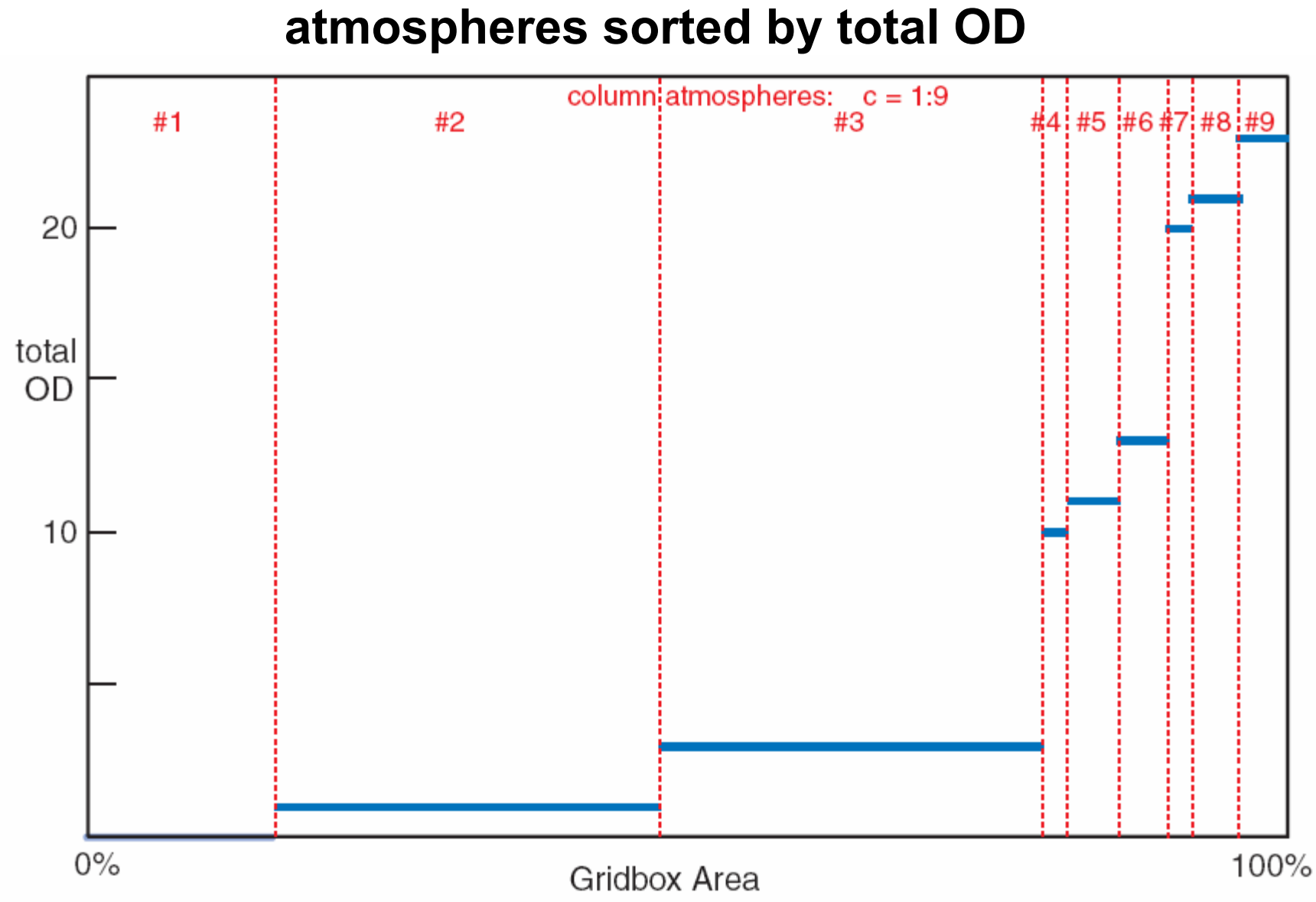


►fractional cloud cover

in a max-random w/ 0%-threshold overlap model
these clouds become 2 groups w/ max overlap

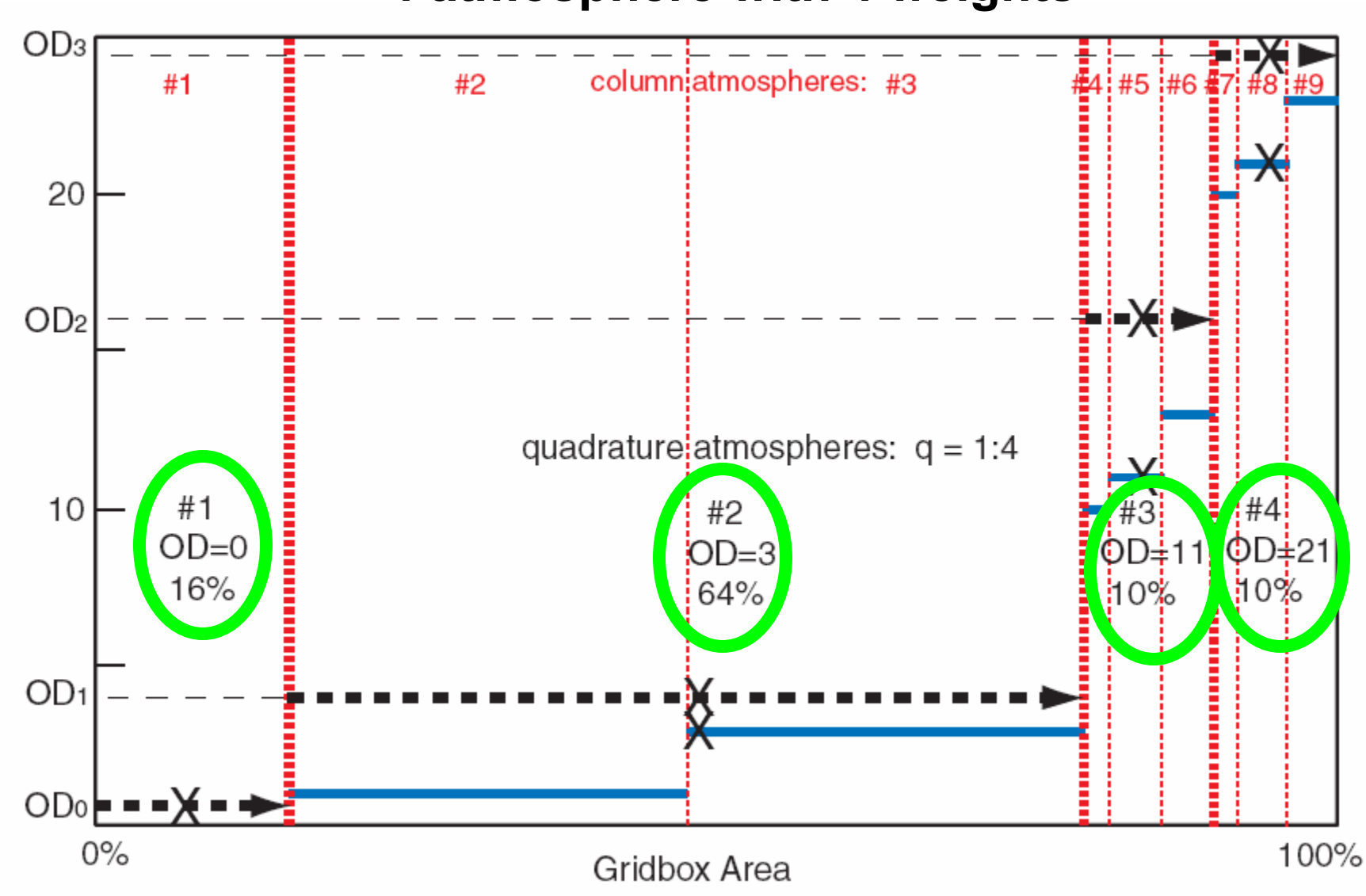


►fractional cloud cover



►fractional cloud cover

quadrature = integral approx as sum of 4 atmosphere with 4 weights



►example: instantaneous tropical box in Oslo/EC T42 for 15 Jan 2001, 00-03Z, ?5°S, ?170°E

ECMWF model reports cloud fraction and the Liquid/Ice Water Path for each model layer.(EC 40 layers =>37)

no

up

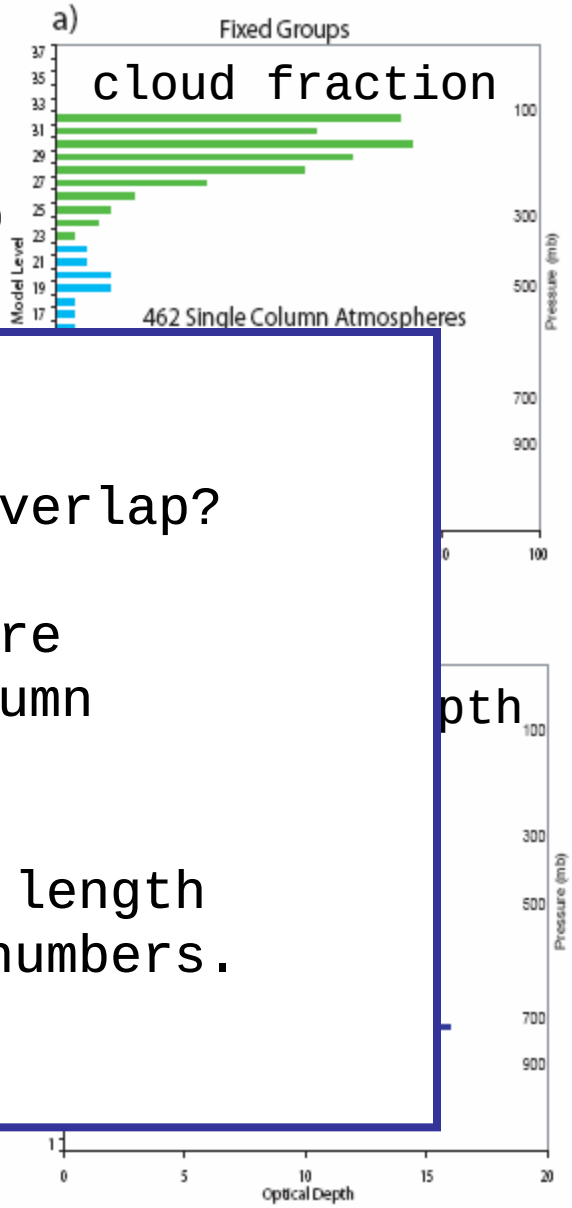
mi

HO

HOW DO these cloud layers overlap?

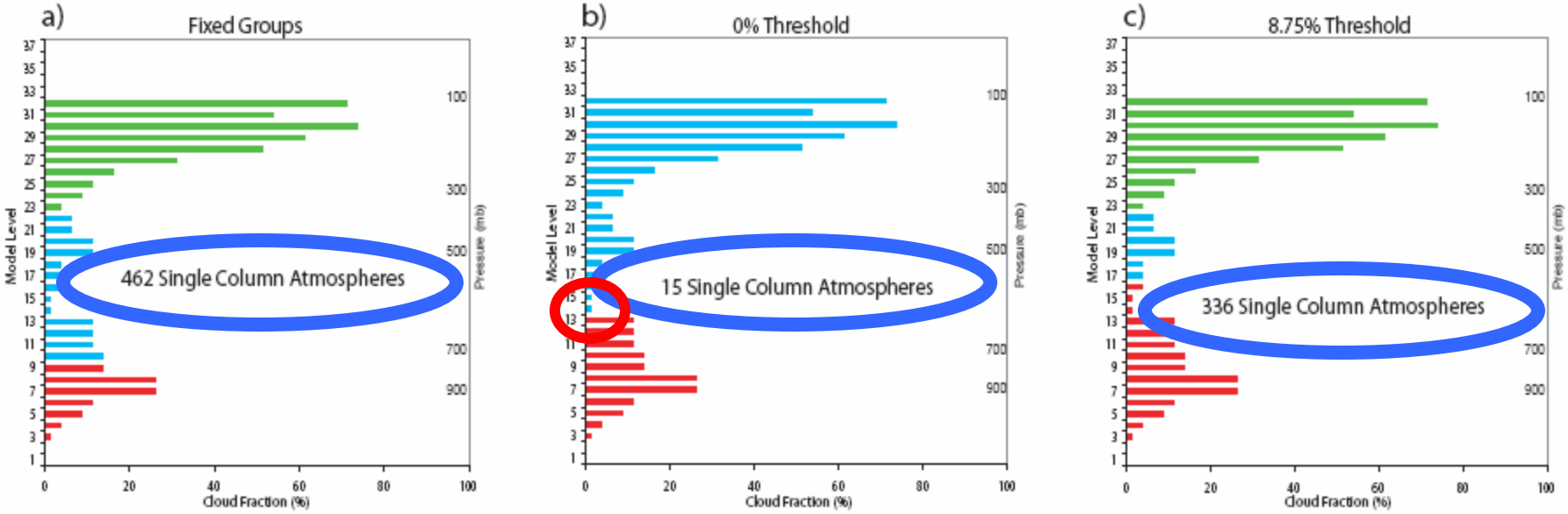
if random then there are $2^{32} \sim 10^9$ individual column atmospheres (ICAs).

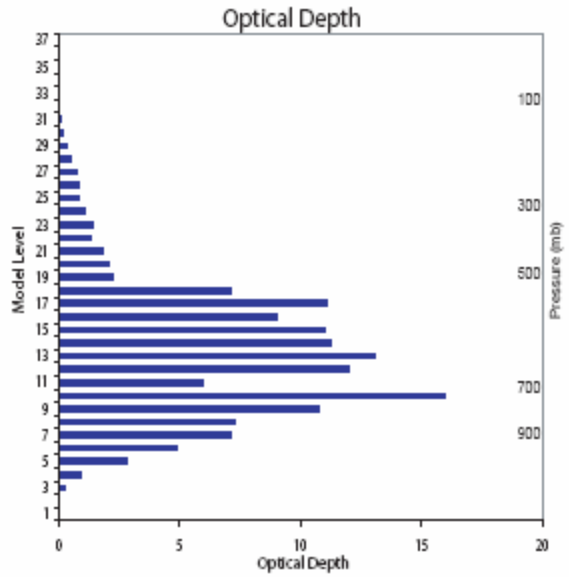
if we assume a correlation length (Rasch et al) then similar numbers.



►what is the true overlap? we choose 3 "true" distributions

3 fixed groups *separate by 0% cld-cvr* *by 8.8% cld-cvr*





To test our method, we use ECMWF 40-layer cloud fraction and liquid and ice water content fields (we collapse the lowest 5 levels into 2, so that we have 37 layers). We bin the cloud fraction into 2.5% bins. The cloud fraction and optical depth shown are for Jan 15 for a single gridbox in the tropics. We define three different maximum-random groupings - one set of fixed groups based on the cross-correlation between cloudy layers (a) and two flexible groups based on a cloudiness "threshold", below which we assume that cloud groups are separated from one another (b) and (c).

How many different Independent Column Atmospheres are we talking about?

statistics for 00-24Z Jan 15, 2001

	<ICA/2.8°grid>	max #
0% threshold	32	1792
9% threshold	122	30240
3 fixed groups	196	1404

►take the 0% threshold for separation = 2 groups,
generate the 15 ICAs,
sort by Total Optical Depth, and

generate the 4 quadrature ICAs

We use total optical depth thresholds of :

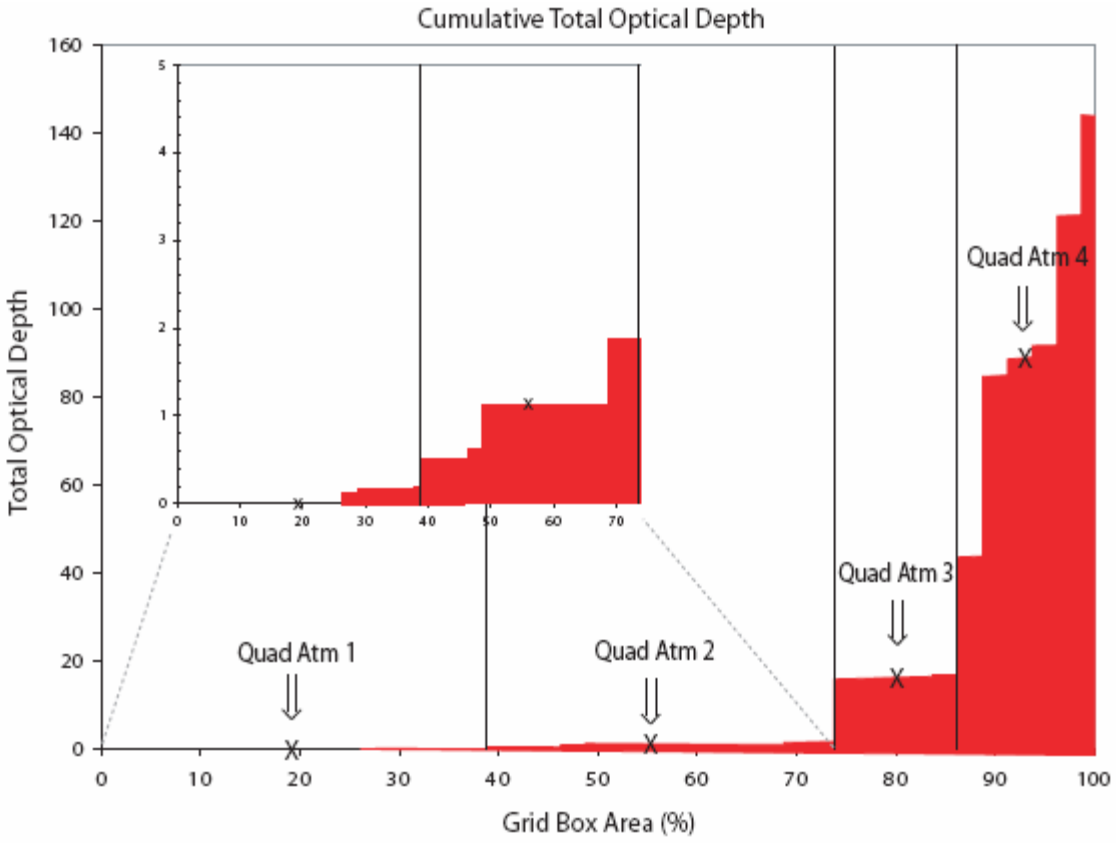
$0<OD\leqslant 0.5$

$0.5<OD\leqslant 4$

$4<OD\leqslant 30$

$30<OD<INF$

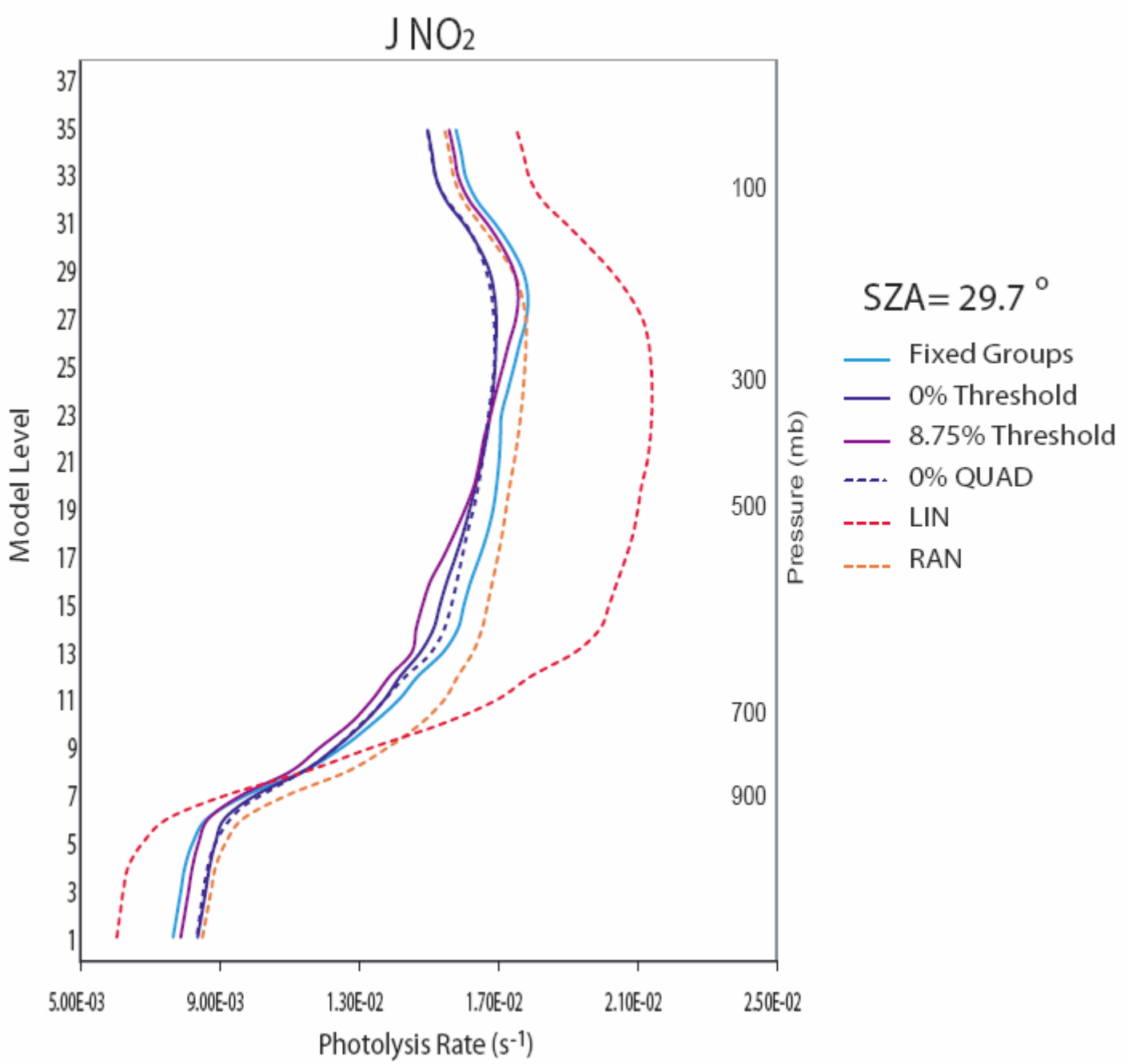
to define our quadrature atmosheres. The cumulative optical depths for the 15 single column atmospheres in Figure b) above are shown, as well as the four quadrature atmospheres for this case.

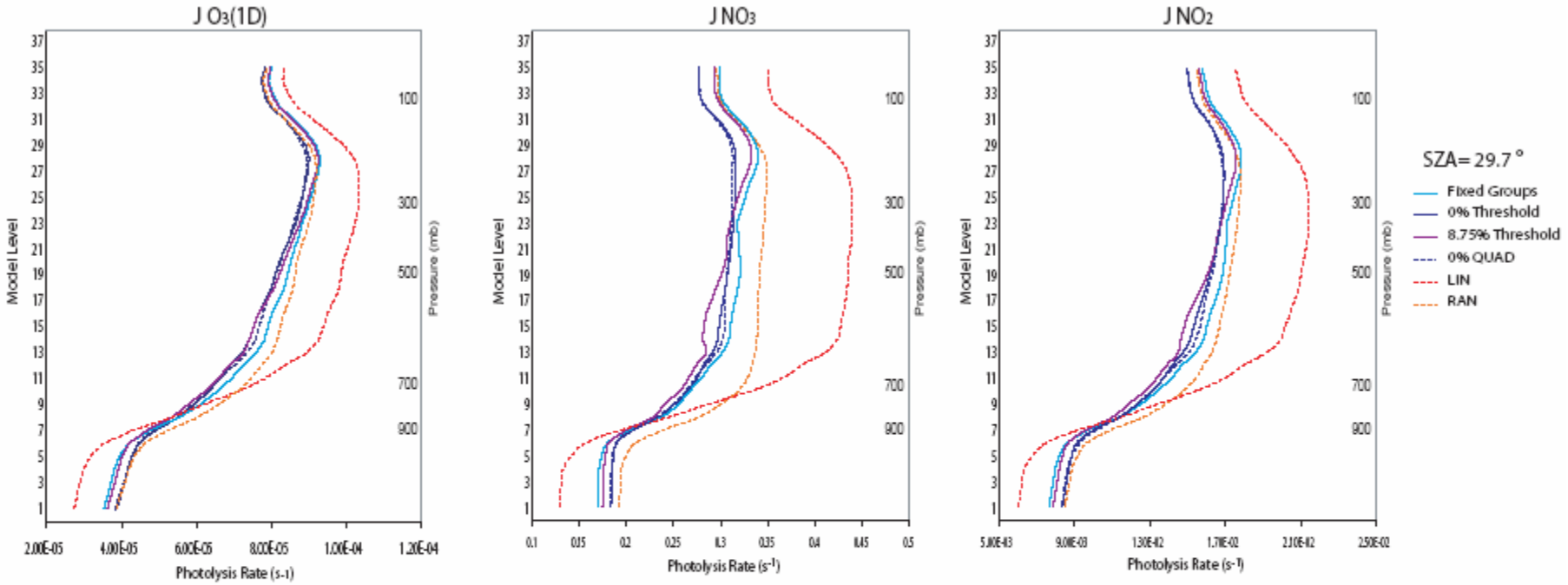


Calculate 3 key J values through the troposphere

	O3->O(1D)	290-330 nm
	NO2	340-400 nm
	NO3	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 ($OD \times CF$)	1 ICA
approx:	RAN = max-ran ($OD \times CF^{3/2}$)	1 ICA
quad#1:	from 0% threshold	4 ICAs
quad#2:	*from 9% threshold*	*4 ICAs*
quad#3	*from 3 fixed-grps*	*4 ICAs*


J NO2
Model Level
37
35
33
31
29
27
25
23
21
19
17
15
13
11
9
7
5
3
1
100
300
500
700
900
Pressure (mb)
5.00E-03
9.00E-03
1.30E-02
1.70E-02
2.10E-02
2.50E-02
Photolysis Rate (s-1)
SZA= 29.7 °
Fixed Groups
0% Threshold
8.75% Threshold
0% QUAD
LIN
RAN



We calculate the gridbox-average photolysis rates using the UCI fast-JX photolysis code for the full set of single column atmospheres for each maximum-random grouping discussed above and compare them to the average photolysis rates calculated for the four quadrature atmospheres. We also compare these to photolysis rates for the linear method and a common approximation to random overlap ($OD*CLDFR^{3/2}$).

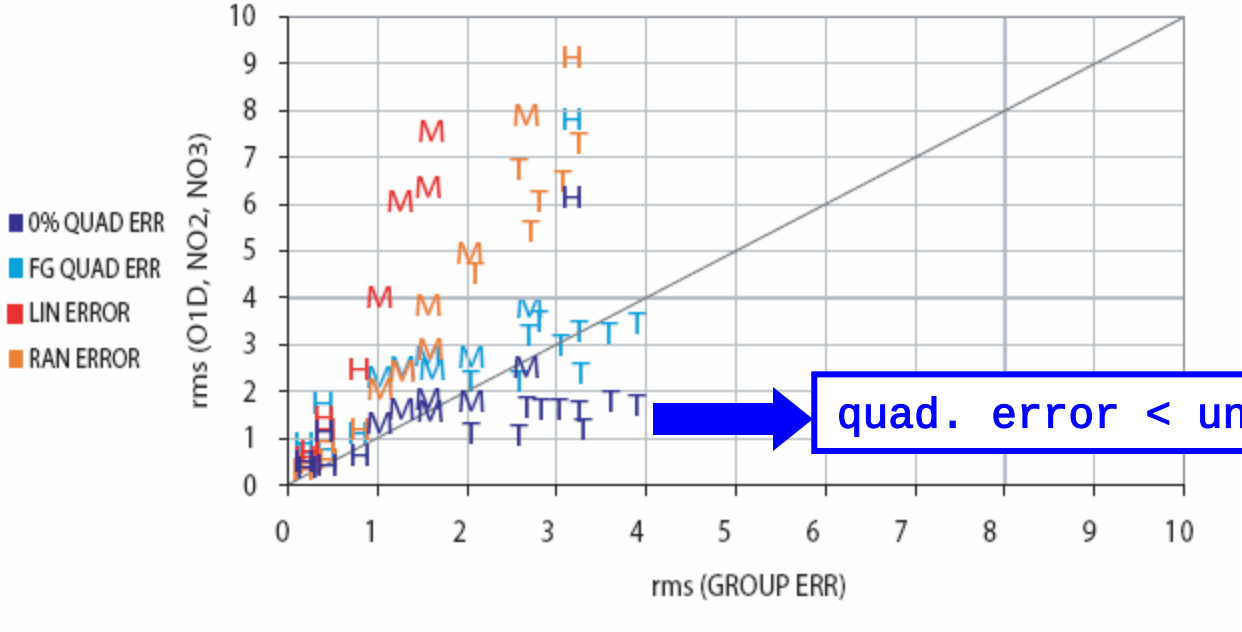
- OK, now do 24-hr integ. (15 Jan 2001, 00-24Z, 8 fields)
- integrate over all grid points (64 x 128) in the tropics, N/S sub-tropics, N/S mid-lats, N/S high-lats
- compute RMS differences in J's (p-weighted over trop)

We calculate the pressure-weighted root mean square error for the 24-hour averaged photolysis rates for the Jan 15 ECMWF cloud fields and average the error over large geographic regions. We use the photolysis rates calculated for the full set of single column atmospheres from the 0% threshold maximum-random grouping as our "truth". The rms errors for the quadrature method are near or less than the rms error that reflects the variability between different methods of maximum-random grouping in almost all cases. The NO_3 photolysis rates in the winter hemisphere high latitudes are an exception. The linear approximation and the random overlap approximation have rms errors much larger than the variability between different grouping methods.

RMS Error						
		GROUP ERR	0% QUAD ERR	FG QUAD ERR	LIN ERR	RAN ERR
TROPICS	O3(1D)	2.8	1.7	3.6	14.9	6.1
	NO2	3.3	1.6	3.4	18.1	7.3
	NO3	3.9	1.7	3.6	24.1	11.9
N SUBTROP	O3(1D)	2.0	1.1	2.3	10.4	4.5
	NO2	2.6	1.1	2.3	13.3	6.8
	NO3	3.3	1.2	2.5	18.2	11.1
S SUBTROP	O3(1D)	2.7	1.7	3.3	14.0	5.5
	NO2	3.1	1.6	3.1	17.0	6.5
	NO3	3.6	1.8	3.3	22.3	10.3
N MIDLATS	O3(1D)	1.0	1.3	2.3	4.0	2.0
	NO2	1.6	1.7	2.8	6.3	3.7
	NO3	2.7	2.5	3.8	11.5	7.9
S MIDLATS	O3(1D)	1.3	1.6	2.5	6.0	2.4
	NO2	1.6	1.5	2.5	7.5	2.8
	NO3	2.0	1.8	2.7	10.3	4.9
N HIGHLATS	O3(1D)	0.2	0.6	0.9	0.6	0.5
	NO2	0.4	1.2	1.8	1.5	0.9
	NO3	3.2	6.2	7.8	12.6	9.2
S HIGHLATS	O3(1D)	0.2	0.4	0.7	0.8	0.6
	NO2	0.4	0.5	0.8	1.3	0.6
	NO3	0.8	0.7	1.1	2.5	1.3

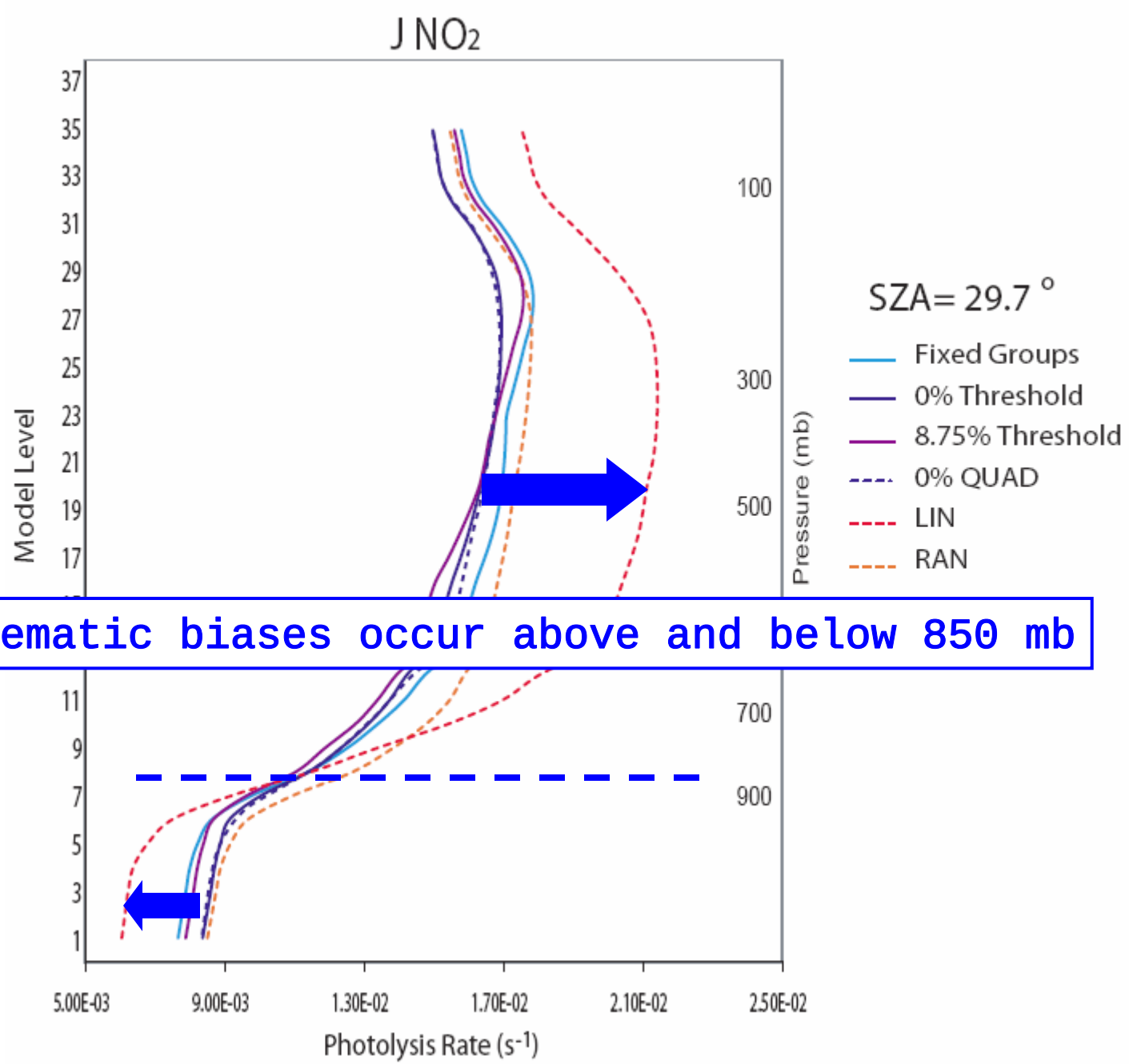
Y-axis = rms error in quadrature vs. truth(#1 or #3)
or
rms error in LIN or RAN vs. truth#1

each letter:
3 J's (O3-1D, NO2, NO3)
T = tropics and sub-tropics(N/S)
M = mid-latitudes
H = high-latitudes



quad. error < uncert. in truth

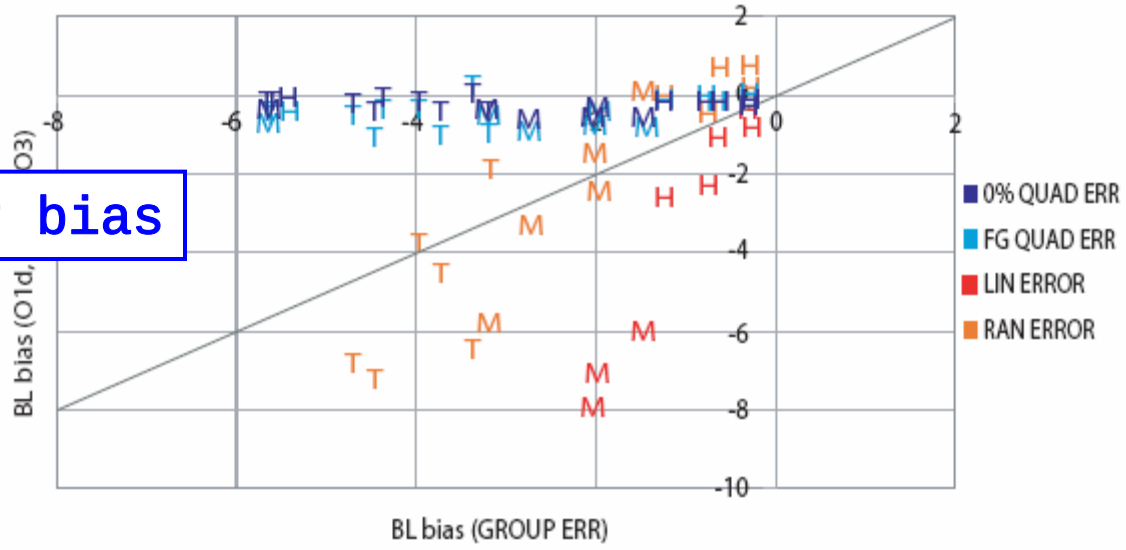
X-axis = rms difference truth#3 vs. truth#1


J NO2
Model Level
Pressure (mb)
Photolysis Rate (s-1)
SZA= 29.7 °
Fixed Groups
0% Threshold
8.75% Threshold
0% QUAD
LIN
RAN
systematic biases occur above and below 850 mb

Boundary Layer Bias						
		GROUP ERR	0% QUAD ERR	FG QUAD ERR	LIN ERR	RAN ERR
TROPICS	O3(1D)	(4.0)	(0.1)	(0.4)	(20.0)	(3.8)
	NO2	(4.7)	(0.1)	(0.5)	(22.4)	(6.8)
	NO3	(5.6)	(0.1)	(0.6)	(26.9)	(10.1)
N SUBTROP	O3(1D)	(3.4)	0.0	0.2	(18.1)	(6.5)
	NO2	(4.4)	(0.0)	(0.3)	(22.5)	(10.5)
	NO3	(5.6)	(0.0)	(0.4)	(28.8)	(16.0)
S SUBTROP	O3(1D)	(3.2)	(0.4)	(1.0)	(16.9)	(1.8)
	NO2	(3.7)	(0.4)	(1.0)	(19.0)	(4.5)
	NO3	(4.5)	(0.4)	(1.1)	(22.9)	(7.2)
N MIDLATS	O3(1D)	(2.0)	(0.2)	(0.4)	(7.1)	(2.5)
	NO2	(3.2)	(0.3)	(0.5)	(11.9)	(5.8)
	NO3	(5.6)	(0.3)	(0.7)	(21.4)	(13.1)
S MIDLATS	O3(1D)	(1.5)	(0.5)	(0.8)	(6.0)	0.1
	NO2	(2.0)	(0.5)	(0.8)	(7.9)	(1.5)
	NO3	(2.7)	(0.6)	(0.9)	(10.9)	(3.3)
N HIGHLATS	O3(1D)	(0.3)	(0.0)	0.0	(0.8)	0.2
	NO2	(0.8)	(0.1)	0.0	(2.3)	(0.4)
	NO3	(5.4)	(0.0)	(0.4)	(16.1)	(10.7)
S HIGHLATS	O3(1D)	(0.3)	(0.1)	(0.0)		
	NO2	(0.6)	(0.1)	(0.1)		
	NO3	(1.2)	(0.1)	(0.1)		

The bias between the various approximations (quadrature, linear, and random) and the "truth" is negative (shown in red) in most cases in the boundary layer (below ~xxx mb). The boundary layer biases for the quadrature method are always much smaller than the bias that reflects the variability between the various grouping methods. In contrast, the large negative biases for the linear and random approximations show that the photolysis rates for these methods are on average much smaller than the "truth" in the boundary layer.

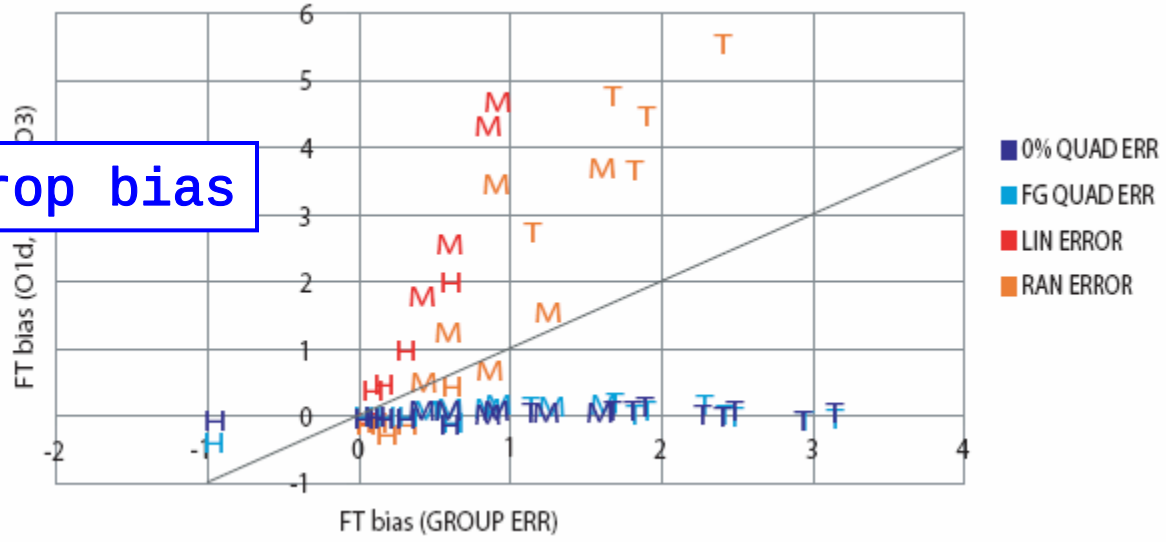
Bndry Lyr bias



Free Trop Bias						
		GROUP ERR	0% QUAD ERR	FG QUAD ERR	LIN ERR	RAN ERR
TROPICS	O3(1D)	1.9	0.2	0.1	11.9	4.4
	NO2	2.5	0.1	0.0	16.3	6.4
	NO3	3.1	0.1	(0.0)	23.3	11.5
N SUBTROPIC	O3(1D)	1.1	0.1	0.2	6.6	2.7
	NO2	1.7	0.1	0.2	9.5	4.8
	NO3	2.3	0.1	0.2	14.2	9.1
S SUBTROPIC	O3(1D)	1.8	0.1	0.0	11.4	3.6
	NO2	2.4	0.0	(0.0)	15.8	5.5
	NO3	2.9	(0.0)	(0.1)	21.8	9.8
N MIDLATS	O3(1D)	0.4	0.1	0.0	1.8	0.5
	NO2	0.6	0.1	0.1	2.5	1.2
	NO3	0.9	0.1	0.1	4.6	3.4
S MIDLATS	O3(1D)	0.8	0.0	0.1	4.3	0.6
	NO2	1.2	0.1	0.1	6.3	1.5
	NO3	1.6	0.1	0.1	9.1	3.6
N HIGHLATS	O3(1D)	0.1	0.0	(0.0)	0.4	(0.1)
	NO2	0.0	0.0	(0.0)	(0.1)	(0.1)
	NO3	(1.0)	(0.1)	(0.4)	(5.8)	(3.3)
S HIGHLATS	O3(1D)	0.2	0.0	(0.0)	0.5	(0.3)
	NO2	0.3	(0.0)	(0.0		
	NO3	0.6	(0.1)	(0.1		

The bias between the various approximations and the "truth" is positive in most cases in the free troposphere (above ~xxx mb). Again, the biases for the quadrature method are always much smaller than the bias that reflects the variability between cloud grouping methods. The biases for the linear and random approximations are much larger than the variability between grouping methods, reflecting much larger free troposphere photolysis rates for these methods.

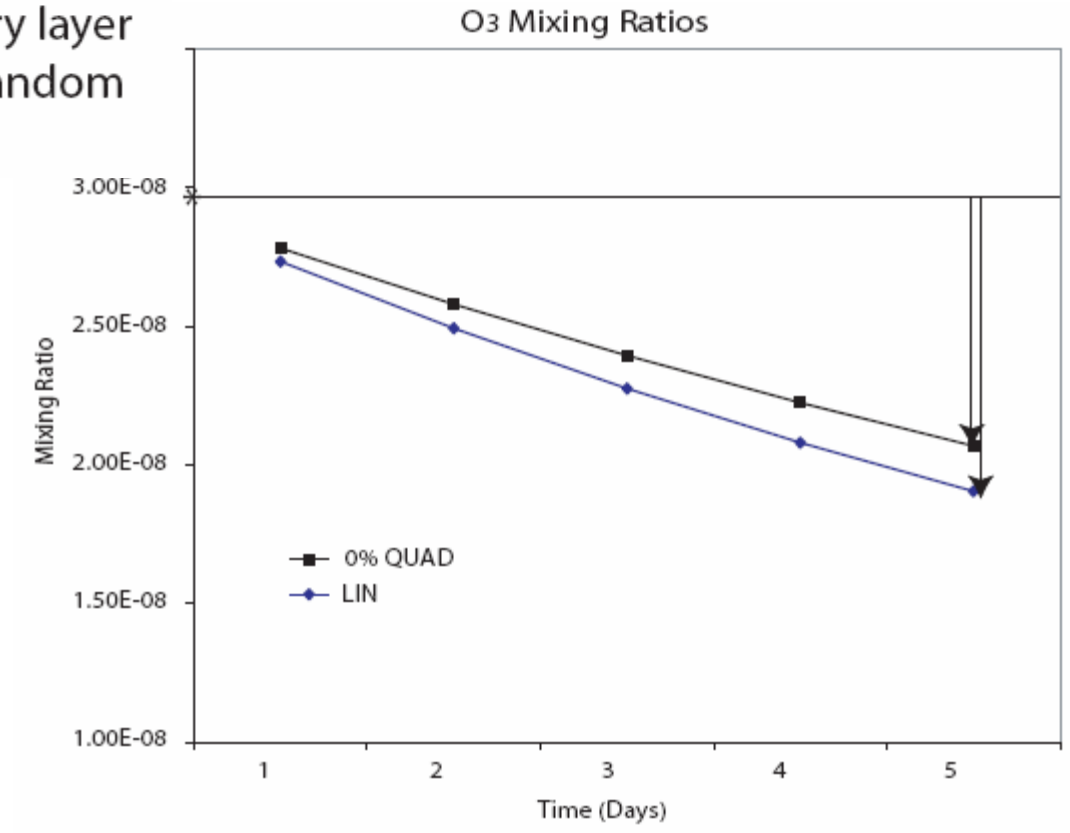
Free-Trop bias



►Does this matter? Look at OxComp IPCC SAR study, 5-day integration of O_3 loss in marine BL

LIN has 15% less loss.

Calculations with a photochemical box model for the grid box shown in the Example panel indicate that the linear approximation results in about 15% less ozone loss in the marine boundary layer over 5 days than the maximum-random overlap method.

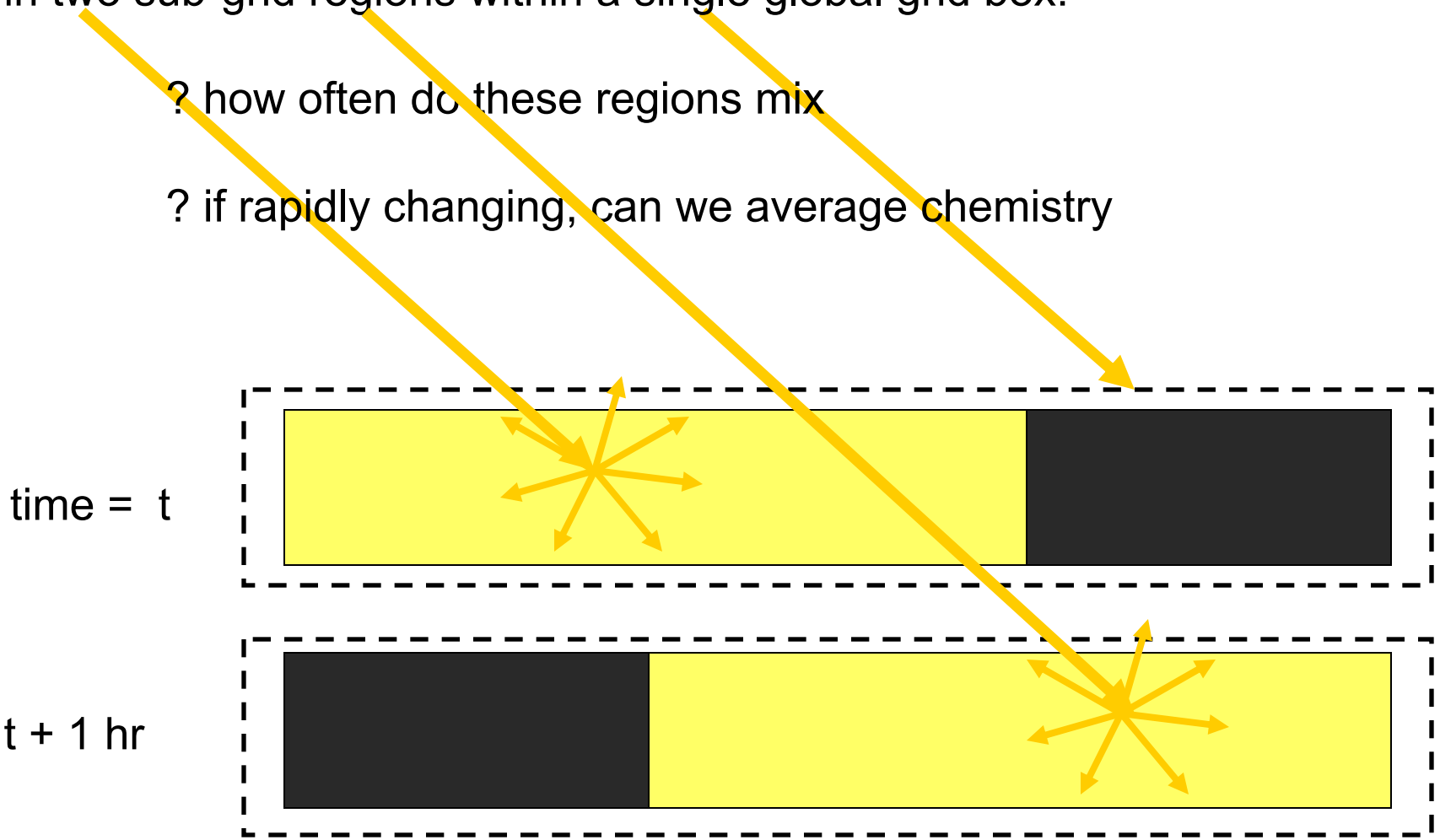


Photochemistry in a real (3-D) world

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

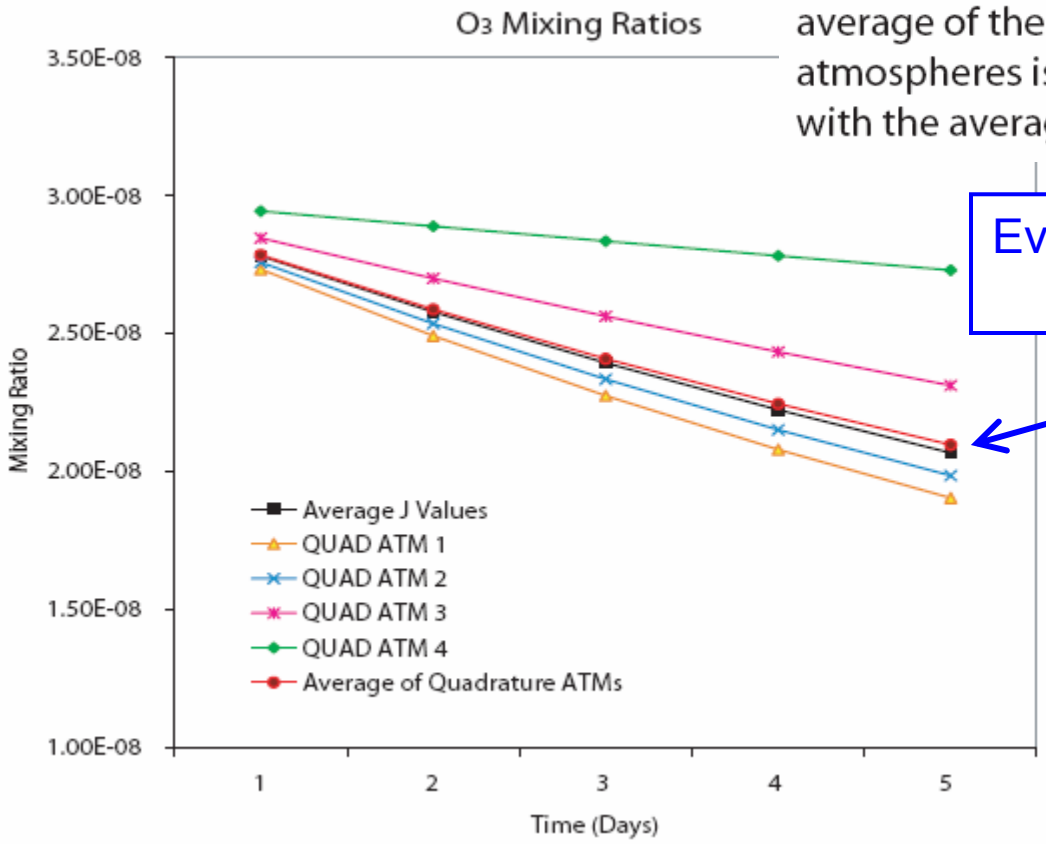
? how often do these regions mix

? if rapidly changing, can we average chemistry



Does CHEM[<J>] = <CHEM(J)>? Without the ability to resolve clouds, it is impossible to know whether averaging the photolysis rates over all of the single column atmospheres is a reasonable representation of reality. However, a box model simulation of the marine boundary layer using the average photolysis rate at the surface for the grid box shown in the Example panel as well as the photolysis rates for each individual quadrature atmosphere shows that even over 5 days, the weighted average of the ozone loss in the four quadrature atmospheres is very close to the ozone loss calculated with the average photolysis rates.

OxComp IPCC SAR - O_3 loss in marine BL



Even with the 4 quad ICAs isolated, pretty close !

►What about the energy budgets ?
look at UV-Vis albedo for 15 Jan 2001

3% abs diff in truth#1 vs. #3

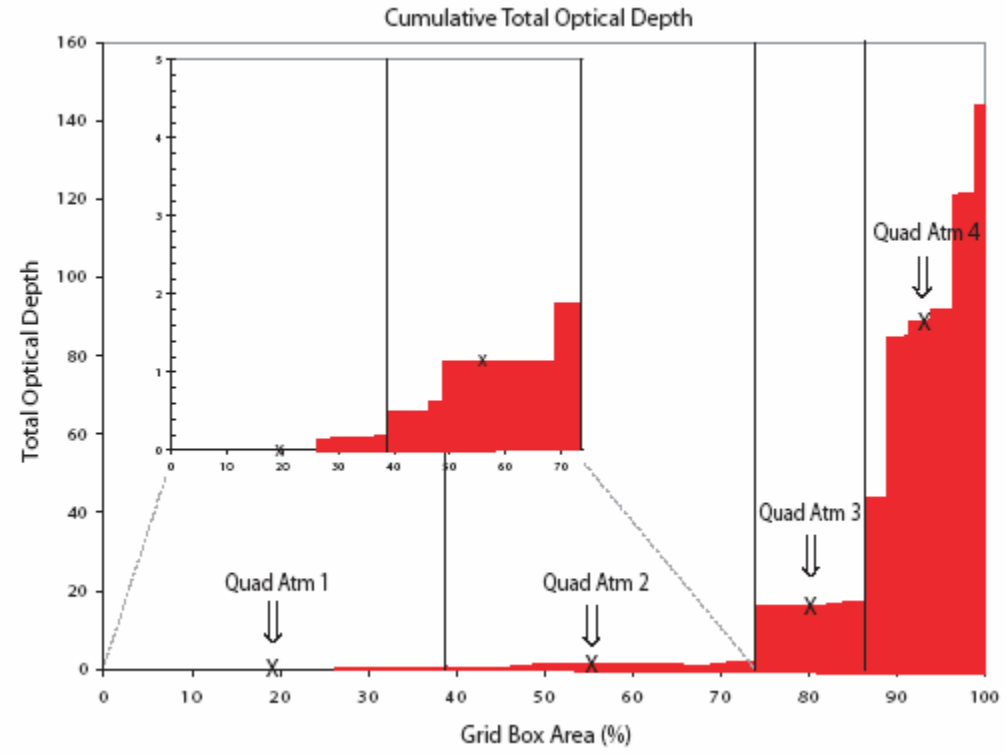
<1% abs error in quad solution

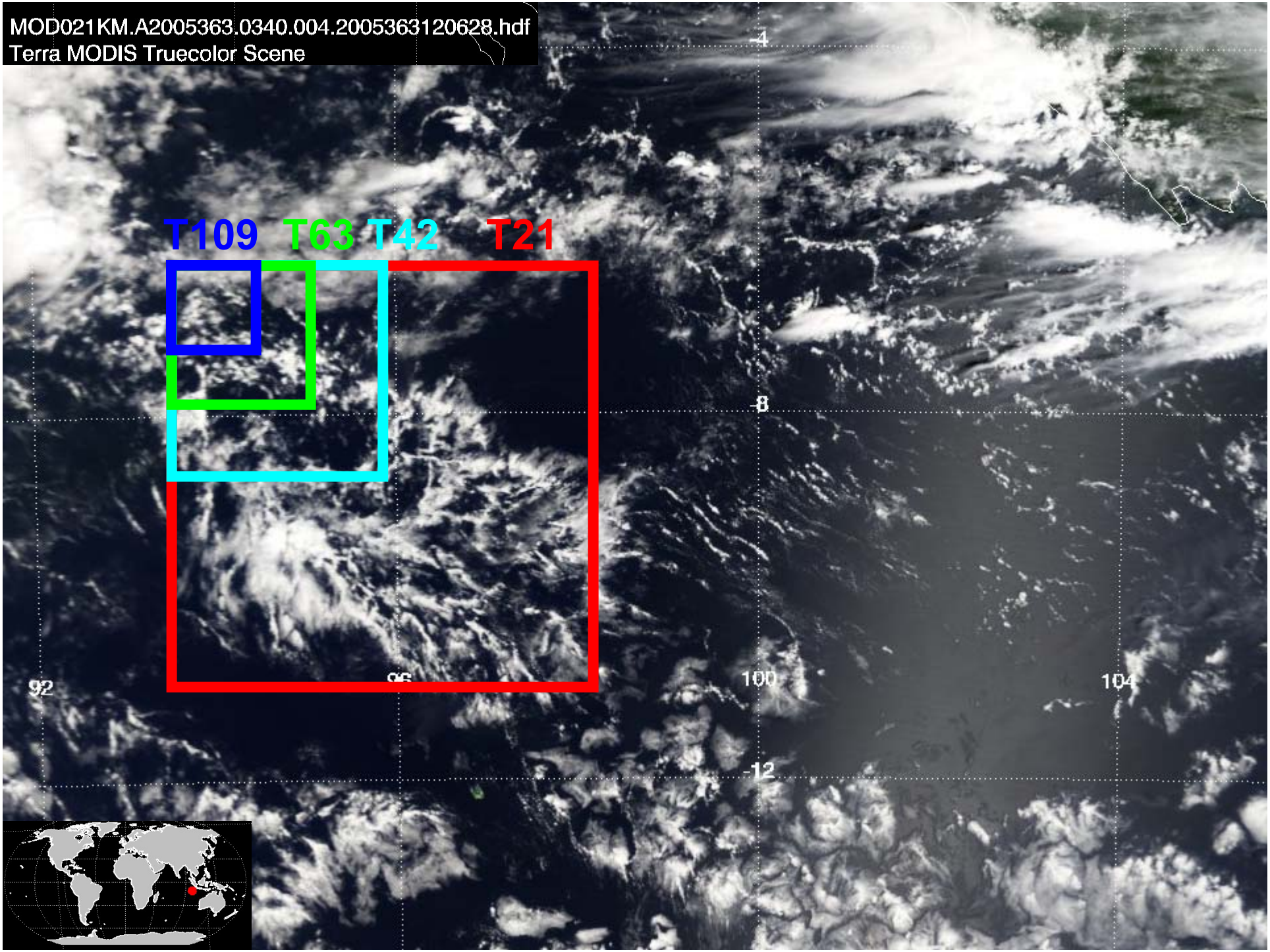
ALBEDO	FIXED GROUP	0% THRESH		QUAD ERR	LIN ERR	RAN ERR
TROPICS	0.388	0.353		0.000	0.188	0.080
MID LATS	0.469	0.451		0.001	0.082	0.030
WIN H LATS	0.663	0.658		0.002	0.022	0.010
SUM H LATS	0.292	0.287		(0.001)	0.016	(0.004)

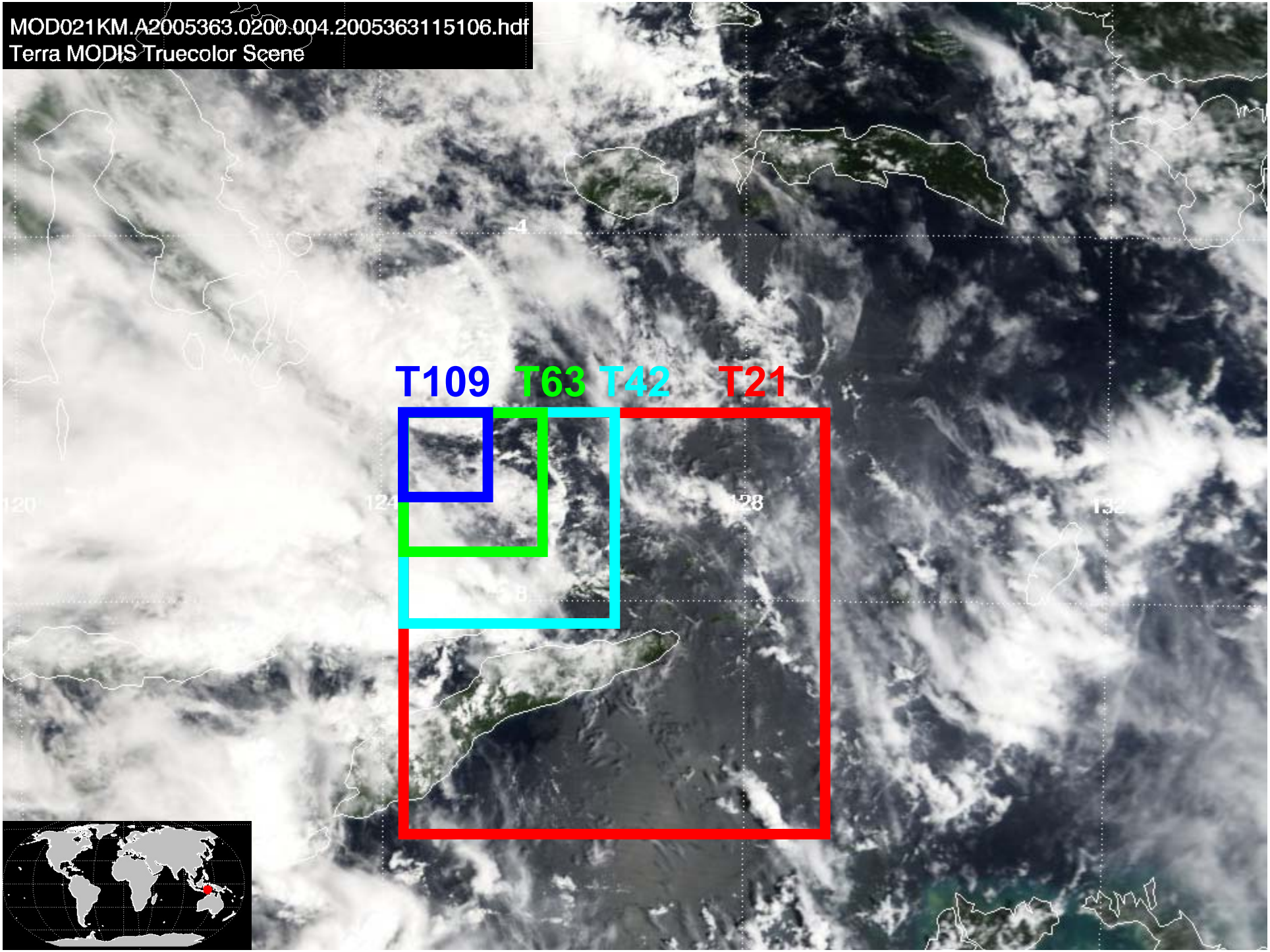
unacceptable errors in LIN & RAN

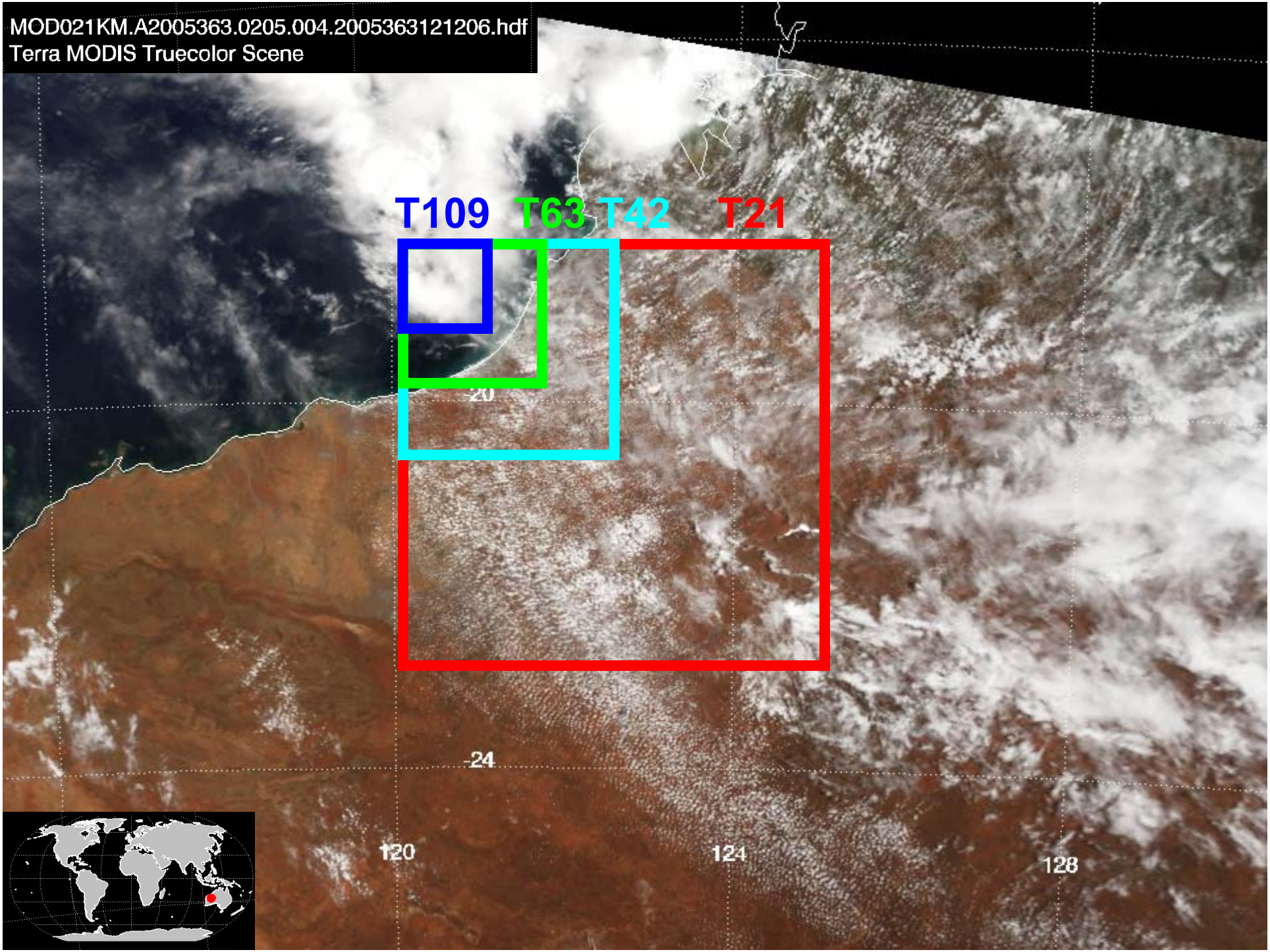
The quadrature approximation results in almost no error in the shortwave (~290 - 800 nm) albedo compared the the full set of maximum-random overlap calculations, while the linear and random approximations result in very large errors in the tropics and midlatitudes. The shortwave albedo is a key term in the energy budget, so that general circulation models will be very sensitive to the type of approximation that is used.

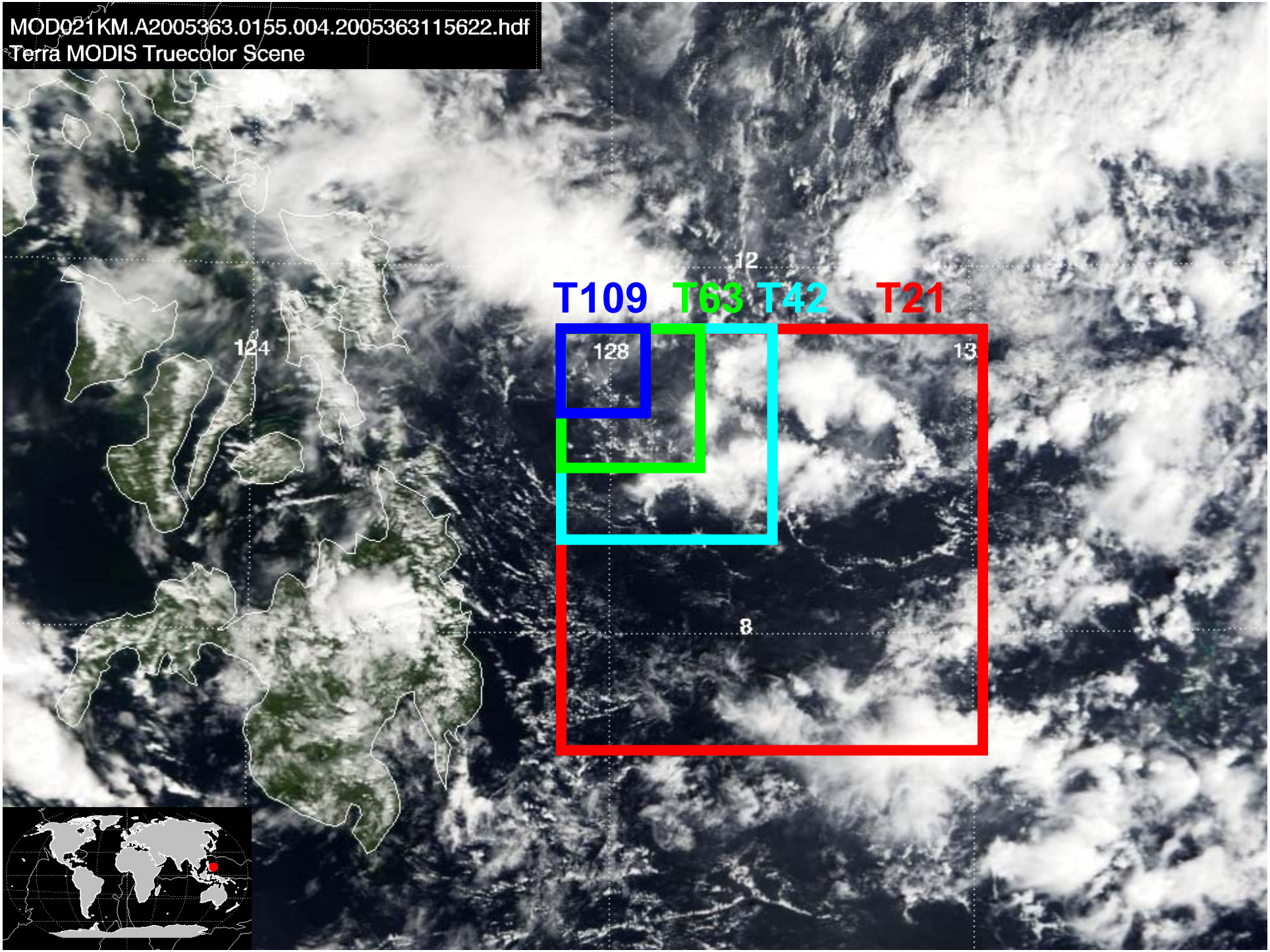
Our distribution of Total Optical Depth generated from the fractional cloud cover *and* the assumptions about overlap should be testable ?




MOD021KM.A2005363.0340.004.2005363120628.hdf
Terra MODIS Truecolor Scene
T109
T63
T42
T21
-4
-8
-12
92
96
100
104

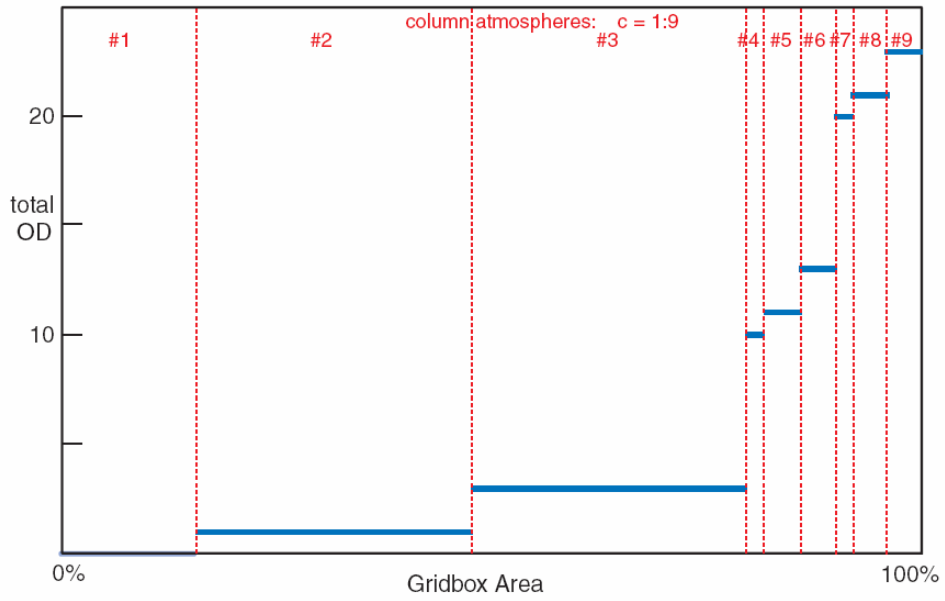

MOD021KM.A2005363.0200.004.2005363115106.hdf
Terra MODIS Truecolor Scene
T109
T63
T42
T21


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


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

GMI Science Team Meeting
11-13 Jan 2006 Georgia Tech

Michael Prather
UC Irvine



- **new STE O_3 diagnos**
  Juno Hsu, Prathe
- **fractional cloud cove**
  Jessica Neu, Prat
- **model validation of cloud cover (next)**
- **transport errors & 2x-to-convergence (next!)**