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2008 MAP/GMI Proposal from UCI

Models, Measurements & Error Analysis in predicting Atmospheric Composition: Applications for GMI and key MAP Components

Michael Prather, Xin Zhu, Juno Hsu, Qi Tang, Jessica Neu
UC Irvine

GOALS:

Improve GMI/MAP capability to predict future atmospheric composition and perhaps most importantly, air quality in a changing climate..

Remain guided by overall science problems:

What is the right answer?
How can we quantify errors in chemistry-climate modeling?
When do improved algorithms pay off,
e.g., alter the scientific conclusions?
Which CCM components lead to the greatest uncertainty
in composition and climate forcing?

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TASKS:

(i) Optimized fast-JX based photolysis & solar heating module

(ii) Precipitation scavenging module focusing on NOy

(iii) Acquire independent, multi-year met fields (EC/Oslo)

(iv) Implement optional tracer-advection code for GMI

(v) Strat-chem module (O_3 & NOy) for long-term climate runs (Linoz)

(vi) Resolution error analysis / correction schemes (also NSF)

(vii) Participate in international community projects (SPARC CCMVal, EU QUANTIFY) to incorporate new findings in MAP/GMI

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(i) fast-JX & (vii) SPARC/CCMVal PhotoComp2008 (w/ H.Bian)

GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L03811, doi:10.1029/2008GL036851, 2009

Tropospheric O_3 from photolysis of O_2

Michael J. Prather[1]

Received 30 November 2008; accepted 6 January 2009; published 7 Februa

[1] Photolytic dissociation of molecular oxygen (O_2) at wavelengths about 205 nm produces ozone (O_3) in the upper tropical troposphere. In tropospheric chemistry models that ignore this process, the O_3 abundance above 14 km in the tropics (a.k.a. Tropopause Transition Layer) is underestimated by 5 to 20 ppb. Even for models including O_2 photolysis, uncertainty in the O_2 cross sections yields similar uncertainty in TTL O_3. The related impact on global atmospheric chemistry is small, i.e., ±0.2% in CO and CH_4 budgets, but the change in the O_3 column, ±1.6 DU in the tropics, may be important in calculating heating rates and climate forcing. **Citation:** Prather, M. J. (2009), Tropospheric O_3 from photolysis of O_2, *Geophys. Res. Lett.*, *36*, L03811, doi:10.1029/2008GL036851.

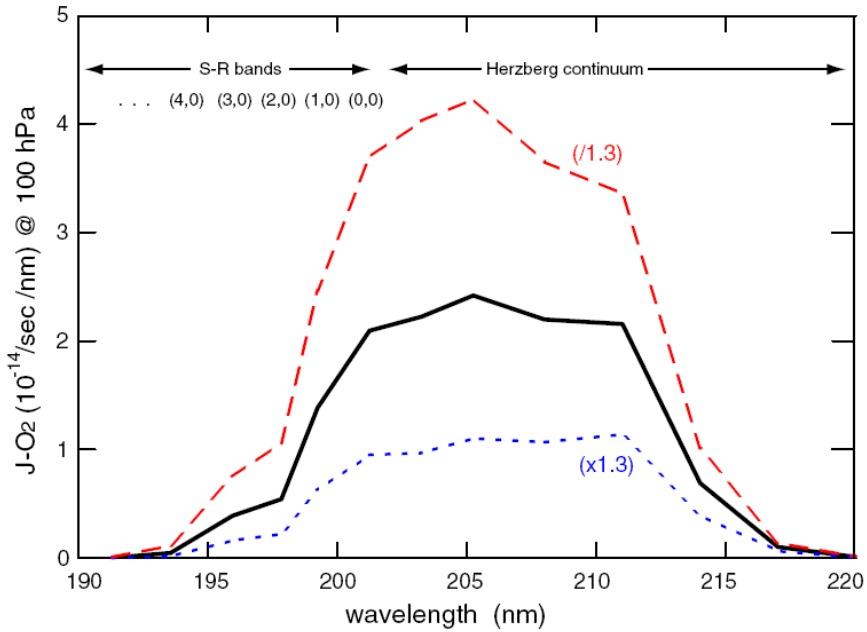

Figure. Photolysis rate of O_2 (/sec /nm) as a function of wavelength (nm).

J-O_2 (per nm) is shown for a solar zenith angle of 15° at 100 hPa for clear sky in the tropics with 238 DU overhead O_3 column.

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(i) fast-JX & (vii) SPARC/CCMVal PhotoComp2008 (w/ H.Bian)

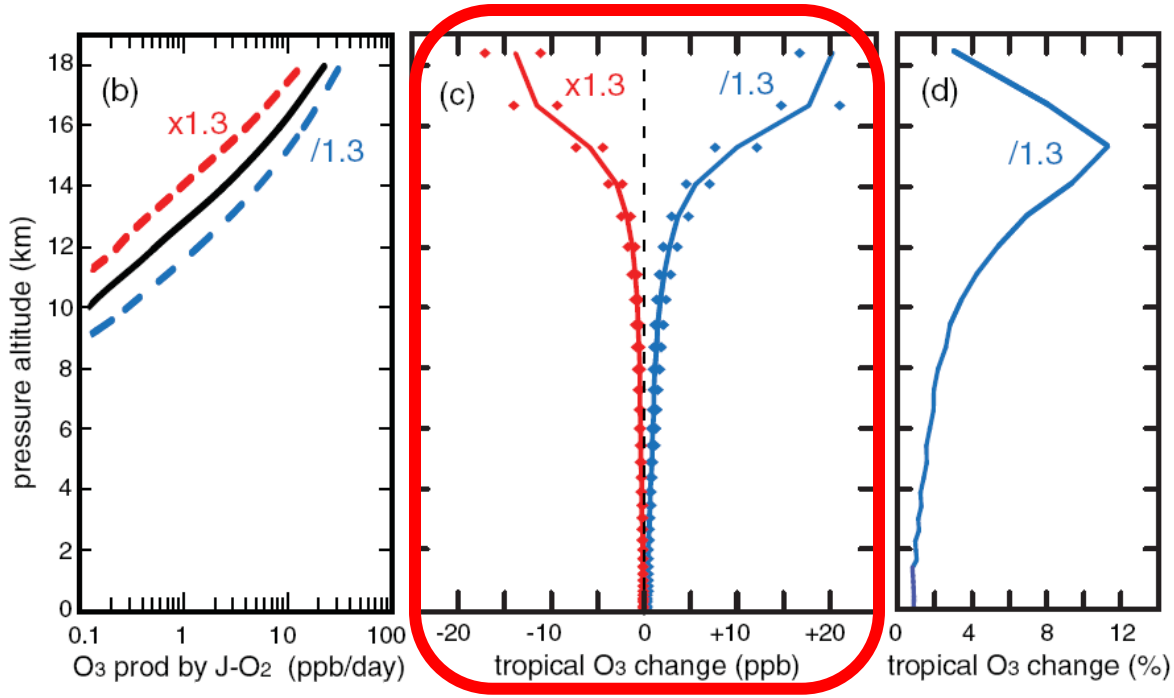

Figure (b). Instantaneous O_3 production (ppb/day) from O_2 photolysis near noon in the tropics (solar zenith angle = 15°, O_3 column = 260 DU) is plotted vs. pressure altitude, z*(km) = 16 $\log_{10}$ 1000/ p(hPa). These noontime rates are about 6x the 24-hour averages. Results are shown for the recommended O_2 cross sections (solid line) and a range of ±30% (x1.3, /1.3).

Figure (c). Change in tropical tropospheric O_3 (ppb) for increased/decreased O_2 cross sections. Solid lines for x1.3 and /1.3 are the annual zonal tropical means; the minimum and maximum range for the monthly means arer shown as symbols.

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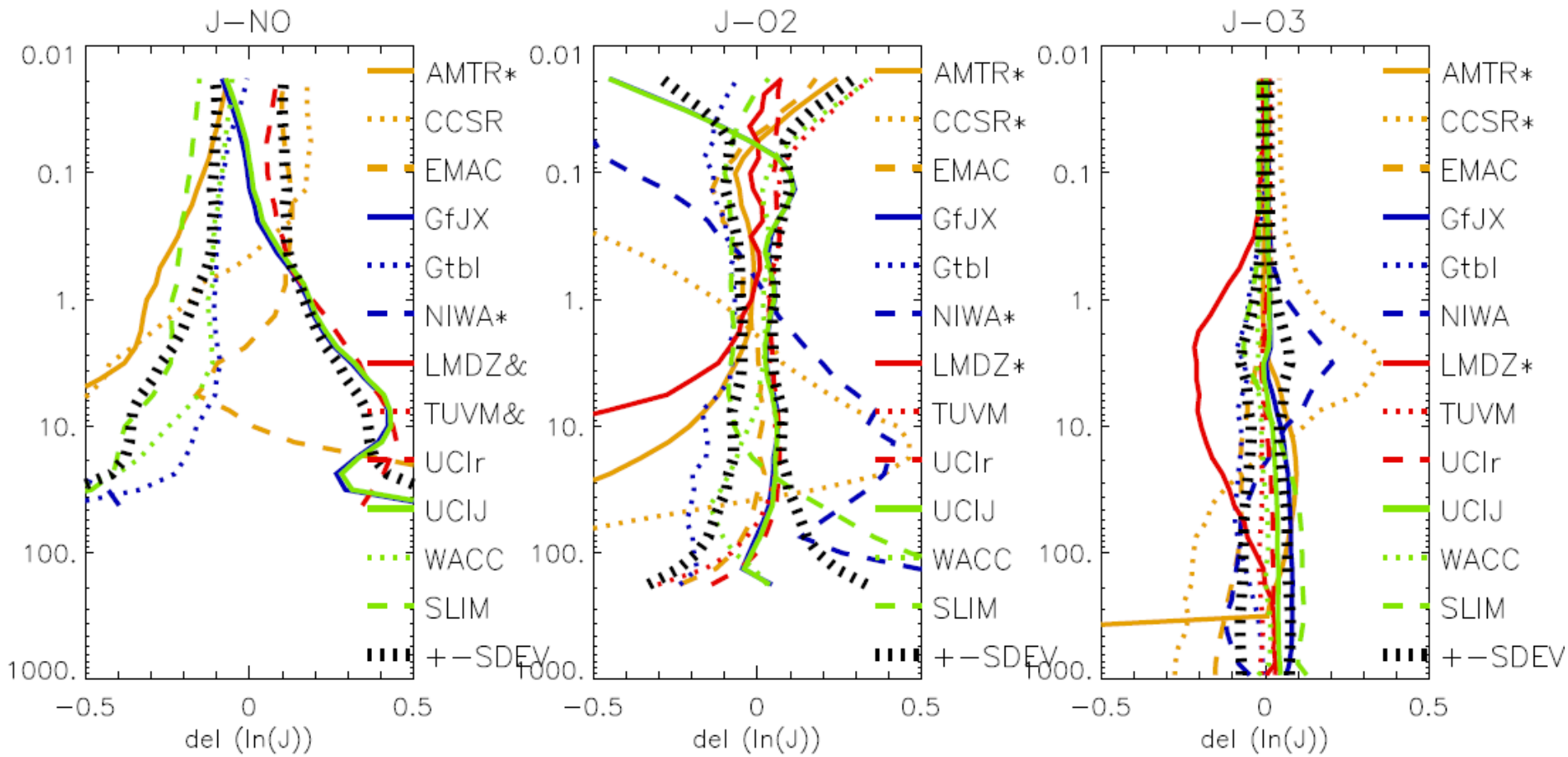
(i) fast-JX & (vii) SPARC/CCMVal PhotoComp2008 (w/ H.Bian)

_fig1

d (ln(J)) * = outside 2 s.d. & = no submisison



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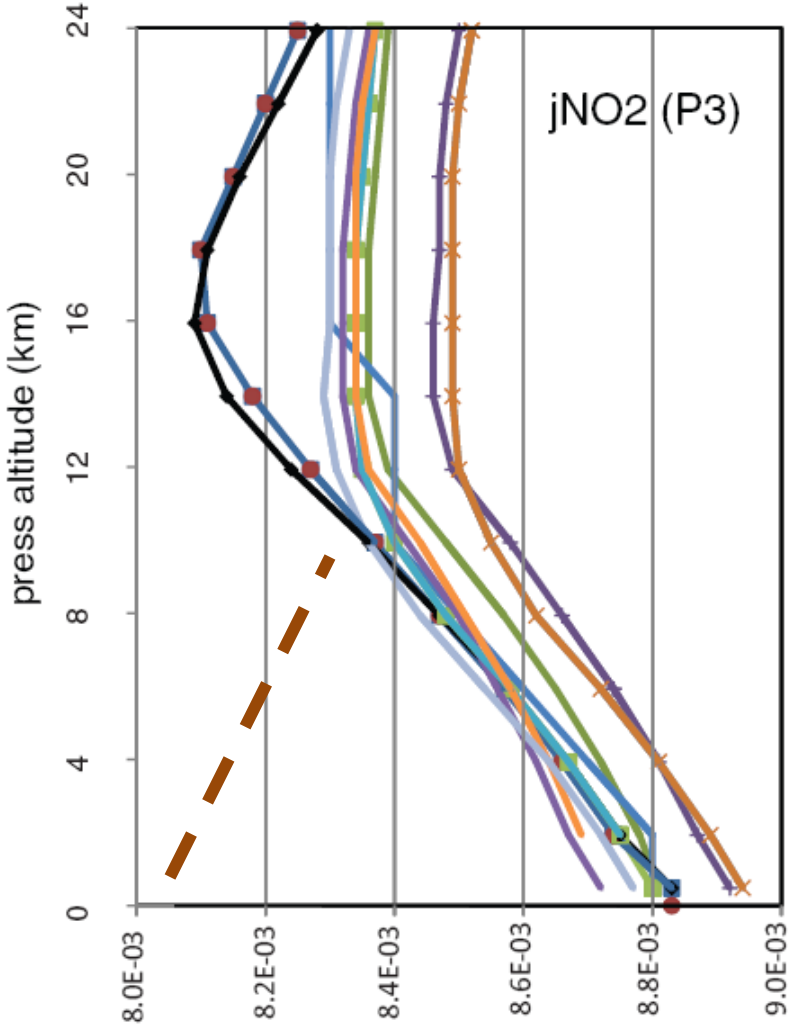

- UCIX-CTM J-NO2
- UCIX-grd J-NO2
- GSFh-NO2 J-NO2
- GSFC-fJX J-NO2
- GSFh-fnT J-NO2
- GSFh-tbl J-NO2
- LMDZ-TUVa J-NO2
- TUV4p6r1 J-NO2
- UCIh-CTM J-NO2
- UCI-fsJX J-NO2
- UCIh-grd J-NO2
- UCI-Jref J-NO2
- WACCMLUT J-NO2

Already identified & corrected long-standing error in JPL tables for J-NO2

UCIX-CTM	0.05 nm (solar, O3), 1 nm (NO2); NO2 (Xs & q) log extrap to all T
UCIX-grd	0.05 nm (solar, O3), 1 nm (NO2); NO2 (Xs & q) log extrap to all T
GSFh-NO2	0.05 nm (solar, O3), 1 nm (NO2); O3 (Xs & q) = fn(T), NO2 (Xs & q) linear between 220 - 298K
GSFC-fJX	std fast-JX: bin mid-pts = 295-303-310-316-333-380-574 nm
GSFh-fnT	0.05 nm (solar, O3, NO2 interp); O3 (Xs & q) = fn(T), NO2 (Xs & q) log extrap to all T
GSFh-tbl	0.05 nm (solar, O3, NO2 interp); O3 (Xs & q) tables for 180K-260K-300K, NO2 (Xs & q) log extrap to all T
LMDZ-TUVa	- - -
TUV4p6SM	1 nm (208-430 nm), 2 nm out to 700 nm
UCIh-CTM	0.05 nm (solar, O3), 1 nm (NO2); NO2 (Xs & q) linear between 220 - 298K
UCI-fsJX	std fast-JX: bin mid-pts = 295-303-310-316-333-380-574 nm
UCIh-grd	0.05 nm (solar, O3), 1 nm (NO2); NO2 (Xs & q) linear between 220 - 298K
UCI-Jref	1 nm (295-320 nm), 2 nm (320-324), 10 nm (325-385nm),...
WACCMLUT	- - -

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(i) fast-JX

➔ fast-Heating (Solar term)

Accurate heating rates (directly calculated deposition of the direct and diffuse fluxes in a pseudo-spherical atmosphere!) is complete for the UV-Vis range.

Completion will be delayed, pending more direct collaboration with NASA MAP GCM to optimize the on the spectral bands for solar near IR.

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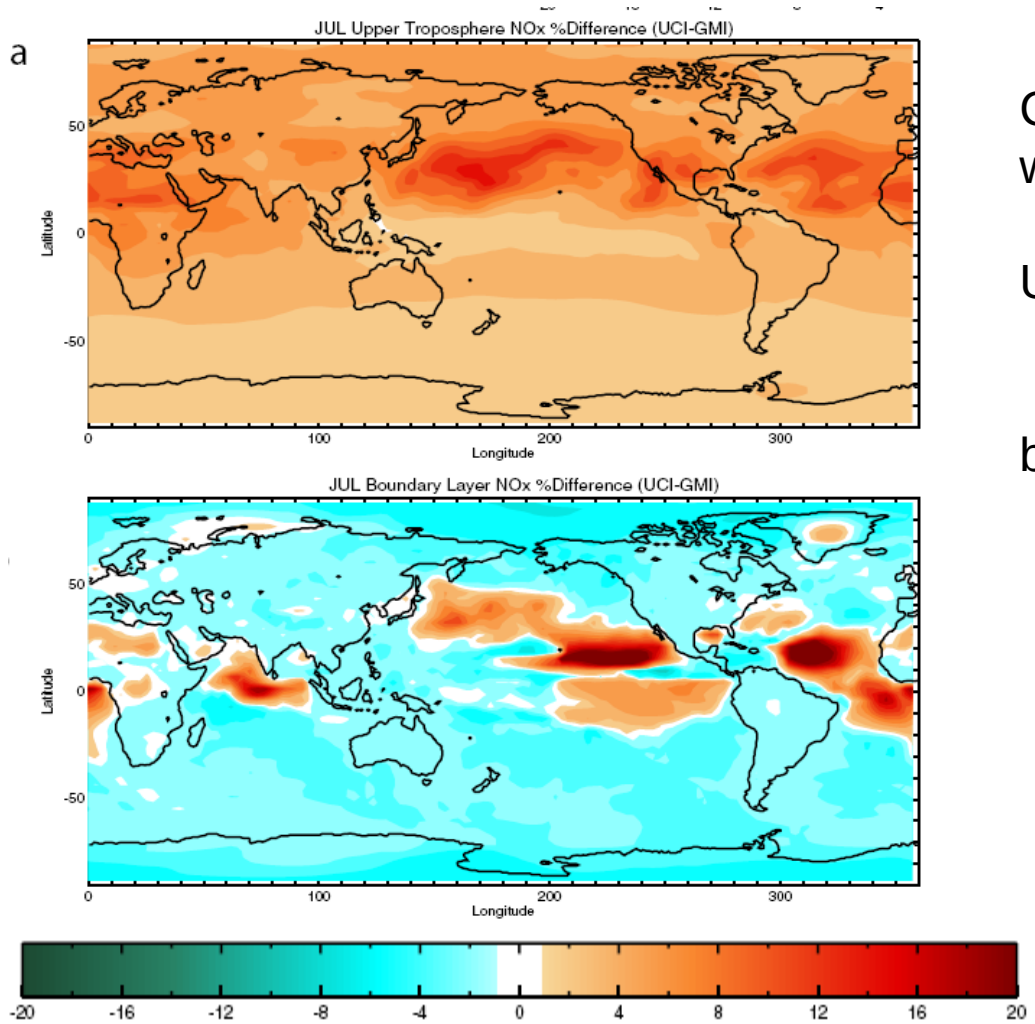
(ii) Precipitation scavenging module focusing on NOy

work of Jessica Neu

NOx



Compare GMI scavenging code with new UCI algorithm:

UCI has more NOx in upper trop
less in boundary layer

both within the UCI CTM

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(iii) Independent, multi-year met fields (EC/Oslo)

UCI CTM with 1° x 1° L40 ECMWF IFS forecast fields (w/ U. Oslo)

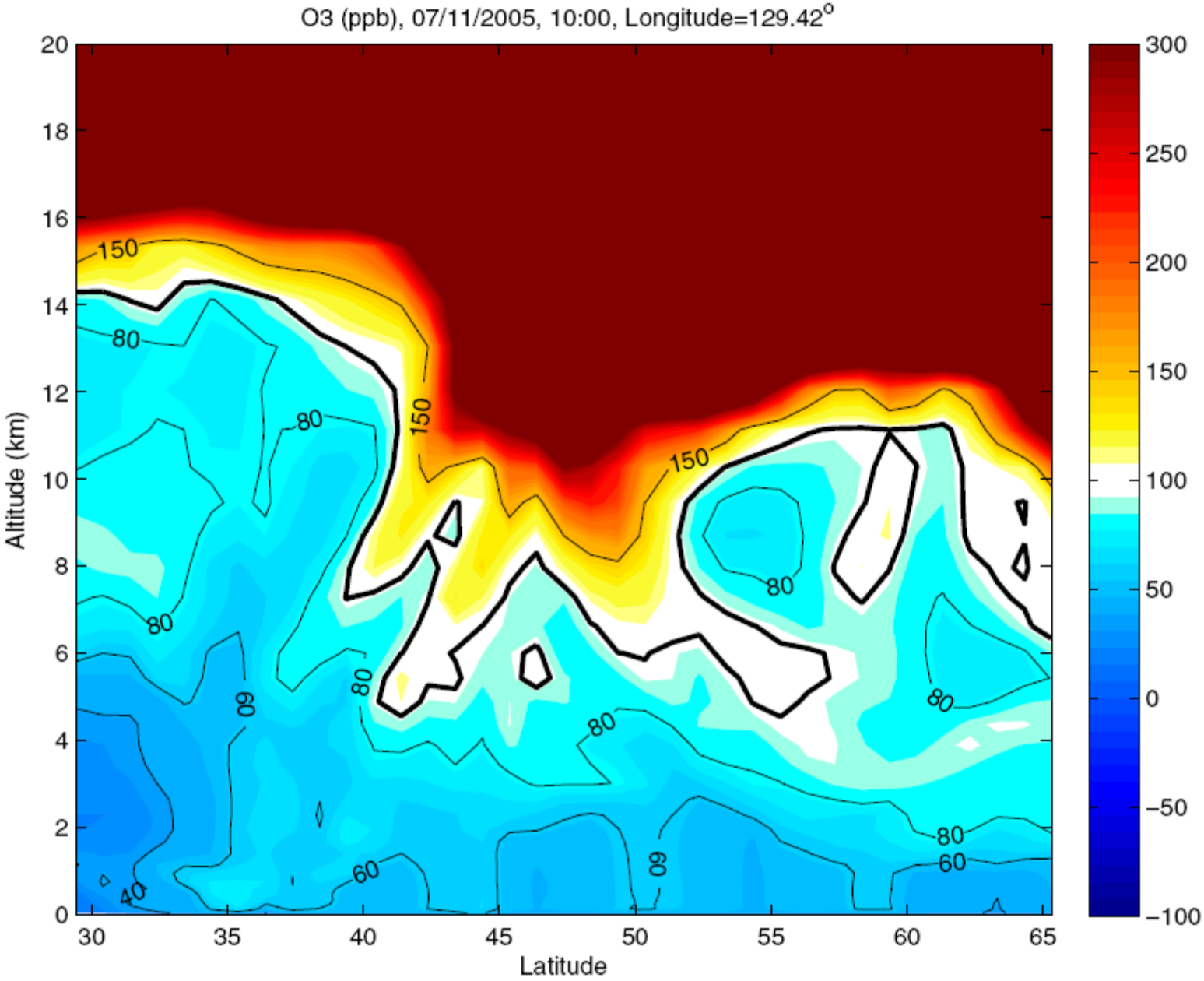
1 Jan 2005 through 31 Dec 2007

Working with Oslo to get ***2004 – 2009 1° x 1° L60***

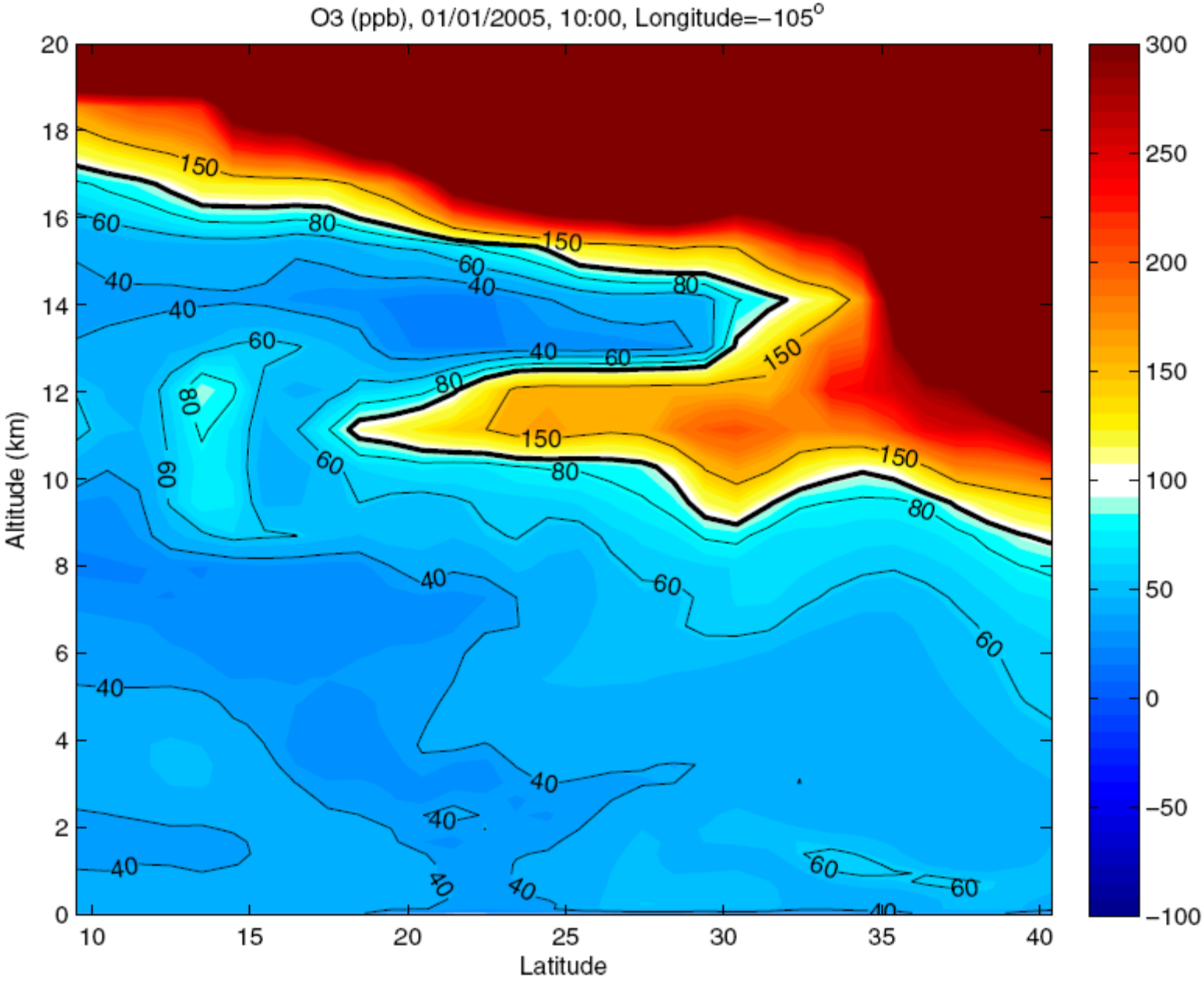
Work with GMI to implement in LR tracer algorithm
(or swap out with SOM tracer algorithm)

Examples from Aura work by Qi Tang

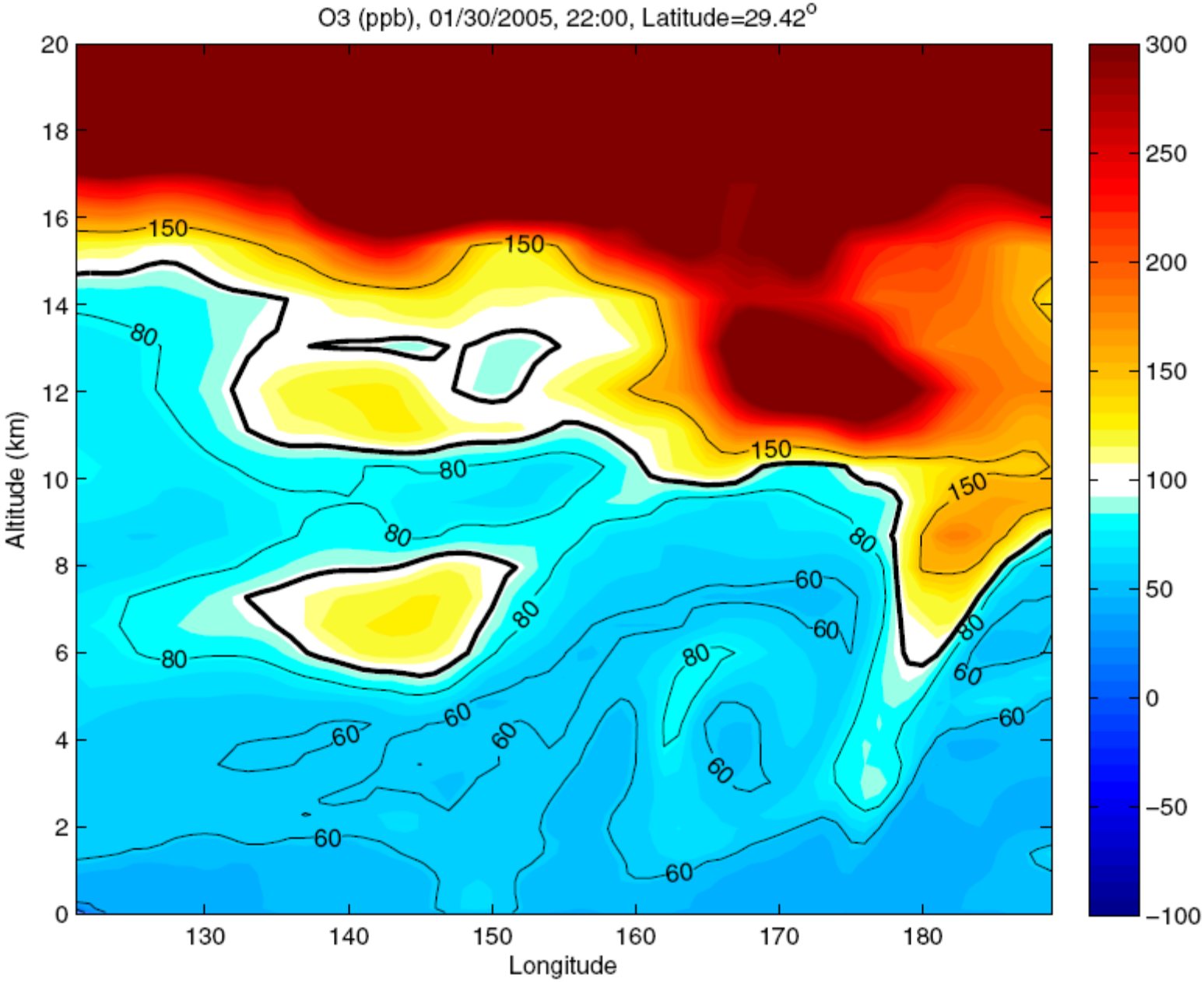
UCI CTM with 1° x 1° L40 ECMWF IFS forecast fields (w/ U. Oslo)



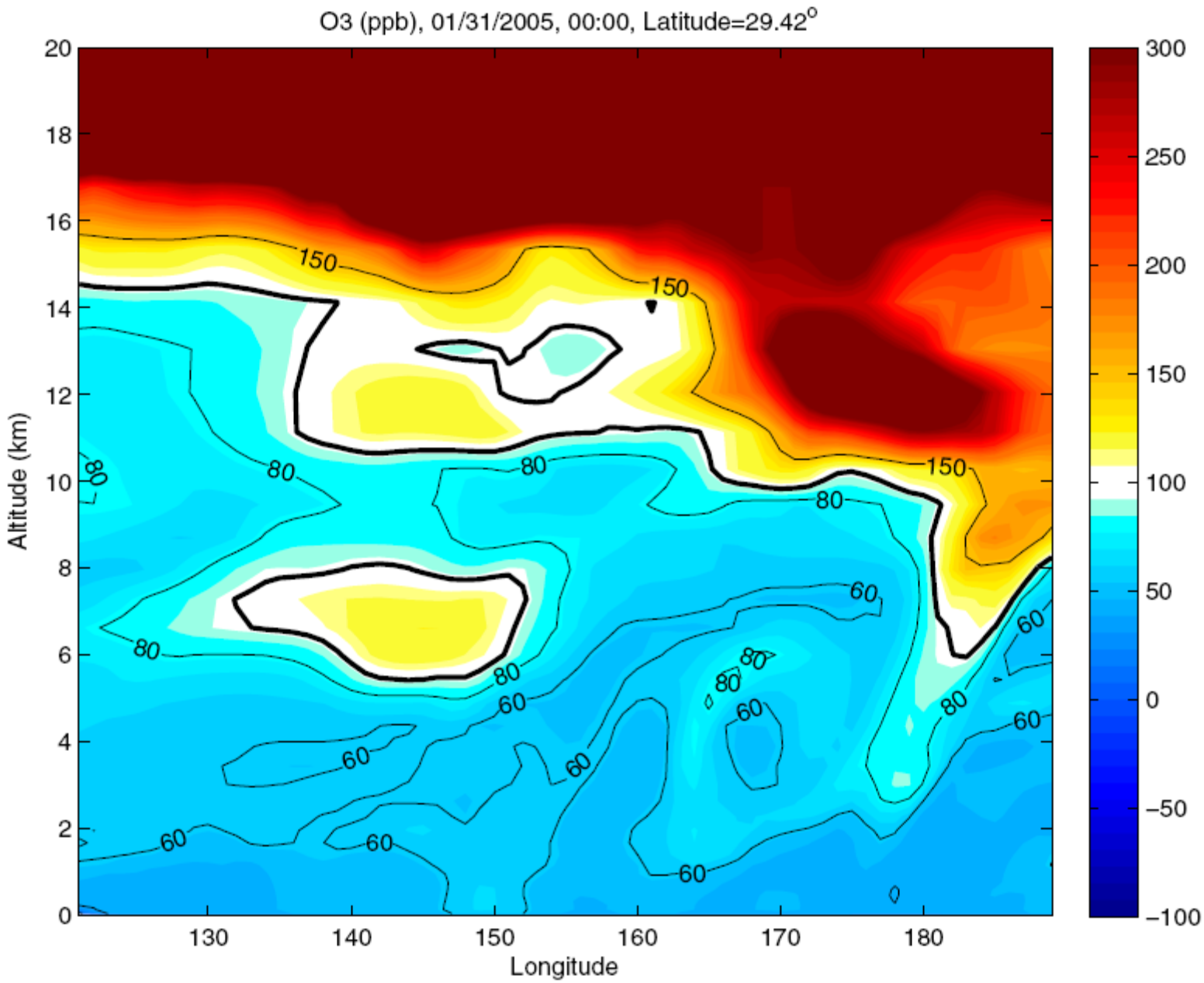
UCI CTM with 1° x 1° L40 ECMWF IFS forecast fields (w/ U. Oslo)



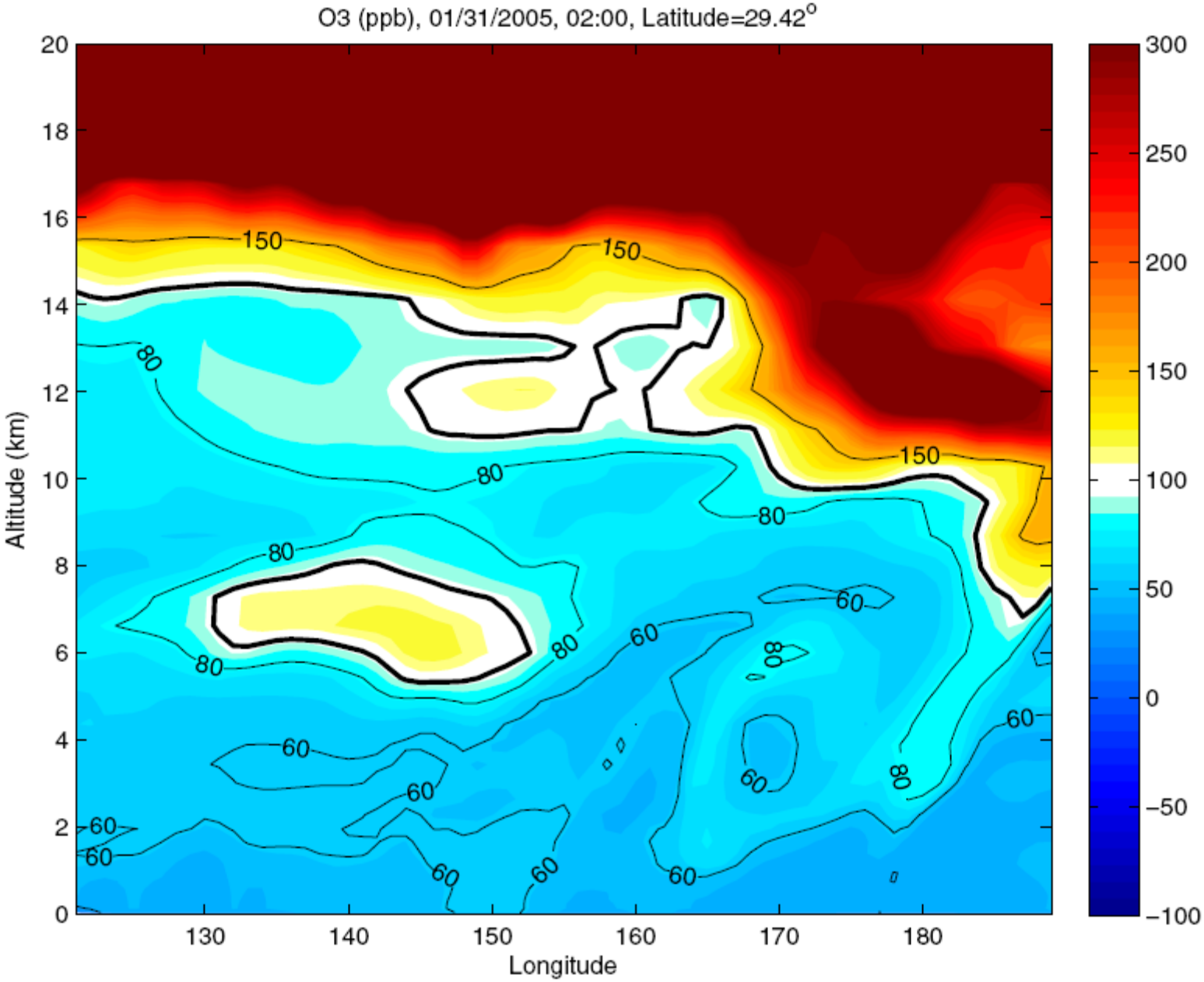
UCI CTM with 1° x 1° L40 ECMWF IFS forecast fields (w/ U. Oslo)



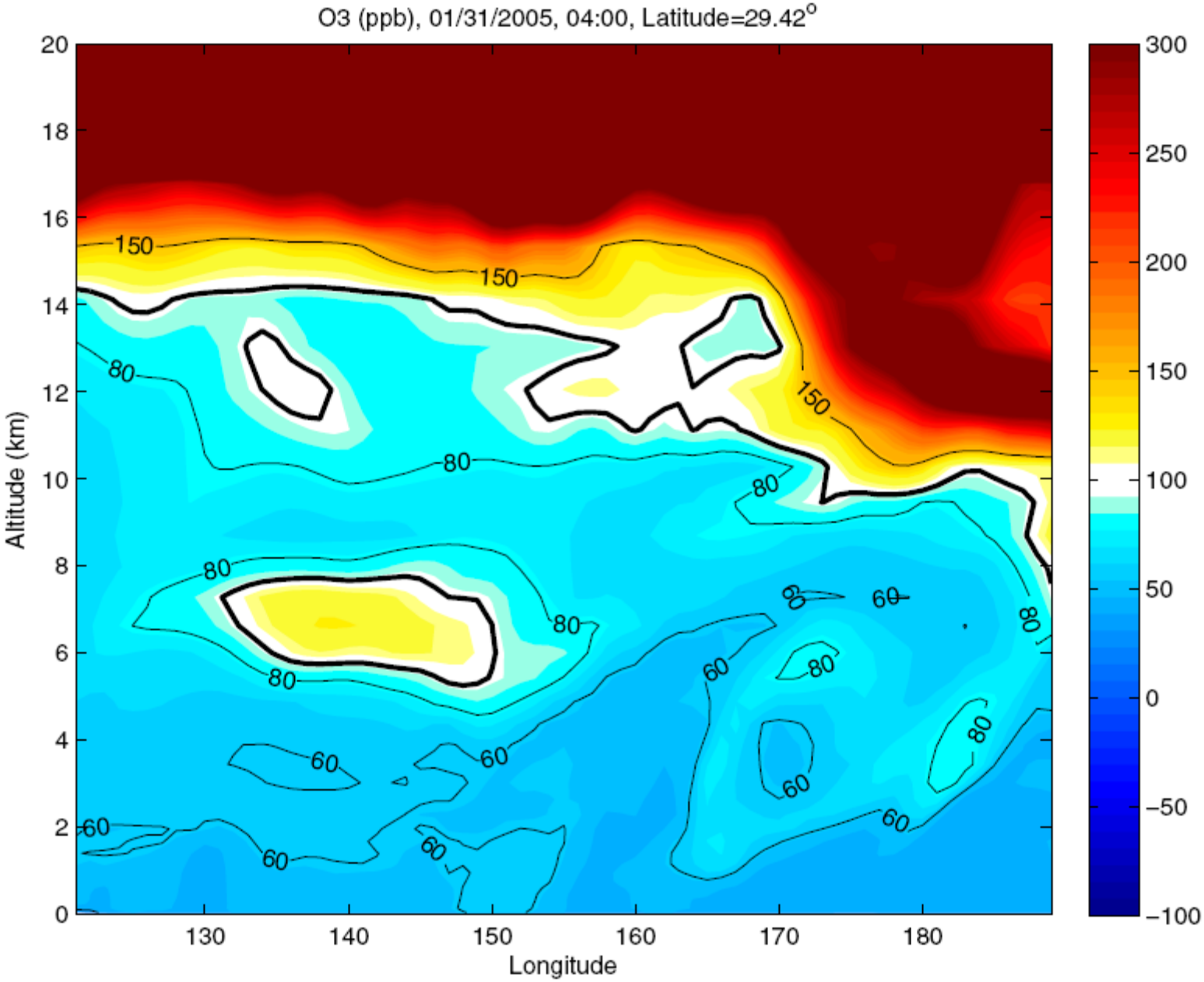
UCI CTM with 1° x 1° L40 ECMWF IFS forecast fields (w/ U. Oslo)



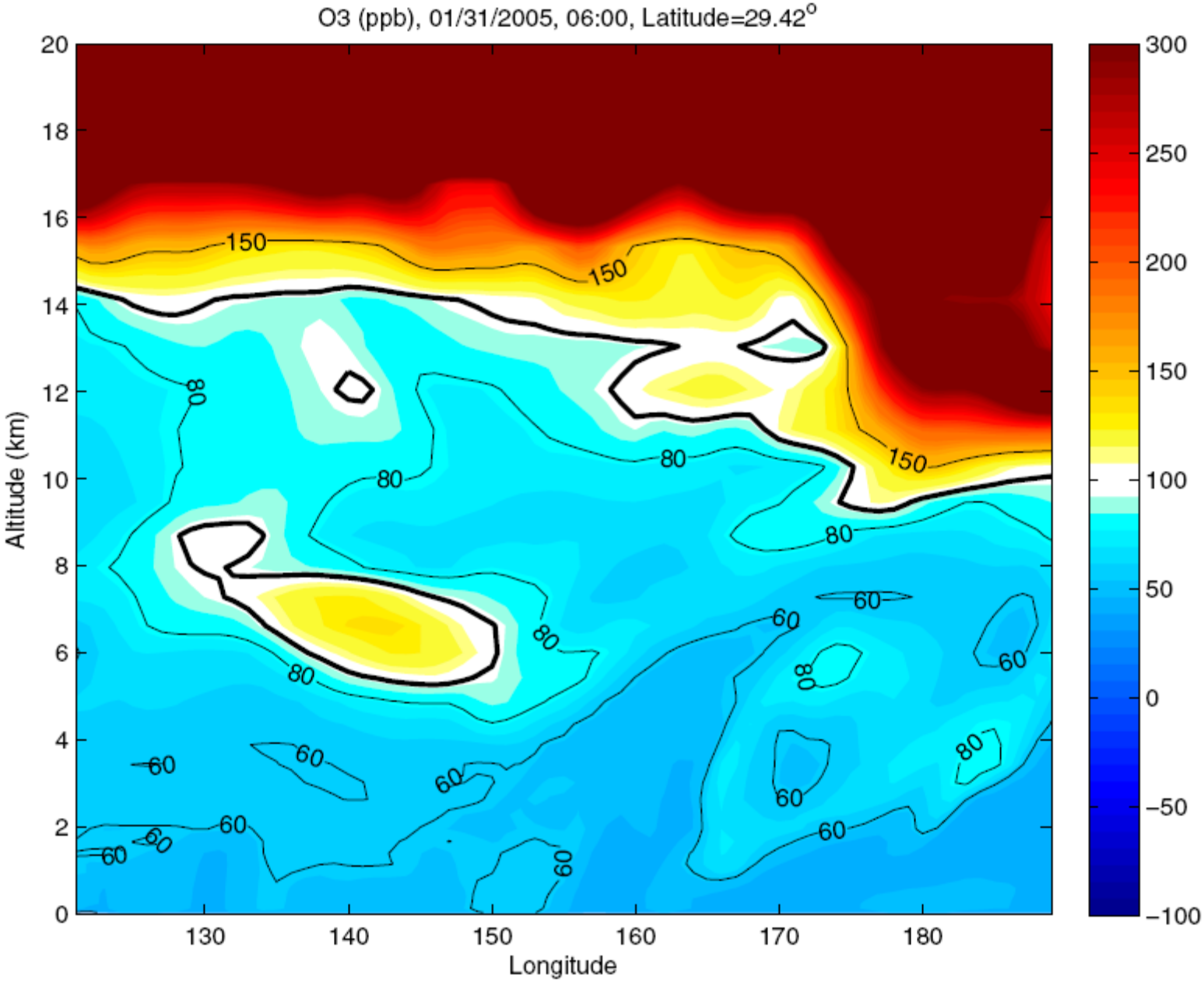
UCI CTM with 1° x 1° L40 ECMWF IFS forecast fields (w/ U. Oslo)



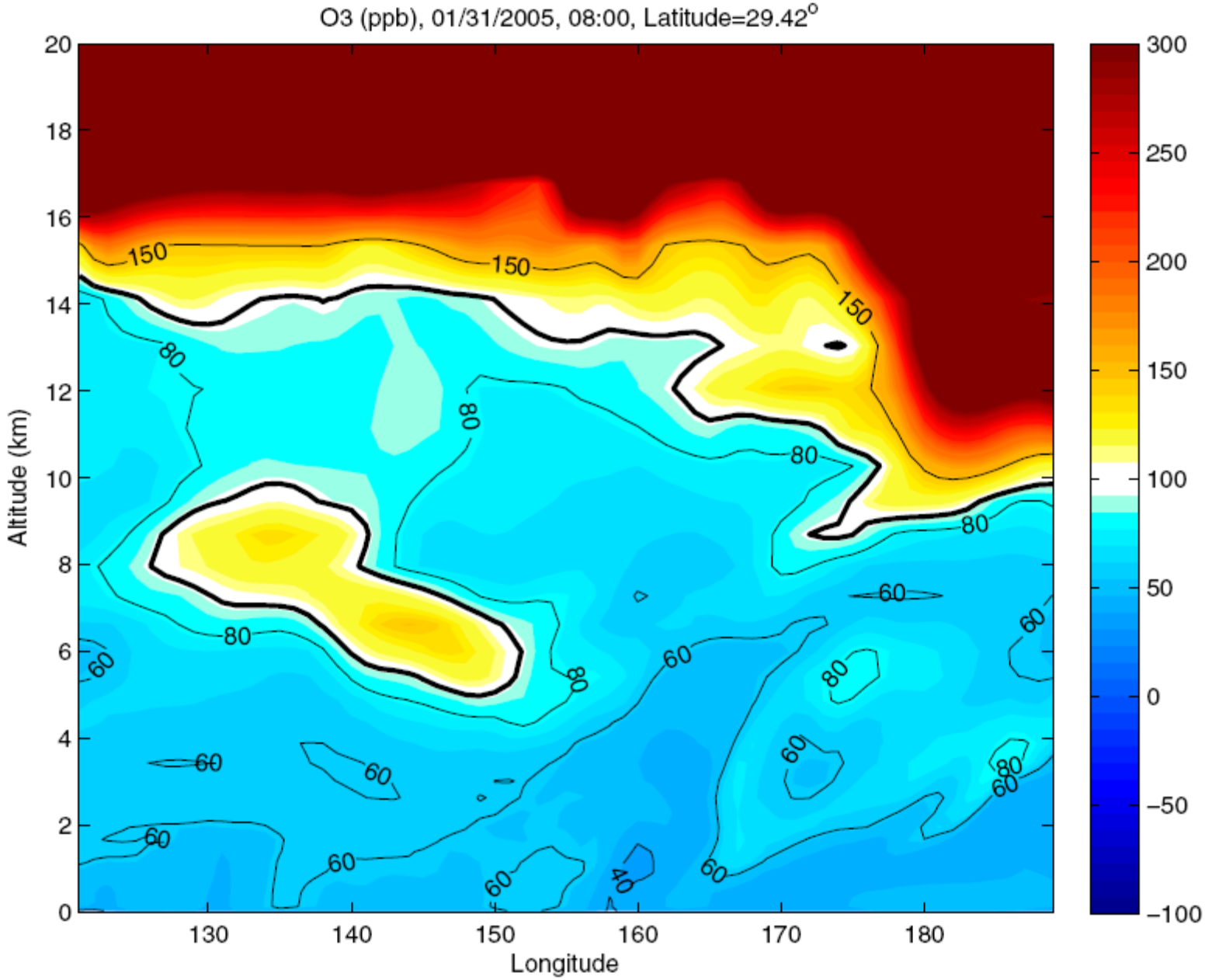
UCI CTM with 1° x 1° L40 ECMWF IFS forecast fields (w/ U. Oslo)



UCI CTM with 1° x 1° L40 ECMWF IFS forecast fields (w/ U. Oslo)



UCI CTM with 1° x 1° L40 ECMWF IFS forecast fields (w/ U. Oslo)



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(iv) Implement optional tracer-advection code for GMI

UCI CTM ver 5.6 delivered to GMI – SIVO a month ago
has stratospheric Linoz chemistry, e90 t-pause, …

Code is clean and optimized, but OpenMP
uses 7 out of 8 cpus
T42 full UCI chemistry (20 hrs/yr on 1 $4K board)

UCI CTM now uses '*e90*' tracer to define tropopause: uniform surface emissions, 90-day e-fold everywhere. Previously used O_3 (e.g., 120 ppb) to define tropopause. Can now compare with t-pause observations *AND* understand seasonality of O_3 at t-pause.

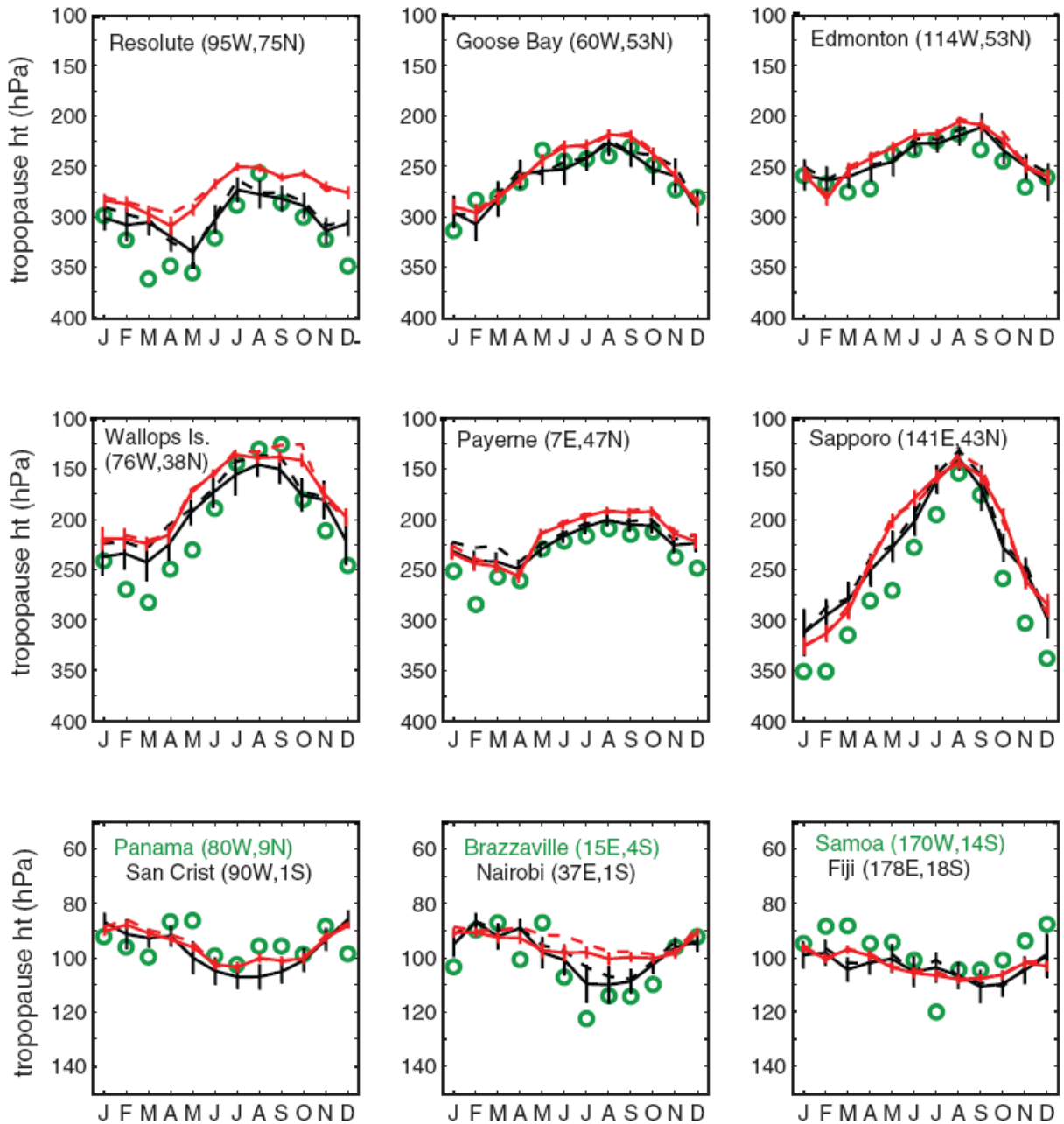
UCI CTM T42 L40 ECMWF IFS forecast fields with e90 tropopause

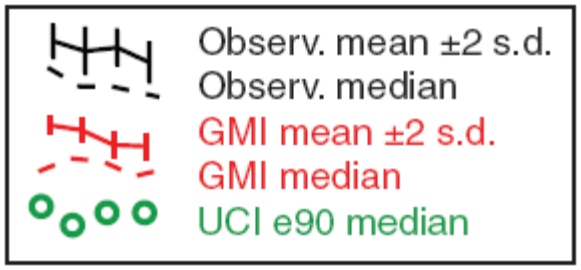
'Upper' t-pause

PRESSURE

CTM evaluation:

e90 works





Considine et al, ACP 2008

UCI CTM T42 L40 ECMWF IFS forecast fields with e90 tropopause

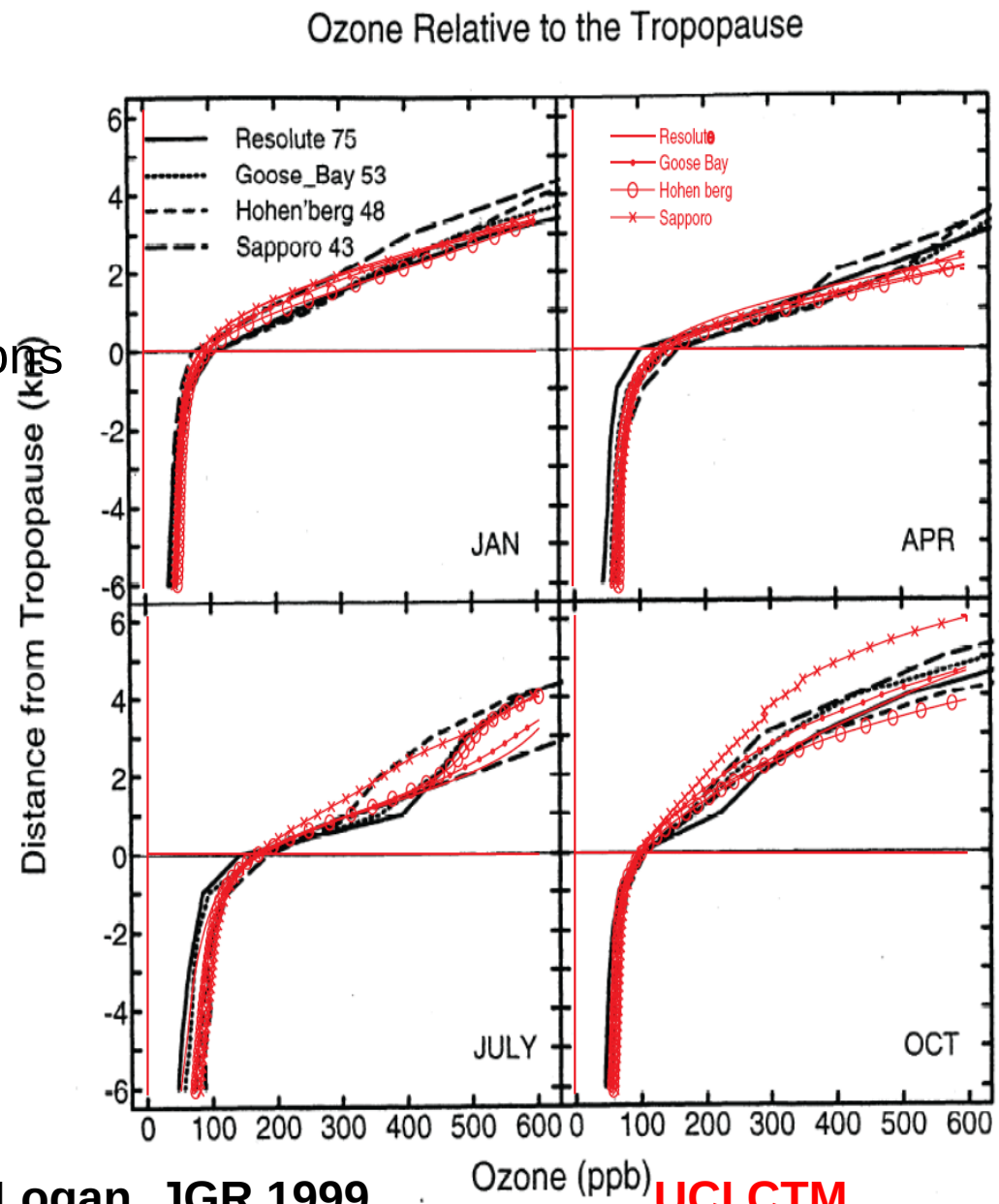
O_3 profile

across tropopause:

4 Canadian sonde stations (Logan, JGR 1999)

CTM evaluation:

not bad



Logan, JGR 1999 **UCI CTM**

UCI CTM T42 L40 ECMWF IFS forecast fields with e90 tropopause

t-pause

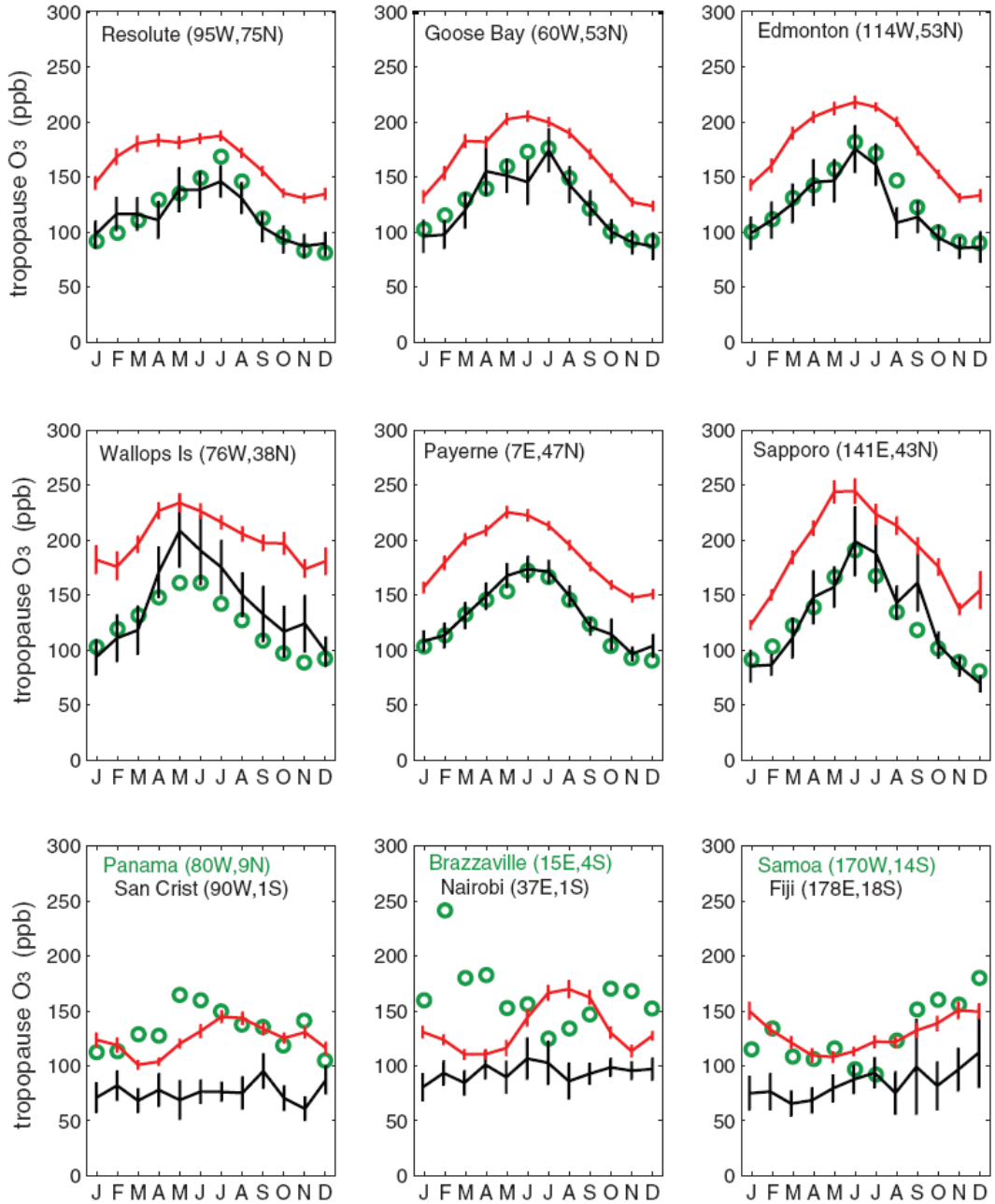
O_3

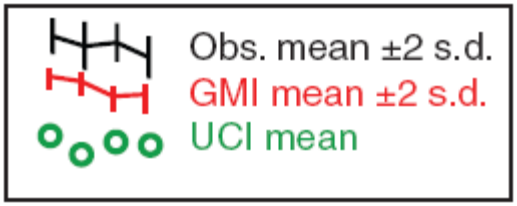
CTM evaluation:

e90 works

CTM looks good !

tropics ??





Considine et al, ACP 2008

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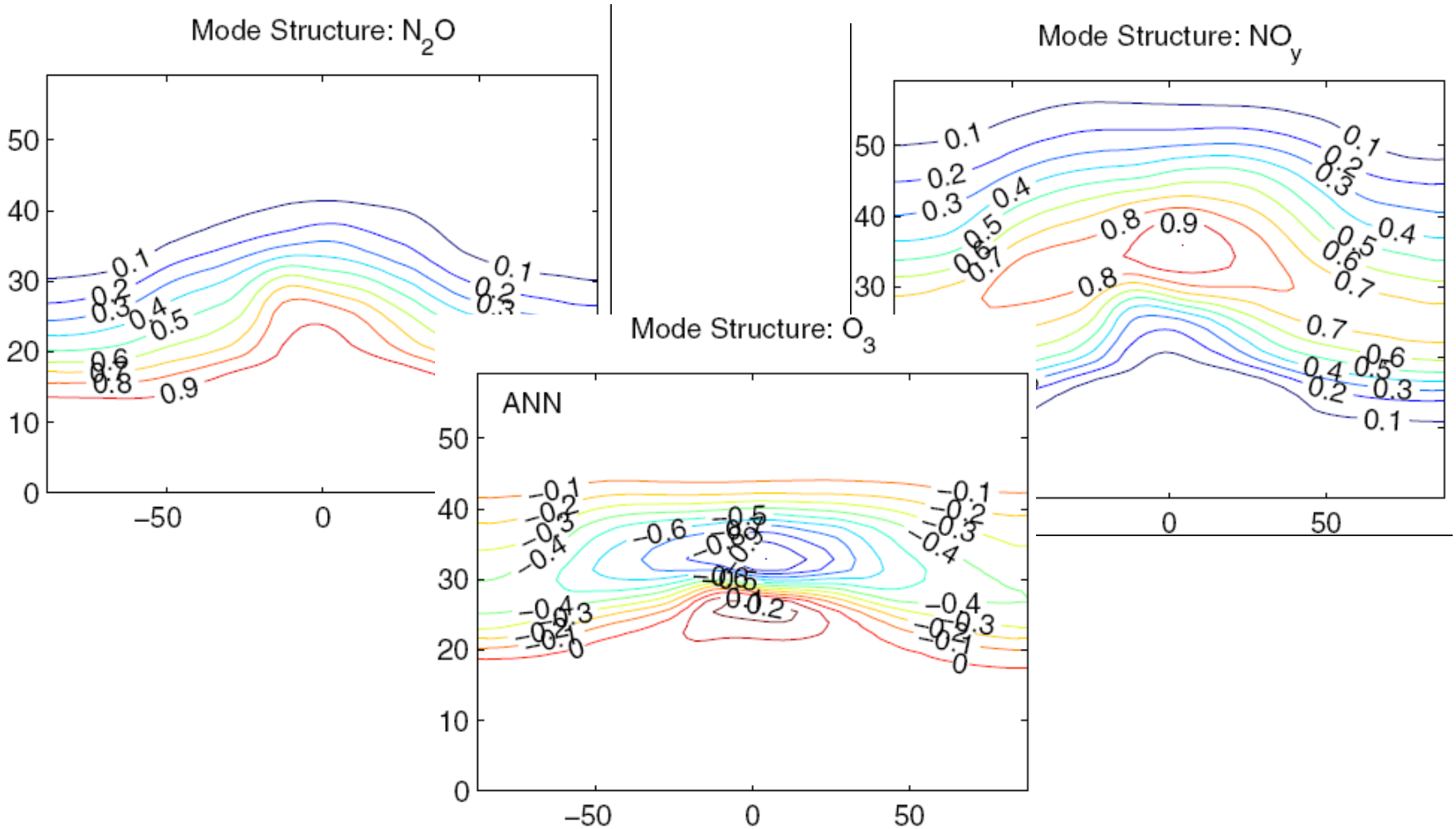
(v) Strat-chem module for long-term climate runs (Linoz based)

Completed and tested O_3, N_2O, & NOy ***(first 3-D modes calculated)***
Decadal tables for CFCs & CH4 to follow



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(vi) Resolution error analysis / correction schemes (also NSF)

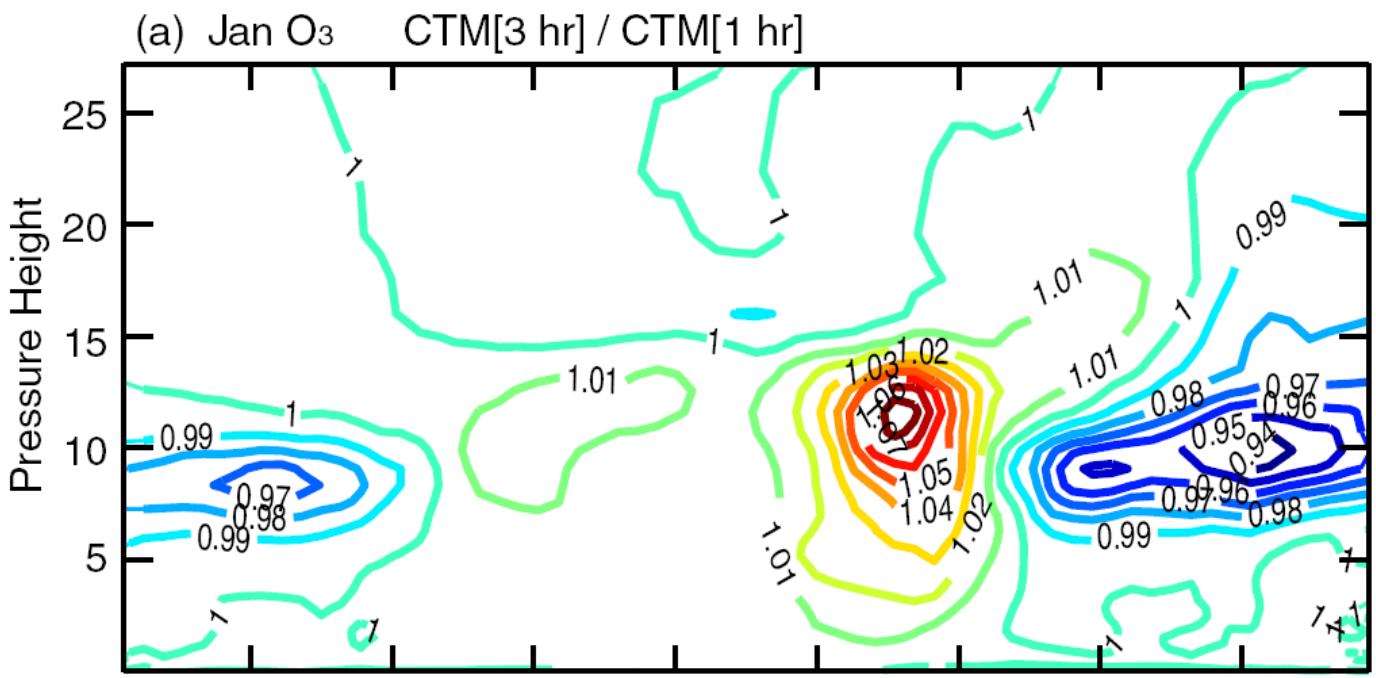

Figure 1. Example of CTM error, first-order in time, from a Linoz O_3 simulation. CTM is initialized from steady-state spinup on Jan 1, run for 31 days, averaged. Ratios of 3 different operator-split time steps are shown: 3 hr, 1 hr, and 1/3 hr.

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PNAS | December 16, 2008 | vol. 105 | no. 50 | 19617–19621

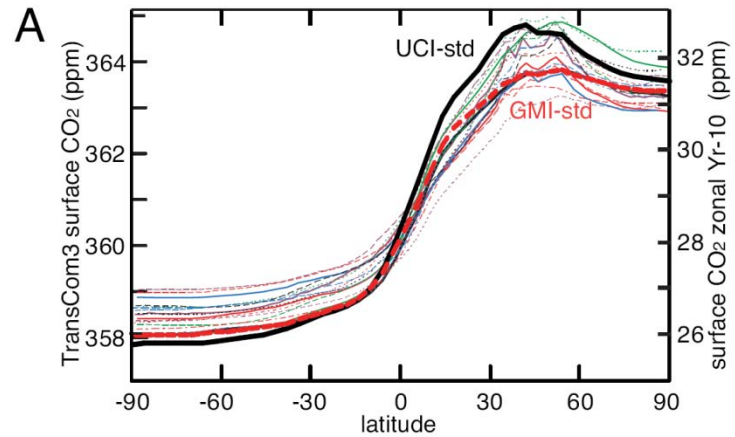
Quantifying errors in trace species transport modeling

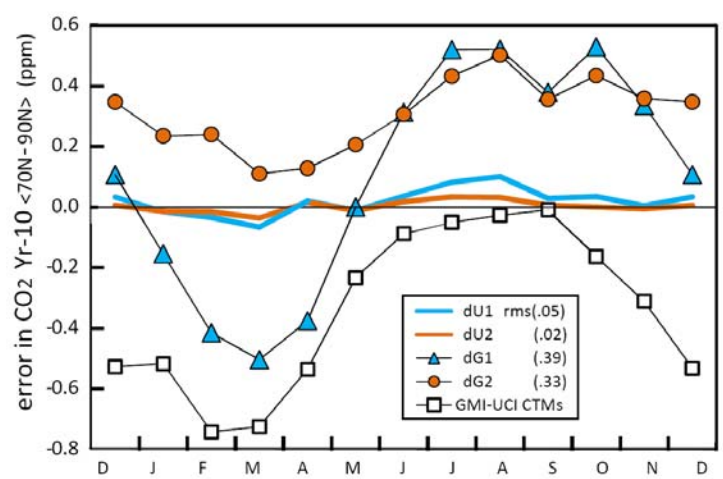
Michael J. Prather[a,1], Xin Zhu[a], Susan E. Strahan[b], Stephen D. Steenrod[b], and Jose M. Rodriguez[c]

[a]Earth System Science Department, University of California, Irvine, CA 92697; [b]Goddard Earth Science and Technology Center, University of Maryland Baltimore County, Greenbelt, MD 20771; and [c]Goddard Space Flight Center, National Aeronautics and Space Administration, Greenbelt, MD 20771

Edited by Veerabhadran Ramanathan, University of California at San Diego, La Jolla, CA, and approved November 7, 2008 (received for review July 7, 2

One expectation when computationally solving an Earth system model is that a correct answer exists, that with adequate physical approximations and numerical methods our solutions will converge to that single answer. With such hubris, we performed a controlled numerical test of the atmospheric transport of CO_2 using 2 models known for accurate transport of trace species. Resulting differences were unexpectedly large, indicating that in some cases, scientific conclusions may err because of lack of knowledge of the numerical errors in tracer transport models. By doubling the resolution, thereby reducing numerical error, both models show some convergence to the same answer. Now, under realistic conditions, we identify a practical approach for finding the correct answer and thus quantifying the advection error.





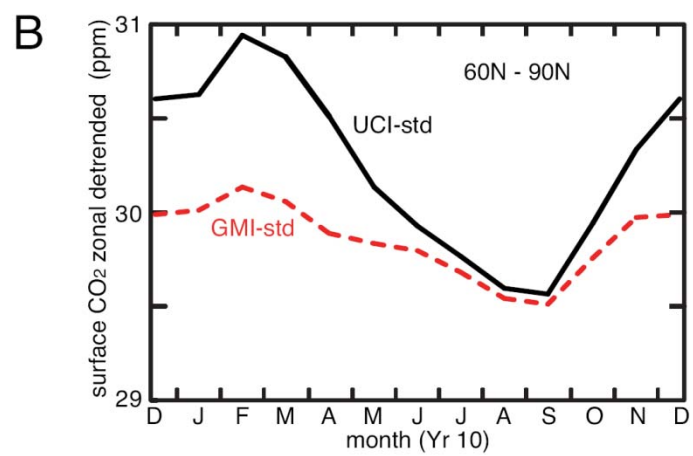


Fig 1X. With 2x resolution, GMI corrects ;arge seasonal error at high latitudes,but identifies polar bias error.

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(vii) Participate in EU QUANTIFY, incorporate findings in MAP/GMI

Atmos. Chem. Phys. Discuss., 8, 18219–18266, 2008
www.atmos-chem-phys-discuss.net/8/18219/2008/
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Atmospheric Chemistry and Physics Discussions

This discussion paper is/has been under review for the journal *Atmospheric Chemistry and Physics (ACP)*. Please refer to the corresponding final paper in *ACP* if available.

The impact of traffic emissions on atmospheric ozone and OH: results from QUANTIFY

P. Hoor[1], J. Borken-Kleefeld[2], D. Caro[3], O. Dessens[4], O. Endresen[5], M. Gauss[6], V. Grewe[7], D. Hauglustaine[3], I. S. A. Isaksen[6], P. Jöckel[1], J. Lelieveld[1], E. Meijer[8], D. Olivie[9], M. Prather[10], C. Schnadt Poberaj[11], J. Staehelin[11], Q. Tang[10], J. van Aardenne[12], P. van Velthoven[8], and R. Sausen[7]

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[2]Transportation Studies, German Aerospace Center (DLR), Berlin, Germany
[3]Laboratoire des Sciences du Climat et de l'Environment (LSCE), CEN de Saclay, Gif-sur-Yvette, France
[4]Centre for Atmospheric Science, Department of Chemistry, Cambridge, UK
[5]DNV, Det Norske Veritas (DNV), Oslo, Norway
[6]Department of Geosciences, University of Oslo, Norway
[7]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpaffenhofen, 82234 Wessling, Germany
[10]Department of Earth System Science, University of California, Irvine, USA

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