Data Assimilation with the Canadian Middle Atmosphere Model: A first look at ozone

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Outline of Presentation

1. Intro. to CMAM data assimilation
2. Progress since last fall
3. Validation of current experiment
   - against last year's results
   - against radiosondes
   - against UKMO
4. Ozone in current experiment
5. Work in progress
6. Plans

Middle atmosphere data assimilation for climate applications (CMAM-DA)

- **Improve understanding of middle atmosphere dynamics by confronting a climate model with observations.**
- **Create platform for assimilation of middle atmosphere measurements from Canadian and international instruments.**
- **Can produce assimilated data sets for climate studies.**

Science Team

Data assimilation (ARMA):
Saroja Polavarapu, Yan Yang
Remote sensing (ARQX):
Yves Rochon
Middle Atm dynamics (UofT):
Shuzhan Ren, David Sankey

Science Advisors

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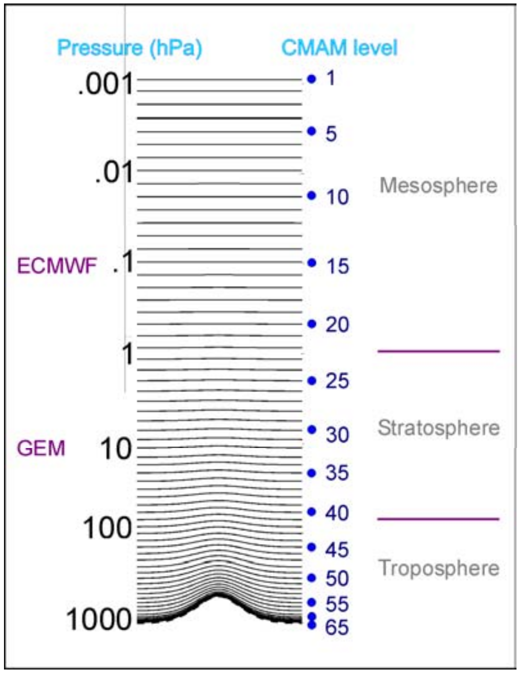
Jack McConnell - York U **Chemistry**
Norm McFarlane - MSC **Climate**
Dave Steenbergen - MSC **Satellite Met.**
David Wardle - MSC **Air Quality**

Collaborators: Richard Ménard **ARQI**, Vitali Fioletov **ARQX**

Canadian Middle Atmosphere Model = CMAM

CMAM is a complex GCM with interactive chemistry, radiation and dynamics

- T47 spectral model
- 65 levels from 0-95 km
- 5 min time step
- T, vort, div, ln ps, q hybrid
- 44 species advected
- 127 gas-phase chemical reactions
- chemistry from 6 km to top



- heterogeneous chemistry
- Hines GWD scheme replaces M-K

← coming soon

Data Assimilation - 3DVAR

Start with CMC's operational 3DVAR scheme

- 3DVAR v9.1.1
- analysis variables: T', y, c', ln q, Ps' (no ozone)
- analysis directly on CMAM's 65 model levels
- digital filter initialization of T, y, c, Ps only

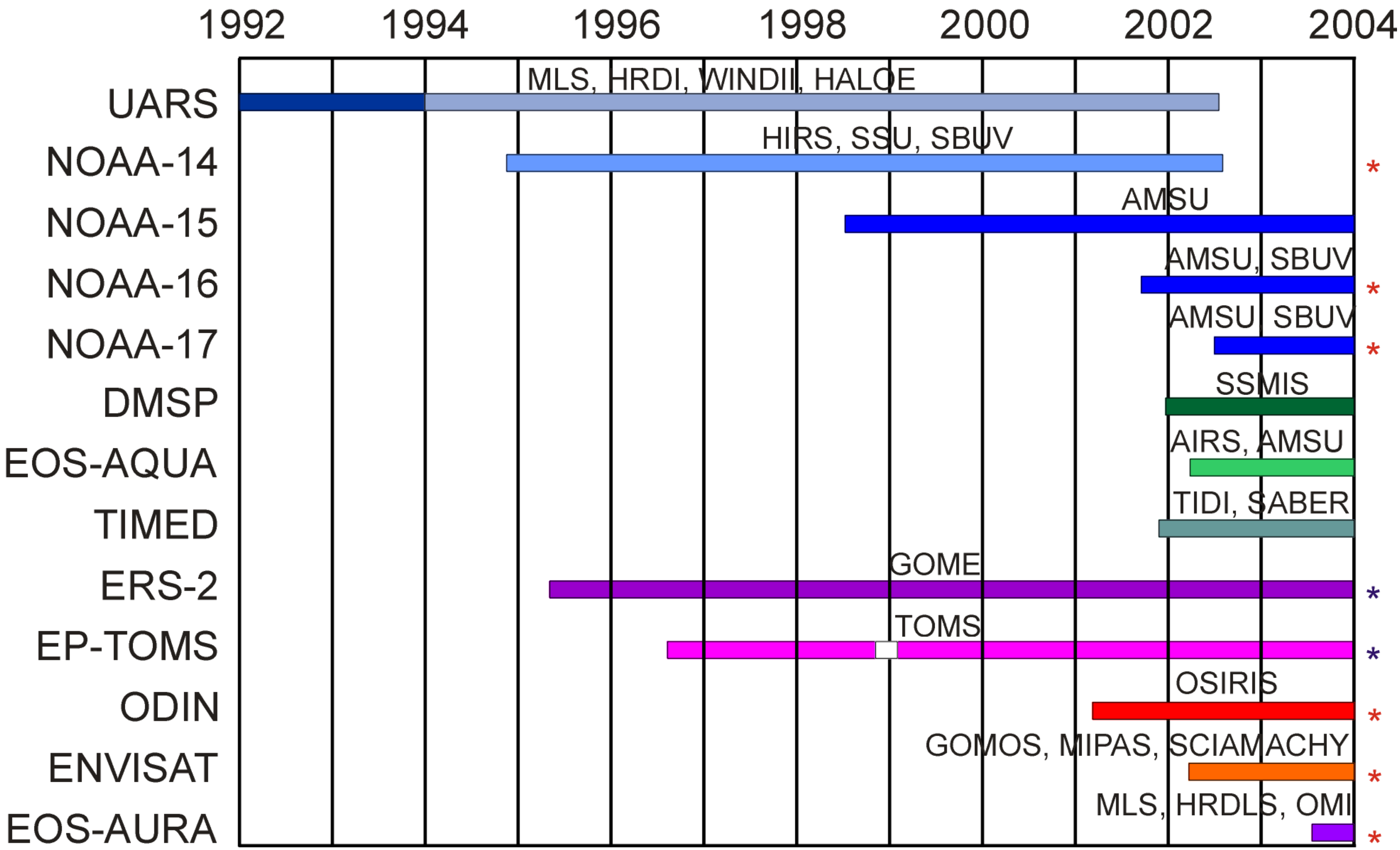
Modify 3DVAR to run with the CMAM

- create interfaces for CMAM state I/O
- generalize 3DVAR to run with CMAM's vertical coordinate
- extend lid to 0.001 mb (95 km)
- remove vertical extrapolation of T and HU in RTTOVS
- derive covariances based on CMAM climate runs only

Changes since last seminar

	Oct. 26, 2001	Nov. 8, 2002
Period of study	**Jan 1994**	**Jan 2002**
3DVAR	**v8.10**	**v9.1.1**
observations	**conv.+SATEM**	**conv.+AMSU+ ACARS**
Machine	**SX4**	**SX5**
Statistics	**climatology of 6h diff.**	**climatology of 6h diff. + tapering**

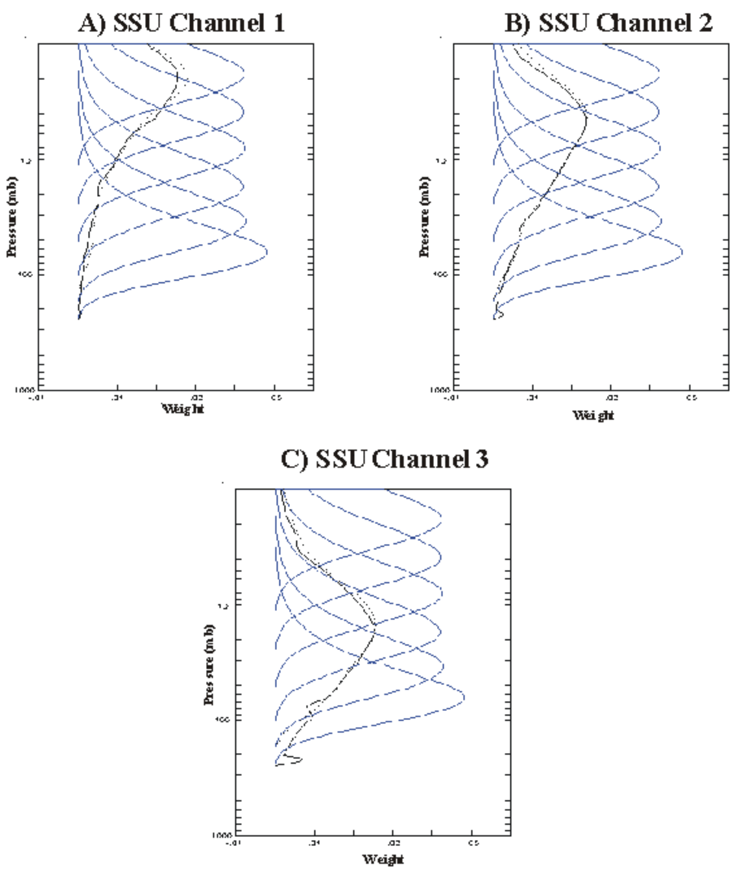
Satellite Missions of interest to CMAM-DA



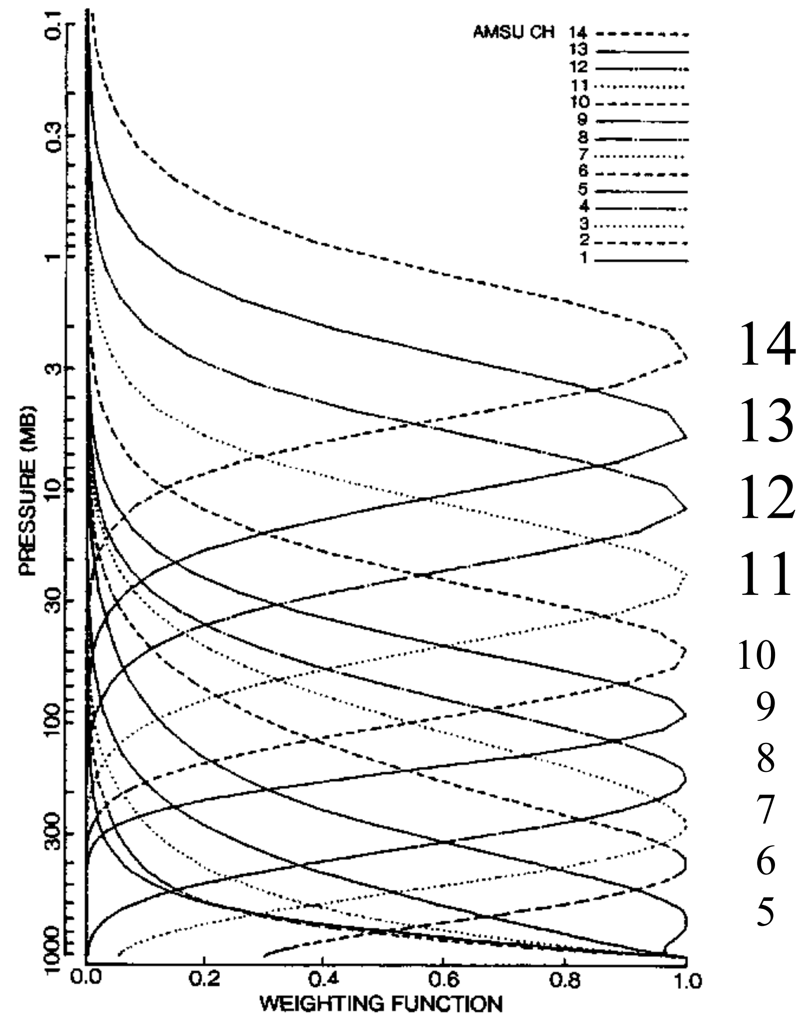
SAGE III - Dec. 10, 2001
SCISAT - late 2002

*O3 total column
*O3 profiles

SSU vs AMSU



Normalized AMSU weighting functions



Current Experiment

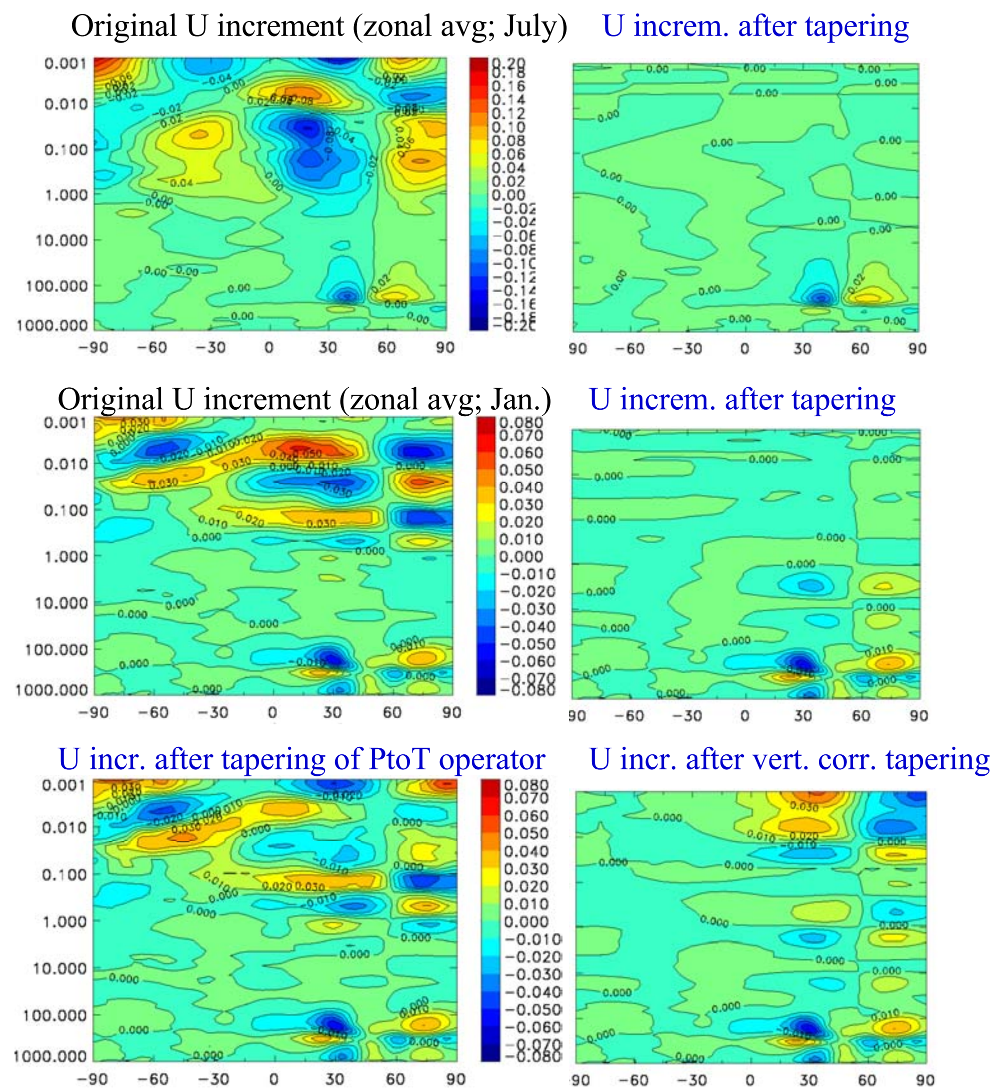
CMAM+3DVAR

- CMAM v5 T47L65 full chemistry
- 3DVAR v9.1.1 on CMAM coordinates, 48x96 grid
- stats = CMAM 6-h diff. climatology with vertical tapering
- data: sondes, aircraft, surface, AMSU ch. 5-10, etc.
- obs are primarily below 10 mb
- Dec. 15, 2001 start-up from climate snapshot for January
- Jan 2002
- humidity not filtered
- 15 chemical species saved in trial fields
- no ozone assimilated yet

Tapering of vertical correlation matrices

Vertical correlations for distant points are small but mesospheric variance is large so covariances can be notable.

One obs: T at 250 mb
(30W, 50N)



Tapering is applied to all vert. corr. and PtoT operator

Diff. in level index

0-10 no change

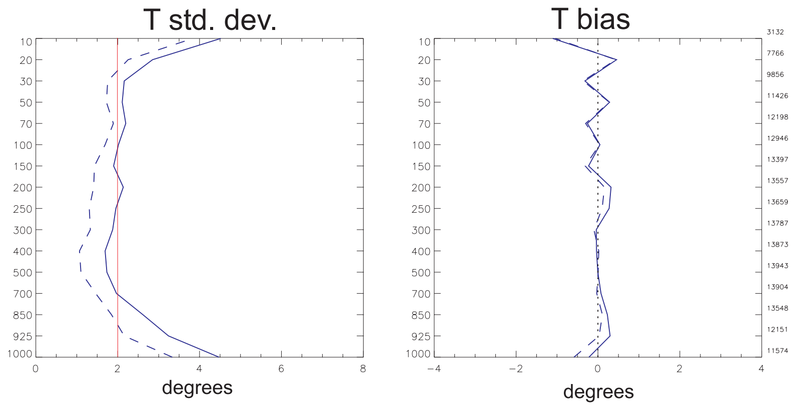
11-19 linear with index

20-66 corr.=0

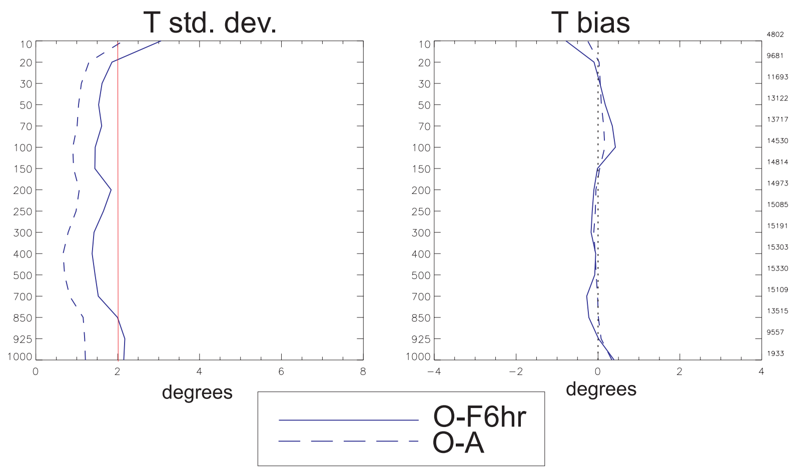
Old run w. SATEMs vs. new run with AMSU

Compare against sondes, global average

Jan 1994 - time mean over days 11-30

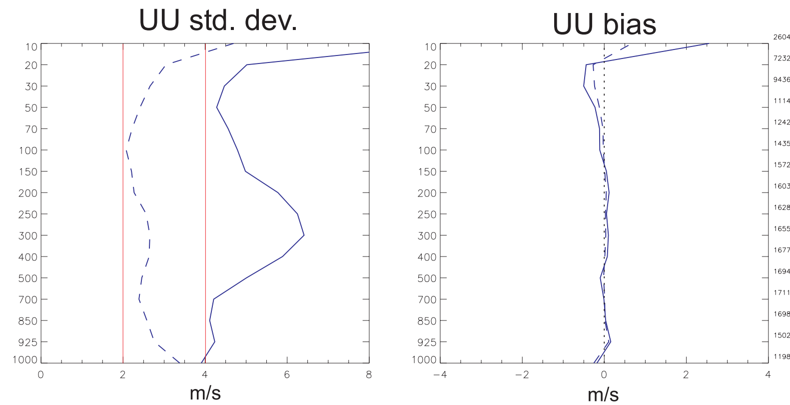


Jan 2002 - time mean over days 1-21
w AMSU ch.5-10, 3DVAR v9.1.1



Compare against sondes, global average

Jan 1994 - time mean over days 11-30



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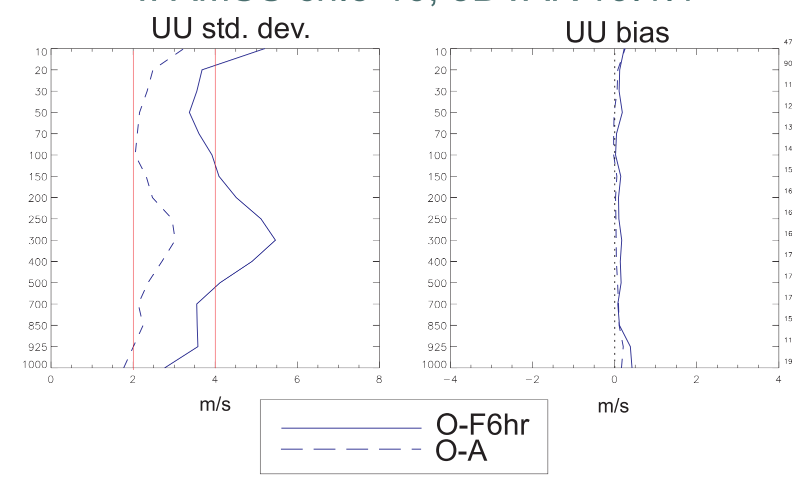
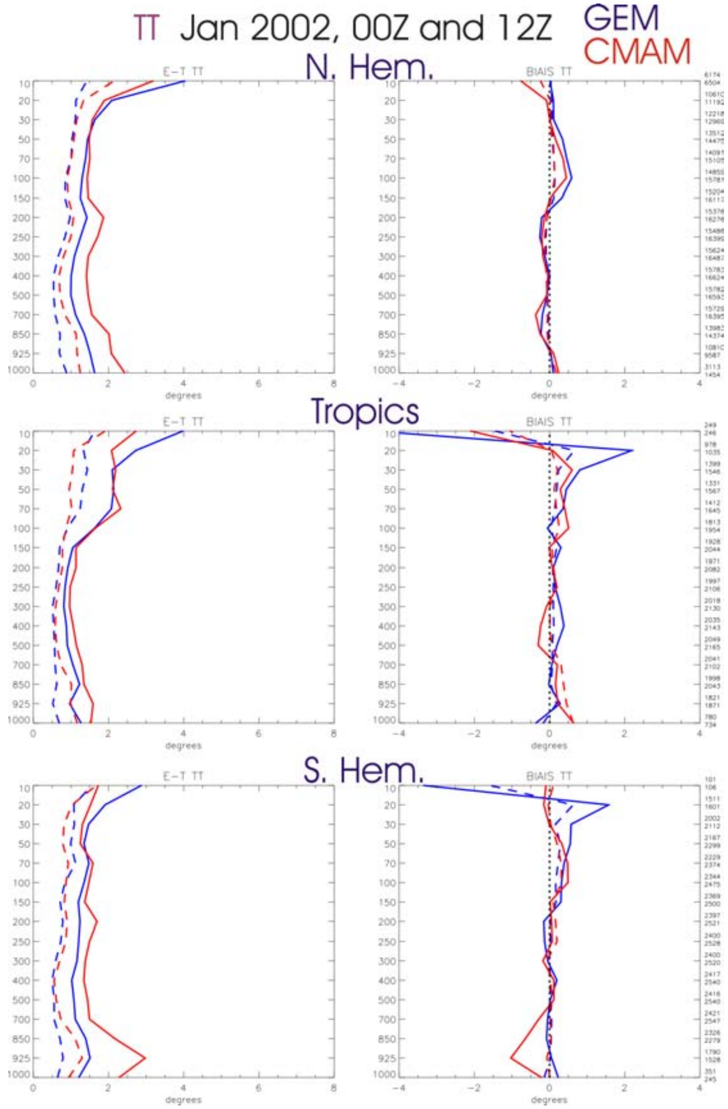
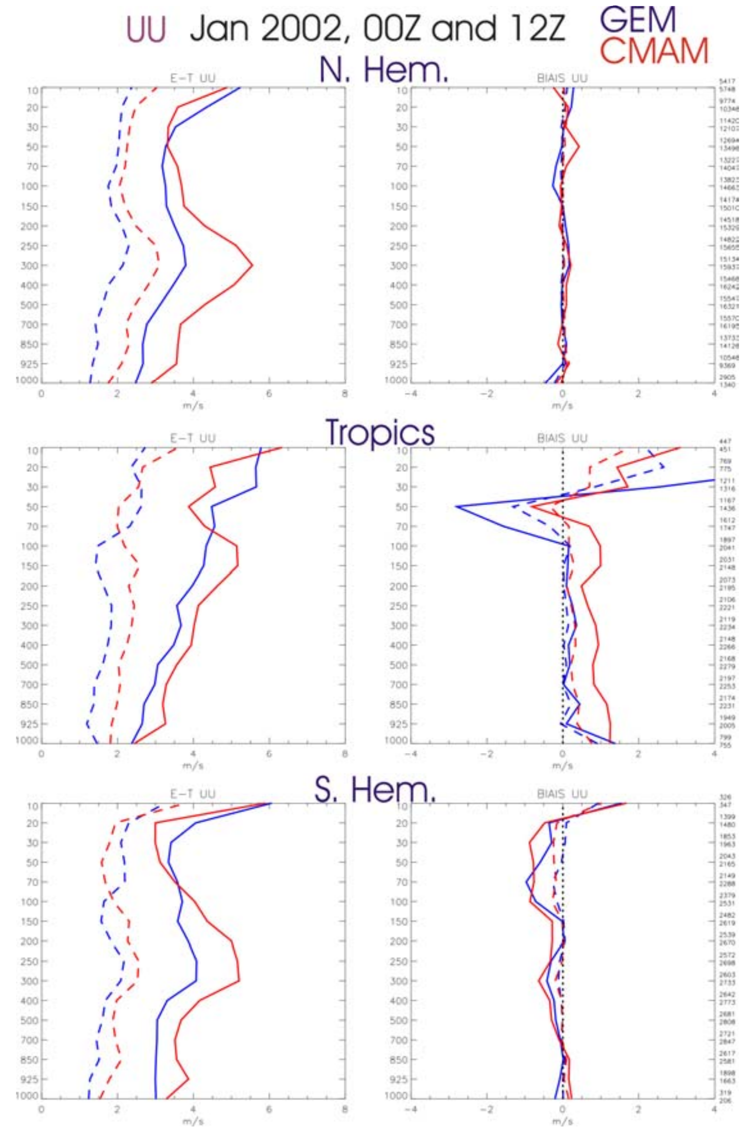


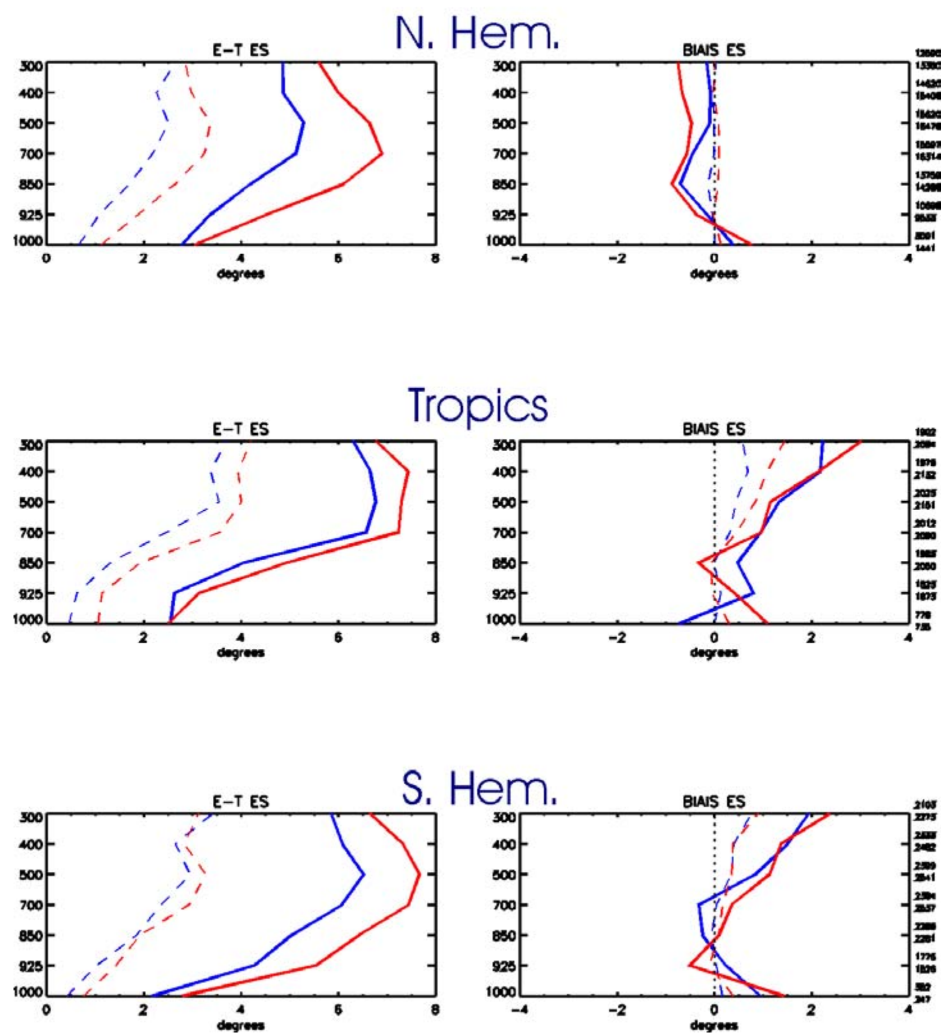
Validation of assimilation of dynamic variables



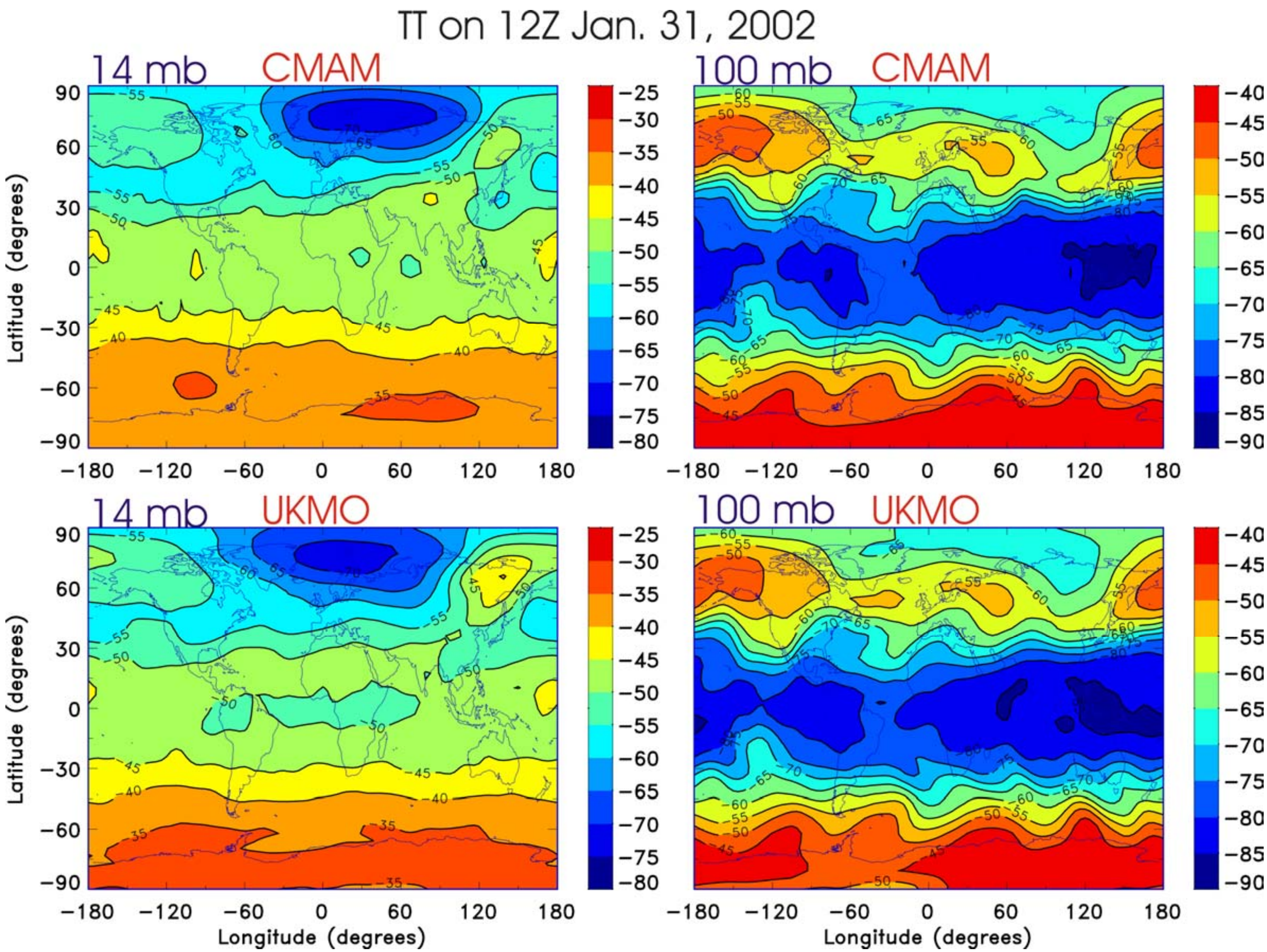


Validation of assimilation of dynamic variables

ES Jan 2002, 00Z and 12Z
GEM CMAM



Validation of stratosphere against UKMO



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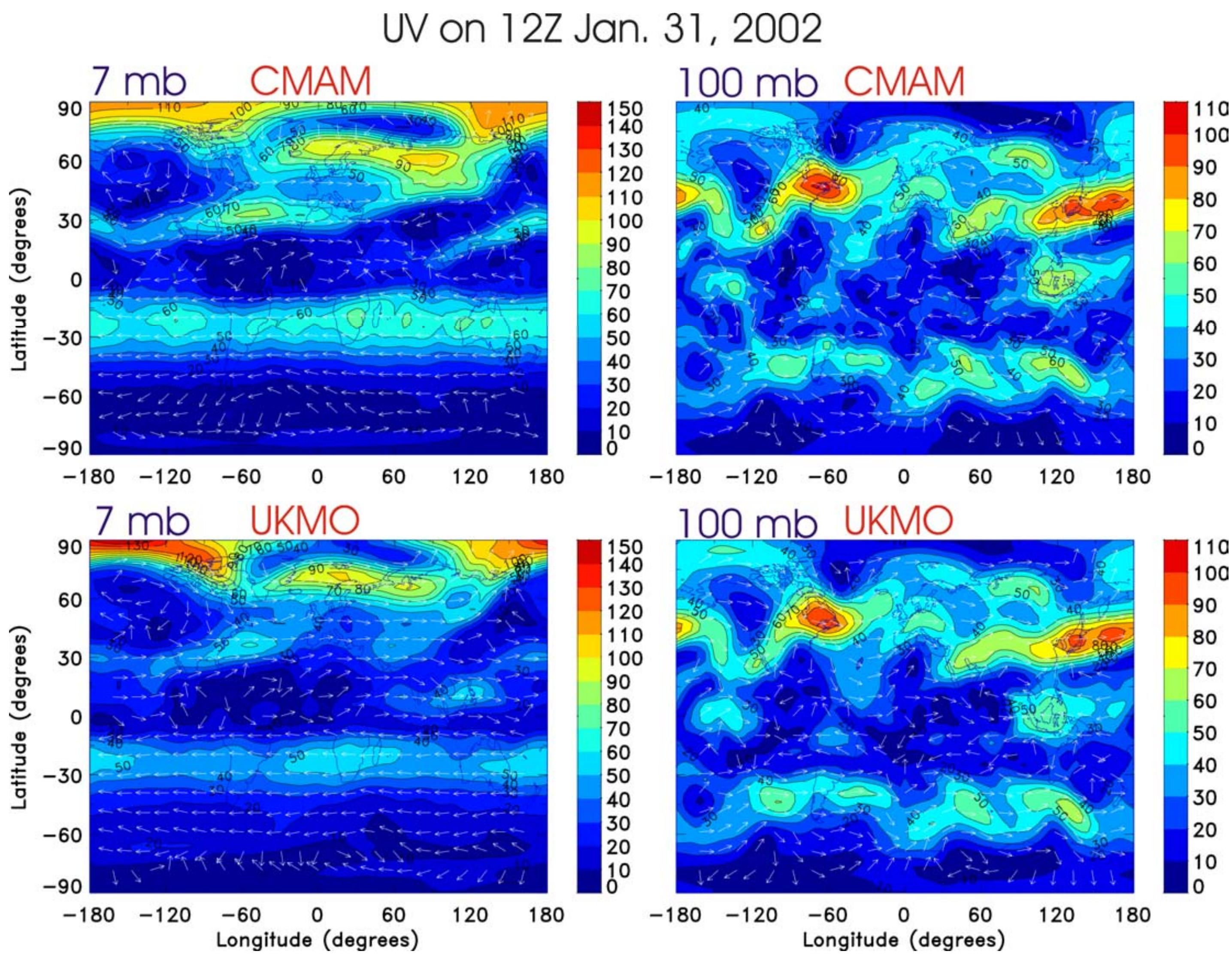

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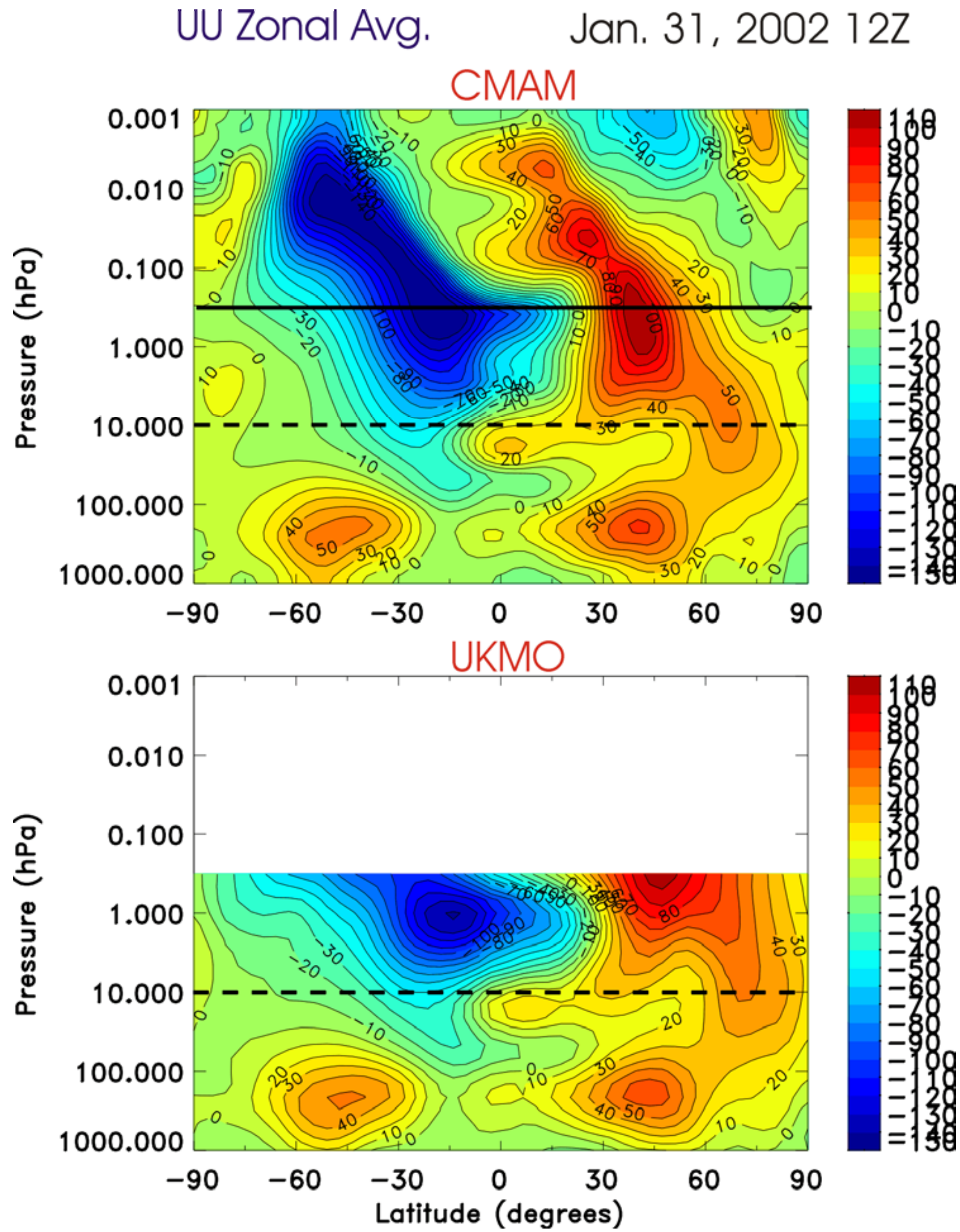
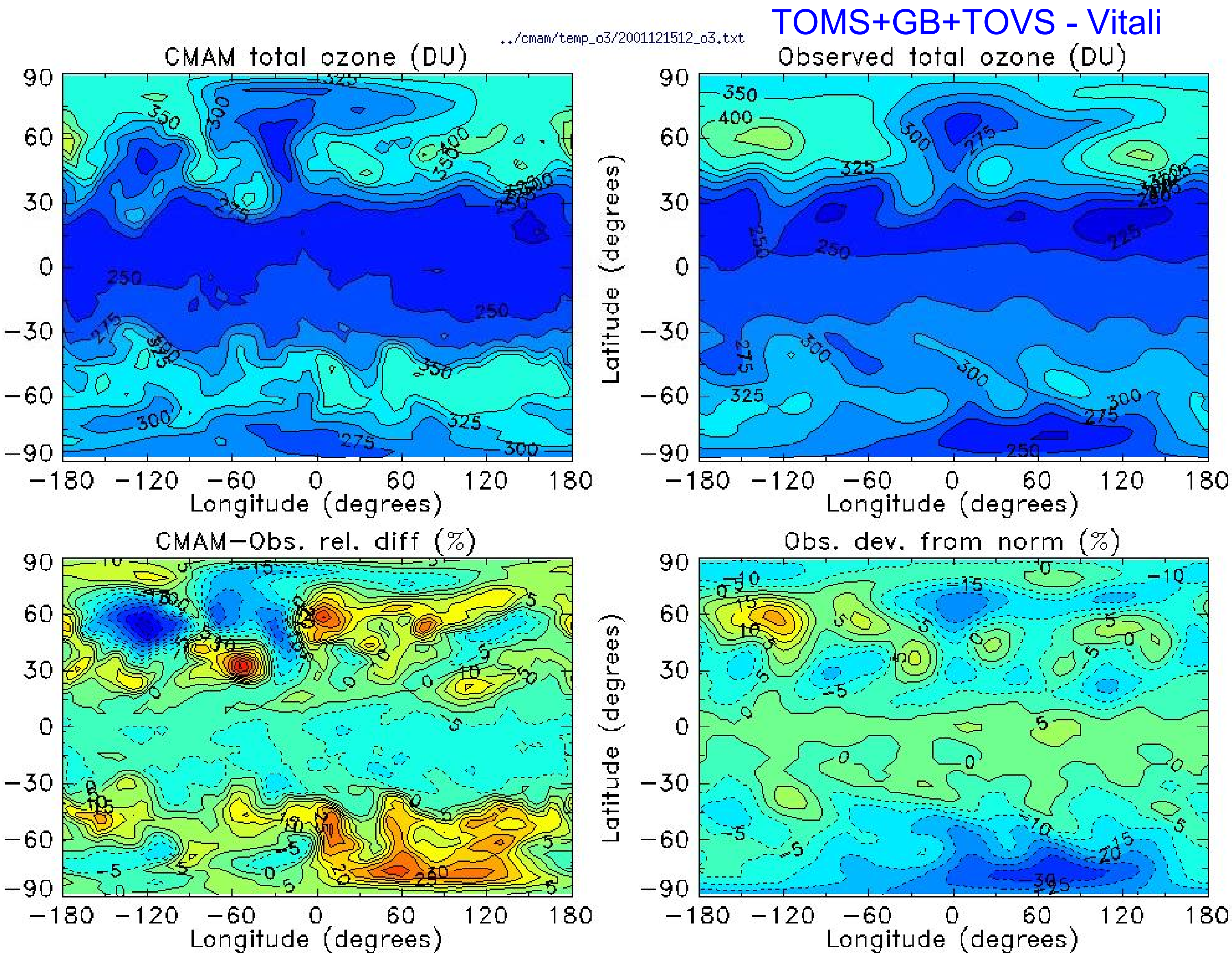


Comparison of total ozone against data



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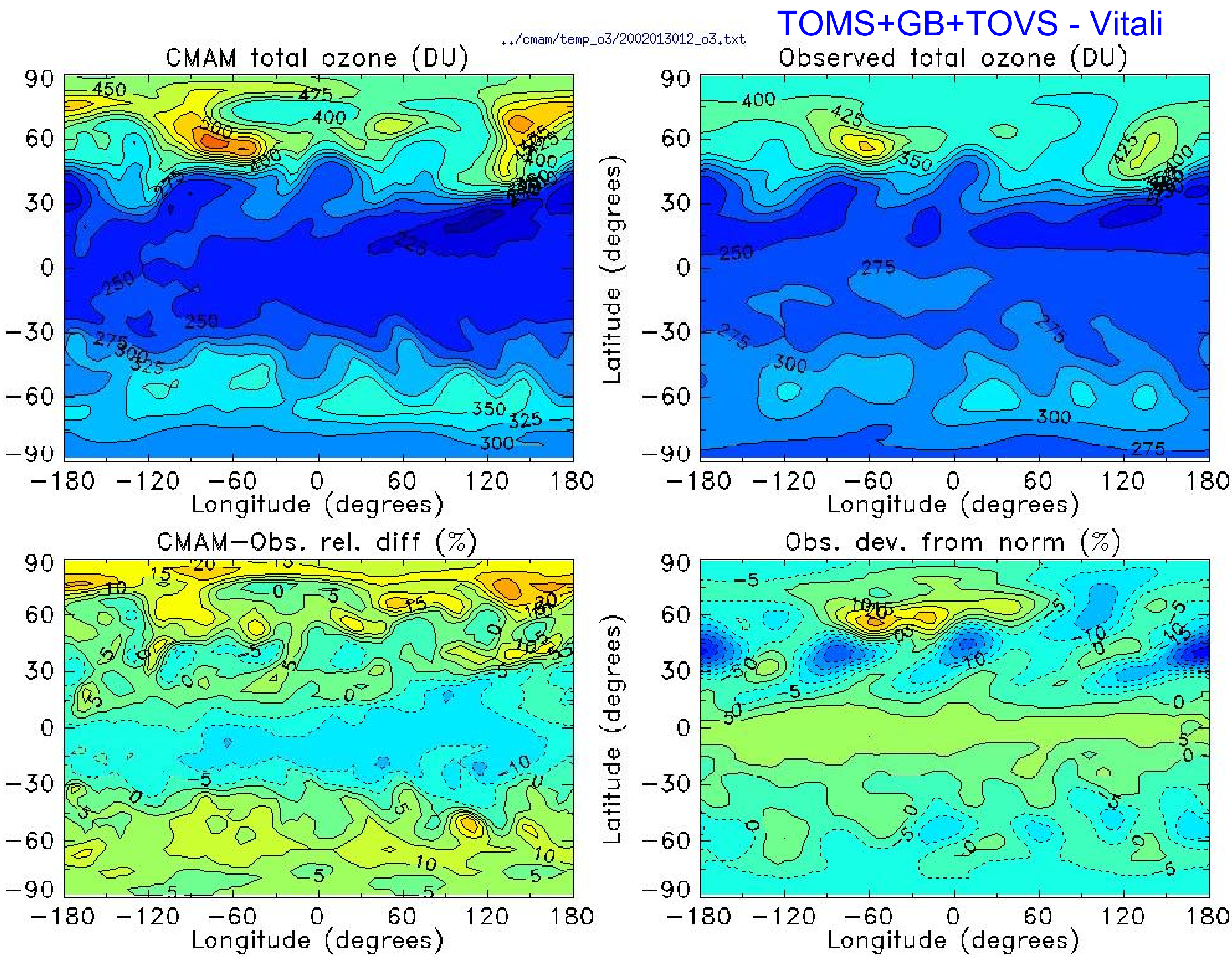
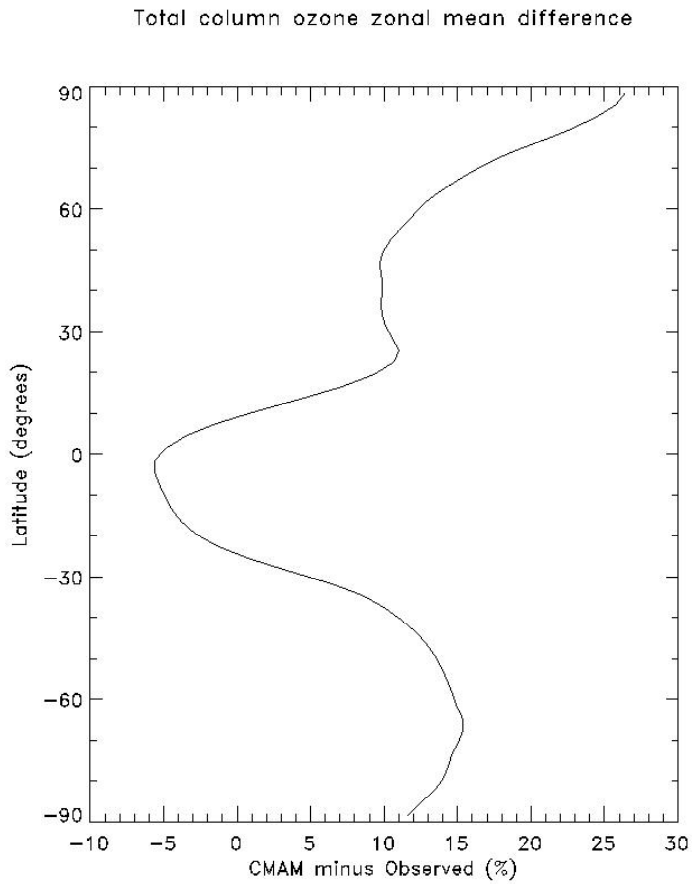
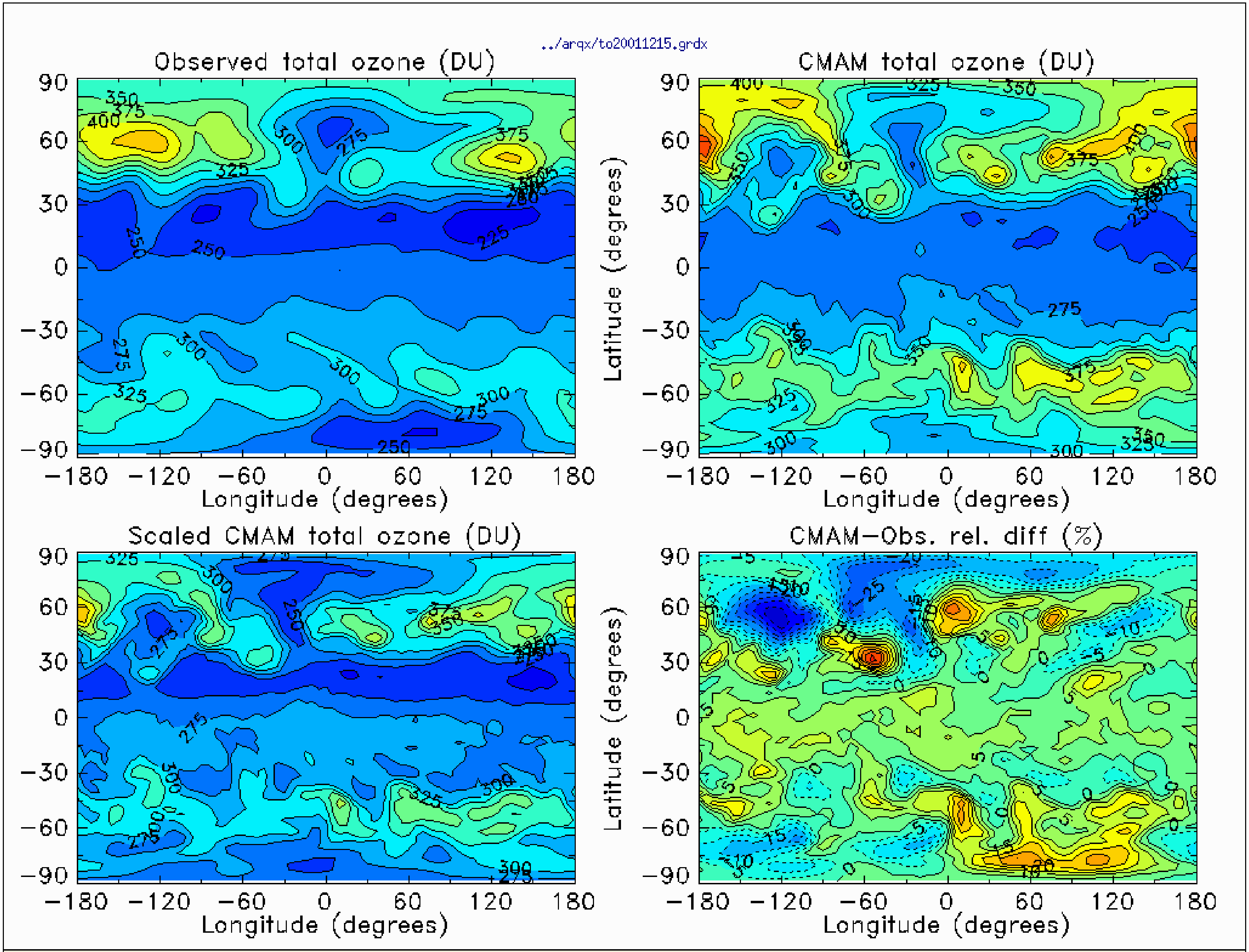


Try scaling ozone by observed values, averaging over one month and over longitudes.





multi_ox_scaled.avi

Comparing CMAM ozone profiles with HALOE observations

HALOE CMAM model CMAM+3DVAR

CMAM anal - Jan. 30/02 12 Z
HALOE - 9 yr. avg.
CMAM - 10 yr. avg.

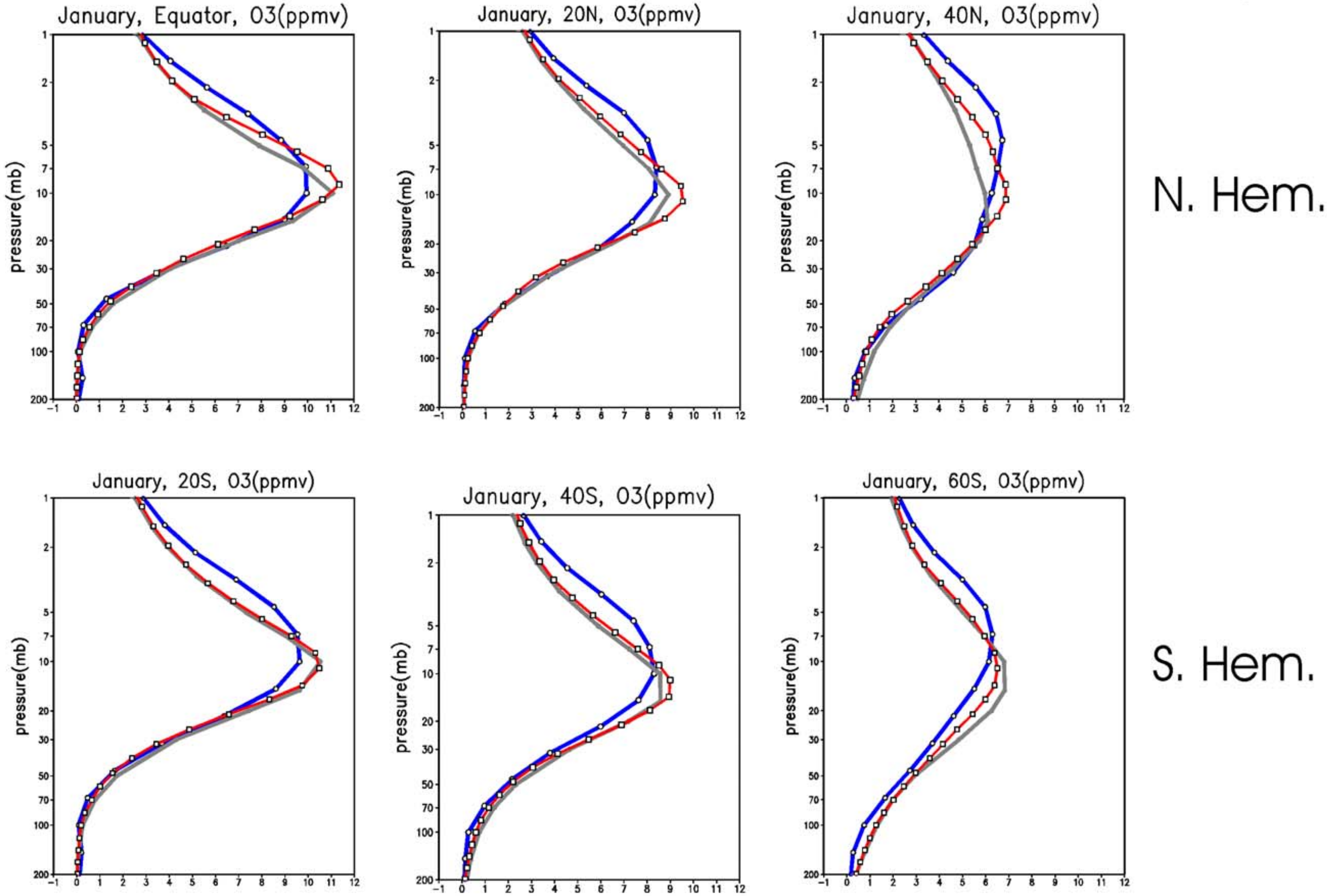


Figure courtesy of Cynthia Zhang, Stephen Beagley, Jack McConnell

Impact of dynamic variable assimilation on ozone fields

Improved ozone fields are due to:

- improved tropopause height
- corrected transport
- improved ozone tendencies?

Why is the error mainly a function of latitude?

- Initial state error?
  - Large annual cycle in midlatitudes (Jan not Dec)
  - Ozone variance has zonal pattern esp. winter
- Model error?
  - too much tropospheric ozone
  - errors in meridional circulation
  - no heterogeneous chemistry yet

Middle atmosphere data assimilation for climate applications

Run currently in Progress

- new model version with het. chem., Hines GWD scheme
- new background error stats for new model
- new stats adjusted using O-P of current run
- new data: AMSU ch. 11-14
- new initial state from Dec rather than Jan
- modified DF parameters for sharper response

Experiments:

•Baseline assimilation of 6 weeks
•Scaled initial ozone field
•No interactive chemistry

Diagnostics

•impact of T assimilation on O3
•time variation of zonal error
•changes in residual circulation

NEXT

- bias correction for AMSU ch. 11-14 (with Hallé, Chouinard)
- provide Jan 2002 fields to C. McLandress for SWIFT studies
- assimilation during Sept.-Oct. 2002 double ozone hole
- provide Sept. 2002 fields to MANTRA team

MANTRA: Middle Atmosphere Nitrogen TRend Assessment
Kim Strong et al., U Toronto
SWIFT: Stratospheric Wind Interferometer For Transport Studies
Ian McDade et al., York U

Other work in progress

1. A new, practical bias correction algorithm (with Yang, Ménard)
2. Theoretical examination of NMC method
3. Relationship between Digital Filtering and IAU

NEXT
Ozone Assimilation

- compare current ozone analysis against
  SBUV, GOME, Brewer, ozone sondes
- univariate ozone analysis

Stratospheric data of Temp. or wind fields:
AMSU, AIRS, SSMIS, SWIFT

Ozone data sources being considered:
SBUV, OSIRIS, GOME, ENVISAT, Brewer?

Ozone data sources for verification:
ozone sondes, Brewer, HALOE, ACE, SAGE?

Validation period: 2002

Stratospheric ozone assimilation systems

	← Operational centres			→	Some Research Groups		
	ECMWF	NCEP	DAO NASA	KNMI	DARC	GEM	CMAM
model lid hPa	NWP 0.1	NWP 0.1	transport 0.2	transport 0.1	NWP 0.3	NWP 10 0.1	GCM 0.0007
chem.	tracer w. sources	tracer w. sources	tracer	tracer w. sources	tracer w. sources	tracer full chem	44 spec. 127 reac.
data assim.	univariate 4DVAR	univariate 3DVAR	univariate 3DVAR	univariate OI	univariate 3DVAR	univariate 3DVAR	univariate 3DVAR
ozone data	SBUV, GOME	SBUV, TOVS	SBUV, TOMS	GOME	MLS, HALOE, GOME	TOVS, ORACLE, OSIRIS	SBUV, OSIRIS
inter-actions	dynamics radiation	dynamics			dynamics radiation		dynamics radiation

plans in red

SCIENCE (to come)

Upward propagation of information: to what extent is the variability of the atmosphere being driven from below?

Explore use of correlations between species for data assimilation.

Do analyses capture individual strat. sudden warmings?

Is the model biased compared to obs? If so, what kind of gravity wave drag parameterization is needed to correct this?

Analyses can capture QBO while climate models usually don't. With data we can perhaps determine the model errors that prevent this.

Comparison of ozone assimilations with observations may be able to provide feedback on measurements.

Acknowledgements

CMAM	3DVAR & Diagnostics	Observations
S. Beagley	C. Charette	C. Haley
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D. Plummer	J. Hallé	G. Verner
J. Scinocca	R. Ménard	C. Zhang
	J. Morneau	

York U MSC