The effects of convection on the extratropical lower stratosphere

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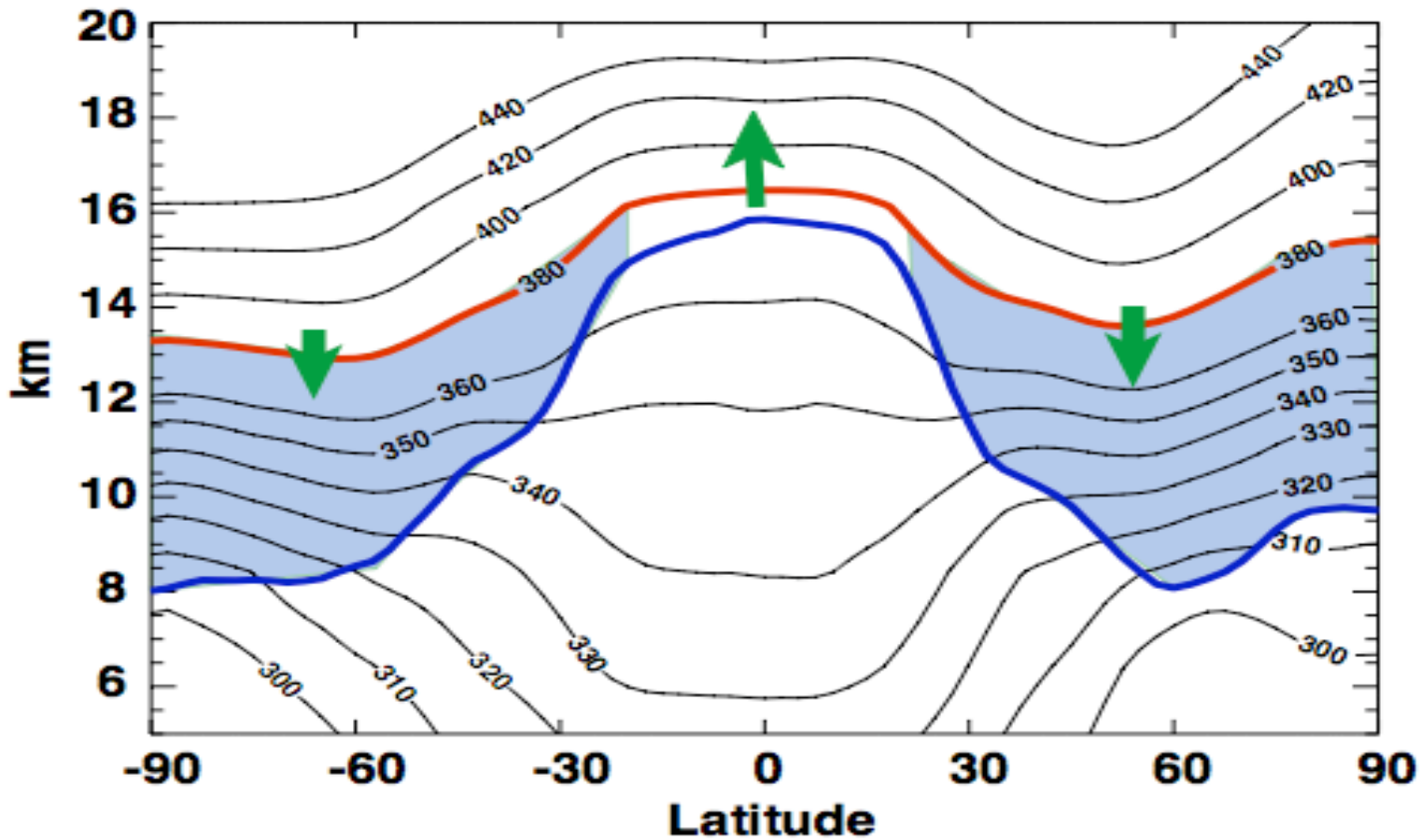
Plot courtesy of Mark Schoeberl



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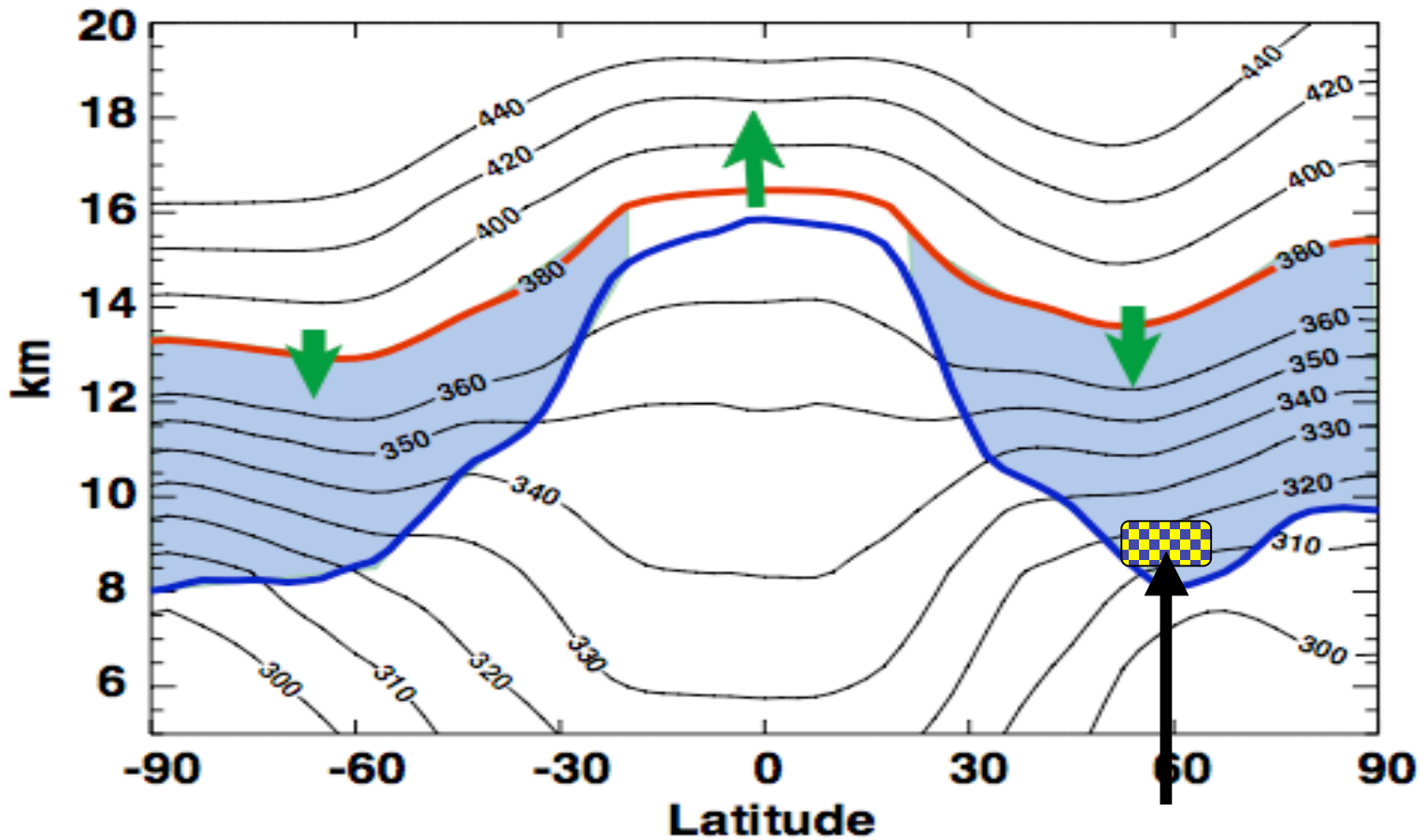

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Evidence for convective transport to 380 K and above:

Fromm et al., Observations of boreal forest fire smoke in the stratosphere by POAM III, SAGE II, and lidar in 1998, Geophys. Res. Lett., 27, 1407-1410, 2000.

Jost et al., In-situ observations of mid-latitude forest fire plumes deep in the stratosphere, *Geophys. Res.* Lett., *31*, L11101, DOI: 10.1029/2003GL019253, 2004.

Ray, E.A., et al., Evidence of the effect of summertime midlatitude convection on the subtropical lower stratosphere from CRYSTAL-FACE tracer measurements, J. Geophys. Res., *109*, D18304, DOI: 10.1029/2004JD004655, 2004.

Livesey et al., Enhancements in lower stratospheric CH_3CN observed by the Upper Atmosphere Research Satellite Microwave Limb Sounder following boreal forest fires, *J. Geophys. Res.*, *109*, D06308, DOI: 10.1029/2003JD004055, 2004.

Wang, P.K., Moisture plumes above thunderstorm anvils and their contributions to cross-tropopause transport of water vapor in midlatitudes, *J. Geophys. Res.*, *108*, 4194, DOI: 10.1029/2002JD002581, 2003.

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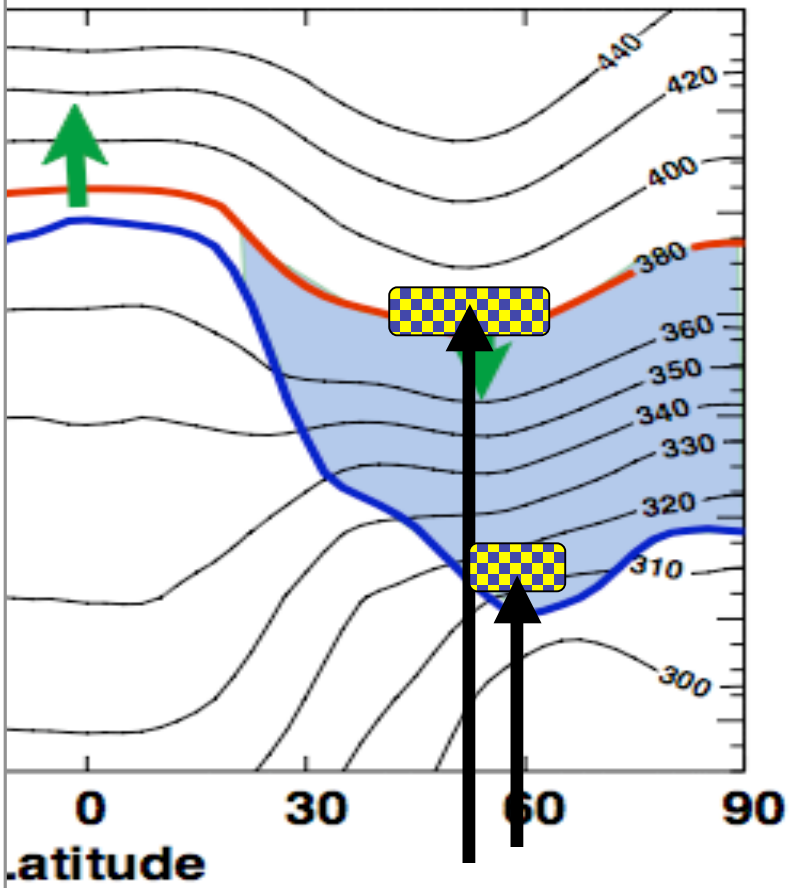
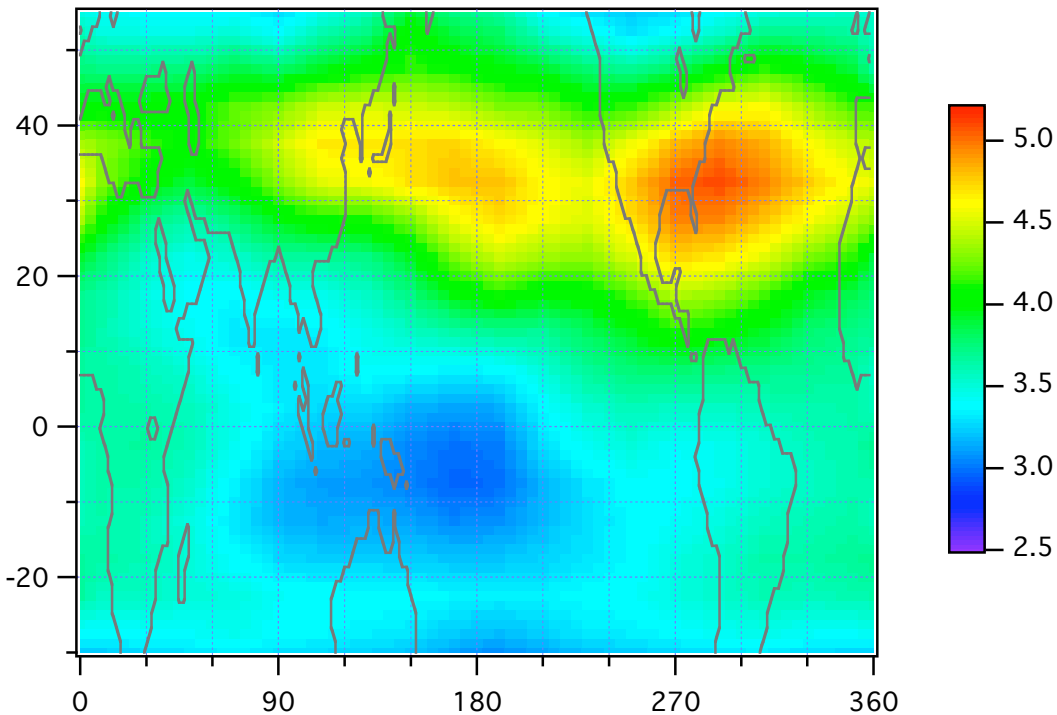
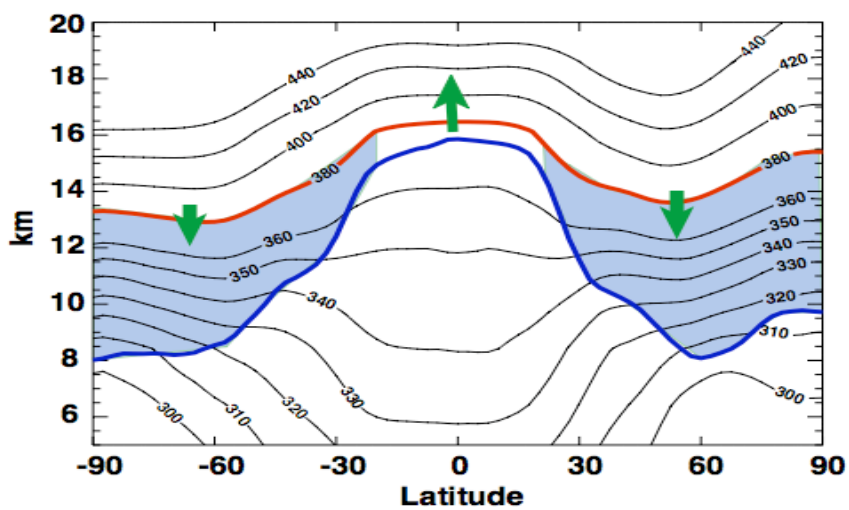




Aura MLS H2O VMR
Aug. 13-Sept. 12, 2004
380-K pot'l. temp.



See also Randel et al., JGR, 2001

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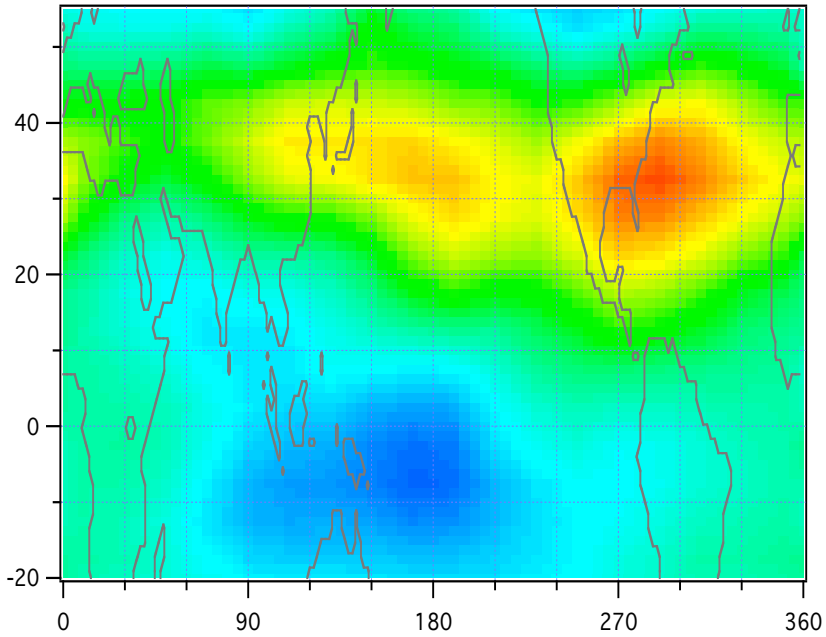

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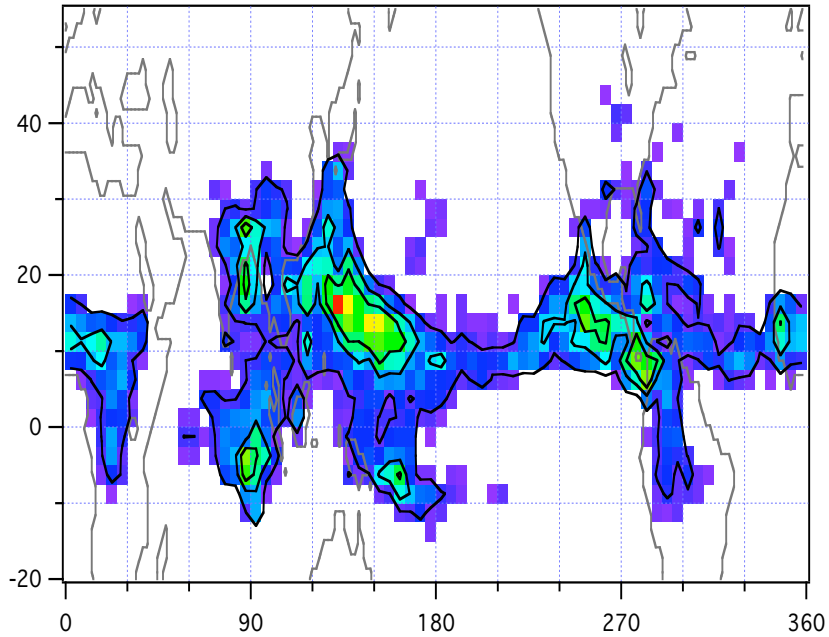


MODIS 11-μm BT < 210 K
Aqua + Terra

$$\frac{\partial[\mathrm{X}]}{\partial t} + \mathbf{V}_H \cdot \nabla[\mathrm{X}] + w\frac{\partial[\mathrm{X}]}{\partial z} + \text{convection} = P - L$$

$$\frac{\partial[\mathrm{X}]}{\partial t} + \mathbf{V}_H \cdot \nabla[\mathrm{X}] + w\frac{\partial[\mathrm{X}]}{\partial z} + \text{convection} = P - L$$

Convective tendency:

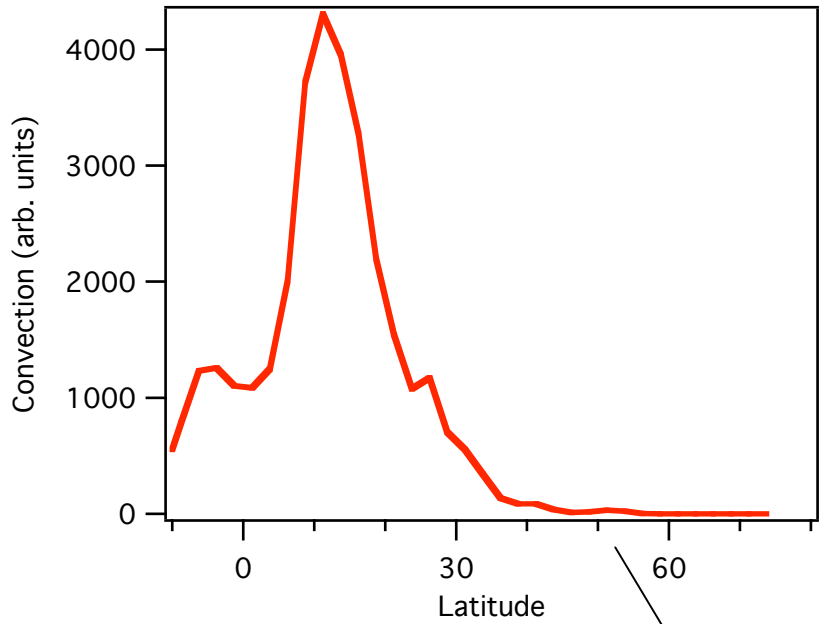
$$\left.\frac{\partial[\mathrm{X}]}{\partial \mathrm{t}}\right|_{\mathrm{conv}} = -\frac{1}{\tau_{\mathrm{c}}}\left([\mathrm{X}] - [\mathrm{X}]_{\mathrm{c}}\right)$$

Convective tendency:

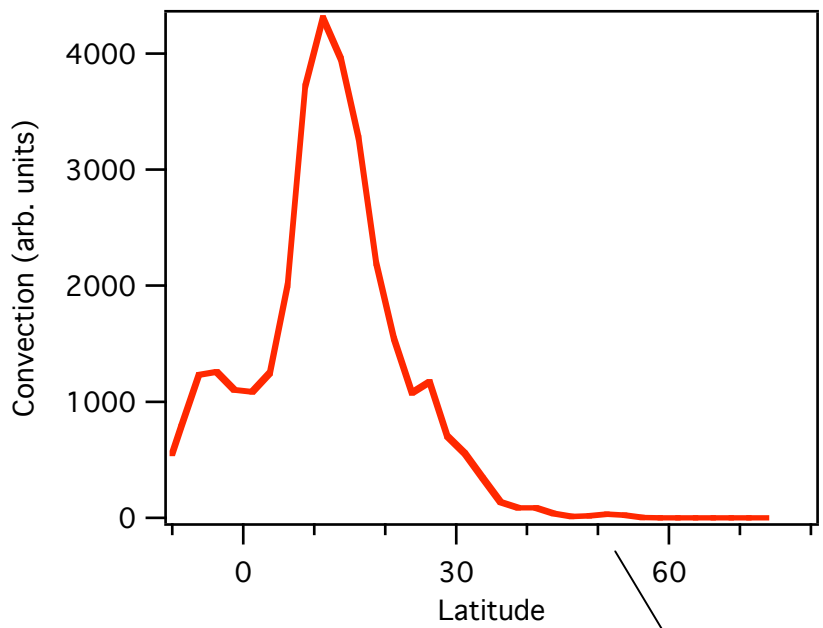
$$\left.\frac{\partial[X]}{\partial t}\right|_{conv} = -\frac{1}{\tau_c}\left([X]-[X]_c\right)$$

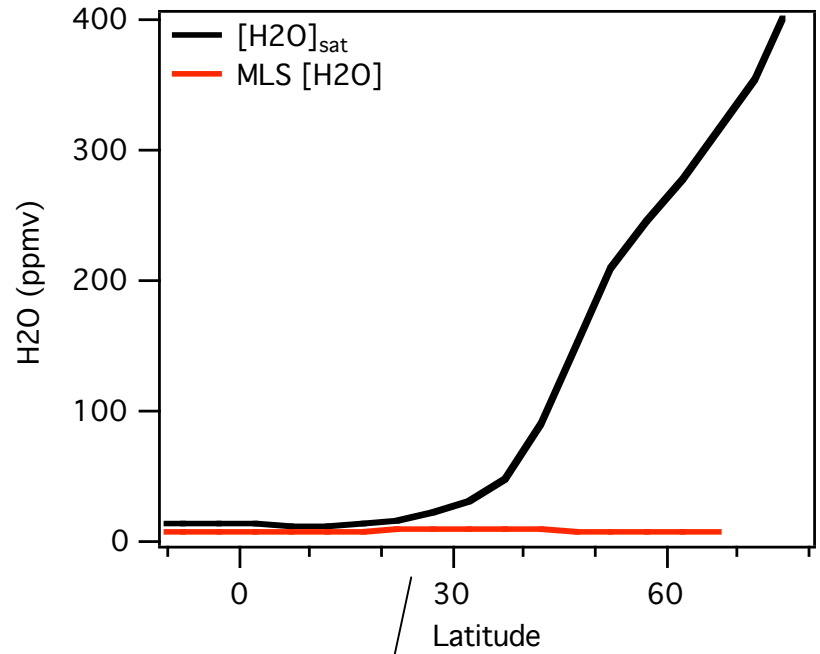
$$\left.\frac{\partial[H_2O]}{\partial t}\right|_{conv} = -\frac{1}{\tau_c}\left([H_2O]-[H_2O]_{sat}\right)$$

$$\left.\frac{\partial\left[\mathrm{H_2O}\right]}{\partial \mathrm{t}}\right|_{\mathrm{conv}} = -\frac{1}{\tau_{\mathrm{c}}}\left(\left[\mathrm{H_2O}\right]-\left[\mathrm{H_2O}\right]_{\mathrm{sat}}\right)$$



$$\left.\frac{\partial[H_2O]}{\partial t}\right|_{conv} = -\frac{1}{\tau_c}\left([H_2O]-[H_2O]_{sat}\right)$$





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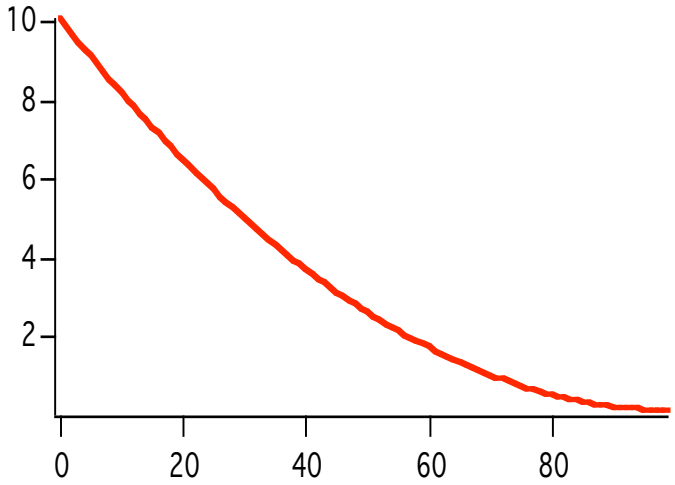
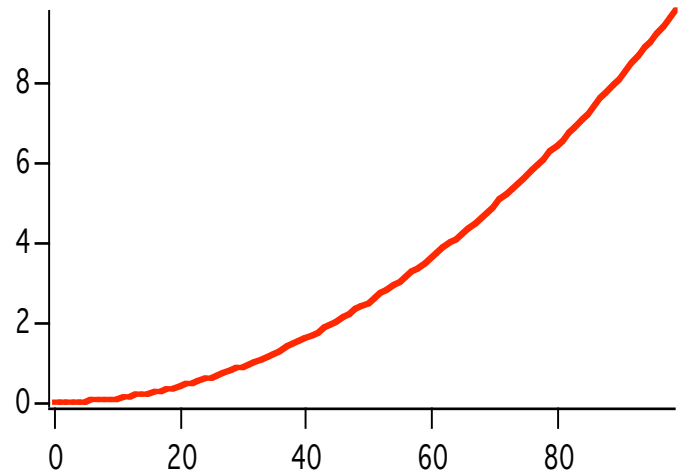
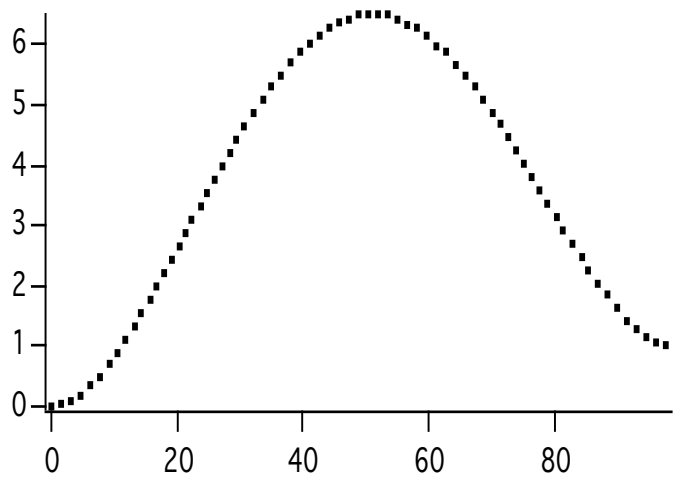
Convection, $1/\tau$



X

$[H2O]_{sat}$-[H2O]





Single-level isentropic model

- August 13-September 12, 2004; 380 K

$$\frac{\partial[\mathrm{X}]}{\partial t} + \mathbf{V}_H \cdot \nabla[\mathrm{X}] + \frac{1}{\tau_{BD}}\left([\mathrm{X}] - [\mathrm{X}]_{BD}\right) + \frac{1}{\tau_C}\left([\mathrm{X}] - [\mathrm{X}]_C\right) = 0$$

- Simulated constituent: H_2O
- Horizontal advection via UKMO winds

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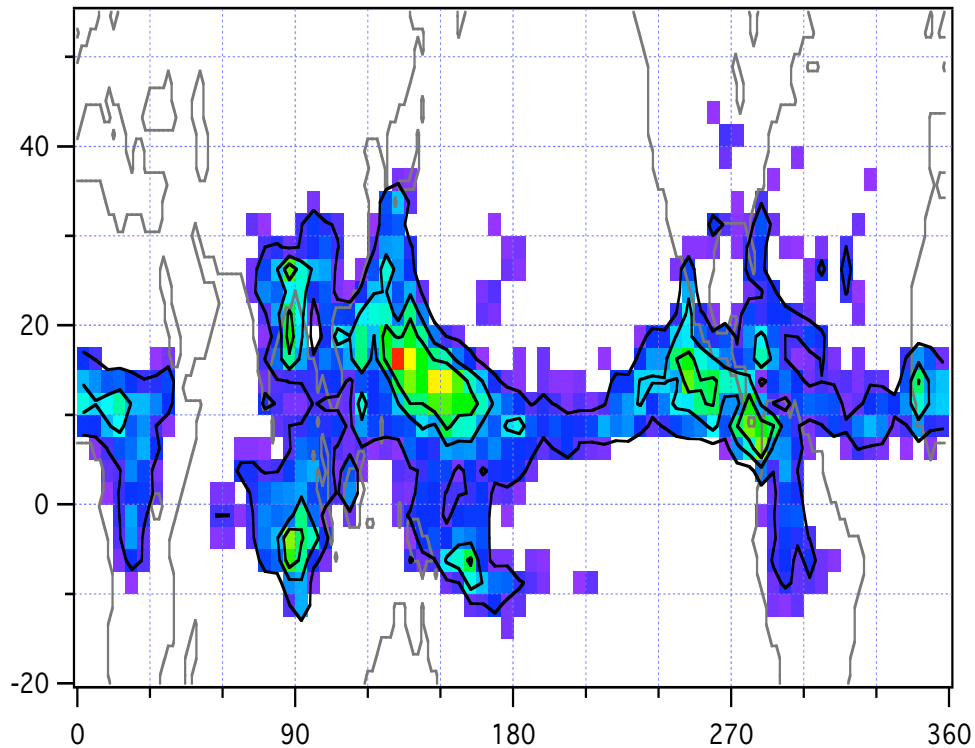
- Convection parameterized as relaxation

Fraction of MODIS obs. with 11-μm BT < 210 K



$$\frac{\partial[X]}{\partial t} = -\frac{1}{\tau_c}\left([X]-[X]_c\right)$$

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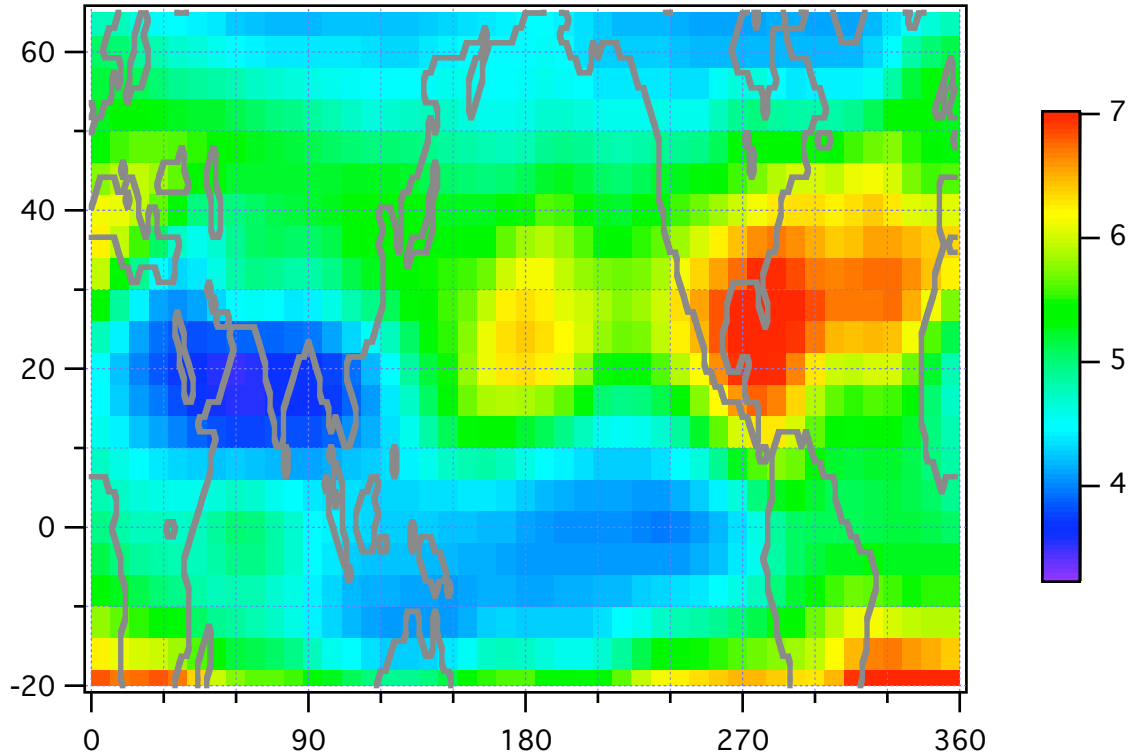
Single-level isentropic model

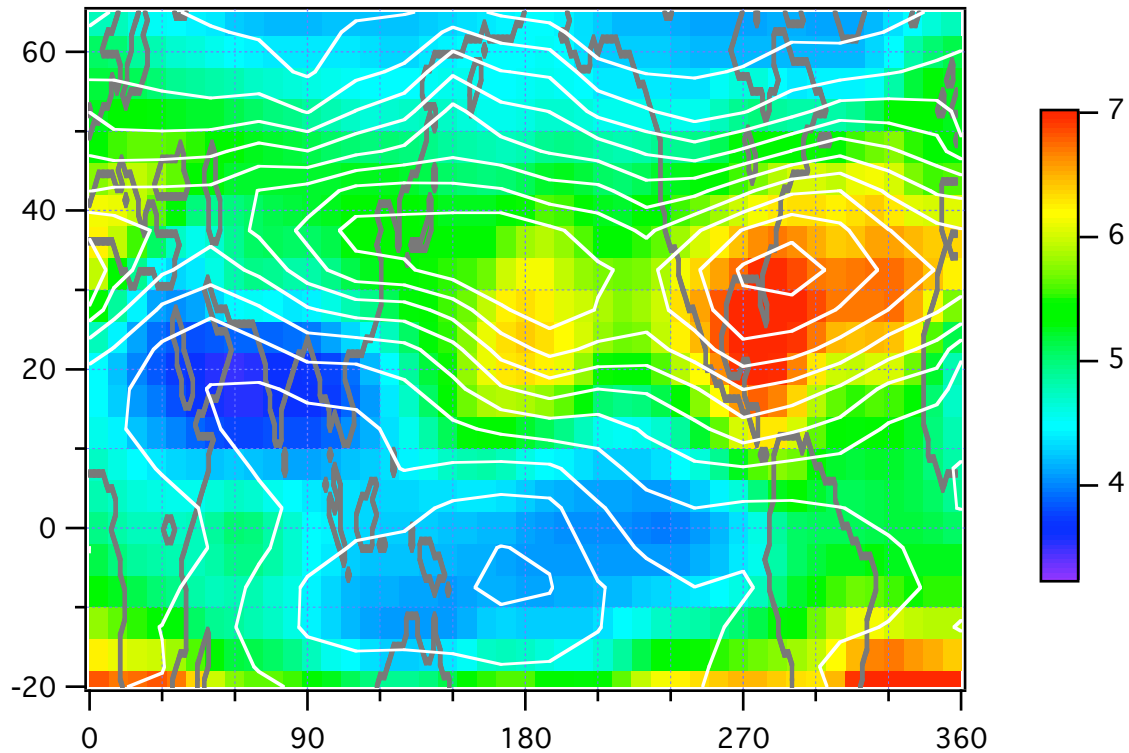
- August 13-September 12, 2004; 380 K

$$\frac{\partial[\mathrm{X}]}{\partial t} + \mathbf{V}_H \cdot \nabla[\mathrm{X}] + \frac{1}{\tau_{BD}}\left([\mathrm{X}] - [\mathrm{X}]_{BD}\right) + \frac{1}{\tau_C}\left([\mathrm{X}] - [\mathrm{X}]_C\right) = 0$$

- Simulated constituent: H_2O
- Horizontal advection via UKMO winds
- Brewer-Dobson circulation parameterized as relaxation
- Convection parameterized as relaxation
  - $1/\tau_\chi$ is proportional to MODIS BT fraction
  - $[X]_c$ is equal to saturation vmr for H_2O

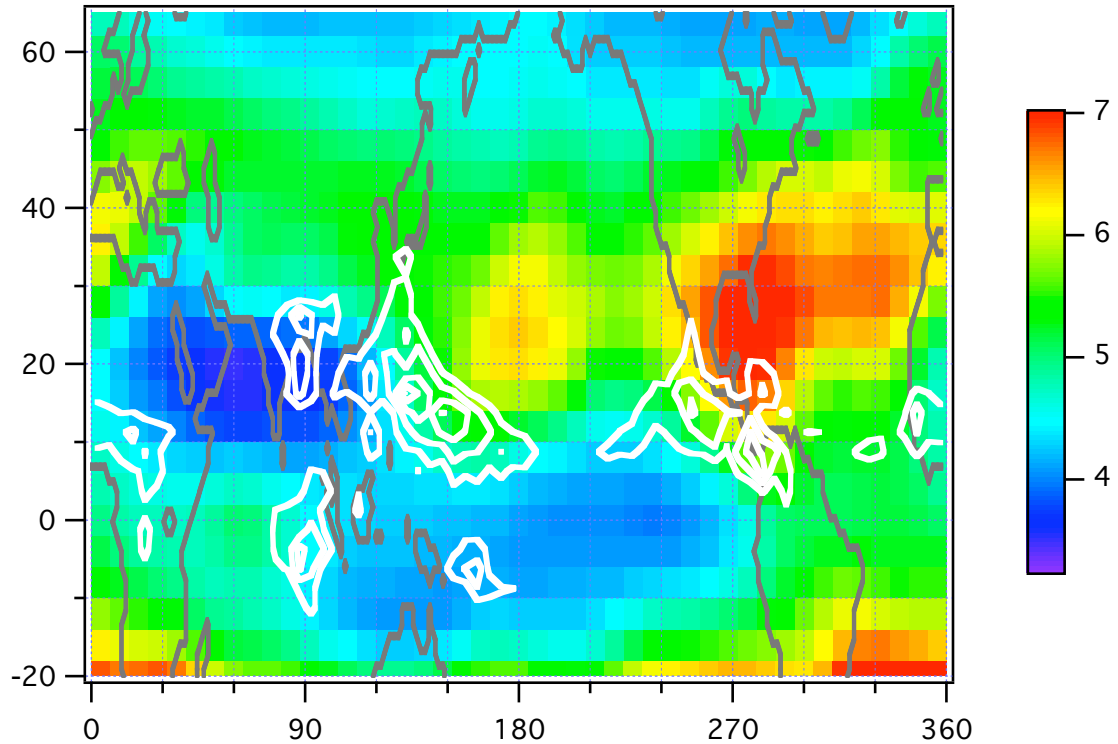


Model simulation of H2O VMR at 380 K, Aug. 13-Sept. 12, 2004 period



Model simulation of H2O VMR at 380 K, Aug. 13-Sept. 12, 2004 period

Contours are Aura MLS H2O for that same period



✓ *Reproduces the mismatch in location of convection and high* H_2O *VMRs.*

What about other species?

Convective tendency: $$\left.\frac{\partial[\mathrm{X}]}{\partial t}\right|_{\mathrm{conv}} = -\frac{1}{\tau_c}\left([\mathrm{X}]-[\mathrm{X}]_c\right)$$

"convective contrast"

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Helium: 5 ppmv, well mixed
small convective contrast
$\partial[He]/\partial t \approx 0$

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"convective contrast"

Species dependent

Helium: 5 ppmv, well mixed
small convective contrast
$\partial[He]/\partial t \approx 0$

Conclusions

- Convection can affect the water abundance of the extratropical lower stratosphere to altitudes of 15 km, 380 K
  - Tail of the convective distribution
  - CRYSTAL-FACE data shows the effect drops off rapidly above 380 K
- Different species affected differently
  - "convective contrast" determines effects
  - Important for H_2O, less so for O_3
  - Does not mean mass transport is significant
- Dessler, A.E., and S.C. Sherwood (2004), The effect of convection on the summertime extratropical lower stratosphere, *J. Geophys. Res.*, **109**, D23301, DOI: 10.1029/2004JD005209.
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