On the Evaluation of Accuracy in global tracer transport modeling using the GMI and UCI CTMs

update of Dec 2003 AGU & last GMI talk

Michael Prather & Xin Zhu (UC Irvine) (24 Feb 2004)
– updated Mar 2004 (on GMI / UCI site)
– updated May 2004

Also considerable effort and advice from
Jae-Hoon Kim, Dan Bergman (LLNL),
Jose Rodriguez (U Miami), & GMI team

The Transport Part of a CTM:

a. Tracer transport & mixing

~~b. Meteorological Fields~~ ← use the same met fields

Transport error occurs due to numerical approximations in the CTM core (e.g., gridding, flux corrections, advection, boundary layer, convection)

Take two CTM 'cores' that we expect to have highly accurate tracer transport and hence expect to give similar answers and help us define transport error

Lin-Rood tpcore: flux-form SLT, stores only tracer mass in each grid cell, calculates high-order polynomial fit for advection (only) and discards after transport, flux corrections to keep positive and eliminate ripples

Prather SOM: flux-form upstream, stores and uses parabolic fit (second-order moments) to each tracer within each grid cell (9 moments), uses moments for advection, boundary layer, convection, emissions.

Why fossil-fuel CO_2 as the test case?

Uniform fossil-fuel CO_2 emissions are only one (boring) piece of the atmospheric CO_2 problem and do not begin to address the missing sink, biomass burning signal, ….

BUT

ff-CO_2 is still the major cause of the North-South gradient in CO_2. TransCom3 produced similar results for a wide range of CTMs.

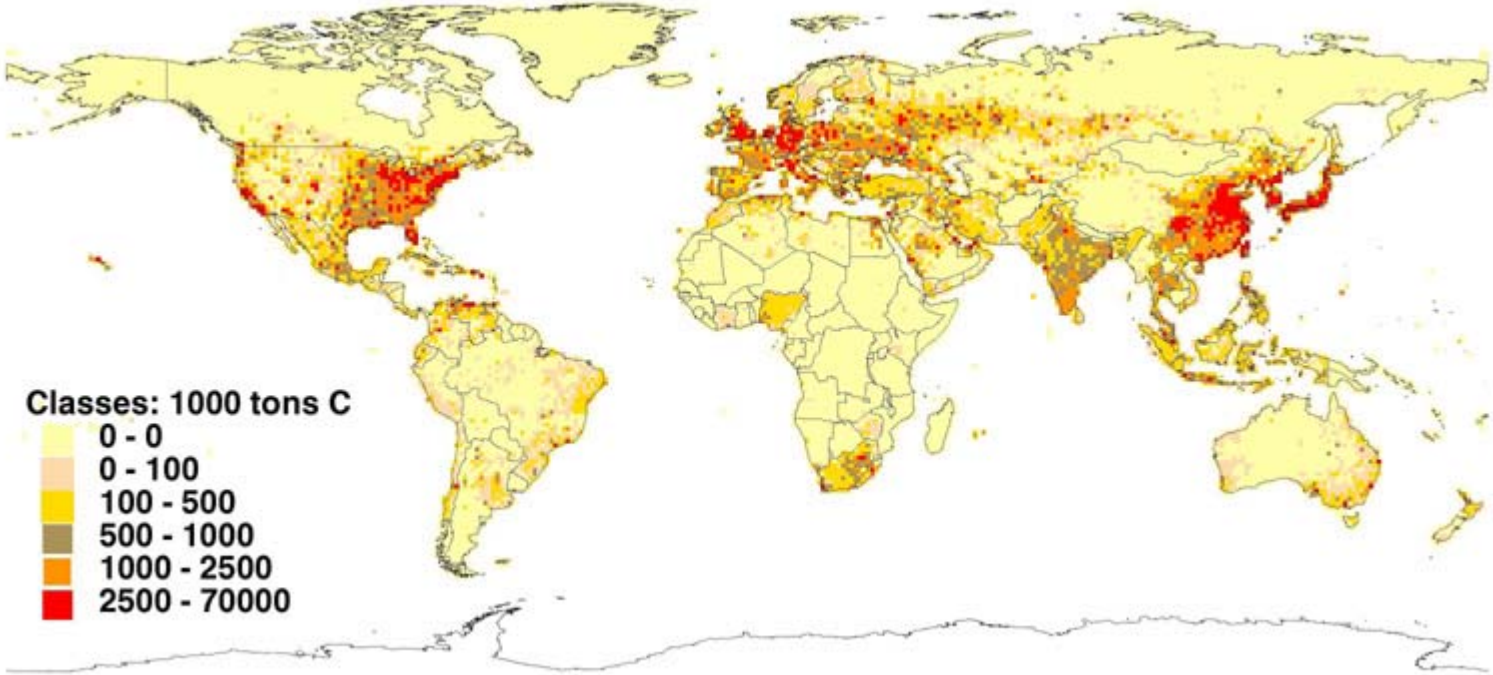
ff-CO_2 is similar to most industrialized emissions (e.g., CFCs in the 1980s, SF_6) and can be scaled to compare with observed inter-hemispheric gradients of these species.

A linearly increasing CO_2 abundance (constant 1995 ff-CO_2 emissions) can be used to track the age-of-air in the stratosphere.

ff-CO_2

Carbon Dioxide Emission Estimates from Fossil-Fuel Burning, Hydraulic Cement Production, and Gas Flaring for **1995** on a 1-deg x 1-deg Grid Cell Basis.

Antoinette L. Brenkert, CDIAC, Oak Ridge National Laboratory

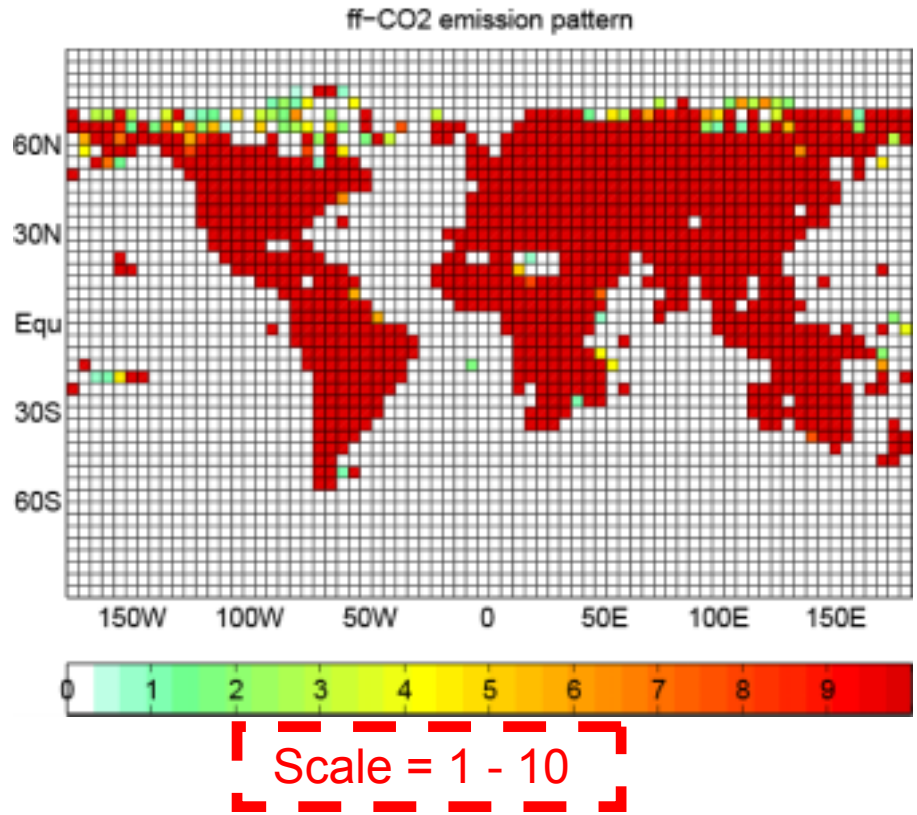


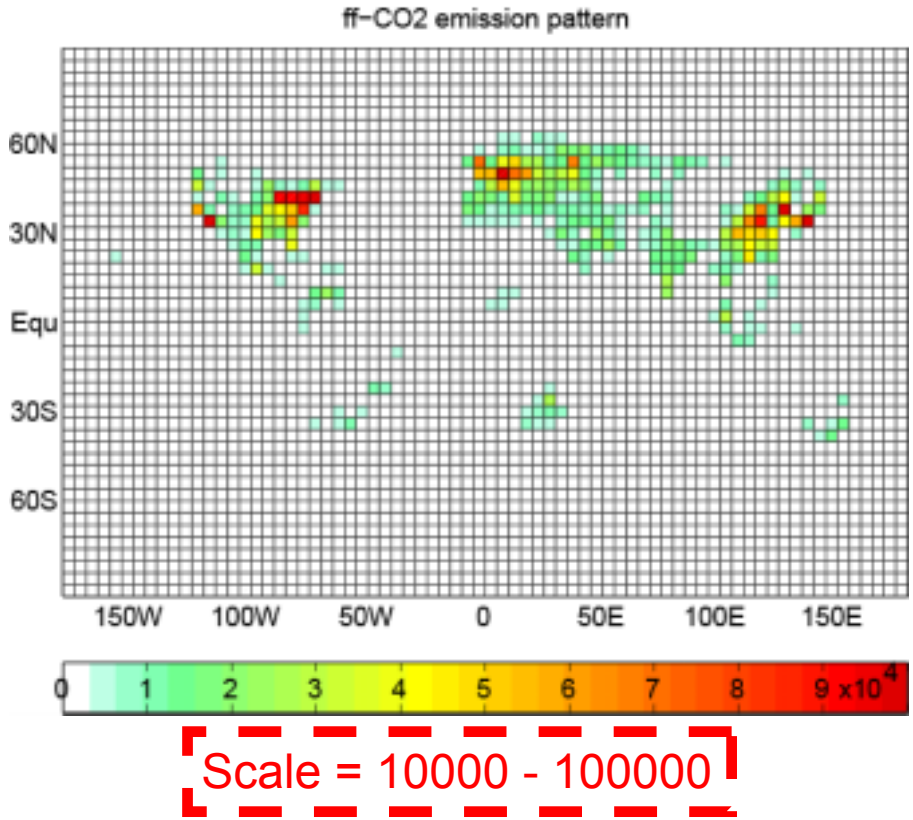
- *initialize with zero fossil fuel CO_2*
- *run for 10 years with 1995 ff-CO_2 emissions*
- *emissions scaled to 6.17 Tg-C/yr = 2.92 ppm/yr*
- *(slightly different from TransCom3: used 1990 → 1995)*

Fossil-Fuel CO_2 emission pattern:

1995 1^ox1^o emission pattern NDP-058A (2-1998)
fossil-fuel burning, hydraulic cement prod. & gas flaring
A.L. Brenkert, CDIAC

>>>uniform emissions of 6.17 PgC/yr = 2.91 ppm/yr, no sinks<<<





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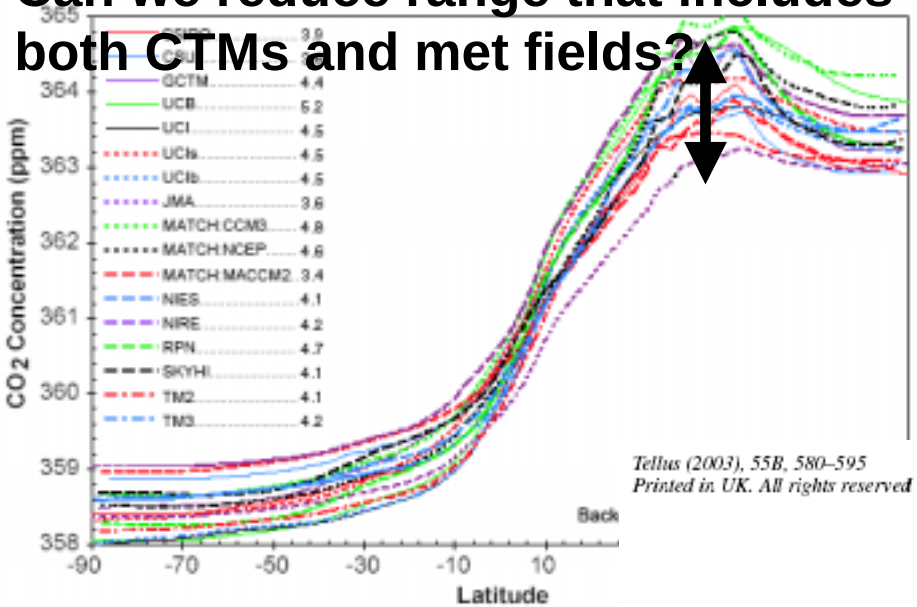
ISSN 0280–6509

TransCom 3 CO_2 inversion intercomparison: 1. Annual mean control results and sensitivity to transport and prior flux information

By KEVIN ROBERT GURNEY[1], RACHEL M. LAW[2], A. SCOTT DENNING[1], PETER J. RAYNER[2], DAVID BAKER[3], PHILIPPE BOUSQUET[4], LORI BRUHWILER[5], YU-HAN CHEN[6], PHILIPPE CIAIS[4], SONGMIAO FAN[7], INEZ Y. FUNG[8], MANUEL GLOOR[9], MARTIN HEIMANN[9], KAZ HIGUCHI[10], JASMIN JOHN[8], EVA KOWALCZYK[2], TAKASHI MAKI[11], SHAMIL MAKSYUTOV[12], PHILIPPE PEYLIN[4], MICHAEL PRATHER[13], BERNARD C. PAK[13], JORGE SARMIENTO[7], SHOICHI TAGUCHI[14], TARO TAKAHASHI[15] and CHIU-WAI YUEN[10]

Can we reduce range that includes both CTMs and met fields?



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Understanding the dispersion and mixing of fossil-fuel CO_2 is a critical element in inversions and understanding sources/sinks.

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Fig. 3. Annual mean, zonal mean surface CO_2 concentration (ppm) resulting a background concentration of 350 ppm) background fluxes for each of the n for the background fossil and combined background CO_2 is listed in the key f for each of the plots.

TransCom 3 CO_2 inversion intercomparison: 2. Sensitivity of annual mean results to data choices

By RACHEL M. LAW[1]*, YU-HAN CHEN[2], KEVIN R. GURNEY[3] and TRANSCOM 3 MODELLERS[4],

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1010, doi:10.1029/2000RG000101

AGE OF STRATOSPHERIC AIR: THEORY, OBSERVATIONS, AND MODELS

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Received 3 April 2001; revised 29 April 2002; accepted 4 November 2002; published 31 December 2002.

[1] We review the relationship between tracer distributions and transport timescales in the stratosphere and discuss the use of timescales to evaluate and constrain theories and nu
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stratospheric ai
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tracers, how se
transport proces
tion to constrain
can be used to infer aspects of the age spectrum, most commonly the "mean age," but also the shape of the spectrum. Observational inferences of transport timescales provide stringent tests of numerical models independent of photochemistry, and comparisons of these observations with chemical transport models have highlighted certain problems with transport in the models. Age simulations and comparisons with data can now be considered standard tests of stratospheric models. INDEX

Tracking the observed falloff of stratospheric tracers like CO_2 and SF_6 has defined the age-of-air.

Can we reduce range that includes both CTMs and met fields?

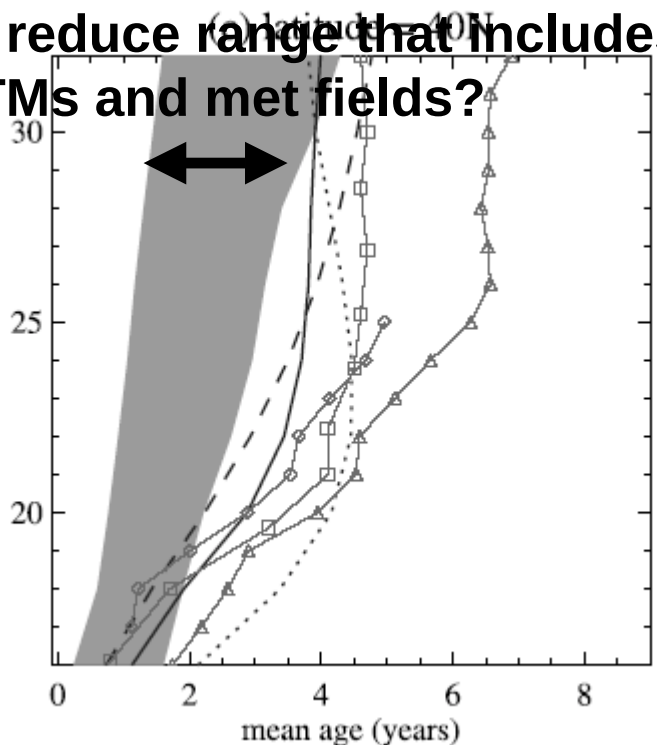


Figure 6. Comparison of observed (red curves with symbols) and modeled (blue shaded area and curves) mean age: (a) z = 20 km and latitude of (b) 5°S, (c) 40°N, and (d) 65°N. The shaded region indicates the range of most models in the Models and Measurements II (MM2) study, while the individual curves represent several models falling outside the range. The symbols represent observations: mean age from in situ CO_2 (diamonds) [*Boering et al.*, 1996; *Andrews et al.*, 2001b], in situ SF_6 (triangles) [*Elkins et al.*, 1996; *Ray et al.*, 1999], and whole air samples of SF_6 (square outside vortex and asterisk inside vortex) [*Hamisch et al.*, 1996]. See *Hall et al.* [1999] for details. See color version of this figure at back of this issue.

GMI study of accuracy in global tracer transport

use same GISS-2' 4°x5°x23-Layer met fields with GMI CTM and UCI CTM

Two basic simulations:

A. 1hr / 3hr step (init f=1 in L=1 & 15, use Jan 1 21-24Z met fields)
B. 10-year run with ff-CO2 emissions (init Jan 1 with f=0)
   (fossil-fuel emissions 1995 pattern, 6.17 Pg/yr = 2.92 ppm/yr)

Focus on:

1. Are we using the same met field (1 hr / 3 hr)
2. Stratospheric age-of-air (10-year run)
3. Surface and column CO_2 patterns (10-year run)

Sensitivity studies:

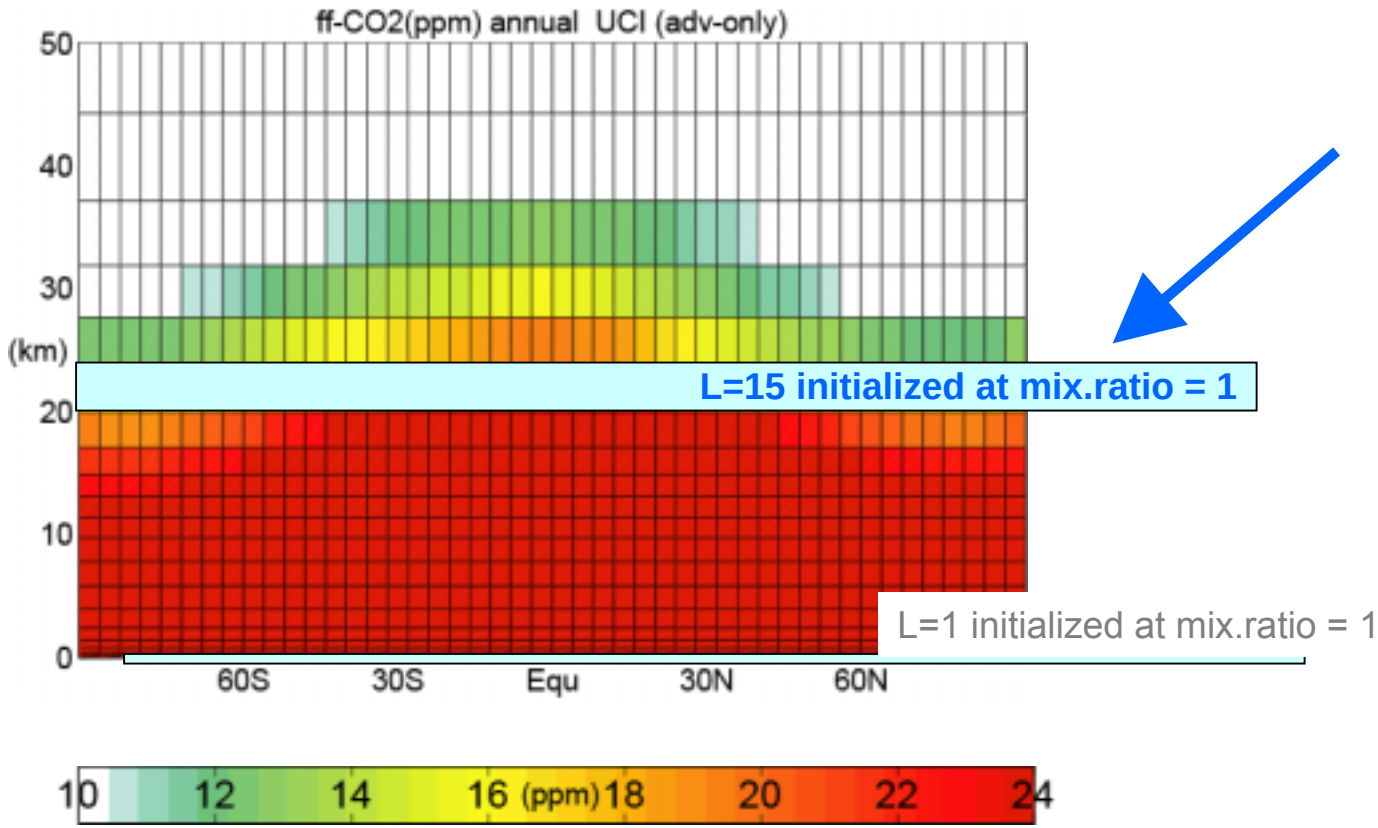
Standard full run (std-A), Advection only (adv-E),
Advection and BL-mixing only (ncnv-F) *with GMI & UCI*

plus

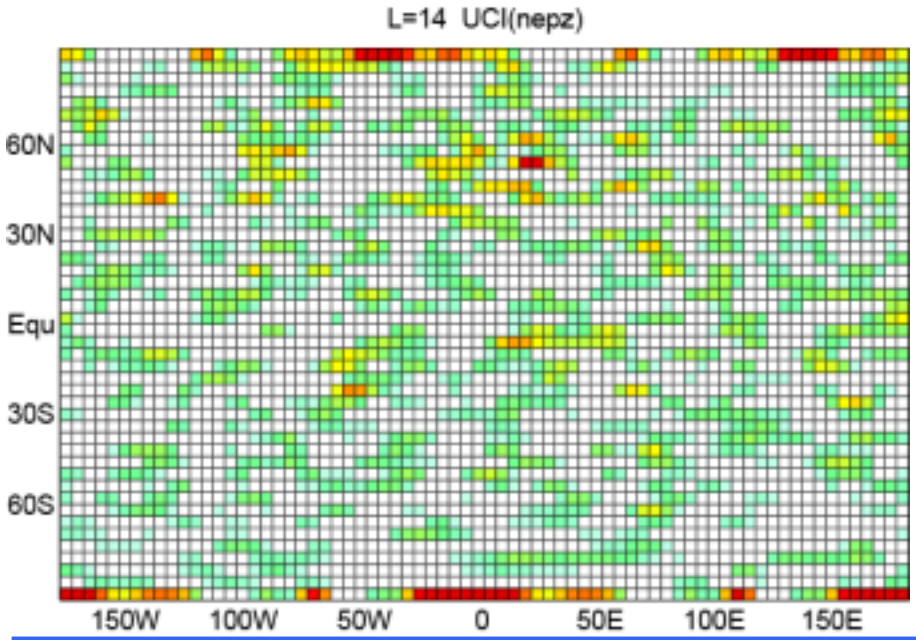
Different methods of BL mixing, convective entrainment,
and averaging over extended polar zones *with UCI only*

1. The 1-hr / 3-hr Calculations:

look at pattern, amount advected from L=15 into L=14 & 16
use ‘std’ run (BL and convection did not impact L=14-15-16)

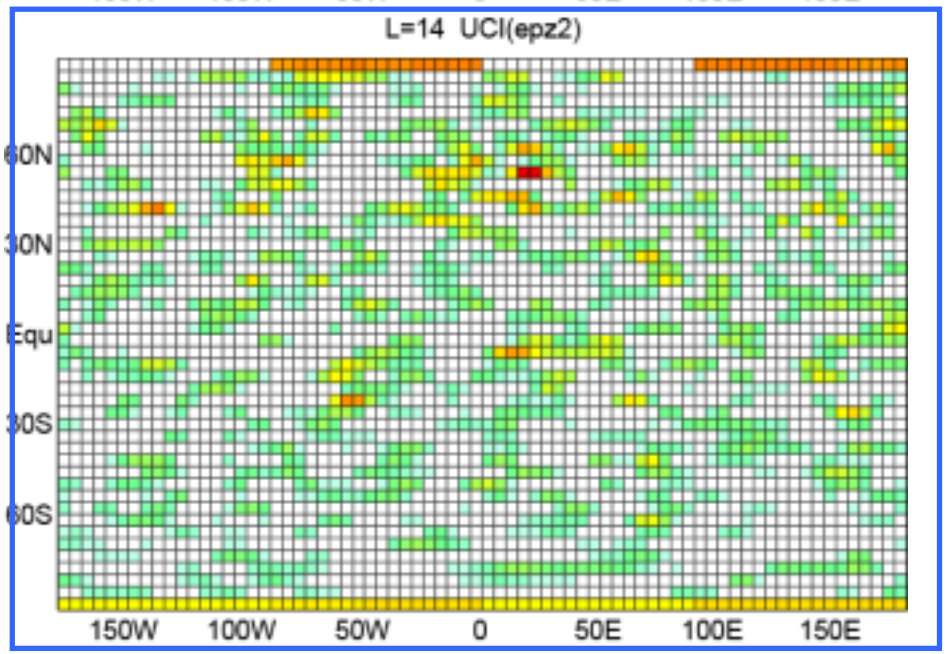


Amount of tracer advected (f=1 @ L=15) to L=14 in 1 hr: *UCI epz options*

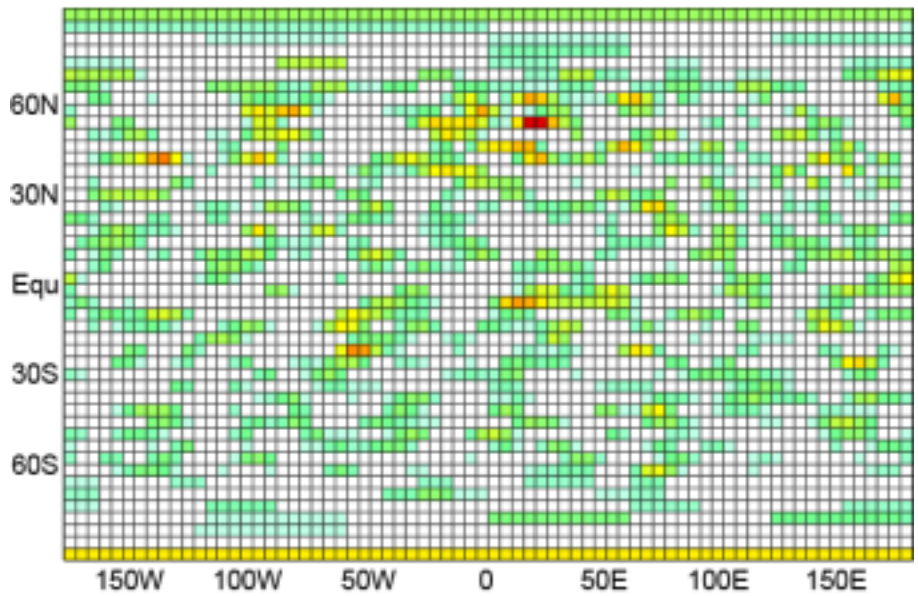


nepz = no extended polar zones
to smooth met fields

epz2 = current standard, small epz filter



epz0 = old extended polar zones
(extensive!)

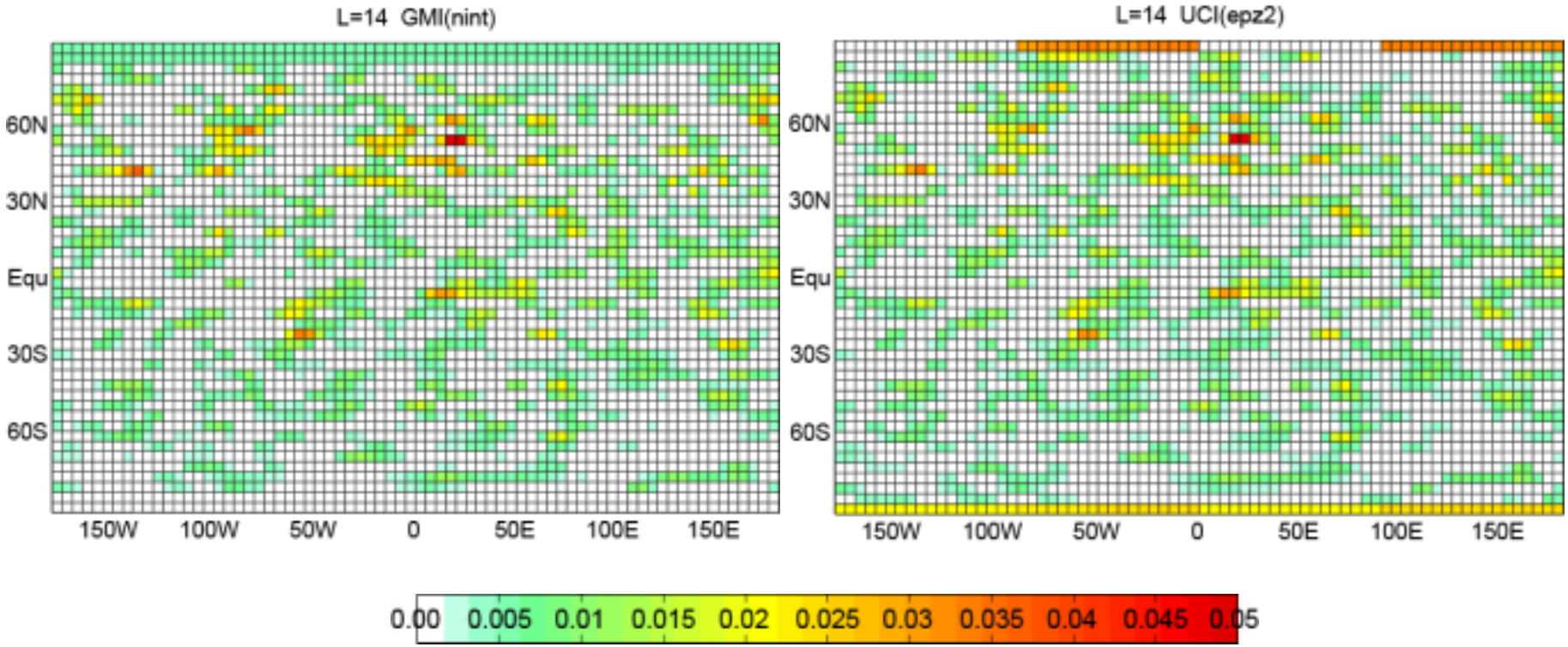


Amount of tracer advected (f=1 at L=15) DOWN to **L=14** in 1 hr: ***GMI vs. UCI***

GMI and UCI look very close, except at the poles

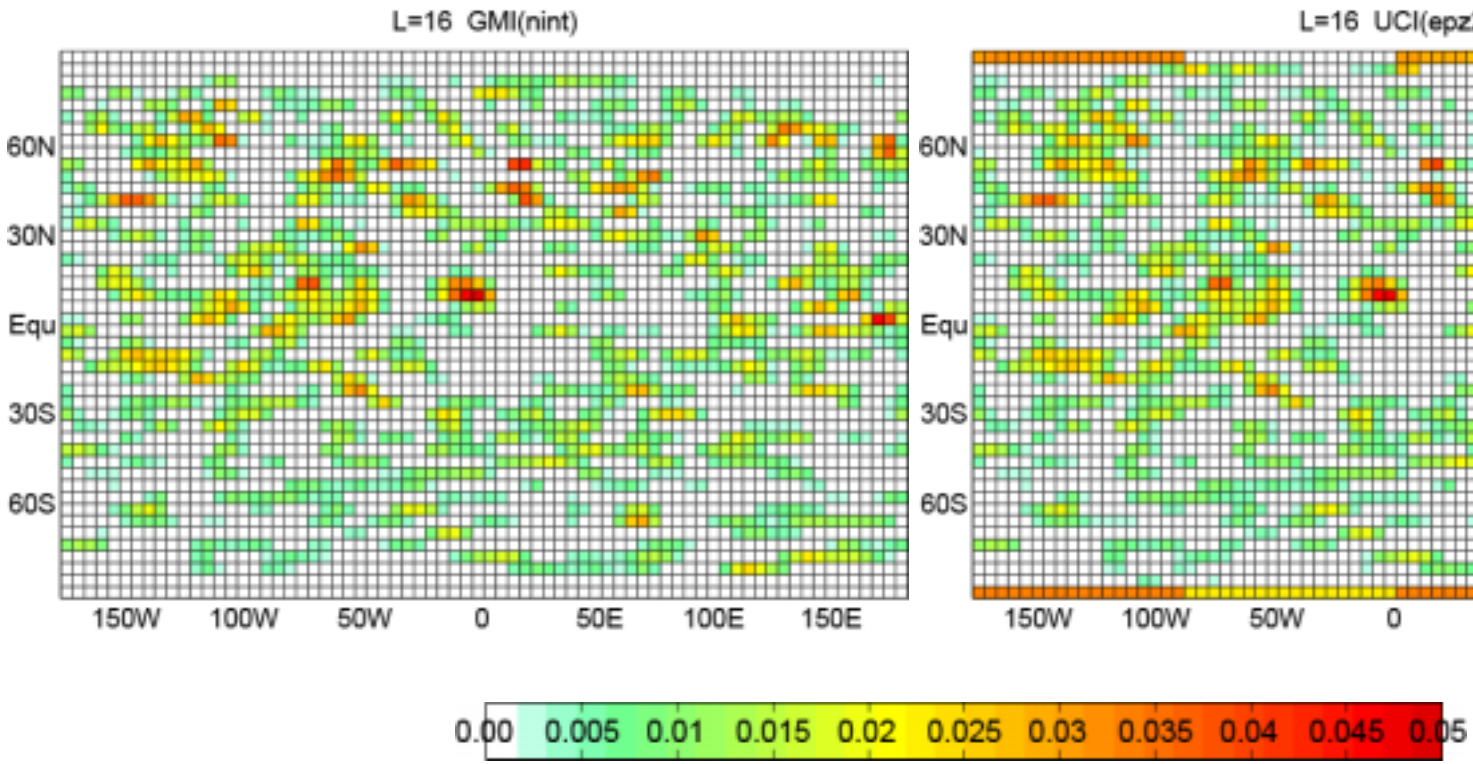
GMI advects then averages over 2 polar boxes

UCI averages met fields (4 x 18 at poles) then advects individually



Amount of tracer advected (f=1 at L=15) UP to **L=16** in 1 hr: ***GMI vs. UCI***

GMI and UCI look very close, except at the poles



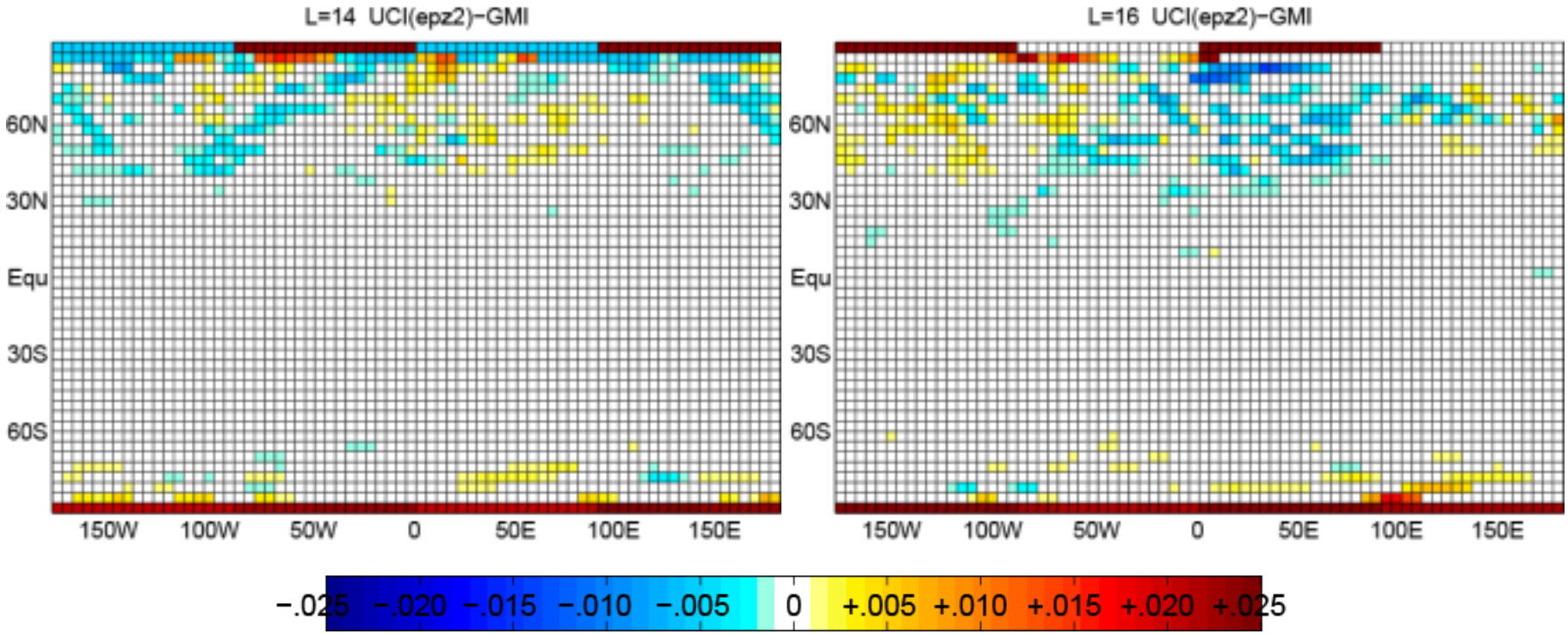
Amount of tracer advected (f=1 at L=15) to L=14 & 16 in 1 hr: ***UCI - GMI***

GMI and UCI look very close, except at the poles

most errors small (±0.003)

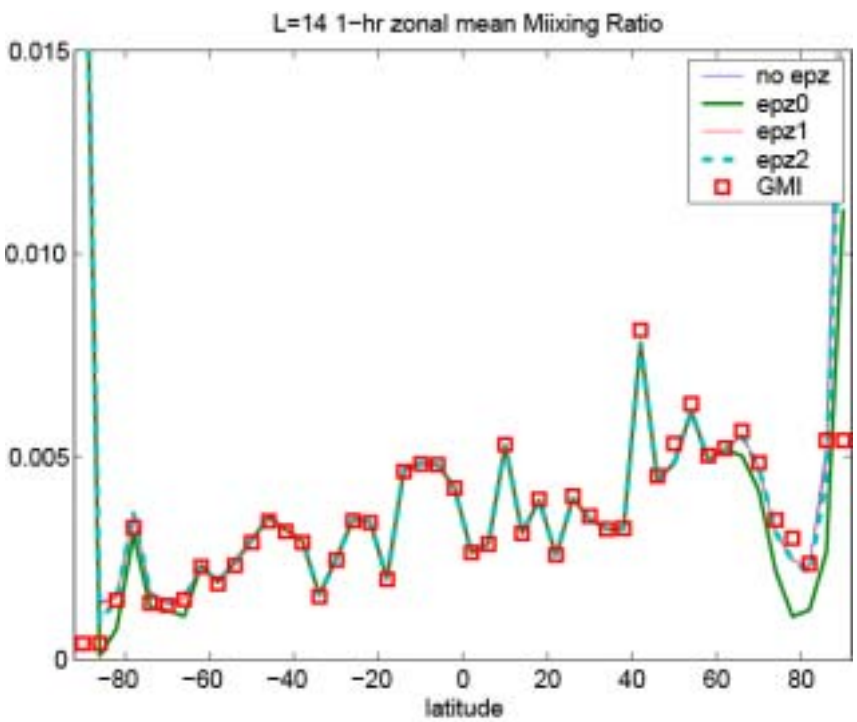
error pattern explained by (u,v,w) advection order

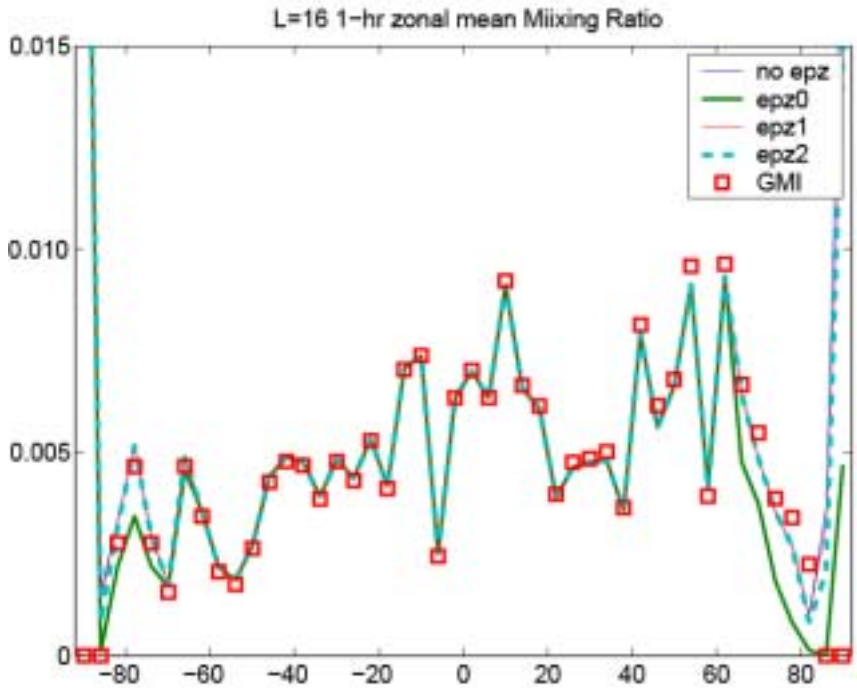
(see next slide of zonal average**)



Amount of tracer advected (f=1 at L=15) to L=14 & 16 in 1 hr: ***zonal mean***

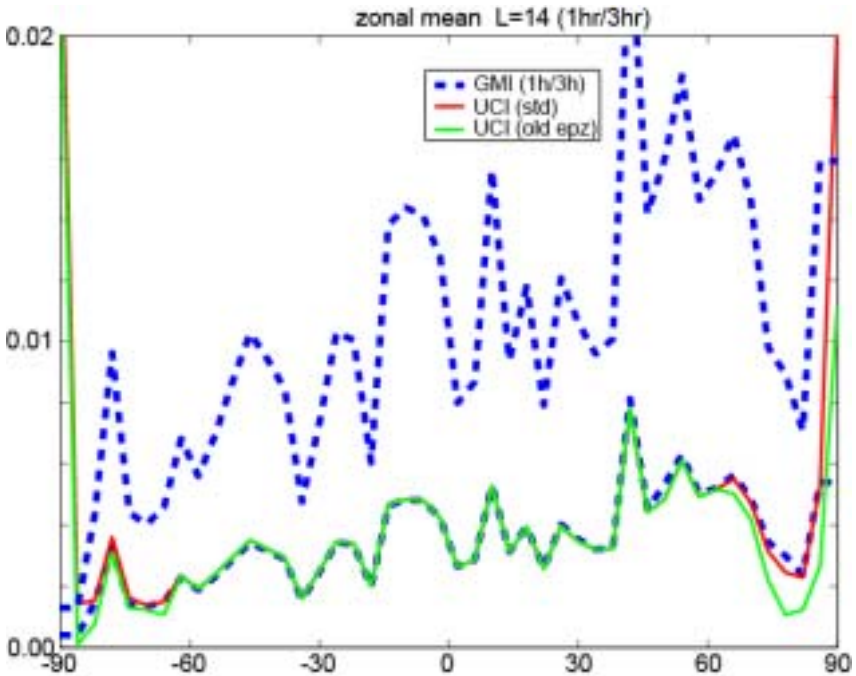
zonally GMI and UCI are almost identical except at the poles**
(where UCI's old epz0 shows 'errors')



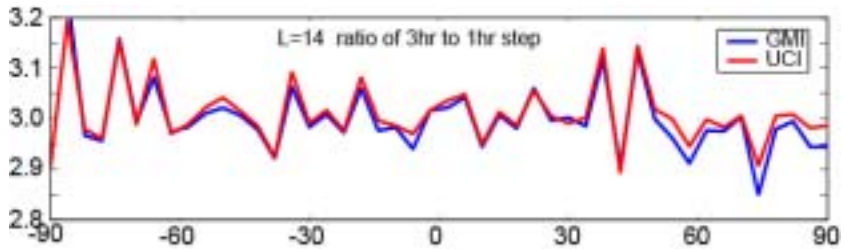


Amount of tracer advected (f=1 at L=15) to L=14 in 1 hr & 3 hr: ***zonal mean***

GMI and UCI both show anticipated 3-fold increase in L=14 after 3 hr AND have same zonal mean variation



ratio 3-hr:1-hr

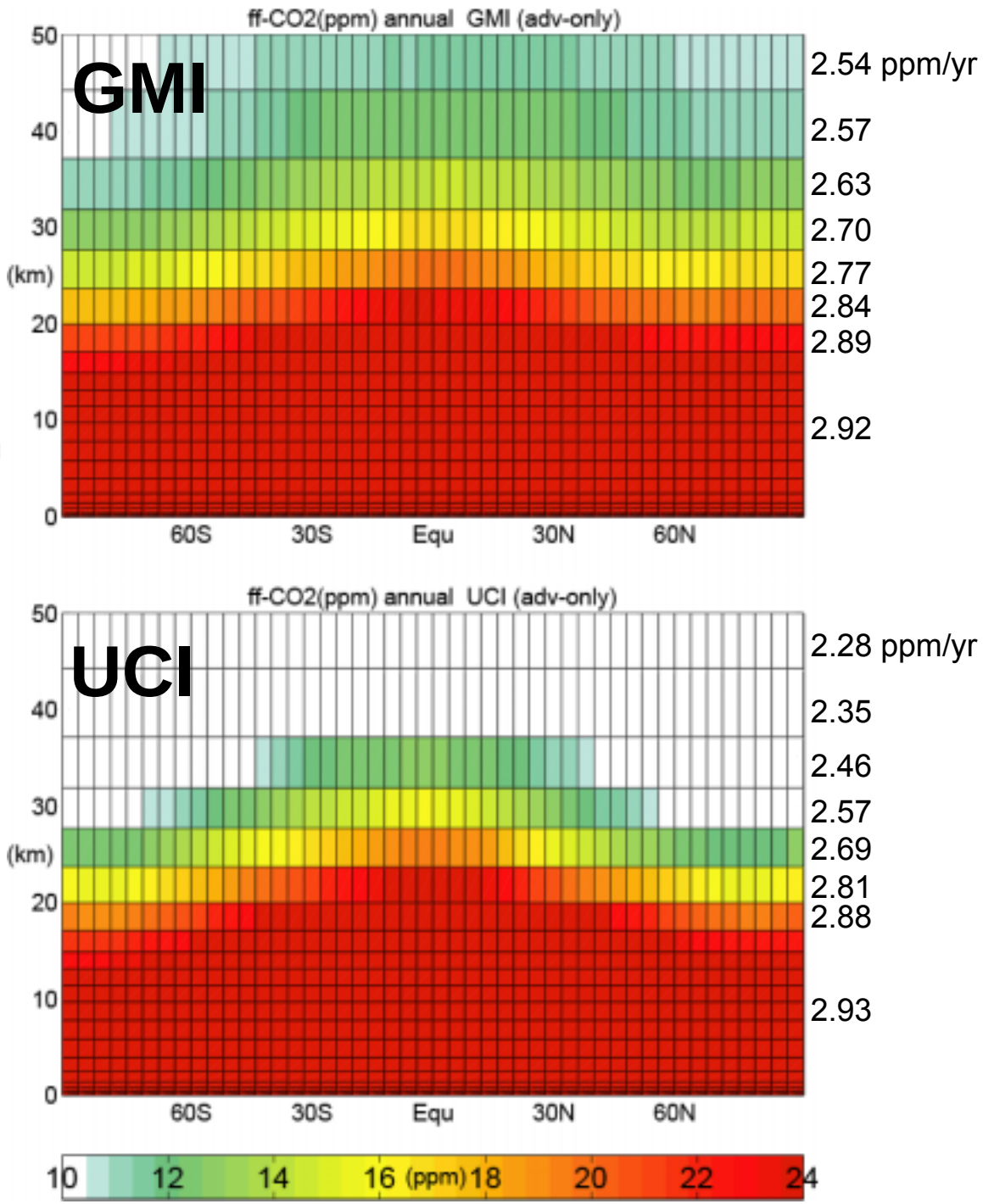


2. 10-yr runs for Stratospheric CO_2

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



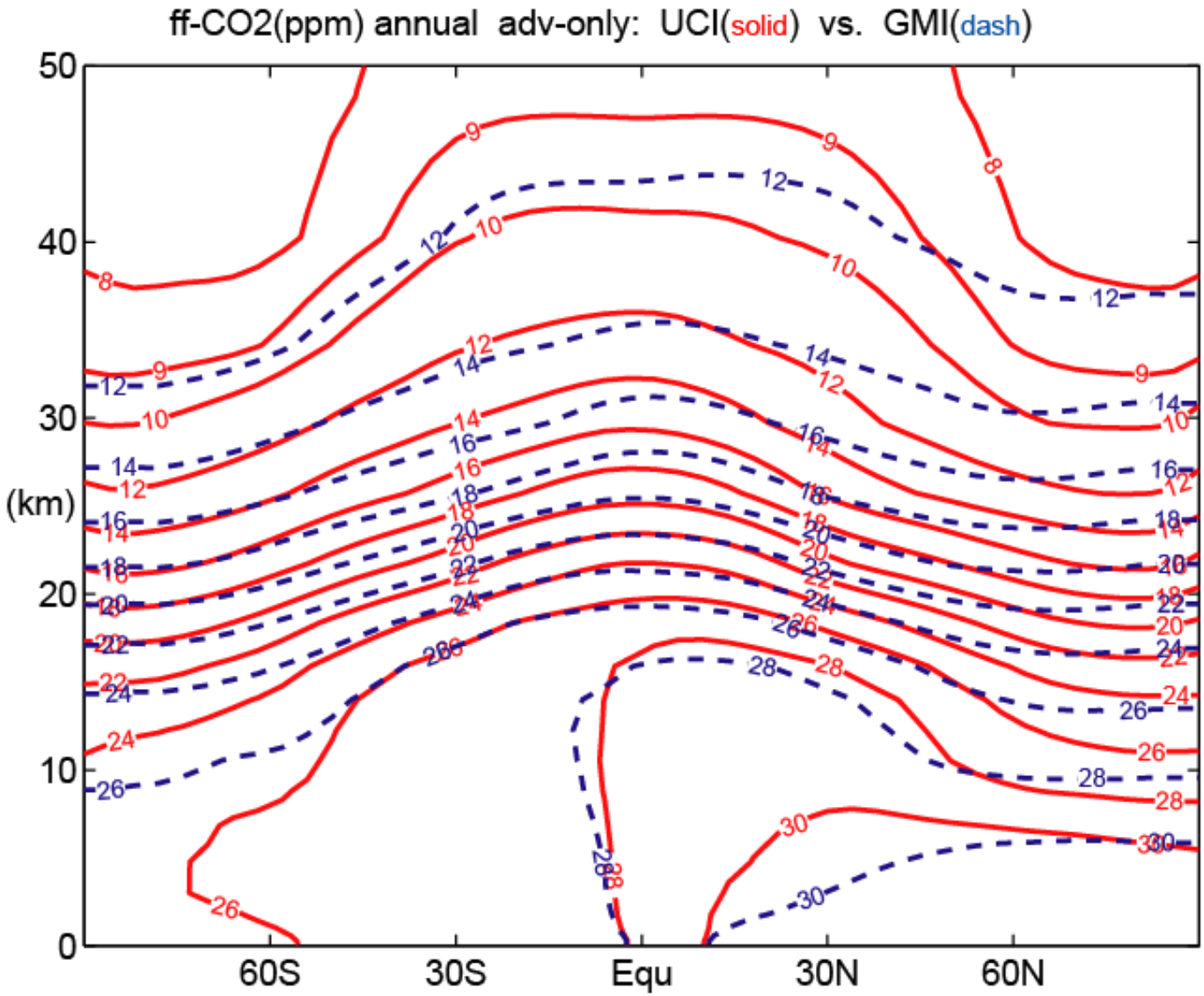
GMI vs UCI CTM (adv-only)

In lower tropics (20-28 ppm = 16-24 km) agreement is OK, but elsewhere

GMI CTM cannot sustain vertical and horizontal gradients that UCI does

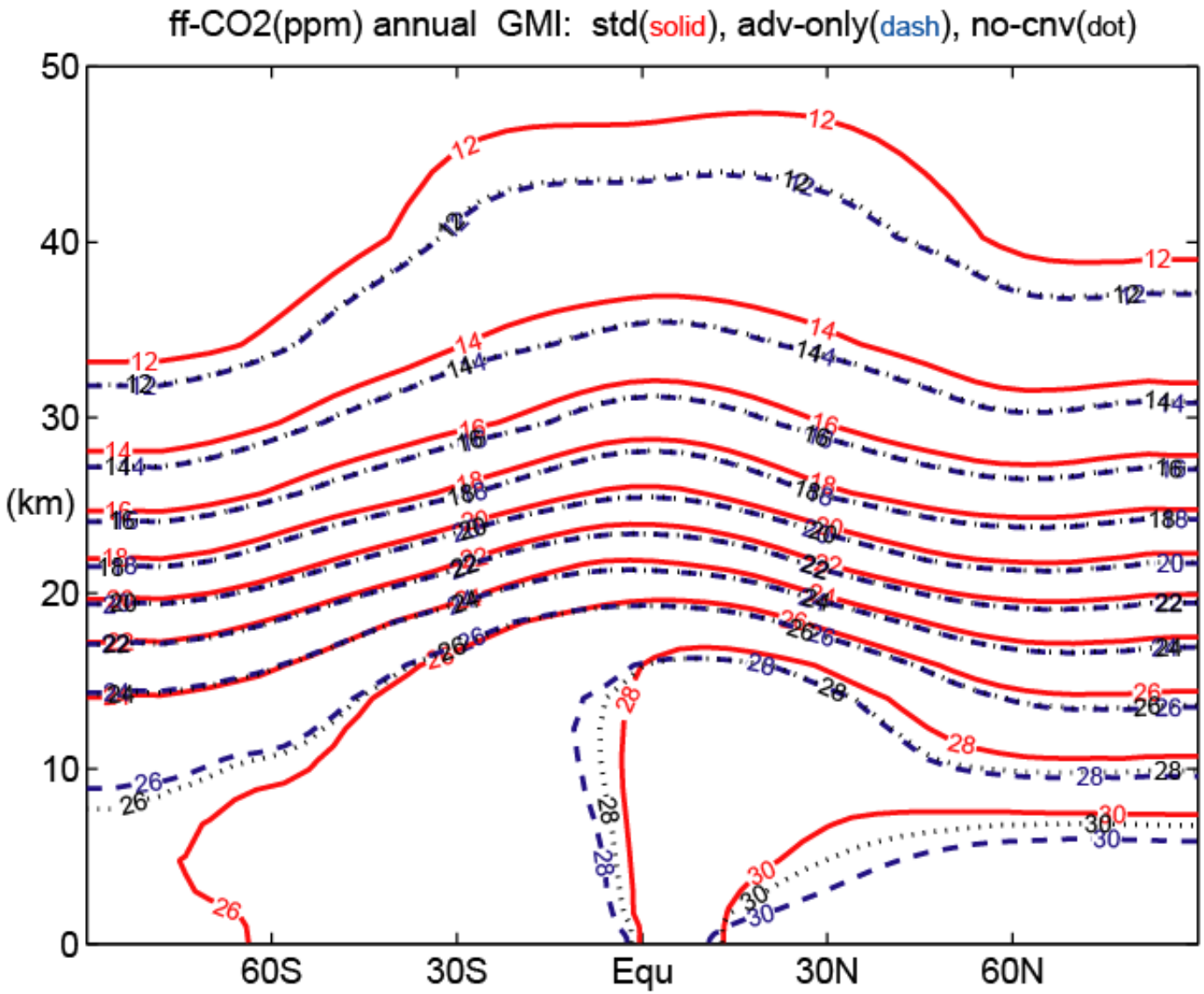
GMI loses the poleward downward slope

errors at 30 km are 2 to 4 ppm (1 yr in age!)

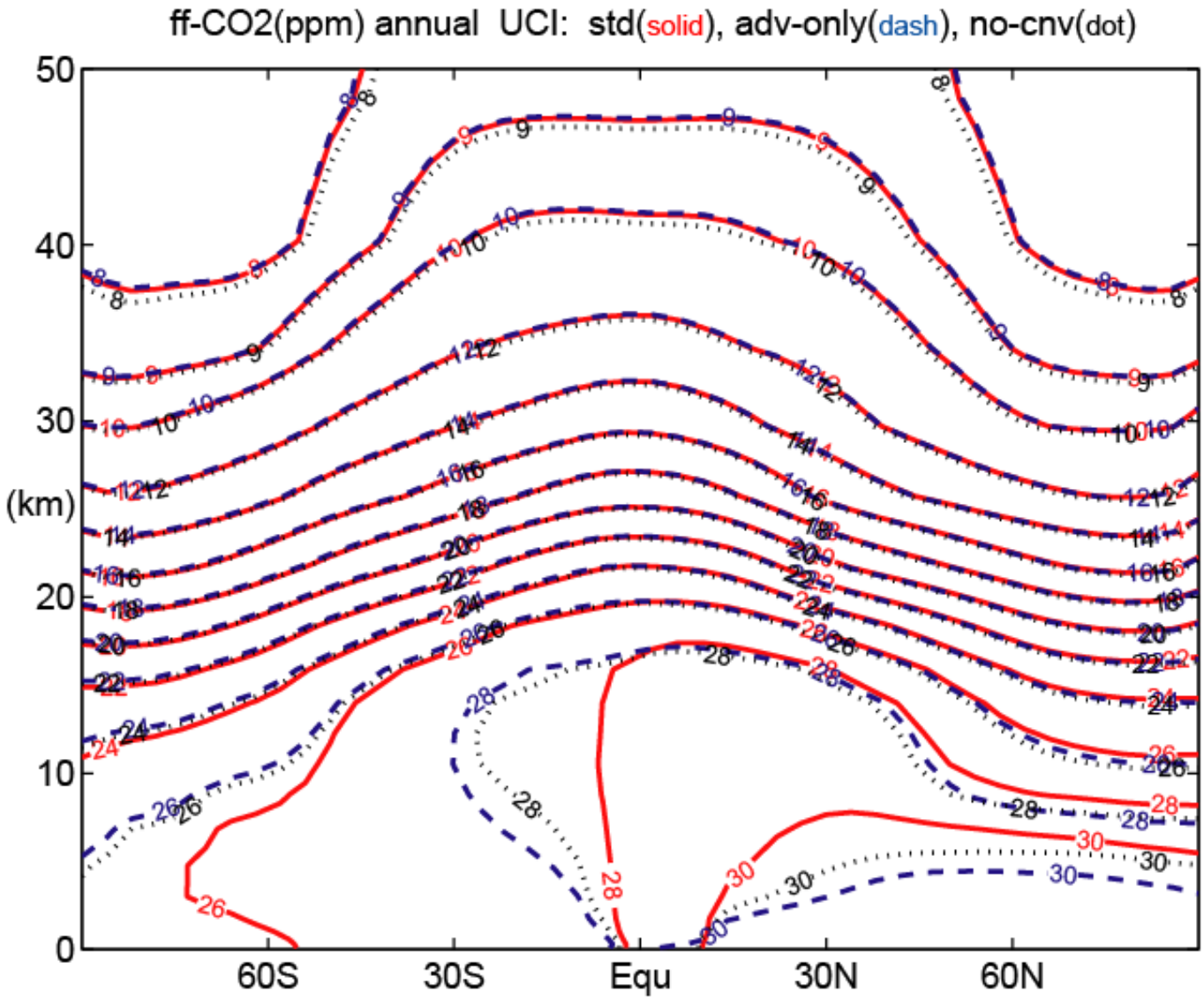


GMI appears to add some vertical diffusion (Kz) terms in the stratosphere?

the std model mixes more vertically than adv-only or no-cnv



UCI shows almost no difference between std, adv-only and no-cnv
but there is a worrying, small difference with no-cnv?



3. 10-yr runs for Trop. CO_2

a. surface CO_2 mixing ratio

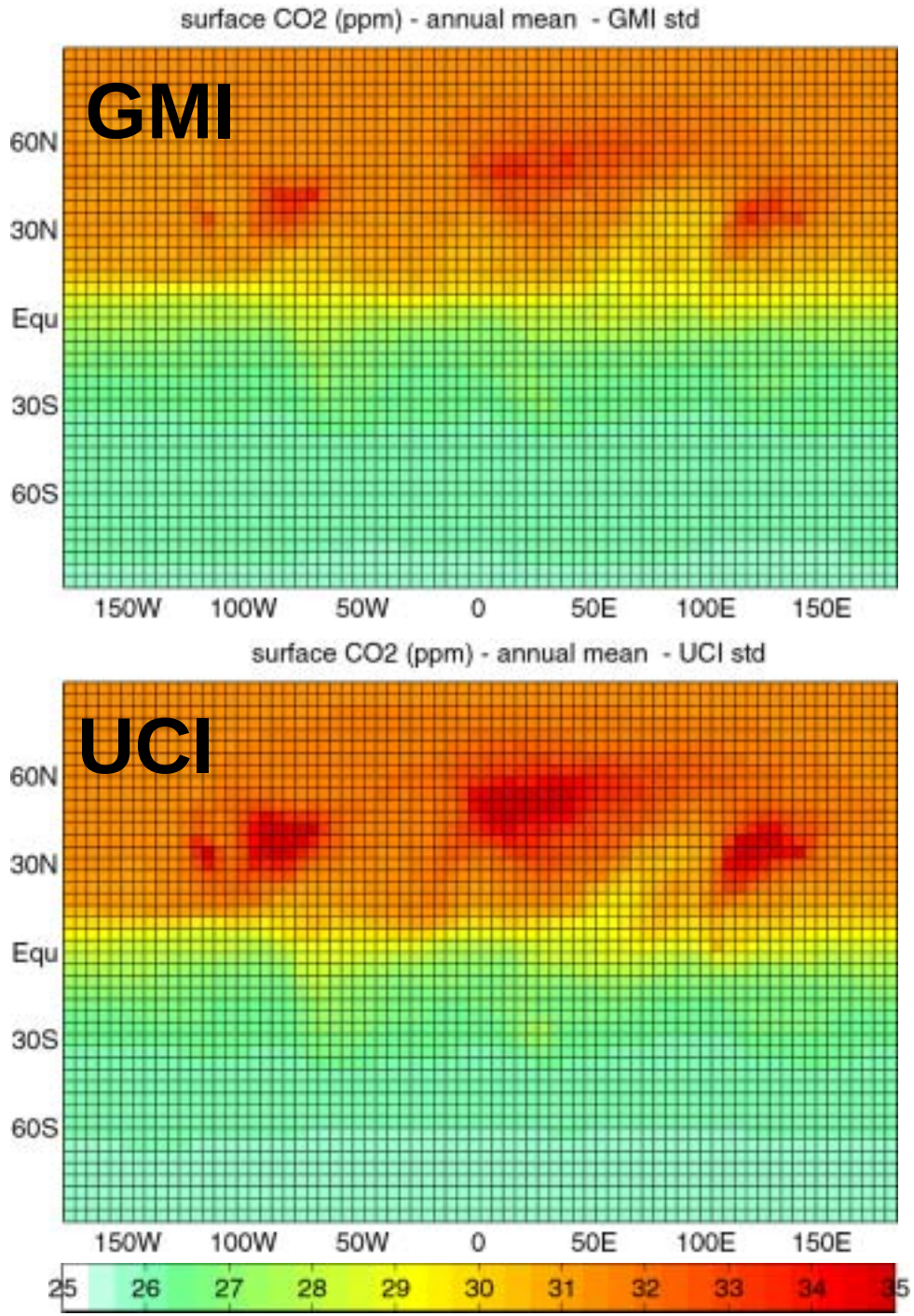
&

b. column CO_2 mixing ratio

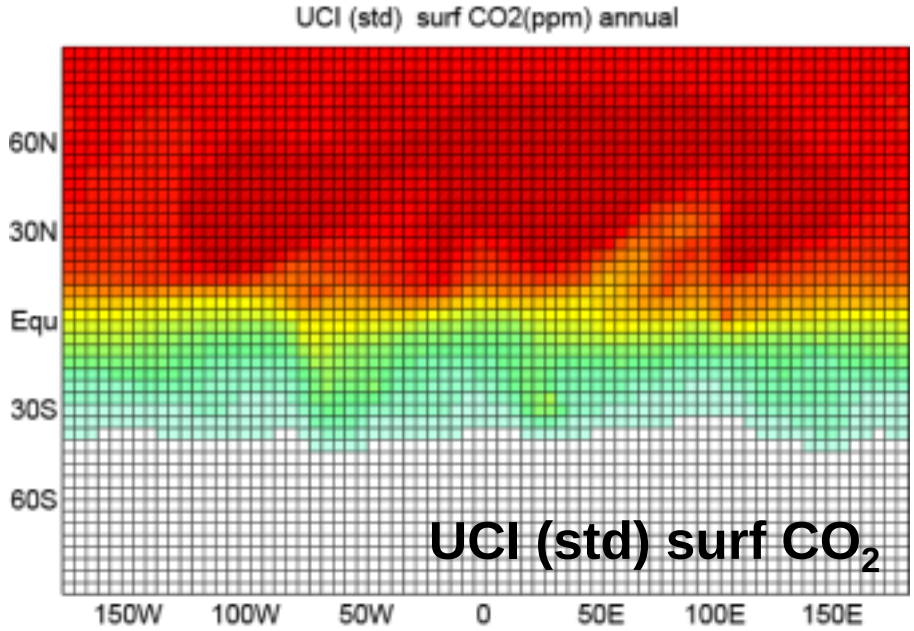
annual or monthly means from Yr 10

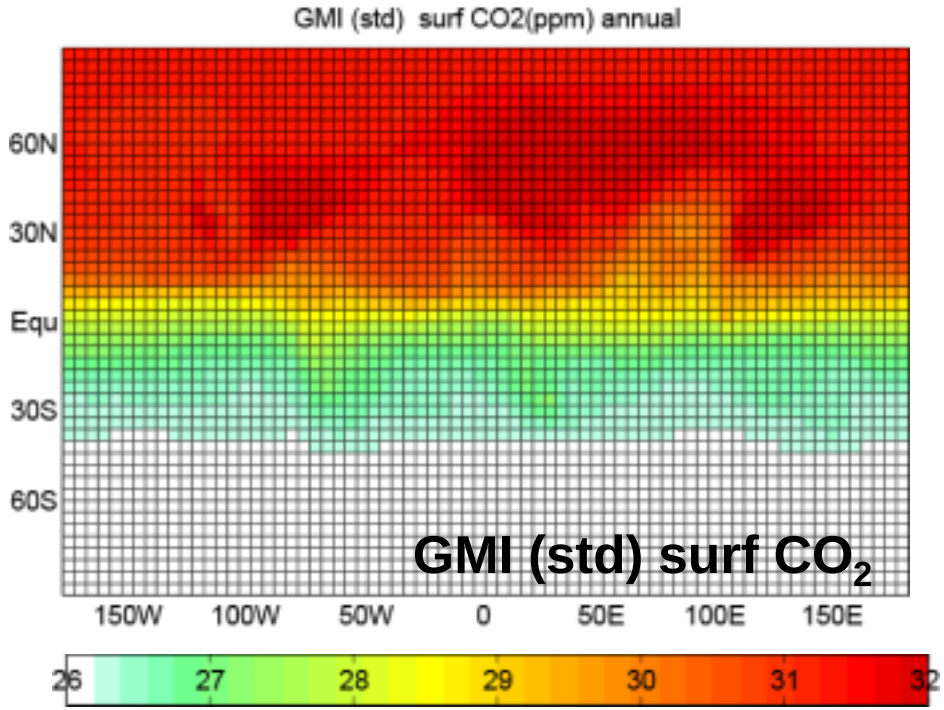
GMI appears more “diffusive”
UCI retains higher abundances
over source regions.

N.B. model 4x5 grid shown

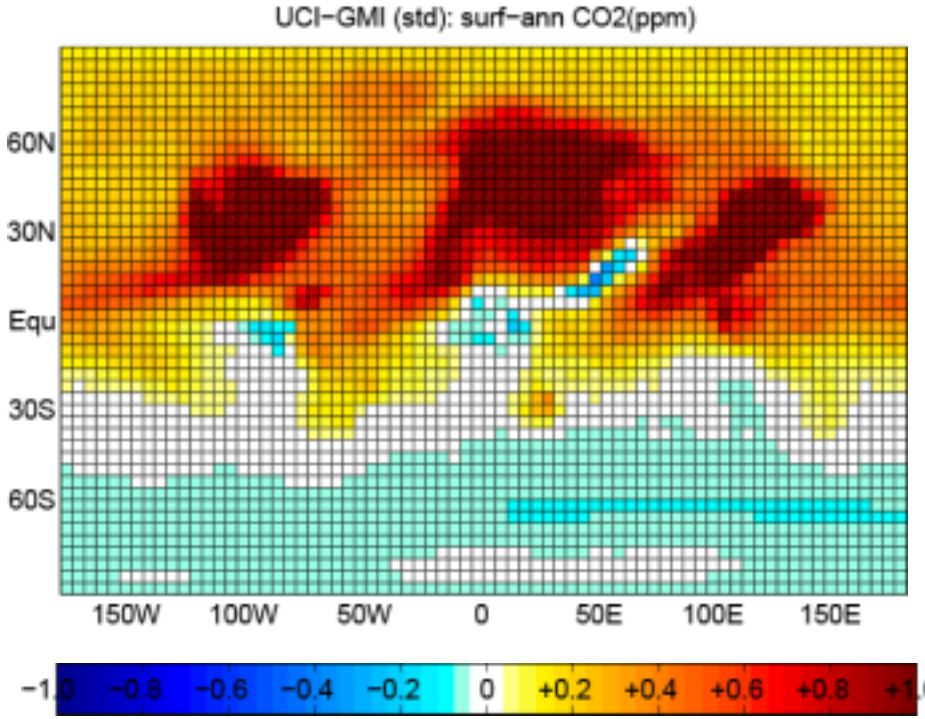


SURFACE CO2





UCI - GMI



Surface CO_2 - Annual mean:

Compare UCI - GMI:

(std) = full, standard CTM with all processes

(ncnv) = advection + boundary-layer mix only

(adv) = advection only

\+ *(BL-up + noED) = UCI to look more like GMI*

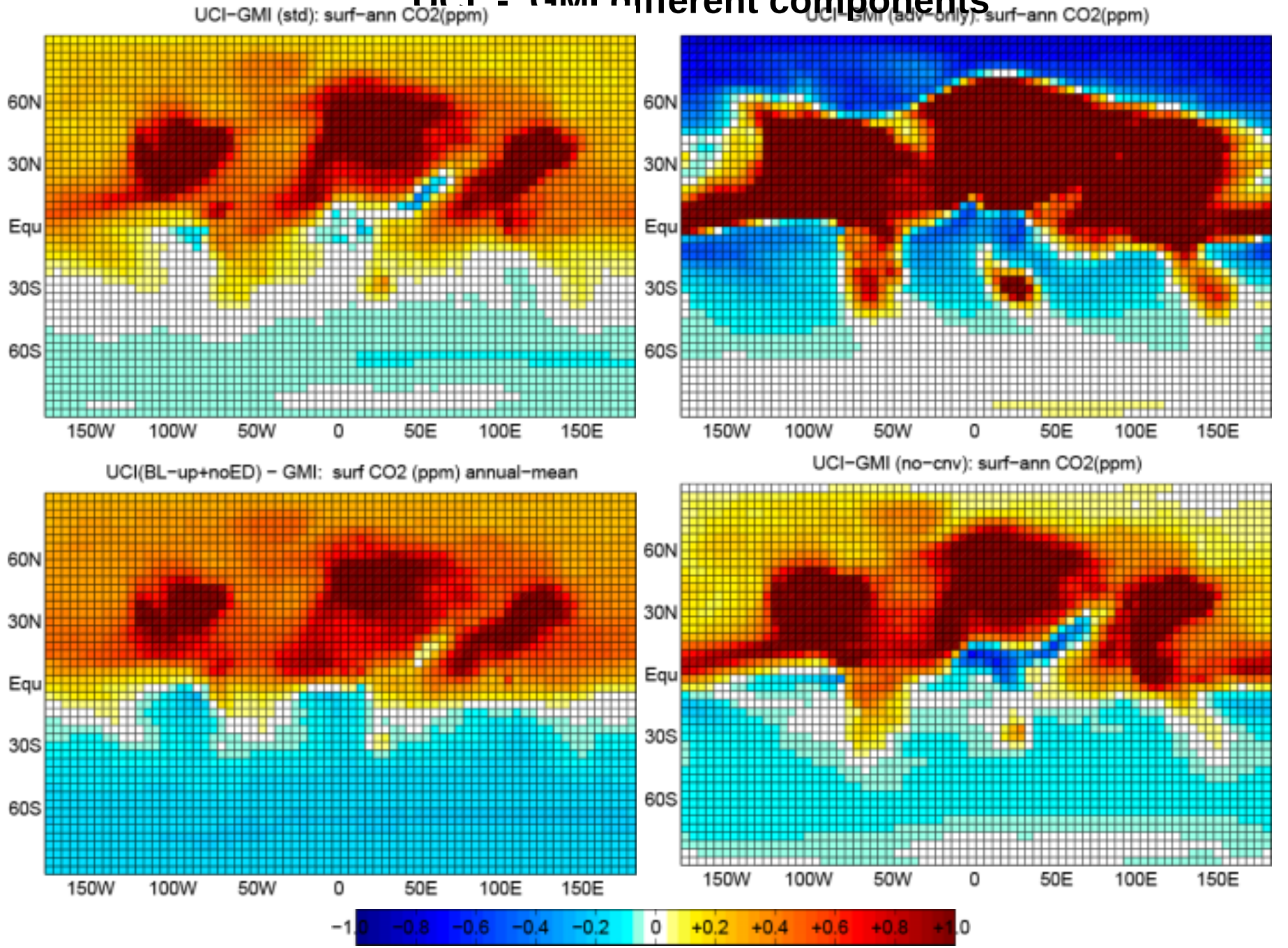
Compare UCI – GMI (std) with met-field differences:

GISS – DAO (GMI)

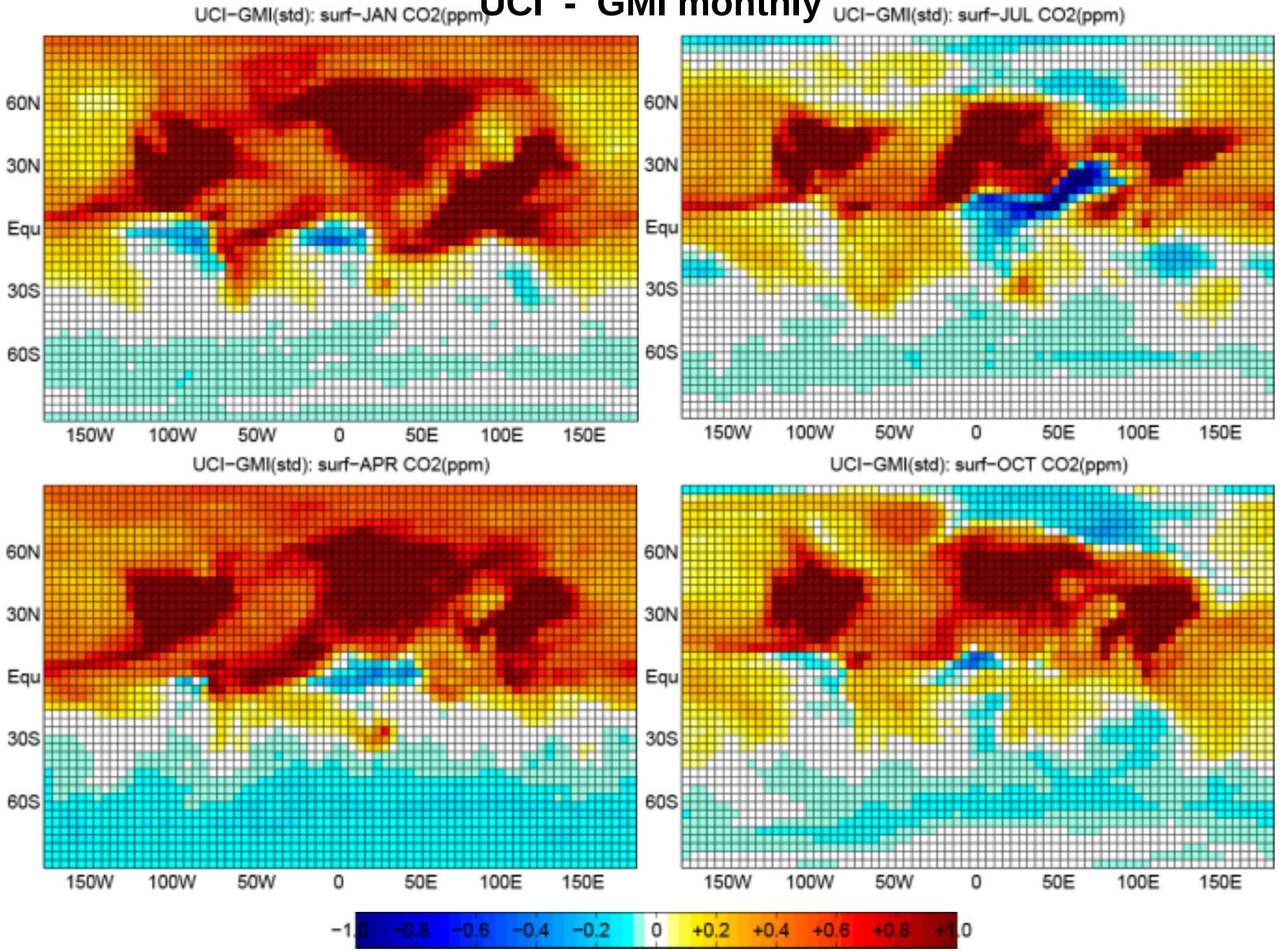
GISS – G78 (UCI, another 4x4x23L GISS met field)

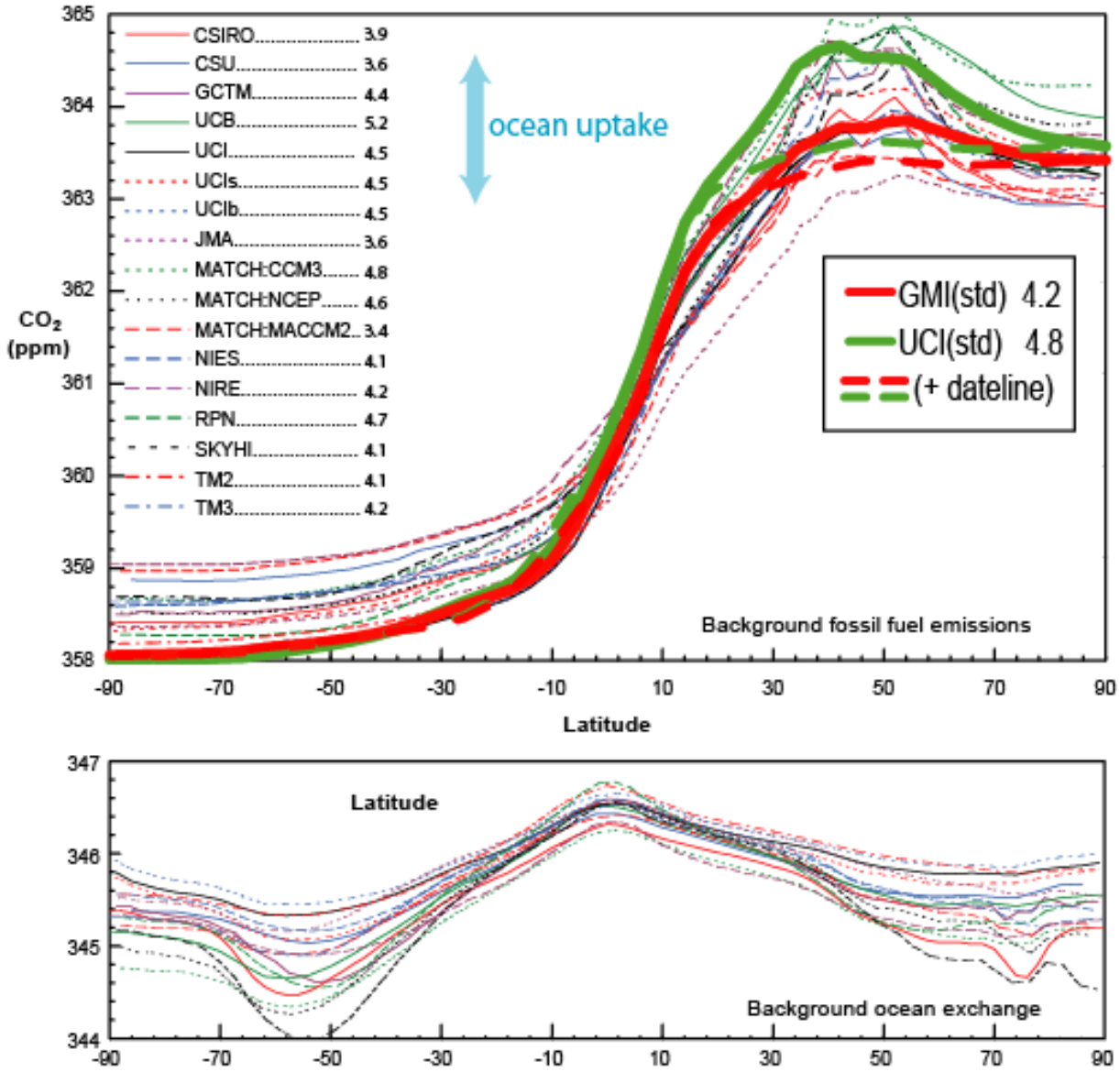
G77 – G78 (UCI, two consecutive years of G78)

UCI - GMI different components



UCI - GMI monthly




CSIRO 3.9
CSU 3.6
GCTM 4.4
UCB 5.2
UCI 4.5
UCIs 4.5
UCIb 4.5
JMA 3.6
MATCH:CCM3 4.8
MATCH:NCEP 4.6
MATCH:MACCM2 3.4
NIES 4.1
NIRE 4.2
RPN 4.7
SKYHI 4.1
TM2 4.1
TM3 4.2
ocean uptake
GMI(std) 4.2
UCI(std) 4.8
(+ dateline)
Background fossil fuel emissions
CO2 (ppm)
Latitude
Latitude
Background ocean exchange

Did not GMI solve this problem about the accuracy of the tracer transport ?

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 104, NO. D22, PAGES 27,545–27,564, NOVEMBER 27, 1999

Choosing meteorological input for the global modeling initiative assessment of high-speed aircraft

A. R. Douglass,[1] M. J. Prather,[2] T. M. Hall,[3] S. E. Strahan,[4] P. J. Rasch,[5] L. C. Sparling,[6] L. Coy,[4] and J. M. Rodriguez[7]

Abstract. The global modeling initiative (GMI) science team is developing a three-dimensional chemistry and transport model (CTM) for use in assessment of the atmospheric effects of aviation. This model must be documented, be validated against observations, use a realistic atmospheric circulation, and contain numerical transport and photochemical modules representing atmospheric processes. The

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 106, NO. D2, PAGES 1669–1691, JANUARY 27, 2001

Global Modeling Initiative assessment model: Model description, integration, and testing of the transport shell

D. A. Rotman,[1] J. R. Tannahill,[1] D. E. Kinnison,[1,2] P. S. Connell,[1] D. Bergmann,[1] D. Proctor,[1] J. M. Rodriguez,[3] S. J. Lin,[4] R. B. Rood,[4] M. J. Prather,[5] P. J. Rasch,[2] D. B. Considine,[6] R. Ramaroson,[7] and S. R. Kawa[4]

Table 2. Summary Table of GMI Algorithms and Model Data

Module	Options
Input meteorological data	NASA Data Assimilation Office (DAO) assimilated fields (NCAR MACCM2 GCM fields) NASA GISS II′ GCM fields
Advection algorithm	semi-Lagrangian transport (SLT) (flux form semi-Lagrangian transport (FFSLT)) second-order moments (SOM)
Mass tendencies	(NASA GISS/University of California, Irvine, pressure filte
Numerical schemes for chemistry solutions	SMVGEAR II (semi-implicit syı

N_2O with GISS met fields & UCI SOM

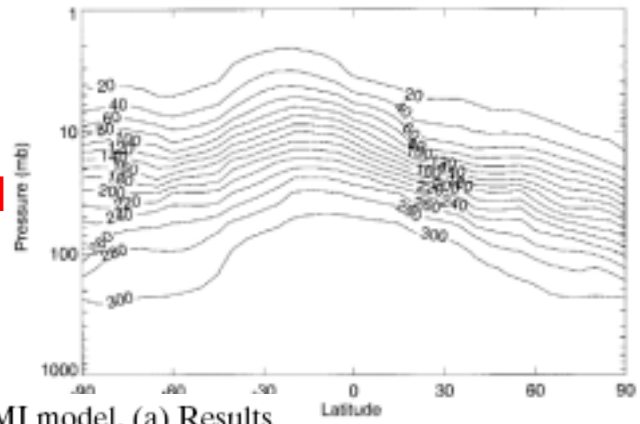
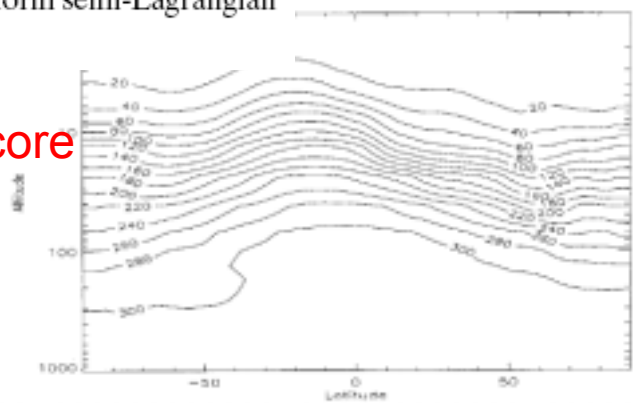
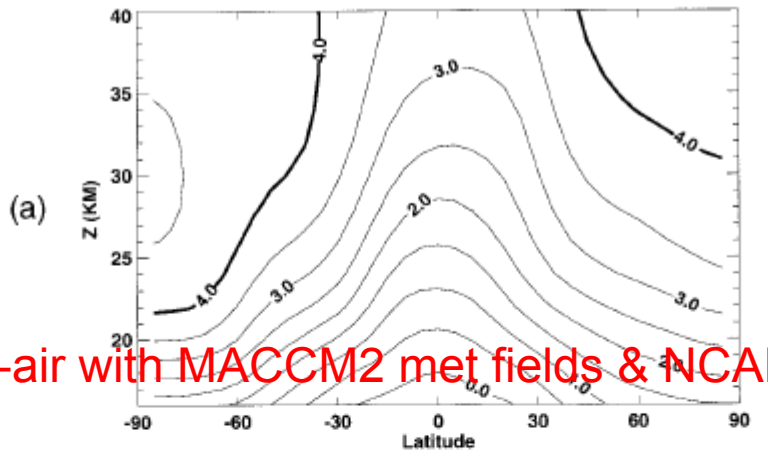


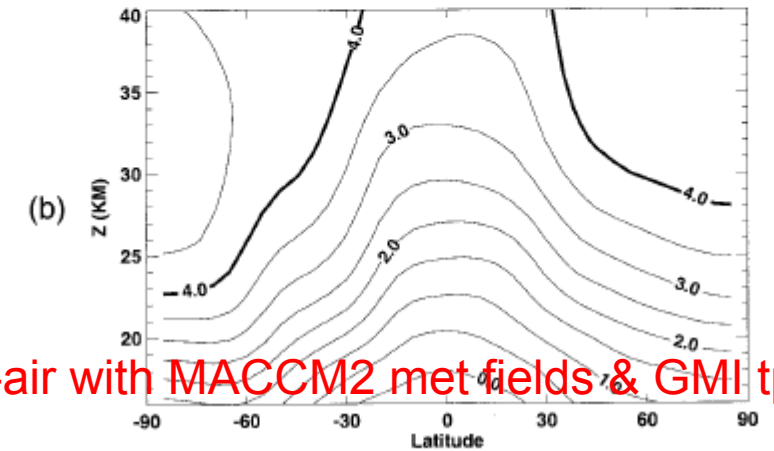
Figure 4. Steady state zonal averaged N_2O simulation results for January using the GMI model. (a) Results obtained using the GISS II′ meteorological input data with the second-order moment method advection scheme. (b) Results obtained using the GISS II′ meteorological input data with the flux form semi-Lagrangian advection scheme. Units are ppbv.

N_2O with GISS met fields & GMI tpcore



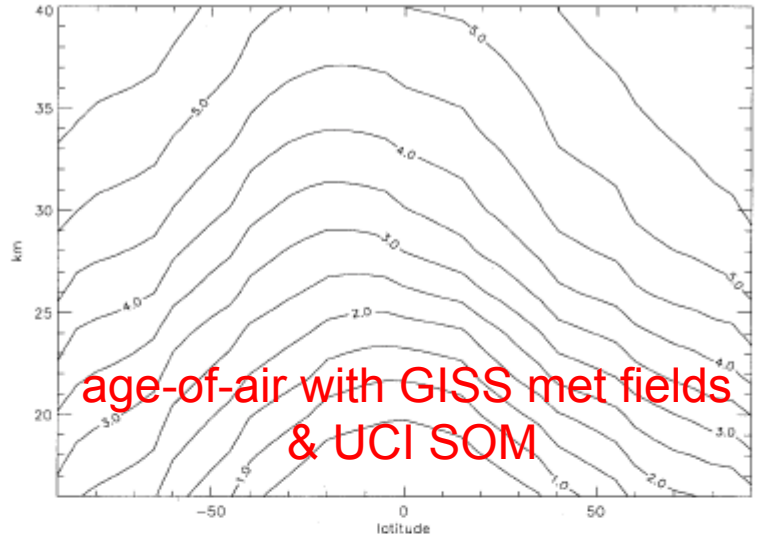


age-of-air with MACCM2 met fields & NCAR SLT

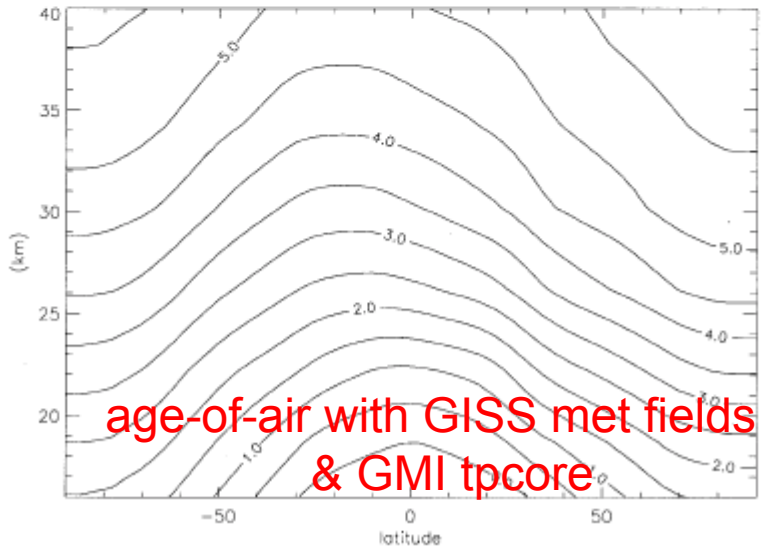


age-of-air with MACCM2 met fields & GMI tpcore

Figure 5. Mean age of air as calculated with the NCAR MACCM2 meteorological input data with (a) the semi-Lagrangian advection scheme and (b) the flux form semi-Lagrangian scheme. Units are years.



age-of-air with GISS met fields & UCI SOM



age-of-air with GISS met fields & GMI tpcore

Figure 6. Mean age of air as calculated with the GISS II' meteorological input data with (a) the second-order moment advection scheme and (b) the flux form semi-Lagrangian scheme. Units are years.

UCI – GMI: 2x to convergence (1)

Assume: Differences between the UCI and GMI CTMs in the simple-tracer CO_2 experiments are due primarily to numerical error.

The numerical error is proportional to Δxyz (grid size).

Alternative: There are systematic errors in the two CTMs in either coding or basic algorithms. Let's not go there.

Let $A(\Delta)$ be the CTM 'answer' computed with grid size Δ have an error $\varepsilon(\Delta)$

$$A^{true} = A(\Delta \rightarrow 0) = A(\Delta) + \varepsilon(\Delta)$$

UCI – GMI: 2x to convergence (2)

$$A^{true} = A(\Delta \rightarrow 0) = A(\Delta) + \varepsilon(\Delta)$$

$$A_1 = A(\Delta)$$

$$A_2 = A(\Delta/2)$$

. . .

When the order of the error (in terms of Taylor series expansion about Δ) is known, a simple approach with only two calculations (e.g., $A(\Delta)$ and $A(\Delta/2)$) can work:

Richardson extrapolation of trapezoidal integration ($\varepsilon \sim \Delta^2$)

$$\varepsilon(\Delta) = a\,\Delta^2 + b\,\Delta^4 + \ldots$$

$$\varepsilon(\Delta/2) = a/4\,\Delta^2 + b'\,(\Delta/2)^4 + \ldots$$

hence

$$4\,A_2 - A_1 = 3\,A^{true} + b''\,\Delta^4 + \ldots$$

and the error

$$\varepsilon(\Delta/2) = (A_2 - A_1)/3 + \text{order}(\Delta^4)$$

UCI – GMI: 2x to convergence (3)

For the CTM calculation, we do not know the order of the error in Δ and hence we resort to Aitkens acceleration.

In this case we assume that the series obtained by successively better approximations by a Δ-halving converges

$$A^{true} = A(\Delta) + [A(\Delta/2) - A(\Delta)] + [A(\Delta/4) - A(\Delta/2)] + [A(\Delta/8) - A(\Delta/4)] + \ldots$$
$$= A_1 + (A_2 - A_1) + (A_4 - A_2) + (A_8 - A_4) + \ldots$$

assume each successive term is smaller than previous by factor k

$$k = (A_4 - A_2) / (A_2 - A_1)$$

then

$$A^{true} = A_1 + (A_2 - A_1)x(1 + k + k^2 + k^3 + k^4 + \ldots)$$

$$= A_1 + (A_2 - A_1) / (1 - k)$$

UCI – GMI: 2x to convergence (4)

Note that we need the sequence A_1, A_2, and A_4, but would like also to calculate A_8 to check that the k-values are stable

$$(A_4 - A_2) / (A_2 - A_1) \quad ?=? \quad (A_8 - A_4) / (A_4 - A_2)$$

UCI – GMI: 2x to convergence (5)

At UCI we recoded the CTM to do automatic grid doubling. The method of interpolating has been checked / run for advection only thus far. (Advection is identified as the primary difference between UCI and GMI CTMs.) For advection we do not interpolate across different grid boxes, but merely sub-divide the advective fluxes equally across the halved grid boxes.

Using the GISS-II' 4x5 GMI met fields, grid = 72(I) x 46(J) x 23(L) there are several experiments:

L1* = F1 = I1:J1:L1 = 72 x 46 x 23 = standard CTM run
L2* = 72 x 46 x 46
L4* = 72 x 46 x 92
L8* = 72 x 46 x 184

F2* = I2:J2:L2 = 144 x 90 x 46
F4** = I4:J4:L4 = 288 x 178 x 92
F8*** = I8:J8:L8 = 576 x 354 x 184

*10-yr run completed, **run to 4 yr, ***run for only 2 months

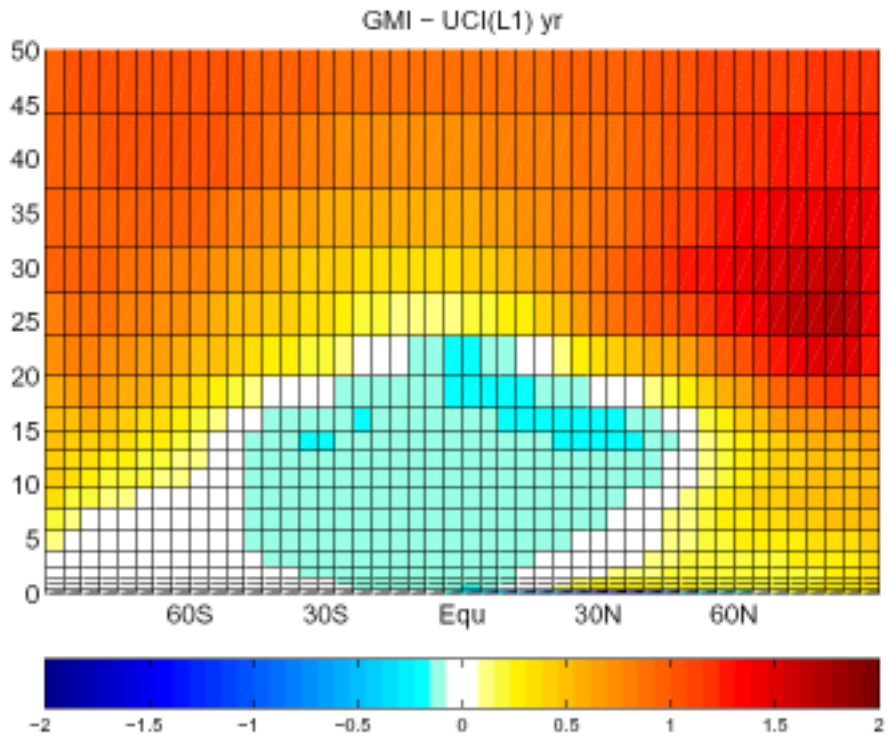
UCI – GMI: 2x to convergence (6)

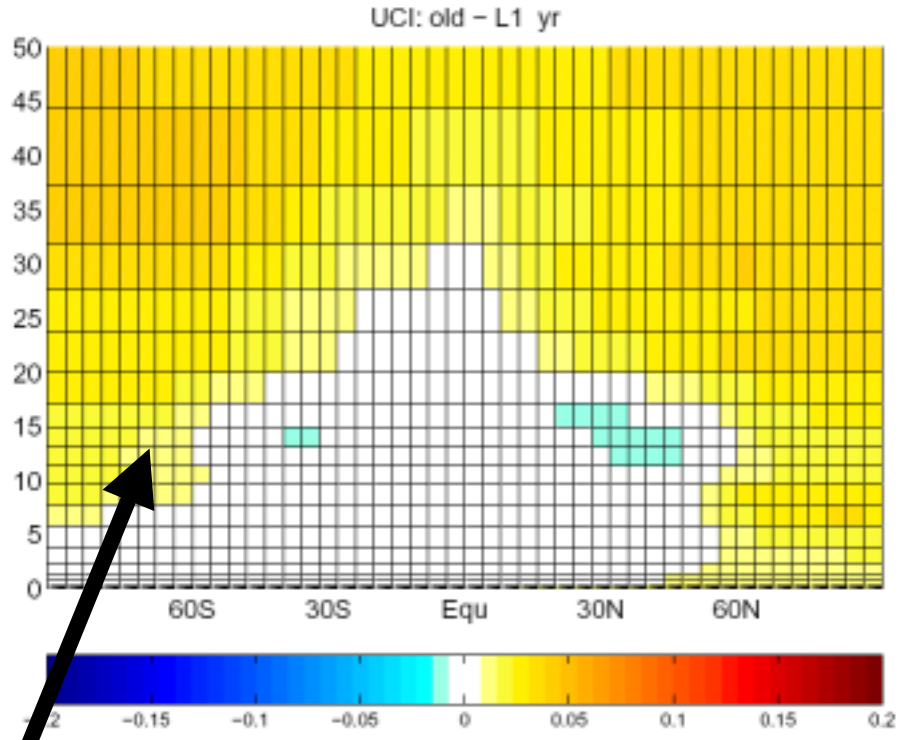
(1) Look at stratospheric age-of-air
(L1=F1, L2, L4, L8, F2 10-yr runs)

(2) Look at columns – combination troposphere + stratosphere

(3) Look at surface
(L1, L2, L4, L8; F1, F2, F4 for year 1+)

UCI – GMI difference large, >1 yr over most of strat.

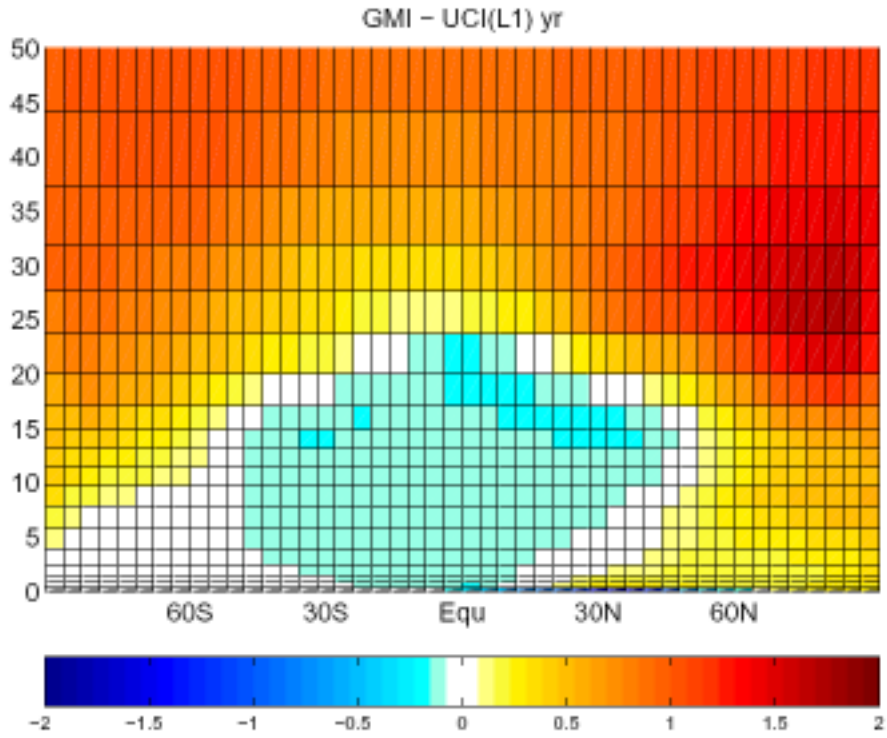


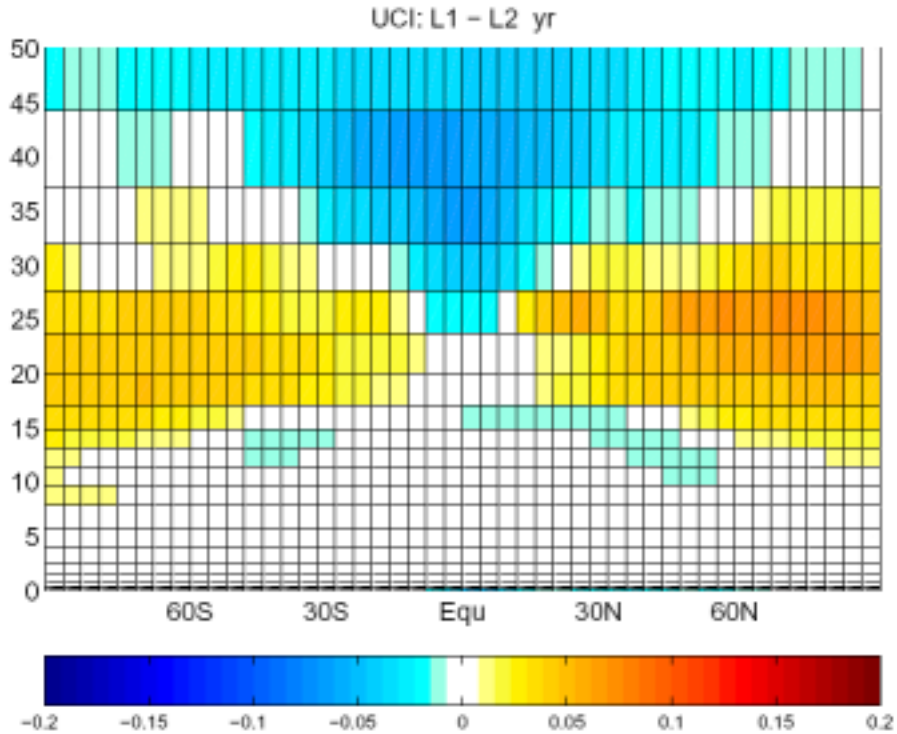


but age-of-air sensitive to small errors/differences in UCI code – NB different scale (0.05 vs 1) !!!

UCI – GMI difference large, >1 yr over most of strat.

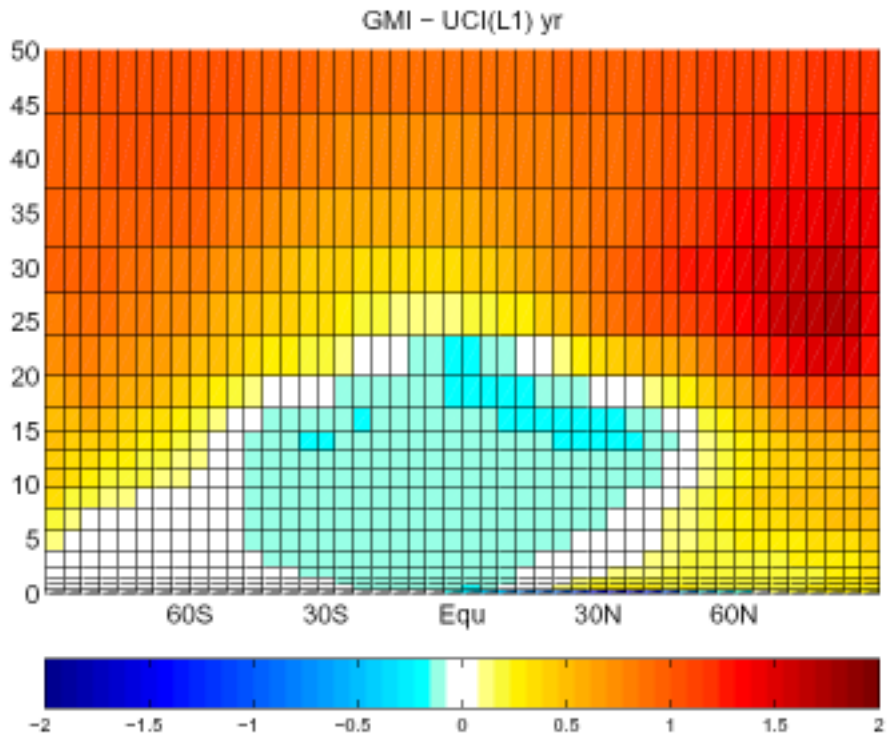
GMI-UCI vs. L1-L2, L2-L4, L4-L8. (different scales)

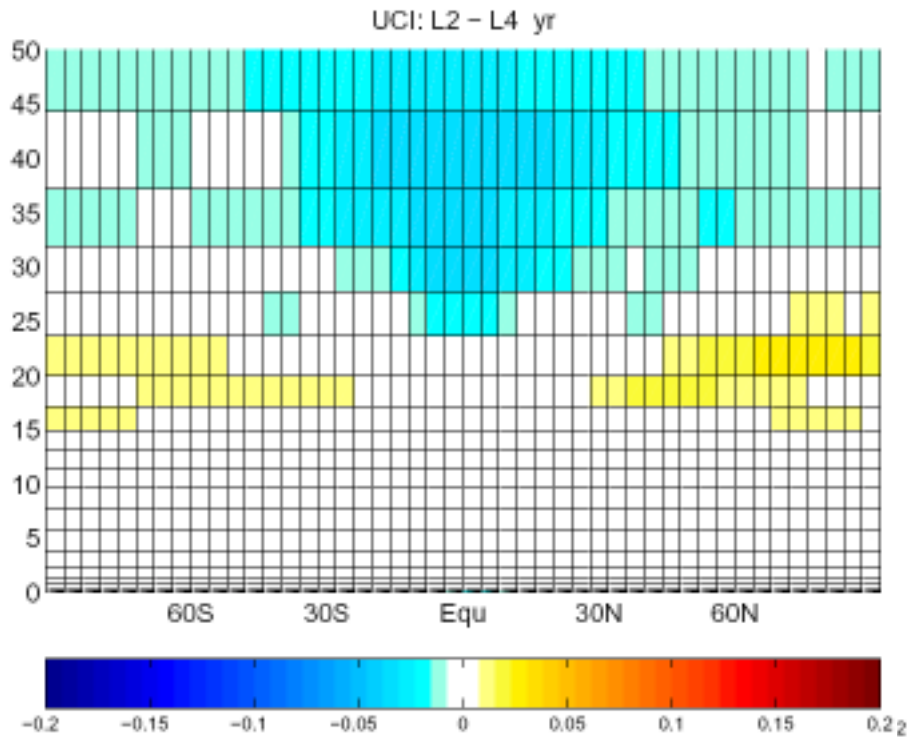




UCI – GMI difference large, >1 yr over most of strat.

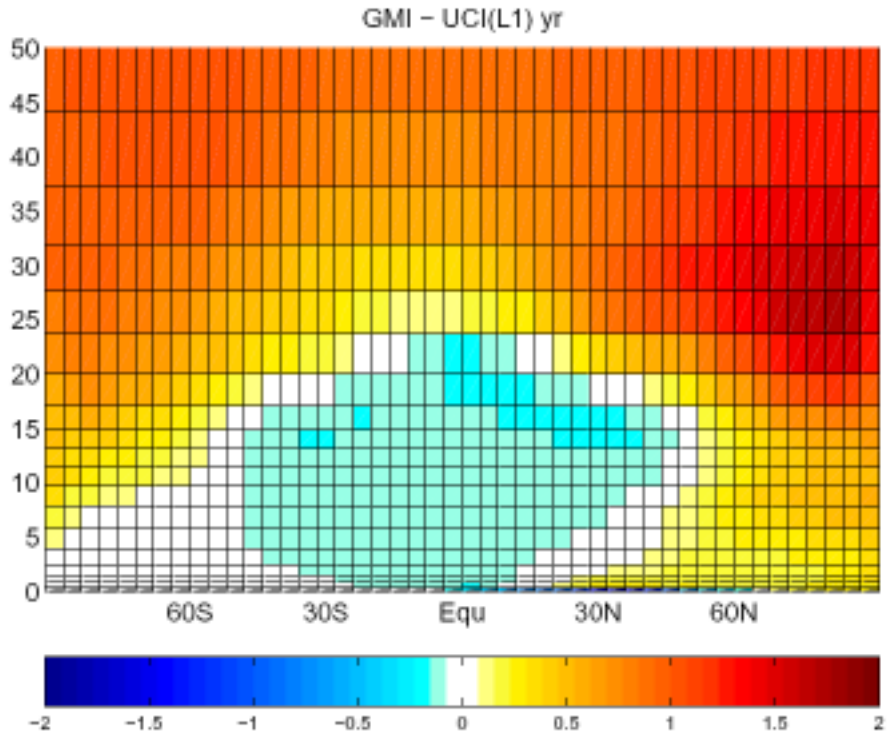
GMI-UCI vs. L1-L2, L2-L4, L4-L8. (different scales)

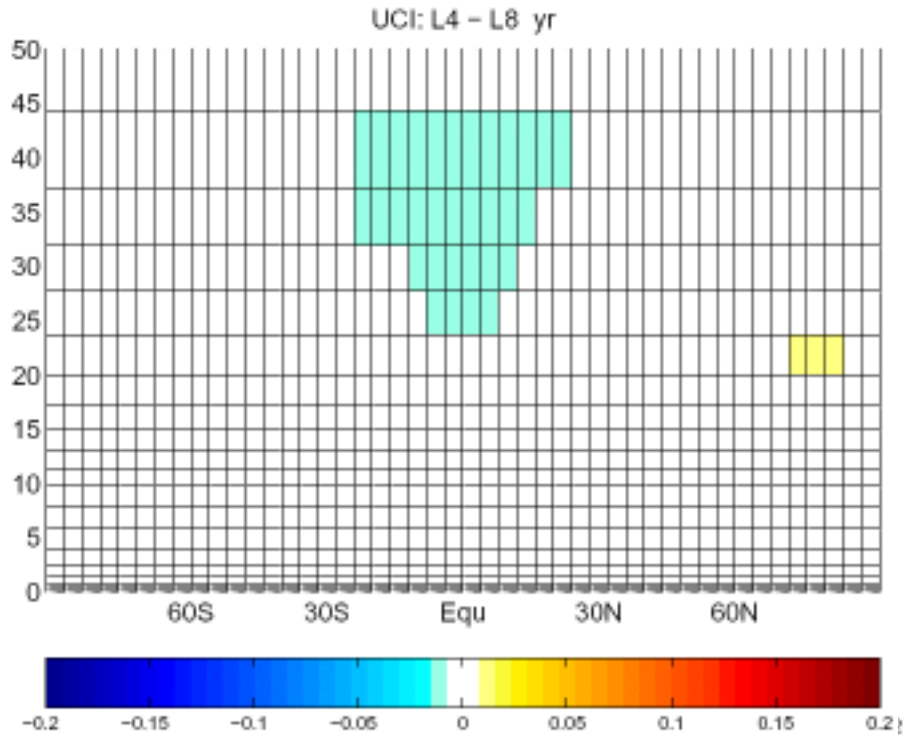


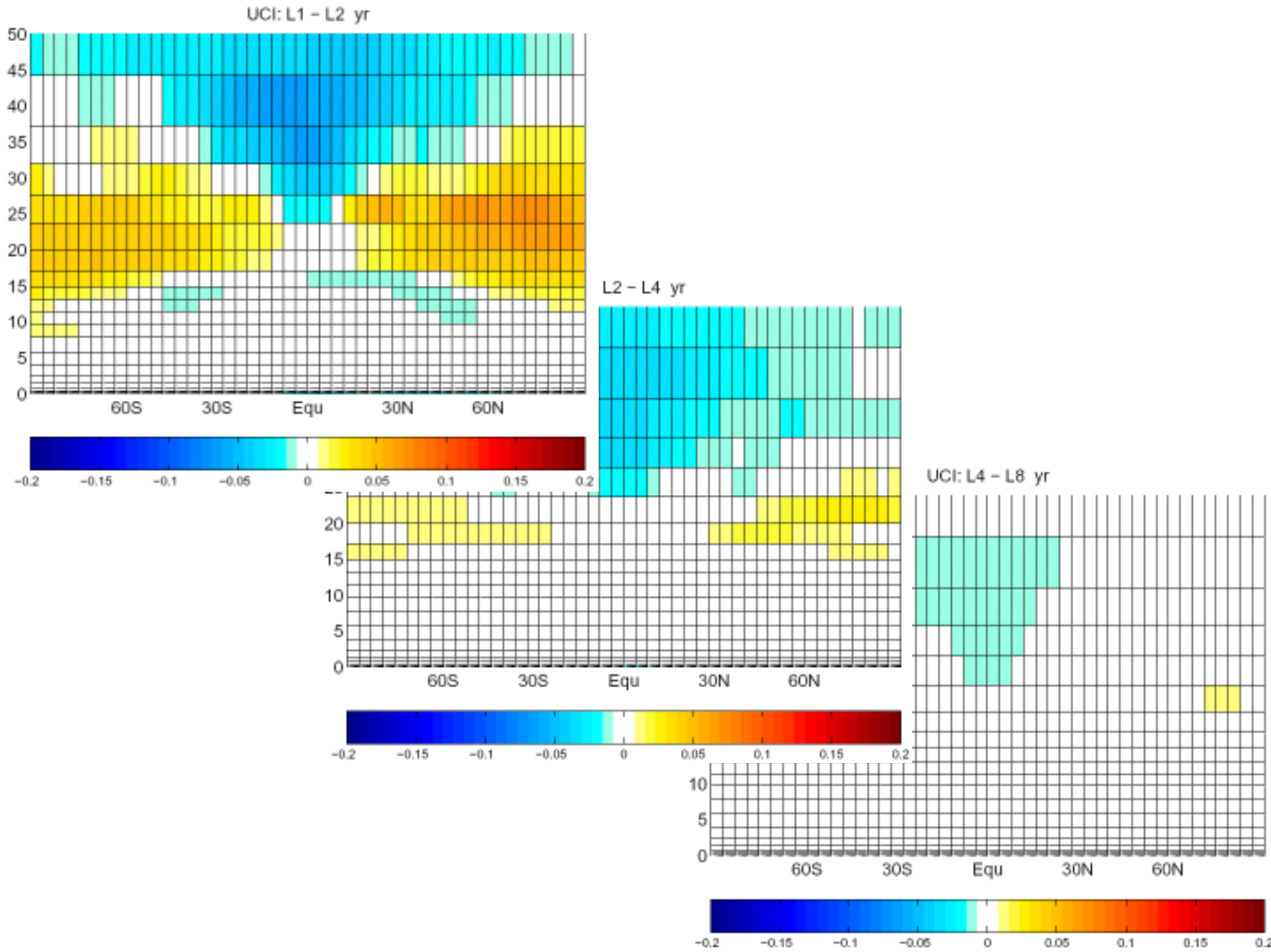


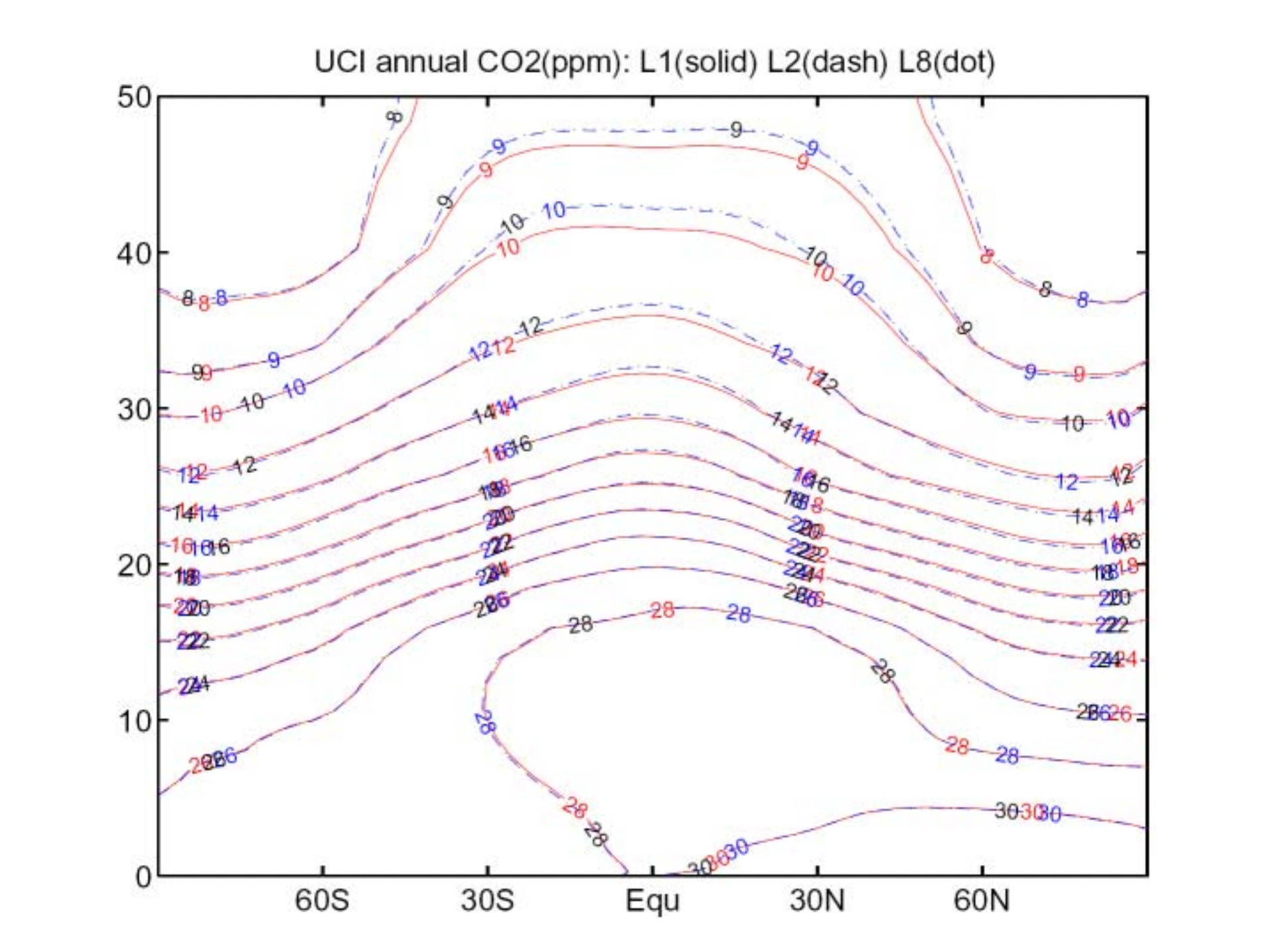
UCI – GMI difference large, >1 yr over most of strat.

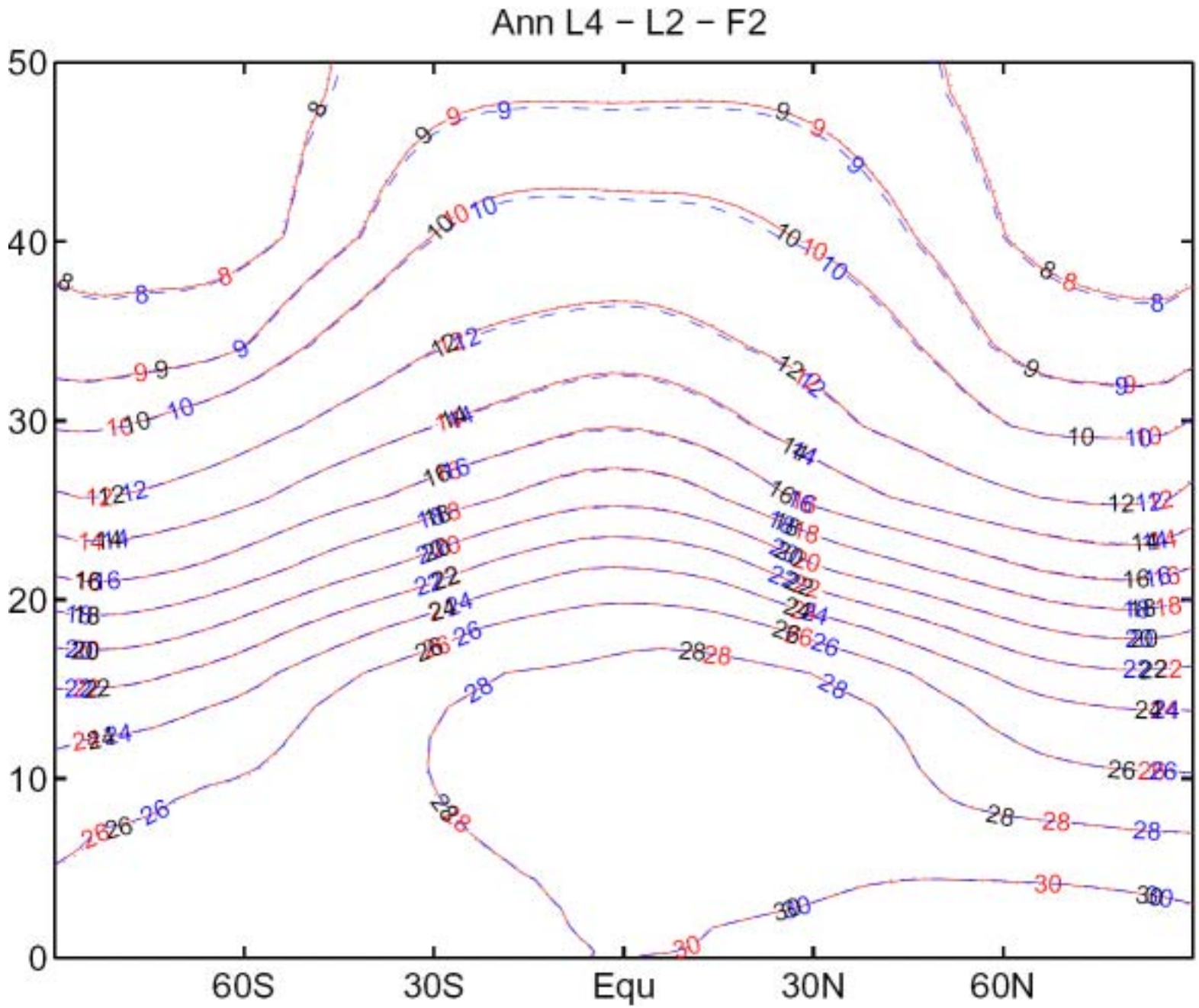
GMI-UCI vs. L1-L2, L2-L4, L4-L8. (different scales)

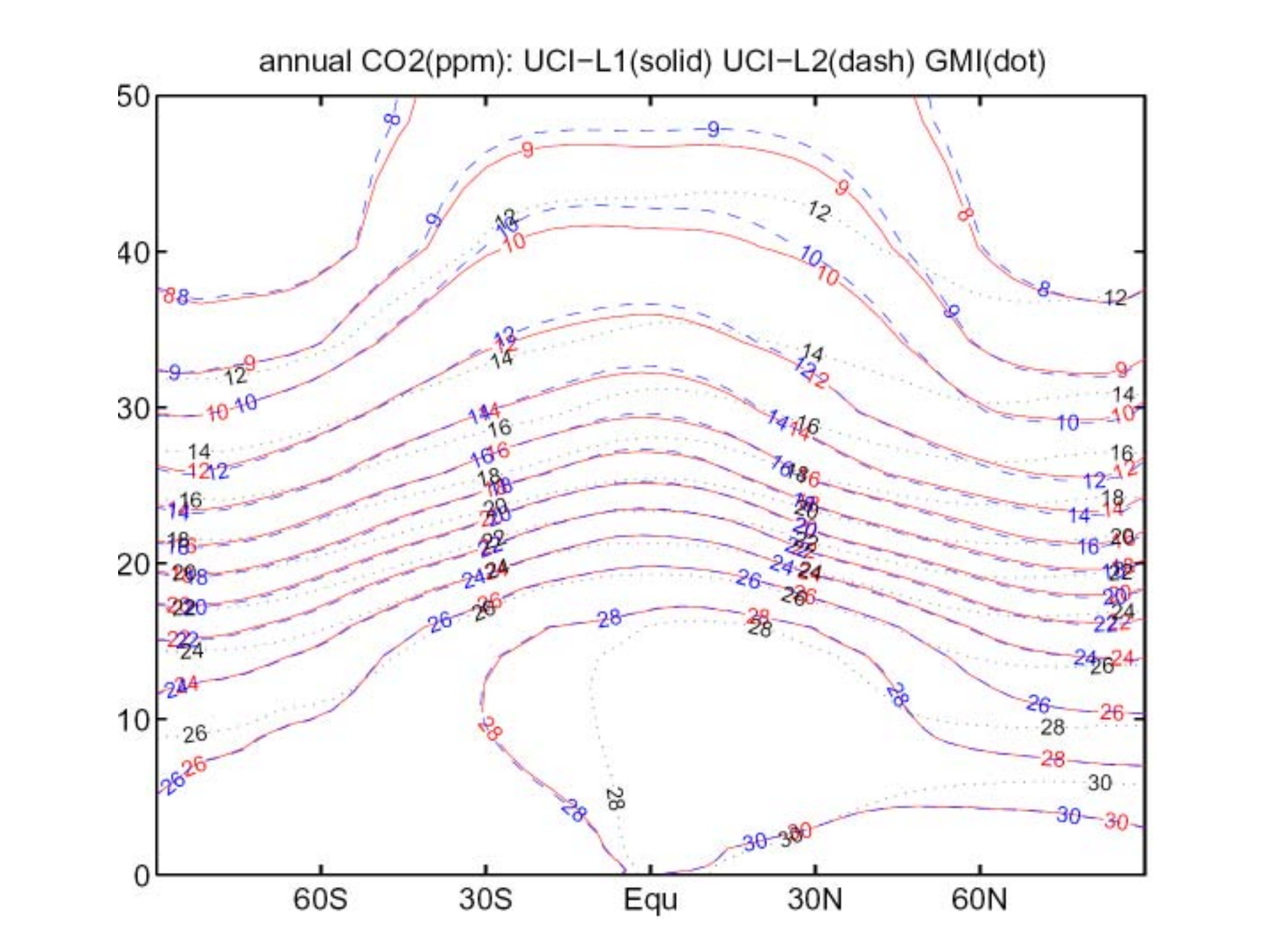





UCI: L1 – L2 yr
50
45
40
35
30
25
20
15
10
5
0
60S
30S
Equ
30N
60N
−0.2
−0.15
−0.1
−0.05
0
0.05
0.1
0.15
0.2
L2 – L4 yr
20
15
10
5
0
60S
30S
Equ
30N
60N
−0.2
−0.15
−0.1
−0.05
0
0.05
0.1
0.15
0.2
UCI: L4 – L8 yr
10
5
0
60S
30S
Equ
30N
60N
−0.2
−0.15
−0.1
−0.05
0
0.05
0.1
0.15
0.2


UCI annual CO2(ppm): L1(solid) L2(dash) L8(dot)
50
40
30
20
10
0
60S
30S
Equ
30N
60N


Ann L4 − L2 − F2
50
40
30
20
10
0
60S
30S
Equ
30N
60N


annual CO2(ppm): UCI-L1(solid) UCI-L2(dash) GMI(dot)
50
40
30
20
10
0
60S
30S
Equ
30N
60N

UCI – GMI: 2x to convergence (6)

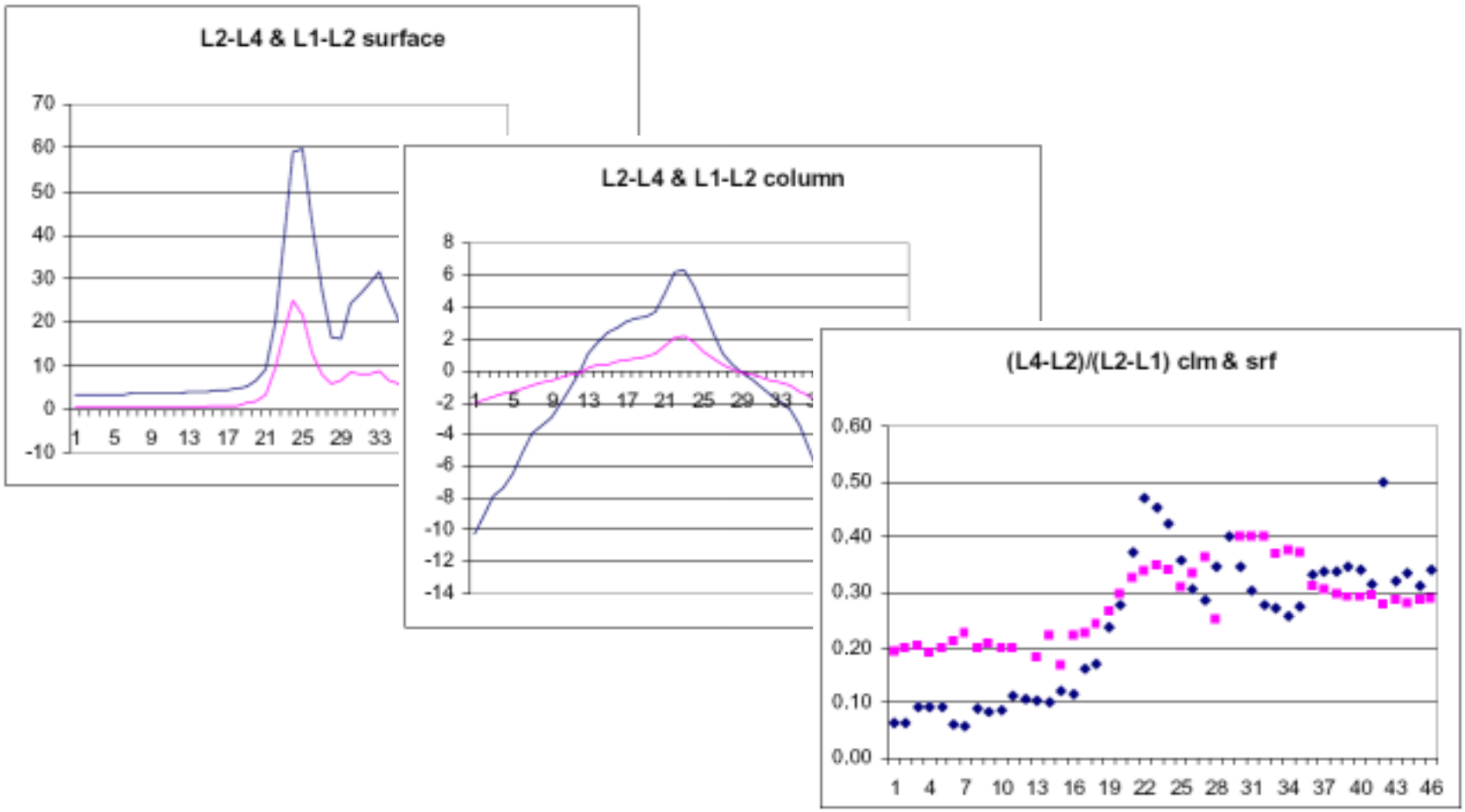
(1) Look at stratospheric age-of-air
(L1=F1, L2, L4, L8, F2 10-yr runs)

(2) Look at columns – combination troposphere + stratosphere

(3) Look at surface
(L1, L2, L4, L8; F1, F2, F4 for year 1+)

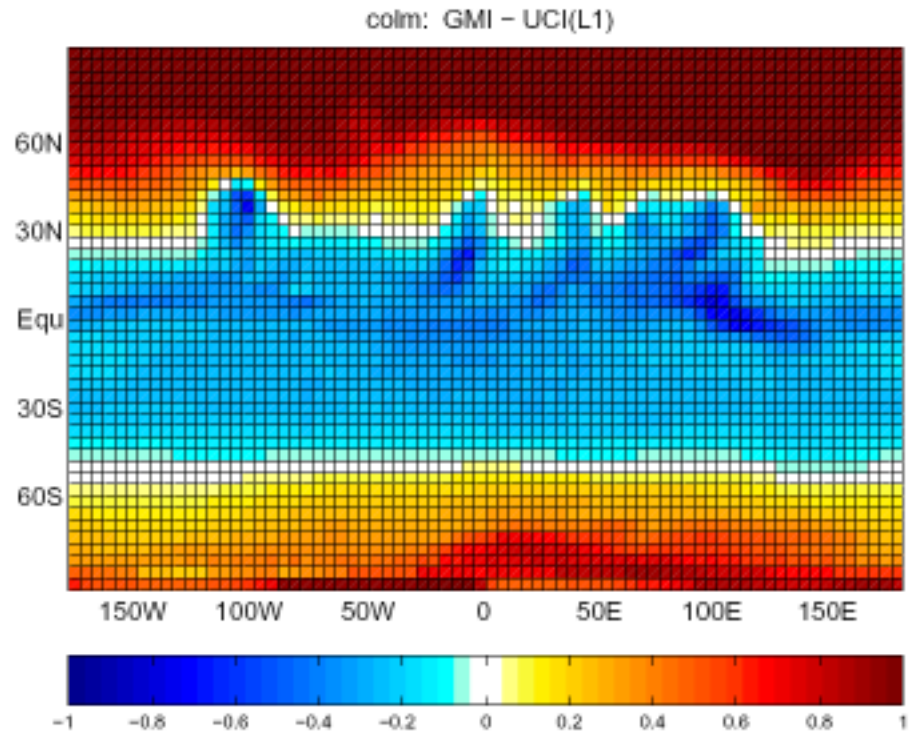
Aitkens acceleration: looking at the sequence L1, L2, L4 for changes $(A_4 - A_2)$ and $(A_2 - A_1)$

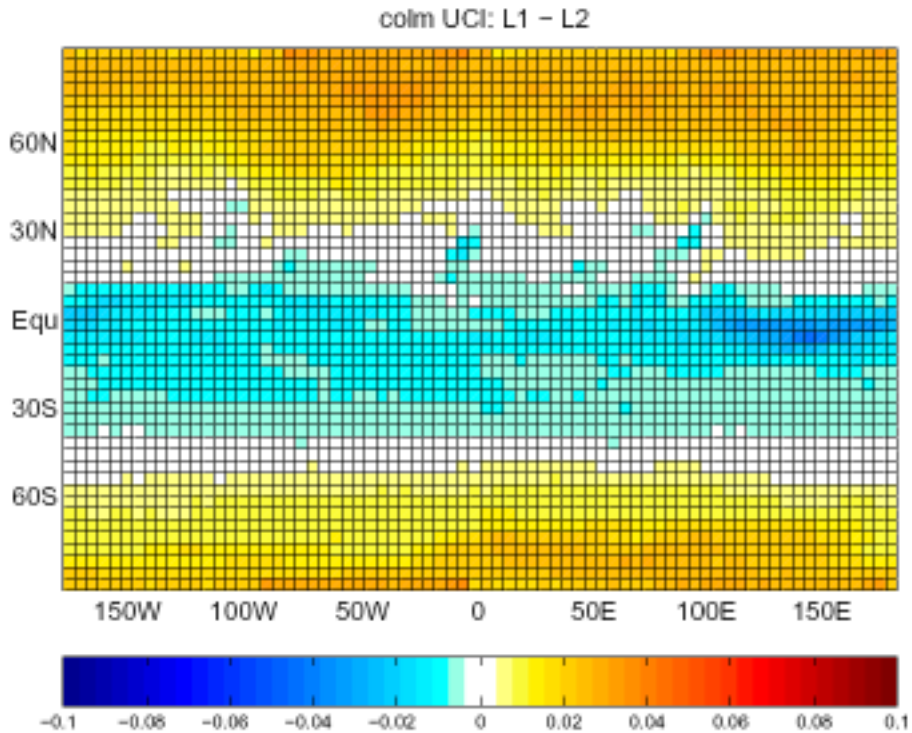
plots: zonal mean, yr 10, units = 0.001 ppm CO2 vs latitude J=1:46

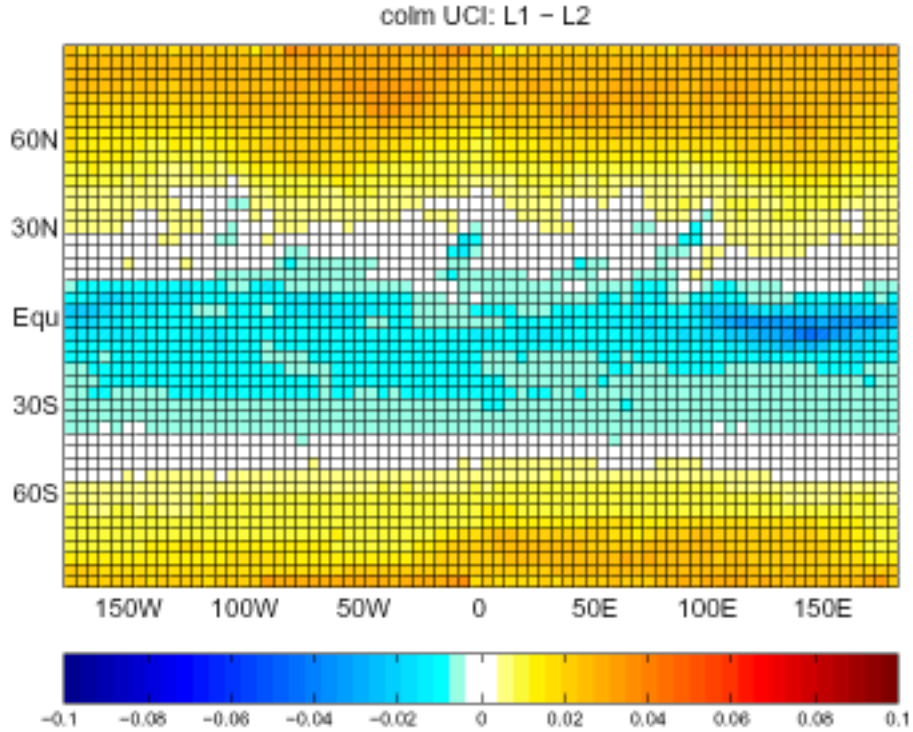


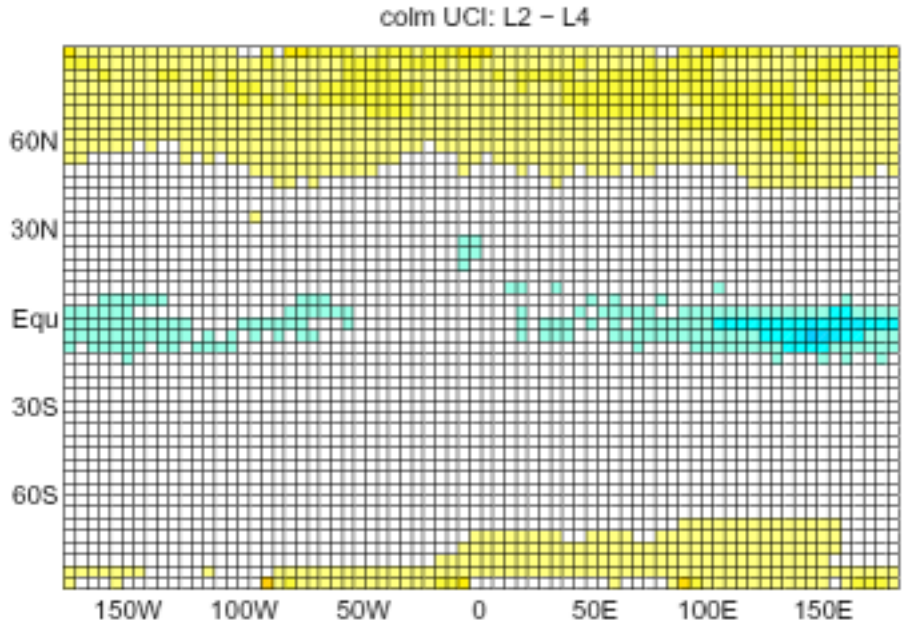
UCI – GMI colm difference large.

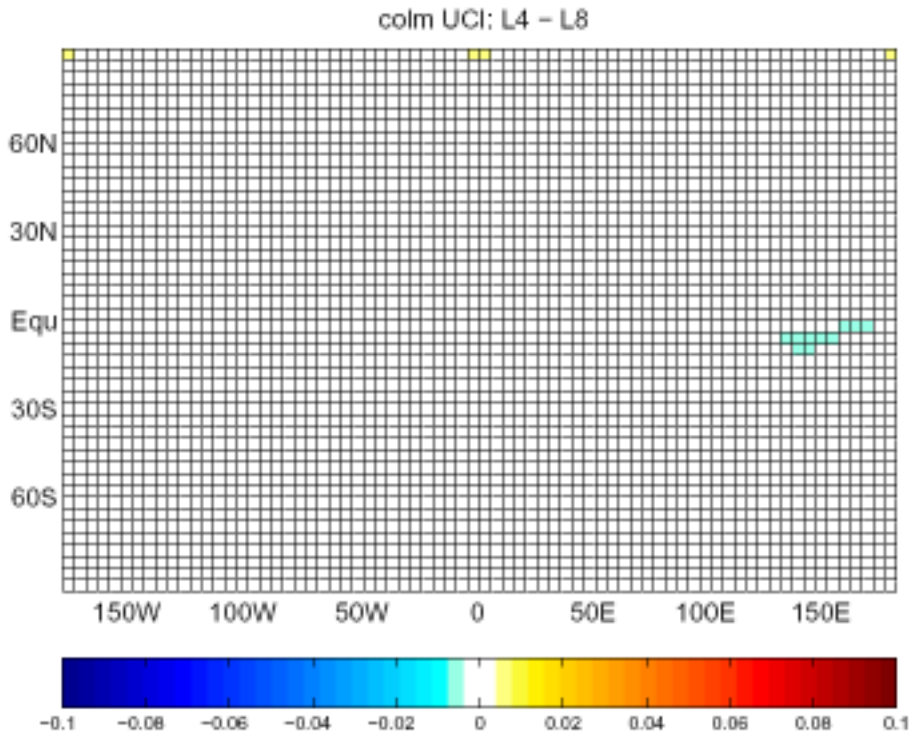
GMI-UCI vs. L1-L2, L2-L4, L4-L8. (***different scales***)






colm UCI: L1 − L2
60N
30N
Equ
30S
60S
150W
100W
50W
0
50E
100E
150E
−0.1
−0.08
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1


colm UCI: L2 − L4
60N
30N
Equ
30S
60S
150W
100W
50W
0
50E
100E
150E

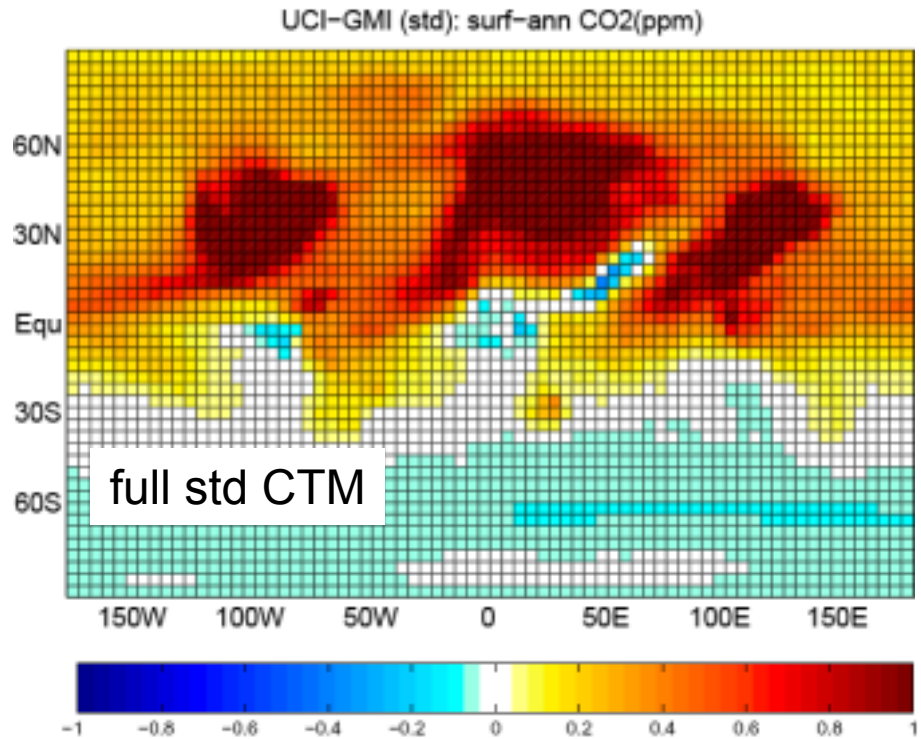

colm UCI: L4 − L8
60N
30N
Equ
30S
60S
150W
100W
50W
0
50E
100E
150E
−0.1
−0.08
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1

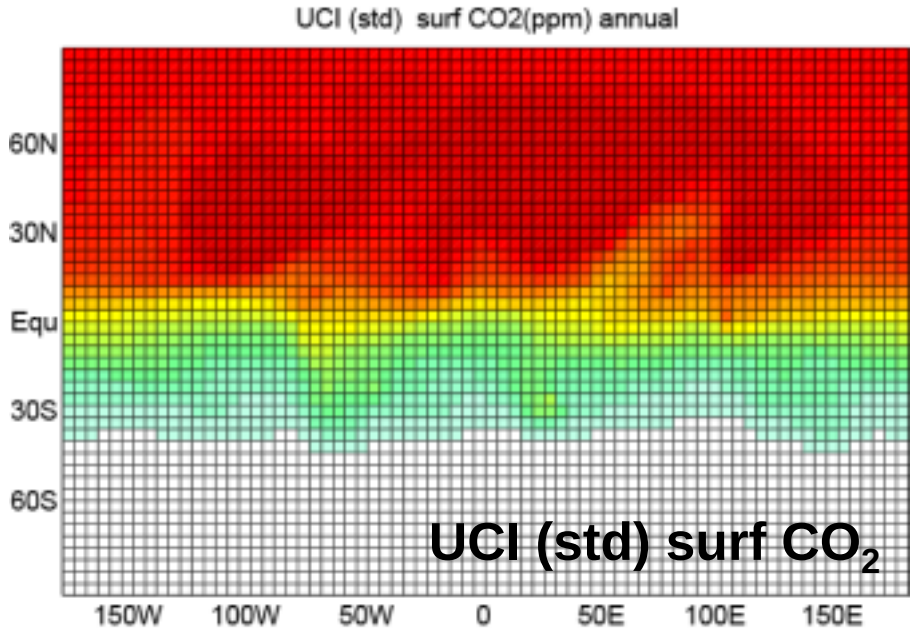
UCI – GMI: 2x to convergence (6)

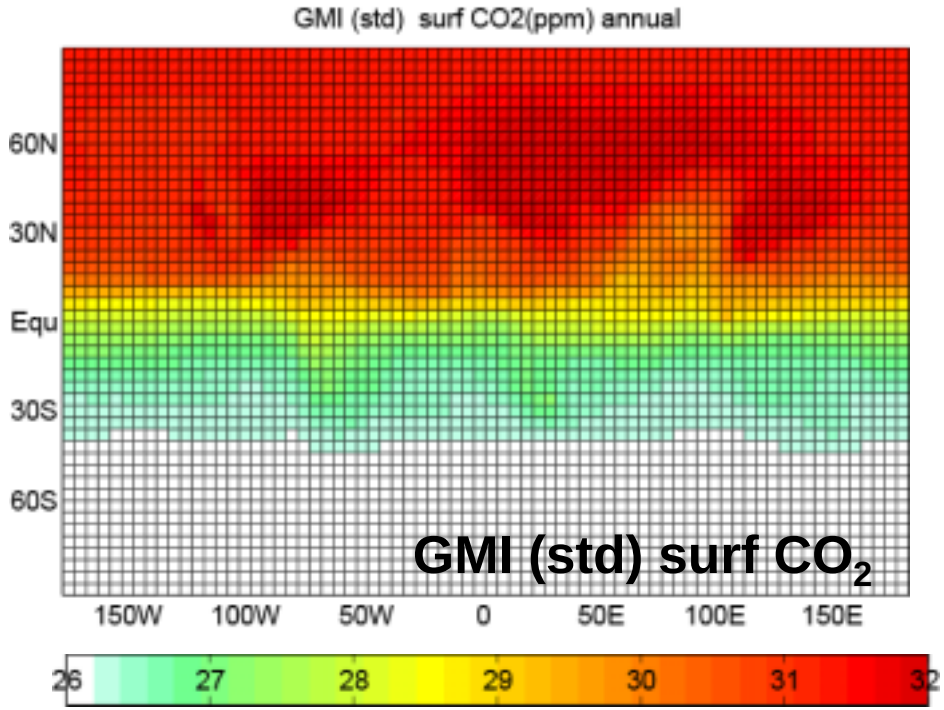
(1) Look at stratospheric age-of-air
(L1=F1, L2, L4, L8, F2 10-yr runs)

(2) Look at columns – combination troposphere + stratosphere

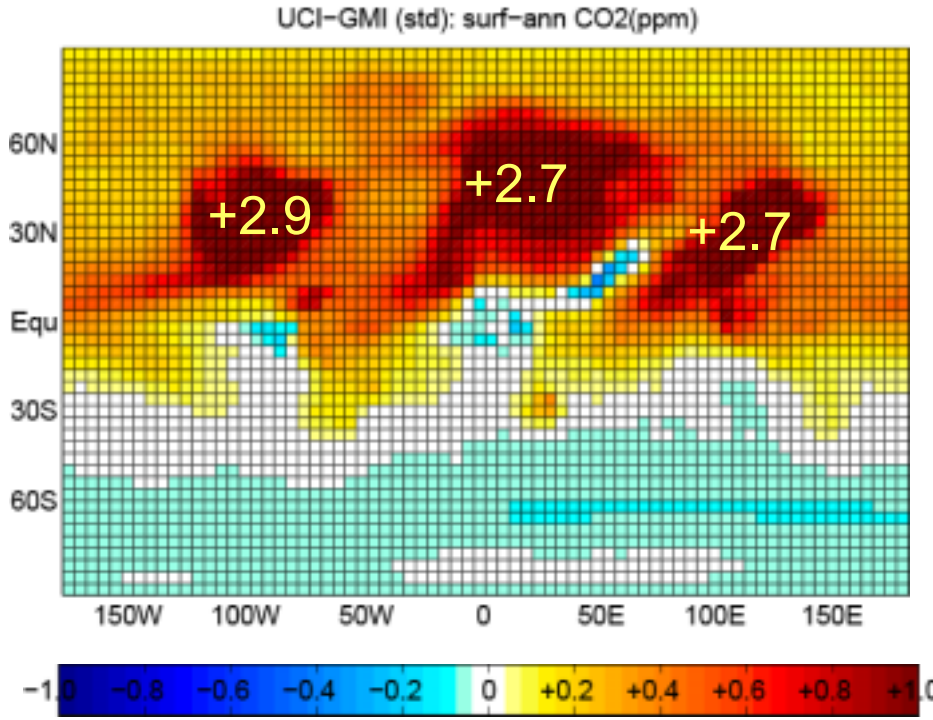
(3) Look at surface
(L1, L2, L4, L8; F1, F2, F4 for year 1+)

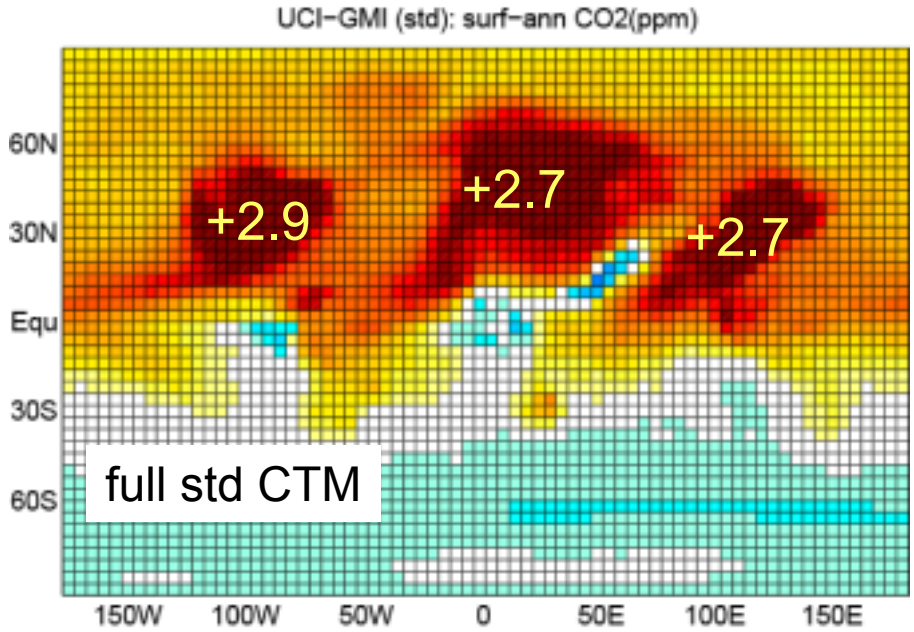



UCI (std) surf CO2(ppm) annual
60N
30N
Equ
30S
60S
150W
100W
50W
0
50E
100E
150E
UCI (std) surf CO_2

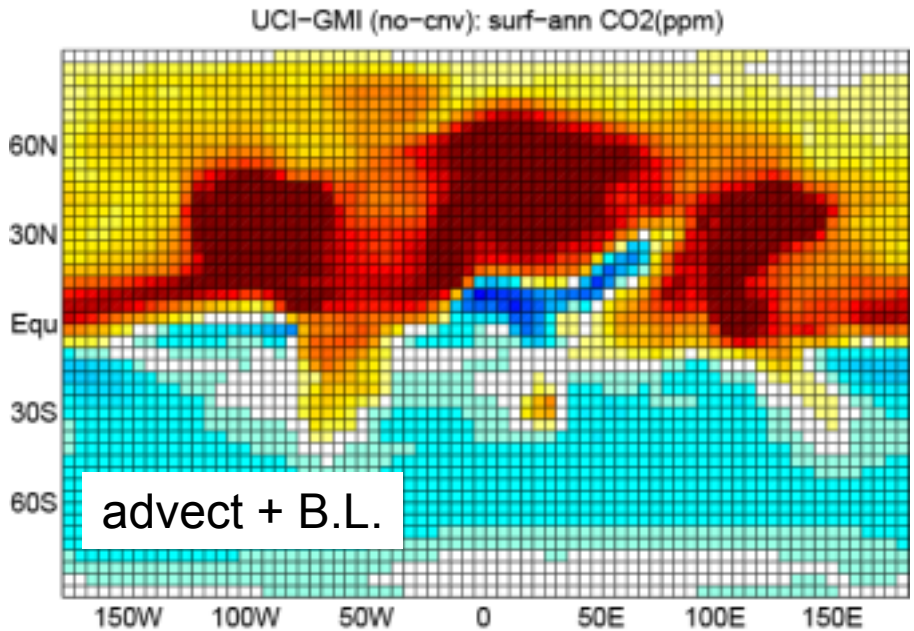

GMI (std) surf CO2(ppm) annual
60N
30N
Equ
30S
60S
150W
100W
50W
0
50E
100E
150E
GMI (std) surf CO_2
26
27
28
29
30
31
32

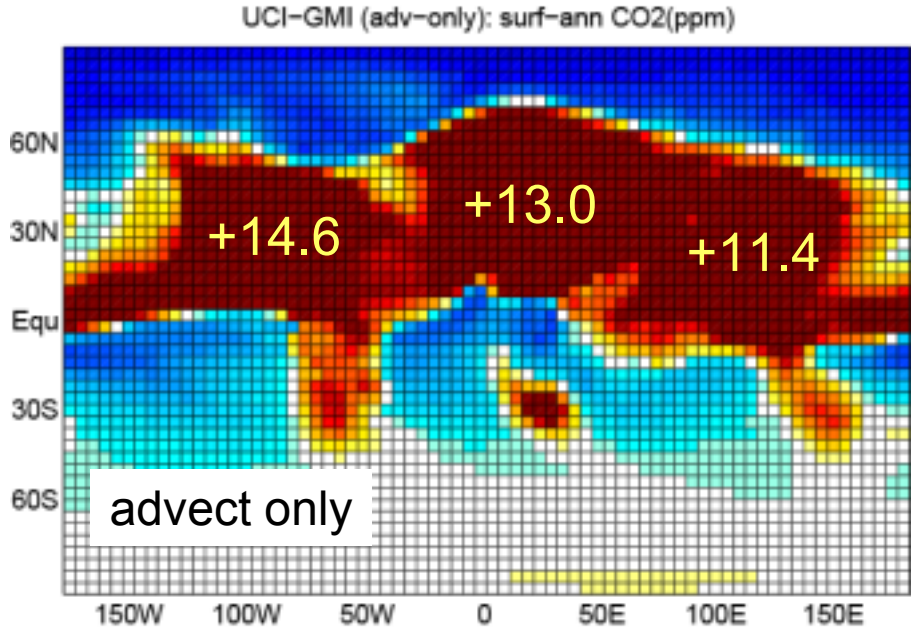
UCI - GMI

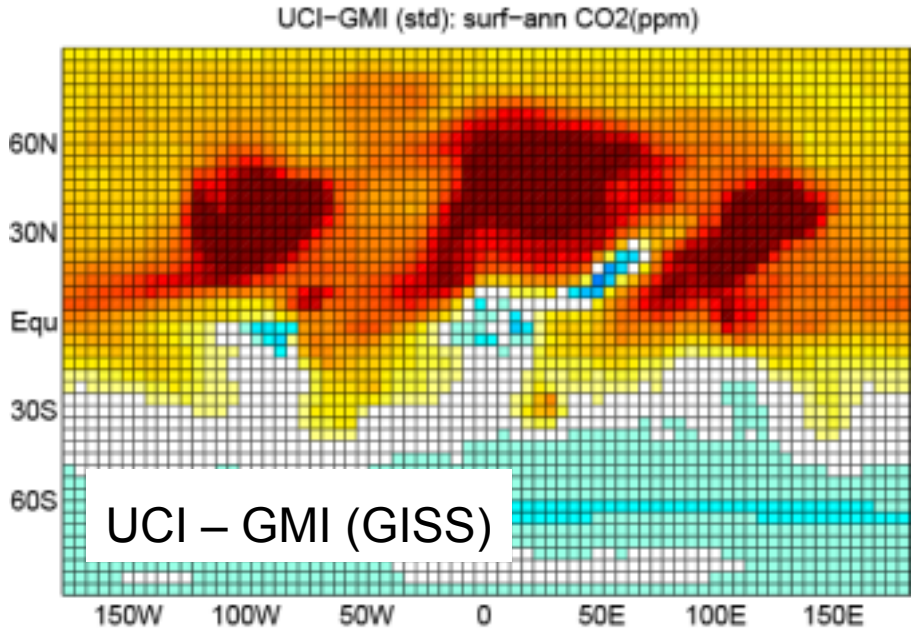

UCI−GMI (std): surf−ann CO2(ppm)
60N
30N
Equ
30S
60S
+2.9
+2.7
+2.7
150W
100W
50W
0
50E
100E
150E
−1.0
−0.8
−0.6
−0.4
−0.2
0
+0.2
+0.4
+0.6
+0.8
+1.0

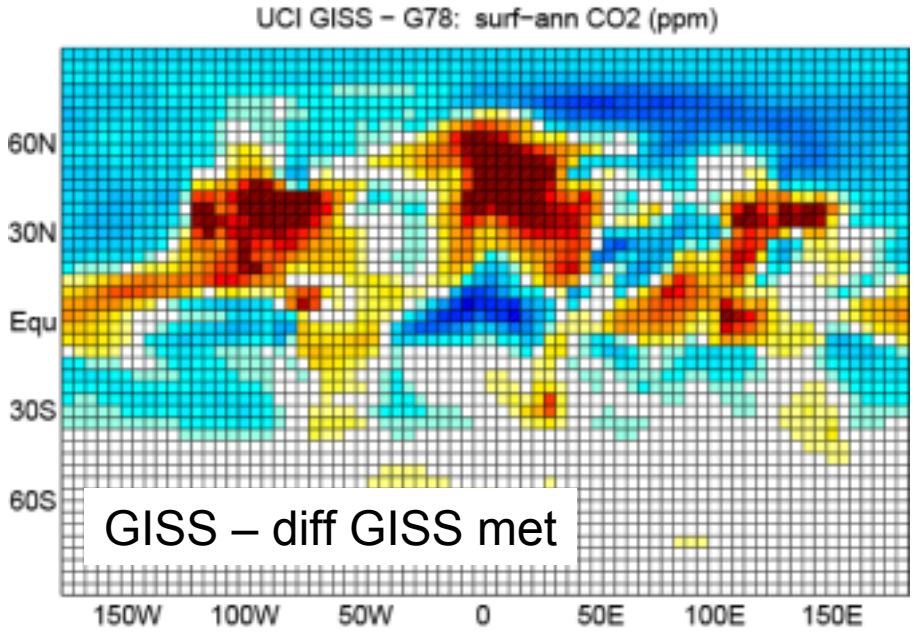


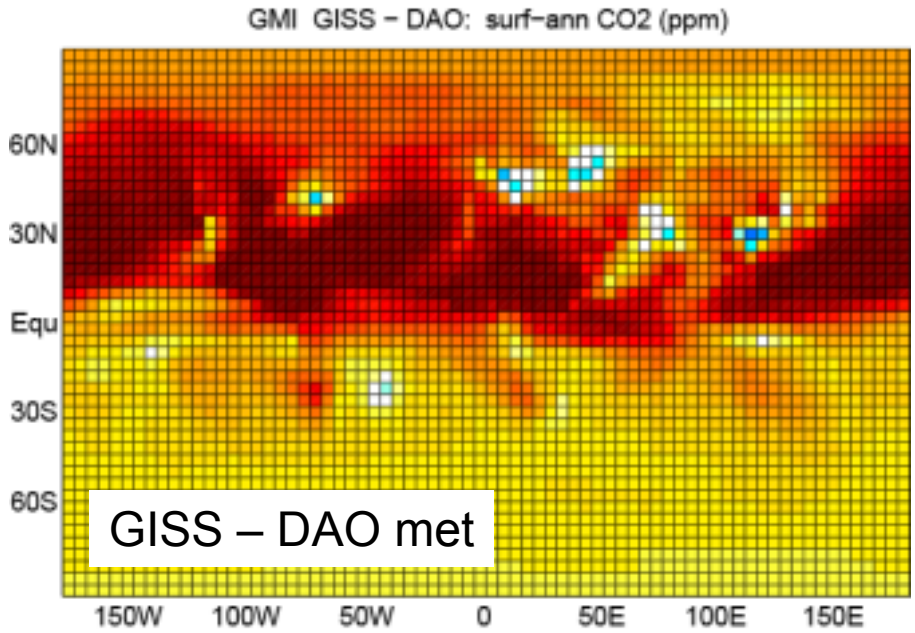
It is the advection algorithm that is the primary cause of the difference; boundary-layer mixing and convection tend to smooth out the CO_2 distribution and reduce differences!

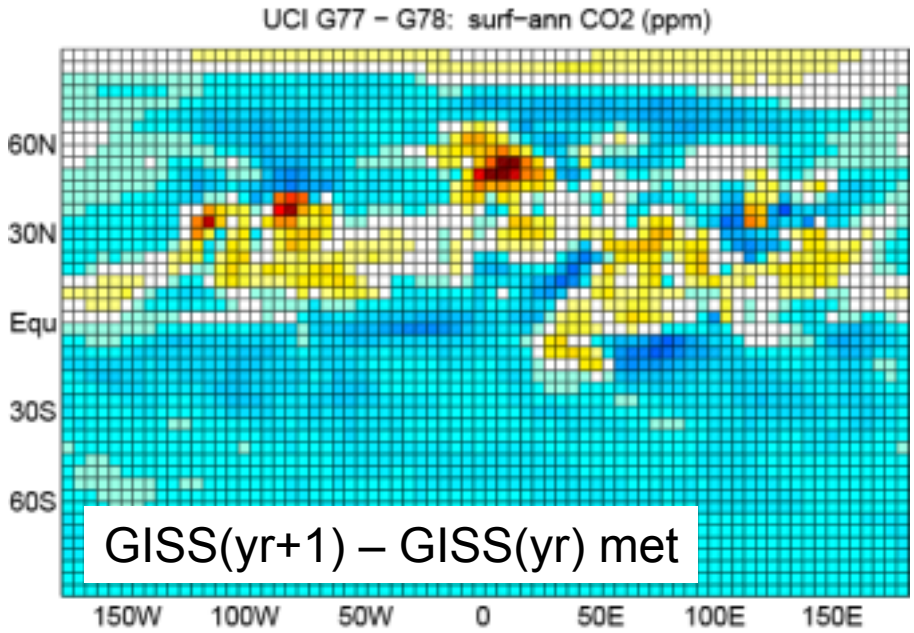





UCI−GMI (std): surf−ann CO2(ppm)
60N
30N
Equ
30S
60S
150W
100W
50W
0
50E
100E
150E
UCI – GMI (GISS)


UCI GISS − G78: surf−ann CO2 (ppm)
60N
30N
Equ
30S
60S
150W
100W
50W
0
50E
100E
150E
GISS – diff GISS met


GMI GISS − DAO: surf−ann CO2 (ppm)
60N
30N
Equ
30S
60S
150W
100W
50W
0
50E
100E
150E
GISS – DAO met


UCI G77 − G78: surf−ann CO2 (ppm)
60N
30N
Equ
30S
60S
150W
100W
50W
0
50E
100E
150E
GISS(yr+1) – GISS(yr) met

updated Mar 2004 – to correct some values, add the L1-L2-L4 converg, include rms var of total surface field.

CO_2 difference at surface (r.m.s. of ann-mean, <*N*> - <*S*> = *4.5 ppm)*

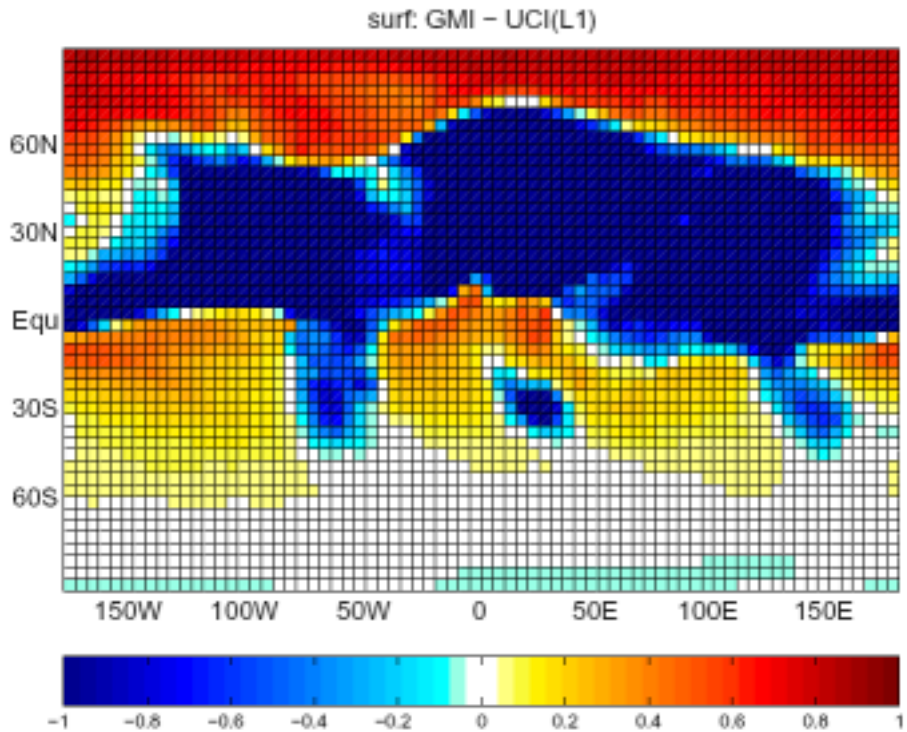
	surf	rms var(UvG)
different CTMs (GISS met fields)		
UCI vs. GMI (std) – Feb'04	**0.55* ppm**	2.64 vs. 2.30
UCI (no ED, BL-up) vs. GMI (std) –better?	**0.47-0.45**	
UCI vs. GMI (adv-only)	2.76	4.76 vs. 2.71
UCI vs. GMI (adv+BL)	0.67	2.71 vs. 2.26
different met fields (GMI & UCI CTMs)		
GISS vs. DAO	**0.56 ppm**	
GISS vs. G-78	**0.32**	
G-78^{YR} vs. G-78^{YR+1}	**0.14**	
different tunings (UCI CTM)		
Convection: no entrain/detrain	**0.13**	**2.64**
BL-mixing: 3-hr vs. instant	**0.11**	
BL round-up to whole layer vs. std	**0.12**	
Polar numerics: ext. polar zones	**0.05**	
Emissions: 1x1 w/SOM vs. 4x5	**0.07**	
Flux-limit: mono vs. pos-def	**0.01**	
GMI: press-error filters (LLNL vs. UCI)	**0.04**	
L1 – L2 (adv only)	**0.088** vs. 2.76 (UCI-GMI)	
L2 – L4 (adv only)	**0.036**	

UCI – GMI: 2x to convergence (6)

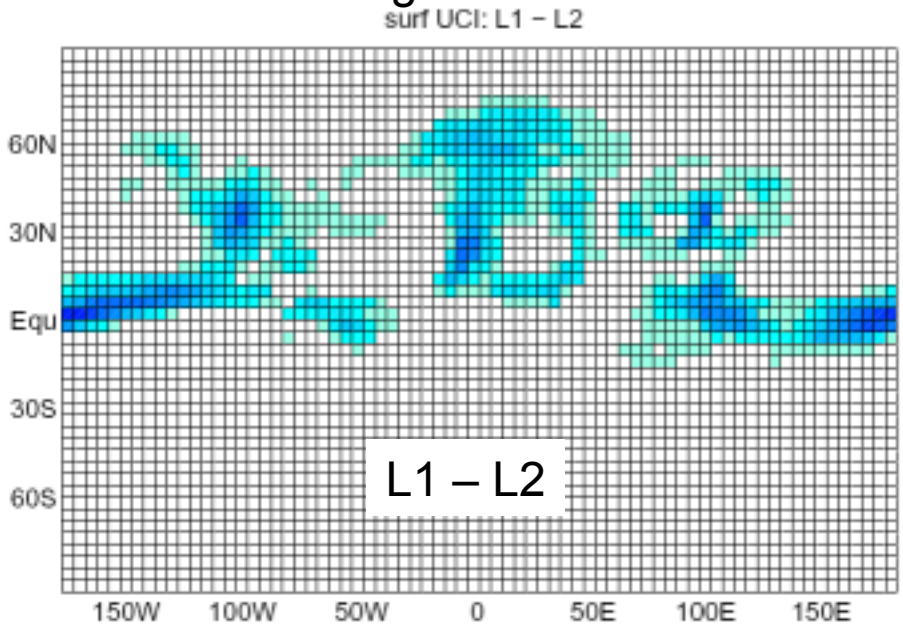
(1) Look at stratospheric age-of-air
(L1=F1, L2, L4, L8, F2 10-yr runs)

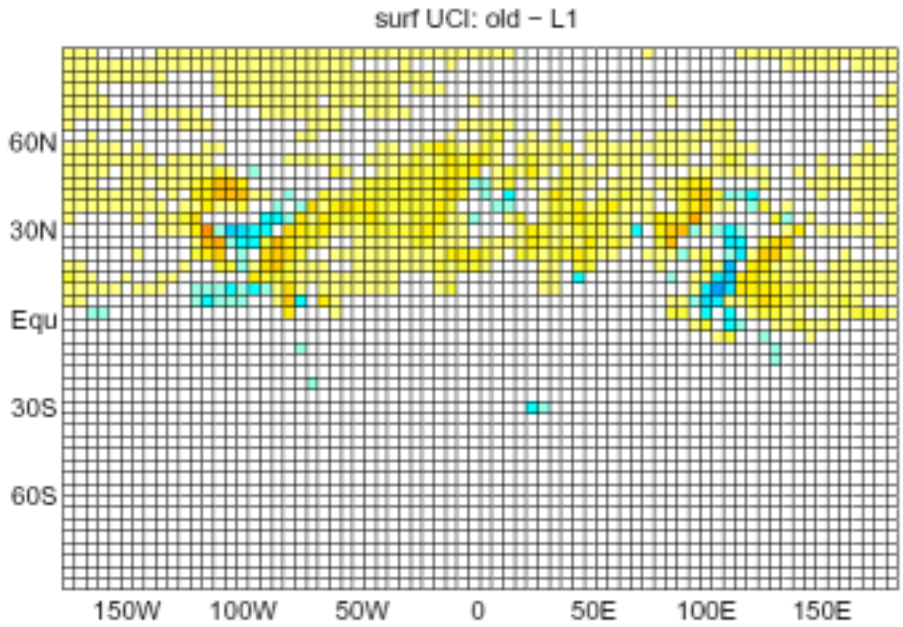
(2) Look at columns – combination troposphere + stratosphere

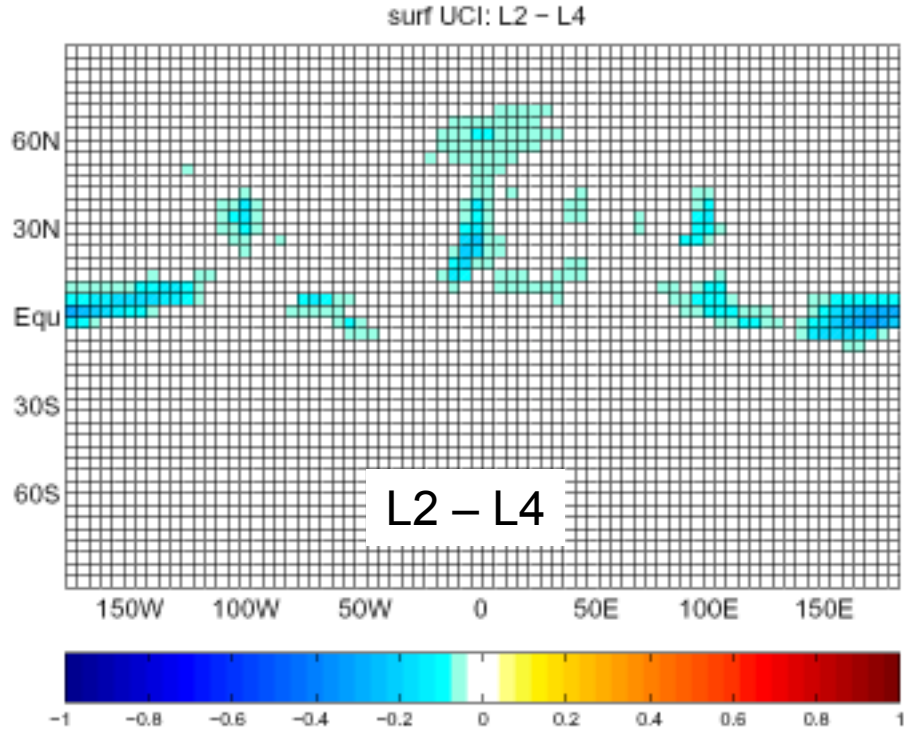
(3) Look at surface
(L1, L2, L4, L8; F1, F2, F4 for year 1+)

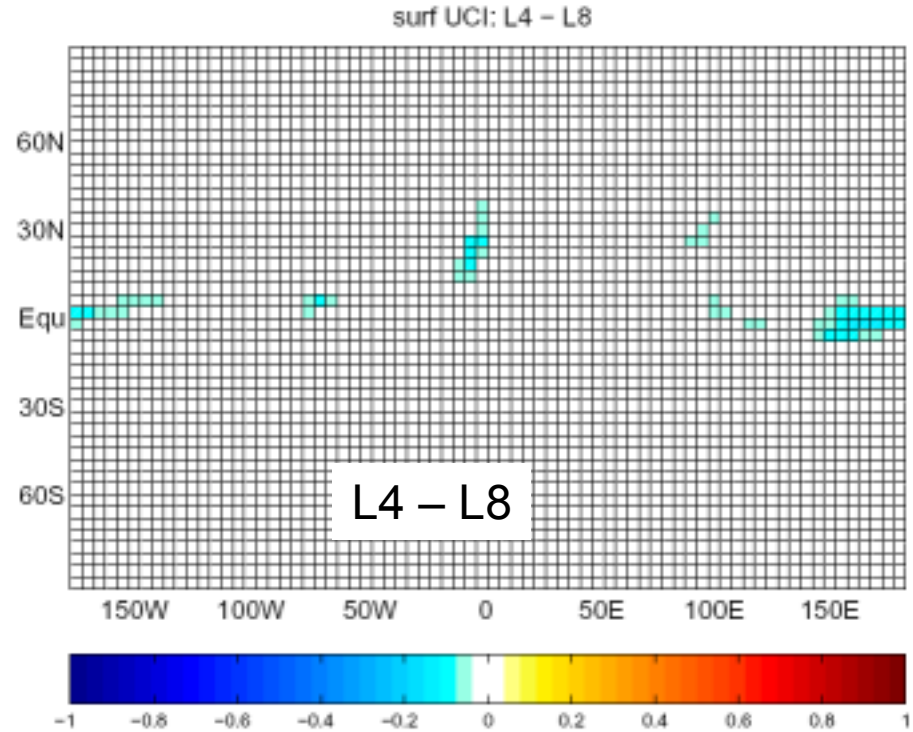


Yr 10 annual average

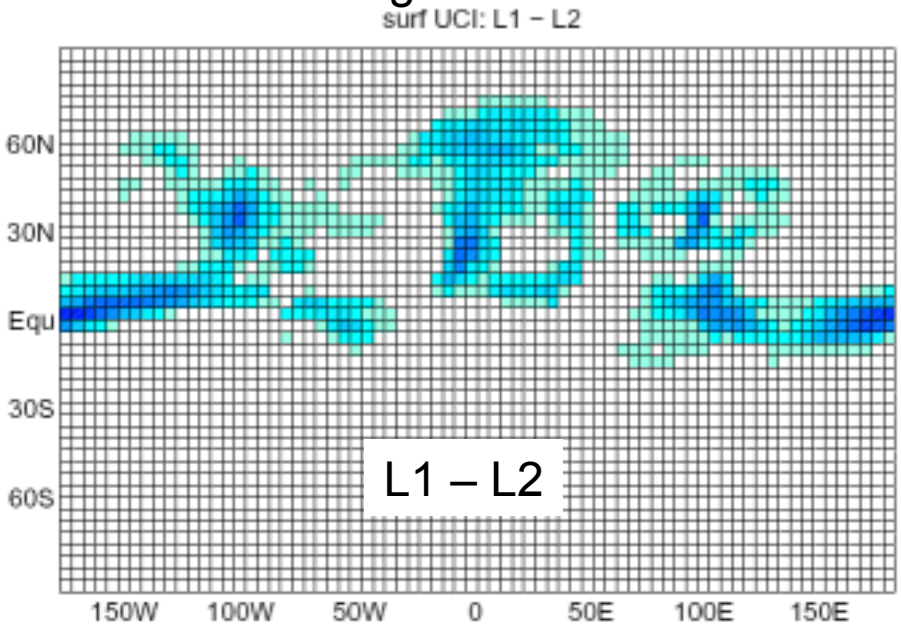


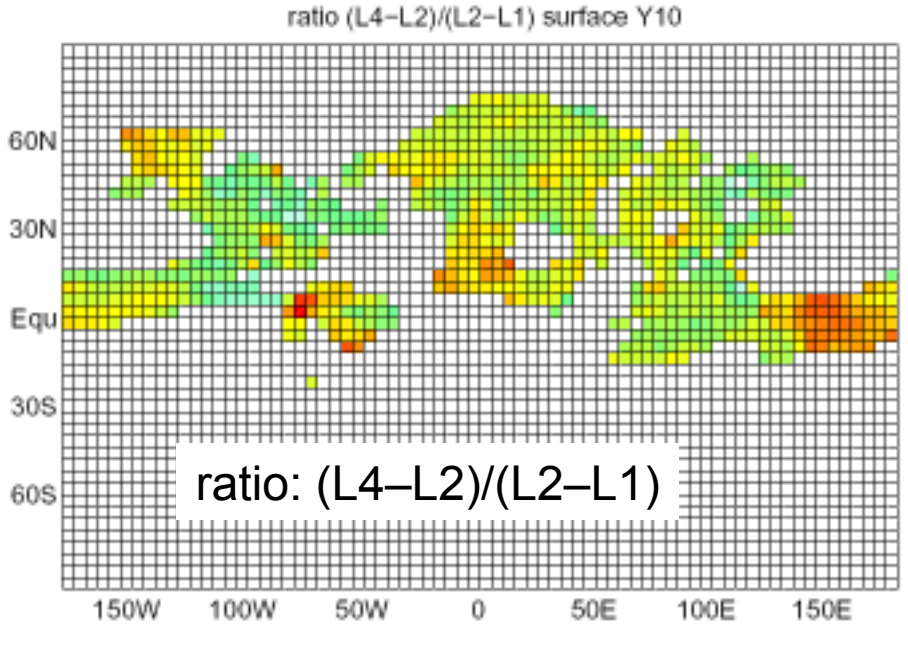


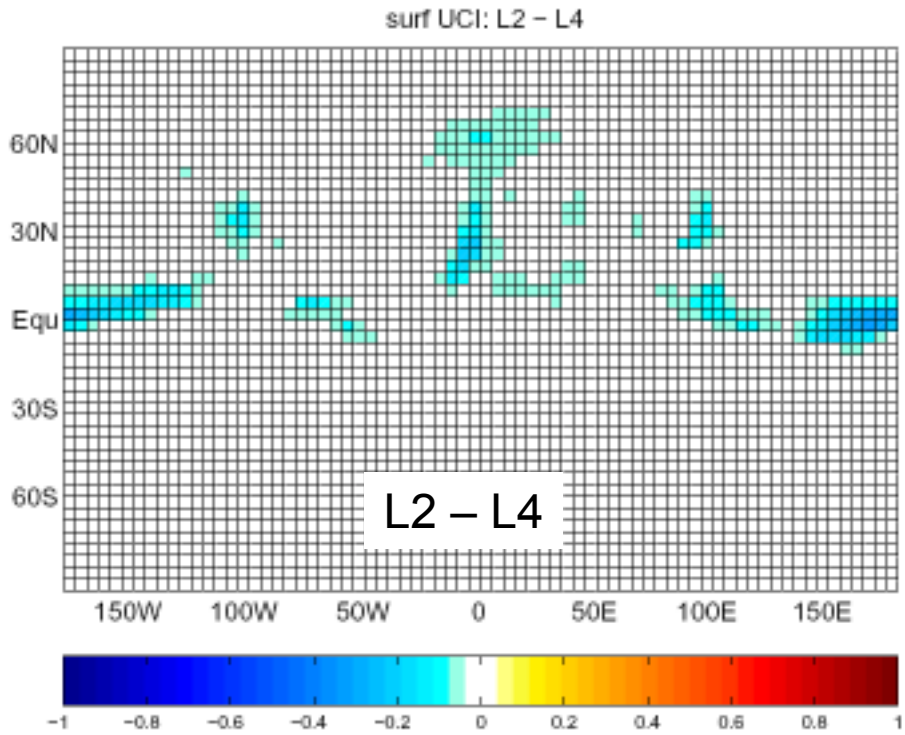


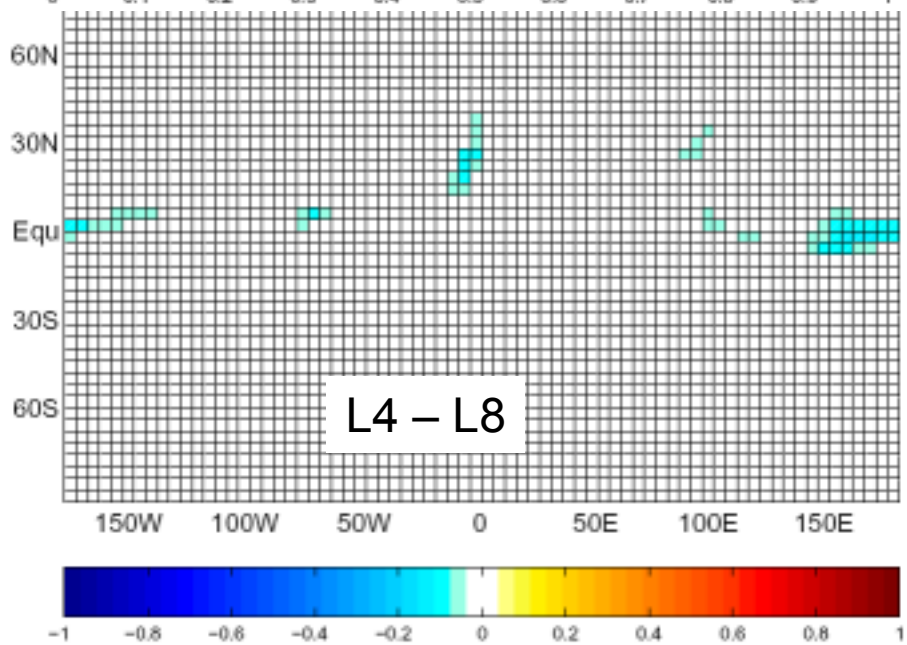


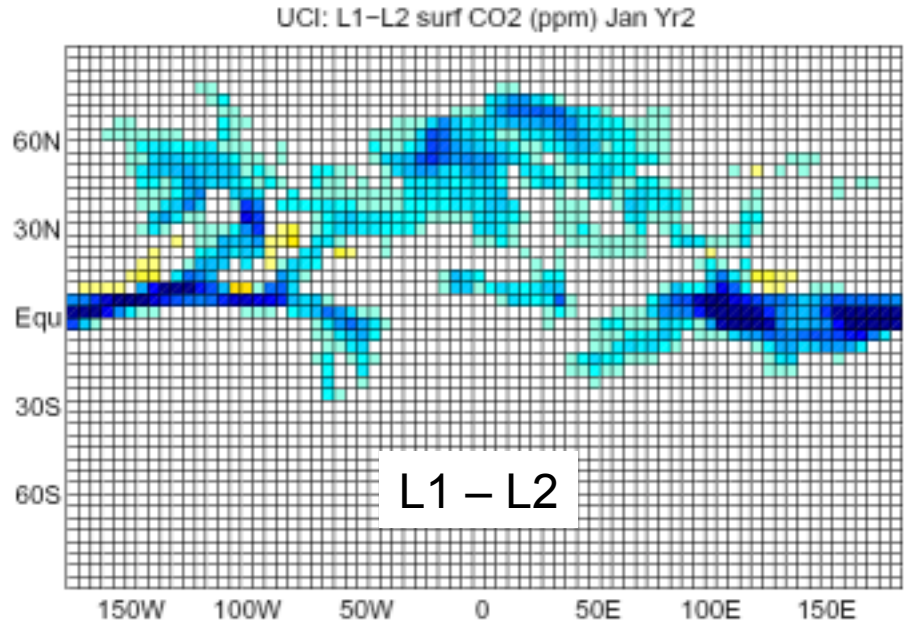
Yr 10 annual average





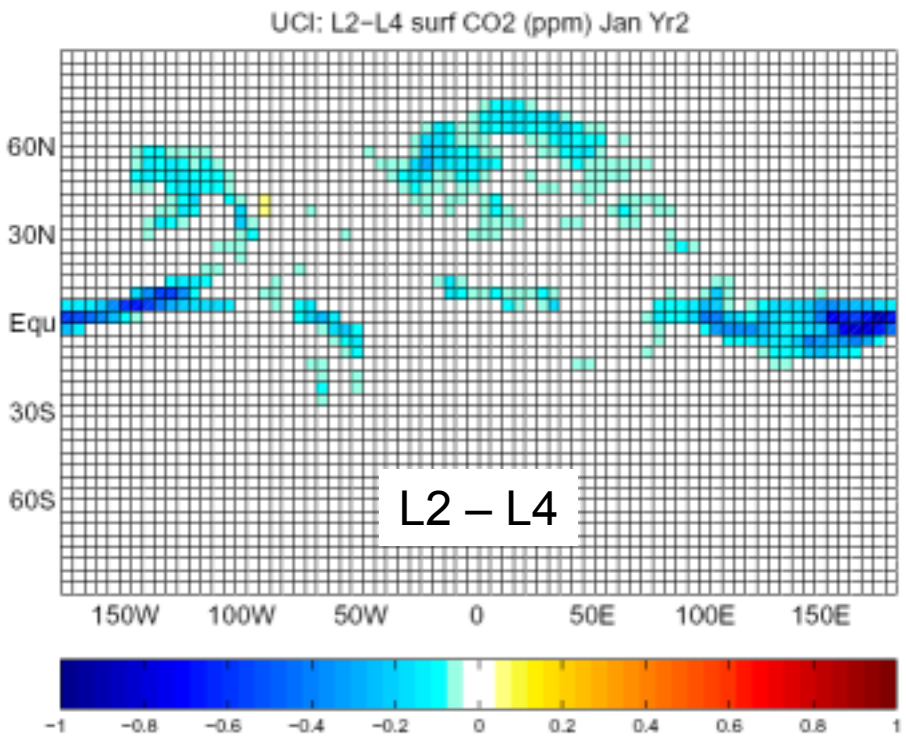


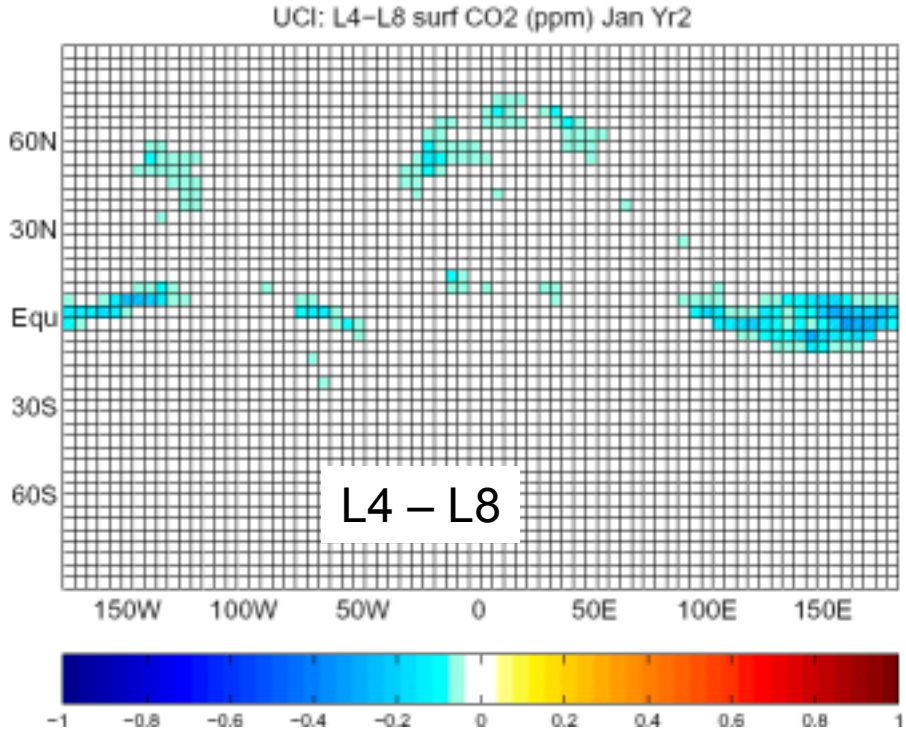


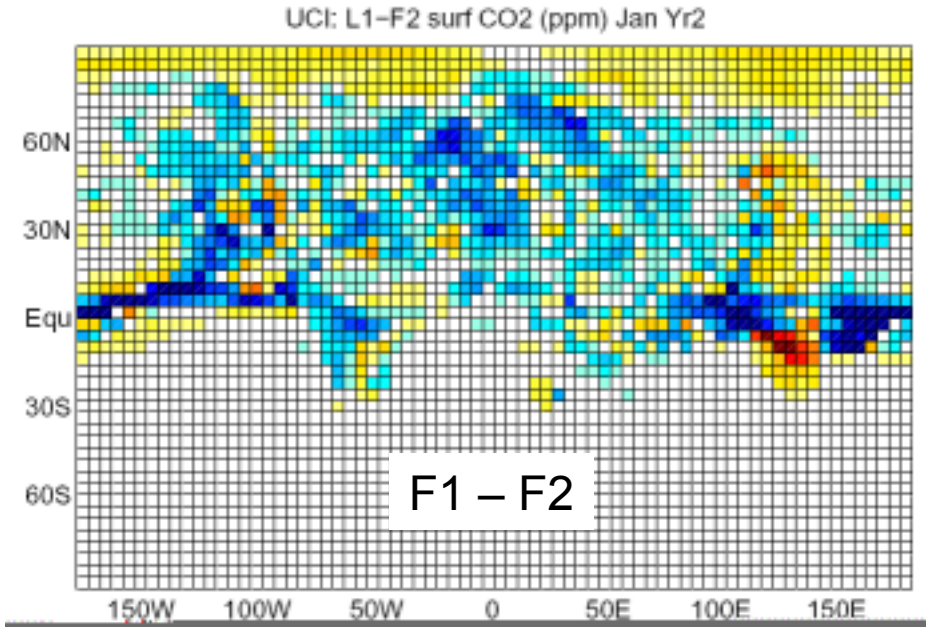


In order to compare with F1:F2:F4

compare Jan Yr 2

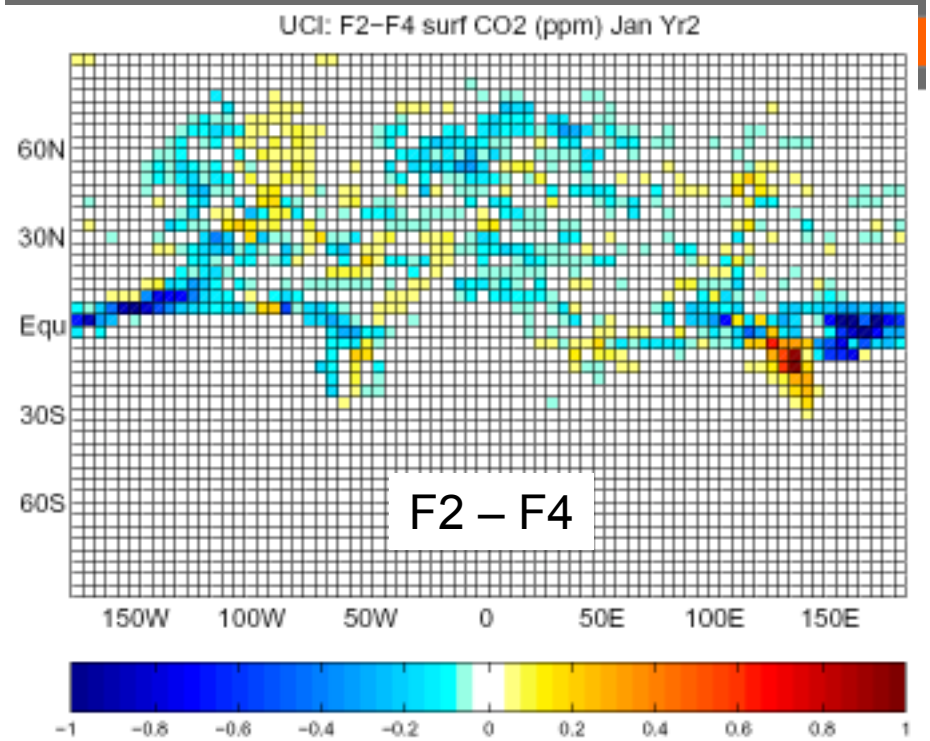


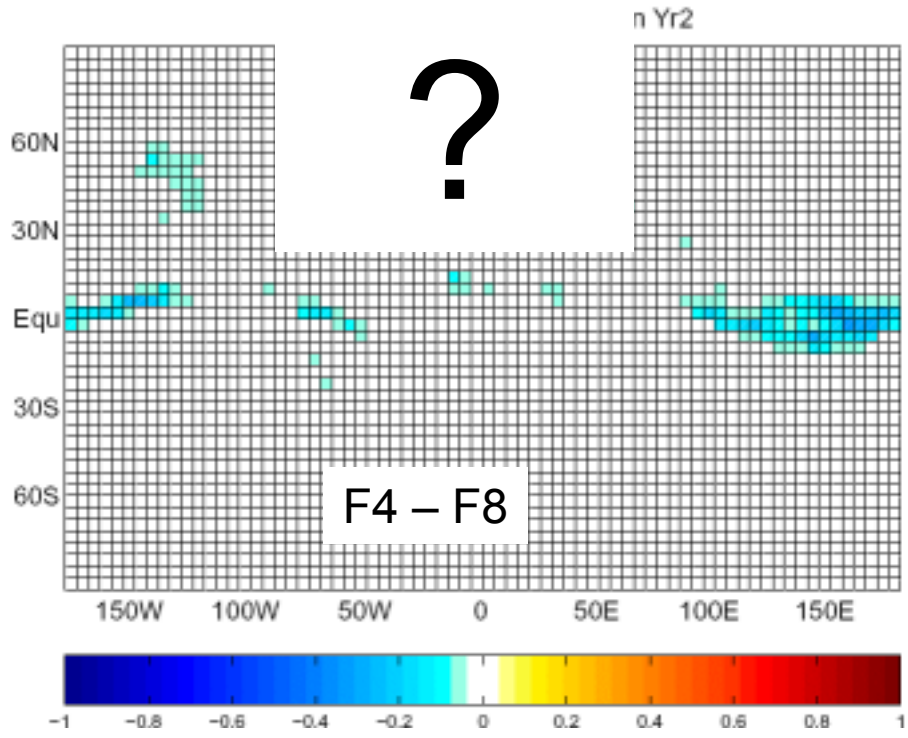


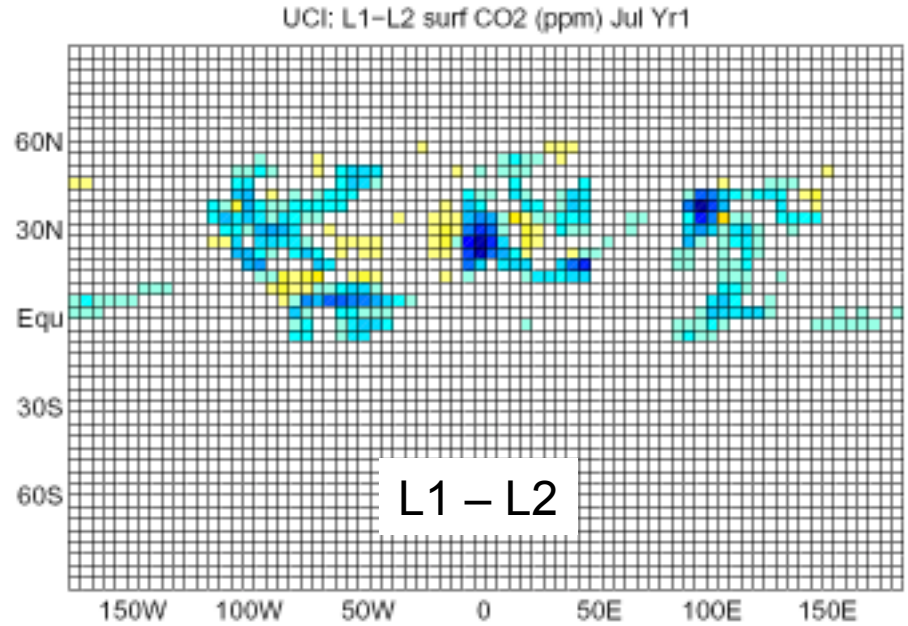


In order to compare with F1 : F2 : F4

Jan Yr 2

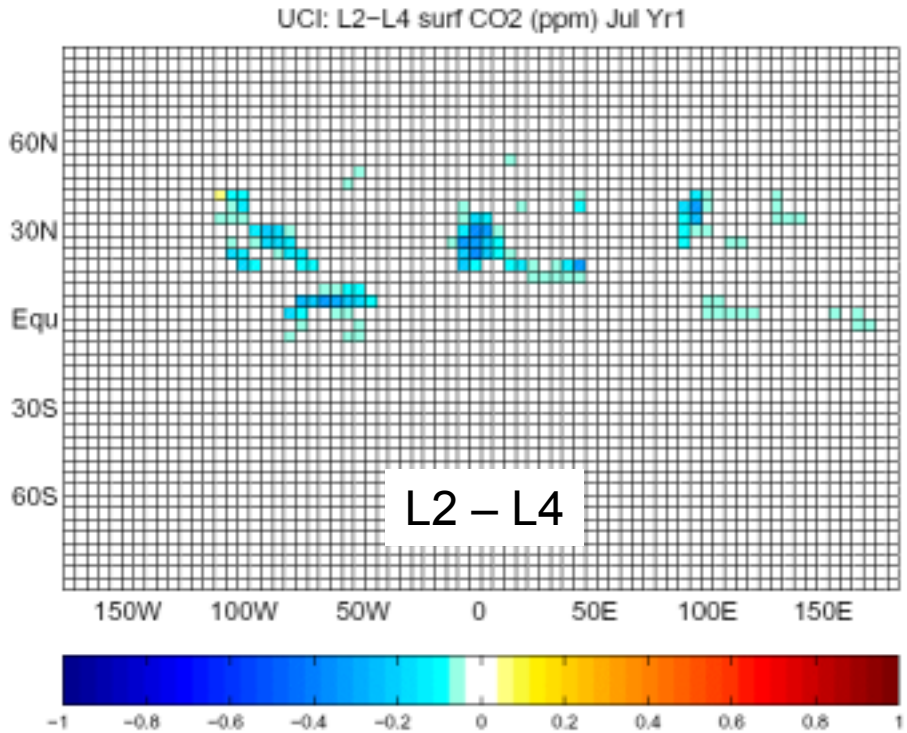


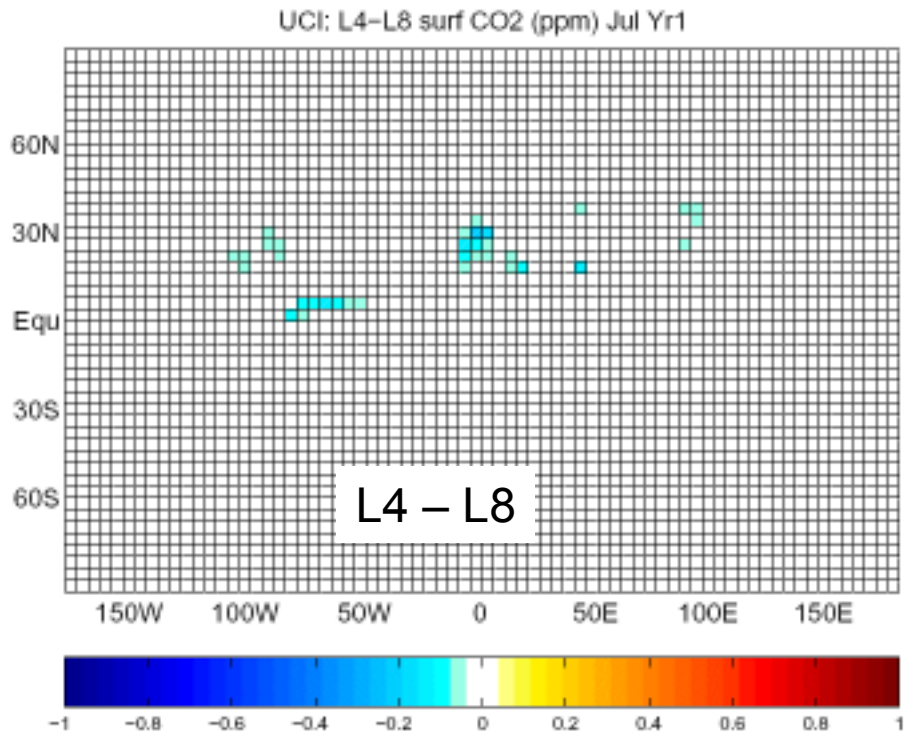


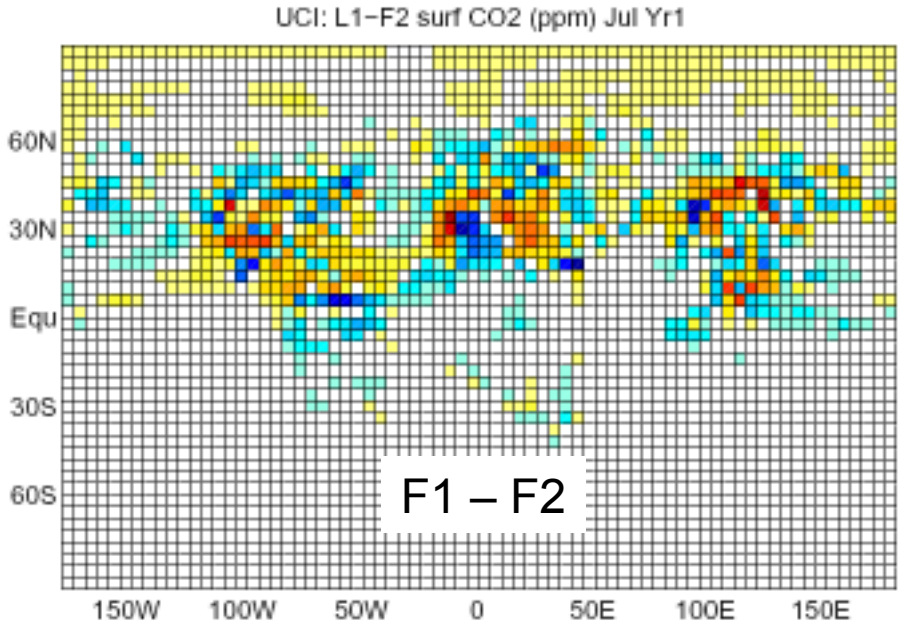


In order to compare with F1:F2:F4

compare Jul Yr1

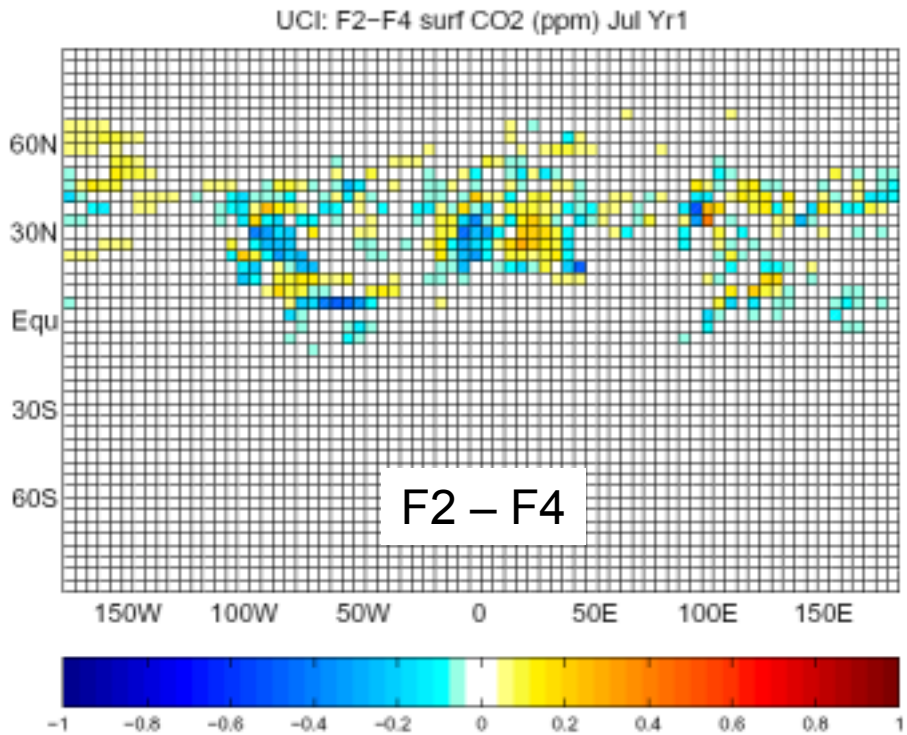


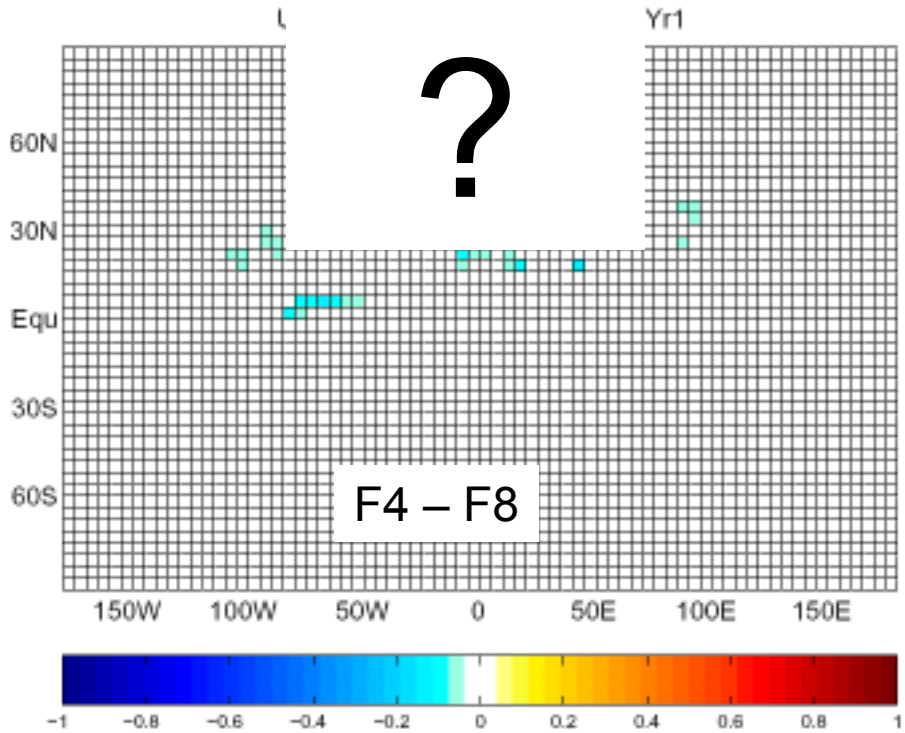




In order to compare with F1 : F2 : F4

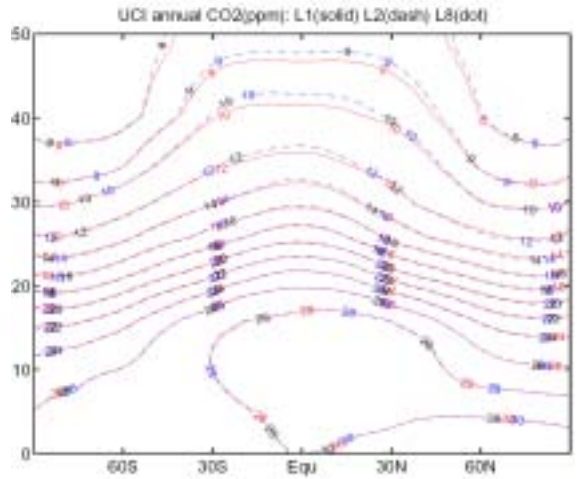
Jul Yr 1





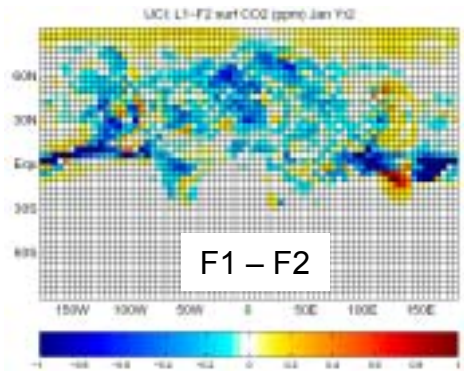
UCI – GMI: 2x to convergence (7)

Prospects look good.
2x is converging.
F4 & F8 runs are getting difficult
(F8 for trop only, 15 mon)



Looks like UCI CTM has error of
about 0.2 ppm in strat ~0.1 yr
→ GMI CTM has error of ~1 yr

Surface errors in UCI CTM are
large in places (1 ppm) but not as
large as GMI-UCI diffs (~10 ppm)



UCI – GMI: 2x to convergence (8)

Propose GMI do the L1:L2:L4:L8 sequence.

The F1:F2:F4:F8 sequence requires VERY careful coding about the poles, not sure GMI can do it without significant effort.

-but it looks like the 2x2.5 and 4x5 cases could be redesigned

Could be a 'first' in proving CTMs converge to same answer. (Presumes that horizontal grid not a problem in stratosphere.)

Priorities? Aerosols and Trop, Chemistry still more important.