12. Examples of Chemical Transport Models, contd.

(b) NCAR Community Climate Model (CCM) (1994)

CCM2 characteristics (P. Rasch & D. Williamson)

$$\text{Vertical:}\quad \left.\begin{array}{l} \sigma = \dfrac{P}{P_s} \quad (\text{terrain following below 100mb level}) \\ P \text{ above 100mb level } (\text{lid at 2.9mb}) \end{array}\right\} \text{18 levels}$$

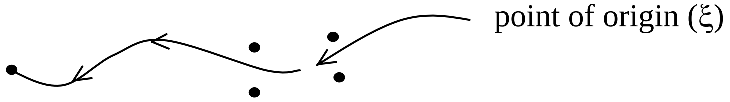
Horizontal: Spectral (T42 with 128 longitude and 64 latitude (gaussian-quadrature grid)

Time: $\Delta t = 20\,\text{min}$, semi-implicit leap-frog

Transport: semi-Lagrangian* scheme for all chemical species (including H_2O) applied on the above grid

Subgrid-scale processes: planetary boundary layer includes eddy diffusivity and counter-gradient transport, bulk atmosphere includes vertical diffusion scheme and gravity wave effects, moist convection by the three-level (entrainment, condensation, detrainment) "Hack" scheme

*Semi-Lagrangian computes current states from past states using integration of Lagrangian form of continuity equation along a back trajectory with the point of origin values obtained by interpolation from adjacent grids



$$X_{ij}^{n+1} = X_{i\xi}^{n} + \int_{\text{trajectory}} \left(\frac{P_i - L_i}{[M]} \right) dt$$

(derived by integrating $\dfrac{dX_i}{dt} = \dfrac{P_i - L_i}{[M]}$)

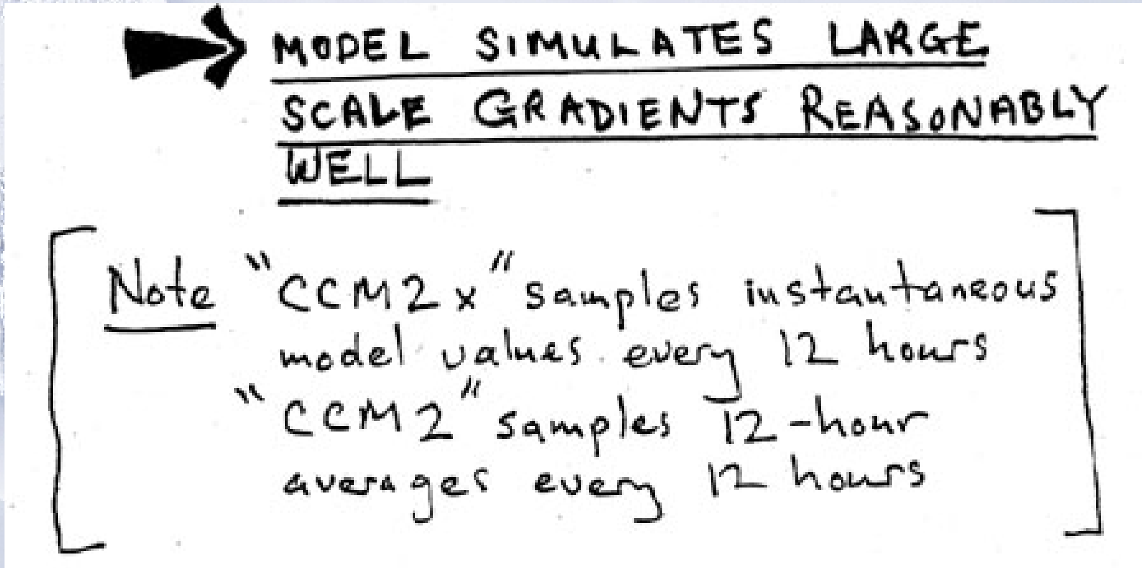
Examination of tracer transport in the NCARCCM2 by comparison of CFCl3 simulations with ALE/GAGE observations

Images removed due to copyright considerations.

See Figure 1, Figure 2 and Figure 3. Hartley, D.E., D.L. Williamson, P.J. Rasch, and R.G. Prinn, Examination of tracer transport in the NCARCCM2 by comparison of CFCl3 simulations with ALE/GAGE observations. Journal of Geophysical Research, 99, 12885–12896, 1994.

Images removed due to copyright considerations.

See Figure 4, Figure 5 and Figure 17. Hartley, D.E., D.L. Williamson, P.J. Rasch, and R.G. Prinn, Examination of tracer transport in the NCARCCM2 by comparison of CFCl3 simulations with ALE/GAGE observations. Journal of Geophysical Research, 99, 12885–12896, 1994.

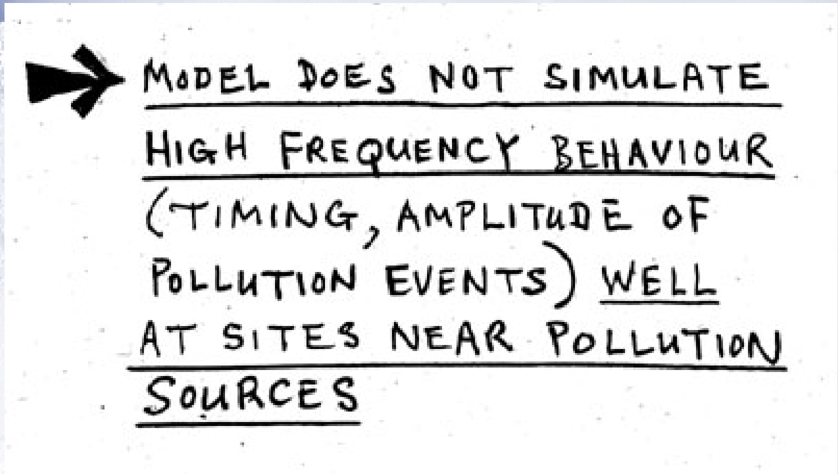


MODEL SIMULATES LARGE SCALE GRADIENTS REASONABLY WELL

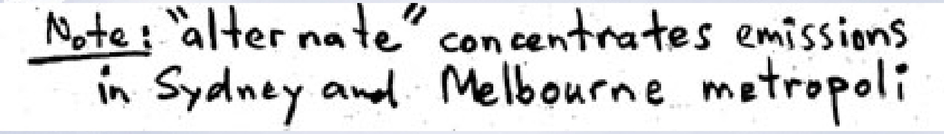
Note "CCM2x" samples instantaneous model values every 12 hours
"CCM2" samples 12-hour averages every 12 hours

Images removed due to copyright considerations.

See Figure 6, Figure 10, Figure 12, Figure 14 and Figure 15. Hartley, D.E., D.L. Williamson, P.J. Rasch, and R.G. Prinn, Examination of tracer transport in the NCARCCM2 by comparison of CFCl3 simulations with ALE/GAGE observations. Journal of Geophysical Research, 99, 12885–12896, 1994.

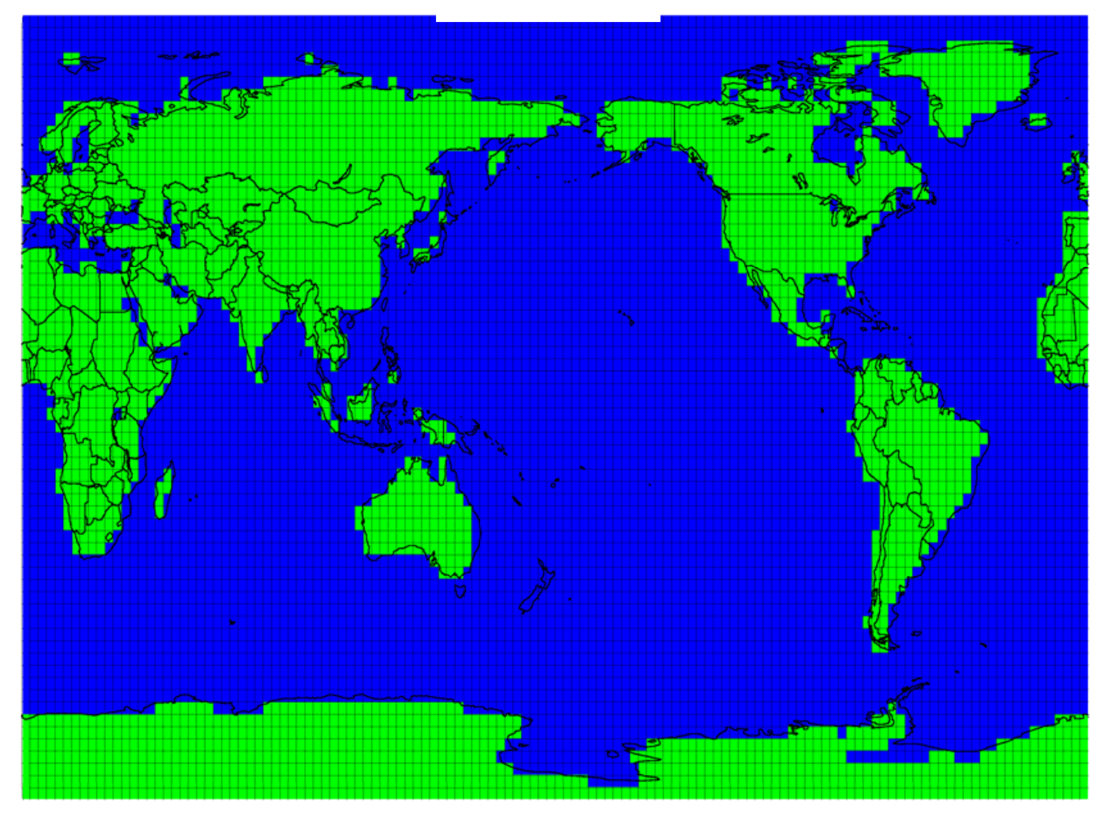


➔ MODEL DOES NOT SIMULATE HIGH FREQUENCY BEHAVIOUR (TIMING, AMPLITUDE OF POLLUTION EVENTS) WELL AT SITES NEAR POLLUTION SOURCES



Note: "alternate" concentrates emissions in Sydney and Melbourne metropoli

(c) MODEL for ATMOSPHERIC TRANSPORT & CHEMISTRY (MATCH)



2.8º x 2.8º (T42)
28 Vertical (sigma) Levels:
1000 to 2.9mb
40 minute time-step (Semi-L.
or mass conserving SPITFIRE)

NCEP Reanalysis Meteorology
Chemical Studies Include:
Rn, CCl_3F, SF_6
Ozone, Sulfur Chemistry
Aerosols, Dust

Methane Simulations using MATCH: Y. Chen, Ph.D. Thesis, MIT,2004

METHANE SOURCE	Total Tg/yr	Range	Type	Data Source for Spatial Distribution
Wetlands	151	115-260	Seas	Fung et al. (1991),*Matthews et al.* (1987); GISS
Animals	103	55-110	Aseas	Olivier et al. (1999),Lerner et al. (1988); EDGAR3.0
Rice	92	30-120	Seas	Matthews et al. (1991); GISS: *Kreileman et al.* (1994))
Waste	65	40-90	Aseas	Olivier et al. (1999),Subak et al. (1992); EDGAR3.0
Natural Gas	51	30-75	Aseas	Olivier et al. (1999),*Sagers et al.* (1990); EDGAR3.0
Coal	39	30-75	Aseas	Olivier et al. (1999), *Smith et al.* (1992); EDGAR3.0
Biomass Burning	30	10-70	Seas	*Hao et al.* (1993),*Hao et al.* (1994); NASA
Termites	23	1-40	Aseas	Fung et al. (1991); GISS
Other Anthro.	36		Aseas	Olivier et al. (1999); EDGAR3.0
TOTAL (Tg/yr)	590*	500-600	* Determined by OH magnitude	

CH_4 Reference Emissions Distribution (Annual Mean)

Image removed due to copyright considerations.

See Figure 3. Chen, Y.-H. and R.G. Prinn, Atmospheric modeling of high-frequency methane observations: Importance of interannually varying transport. Journal of Geophysical Research, 110, D10303, doi: 10.1029/2004JD005542, 2005.