Stratospheric Water Vapor

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Project Title: Improving the Prognostic Ozone Parameterization in the NCEP GFS & CFS for Climate Reanalysis and Operational Forecasts

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- In addition to ozone, part of this CRTF project is to improve treatment of stratospheric water vapor in NCEP GFS/CFS
- Implement zonal monthly mean climatology of water vapor mixing ratio for stratosphere and mesosphere
- Parameterize photochemical production and loss (P-L) of water vapor due to methane oxidation (stratosphere) and photolysis (mesosphere)

Methodology

The NRL linearized parameterization of stratospheric and mesospheric water vapor photochemistry (McCormack et al., ACP, 2008) applies a linearized photochemical tendency to specific humidity q of the form

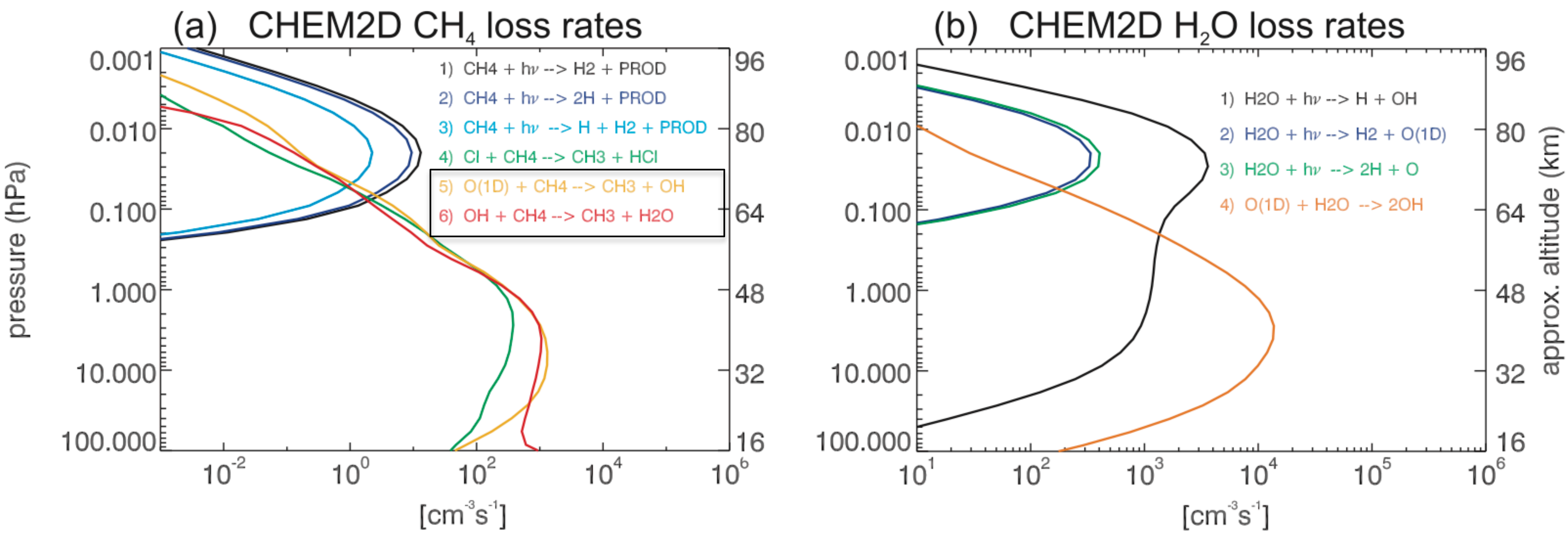
$$\frac{dq}{dt} = (P-L)_0 + \left.\frac{\partial(P-L)}{\partial q}\right|_0 (q-q_0)$$

The second term on the right hand side quantifies the linearized sensitivity to local changes in q, and yields photochemical relaxation to equilibrium specific humidity q_0

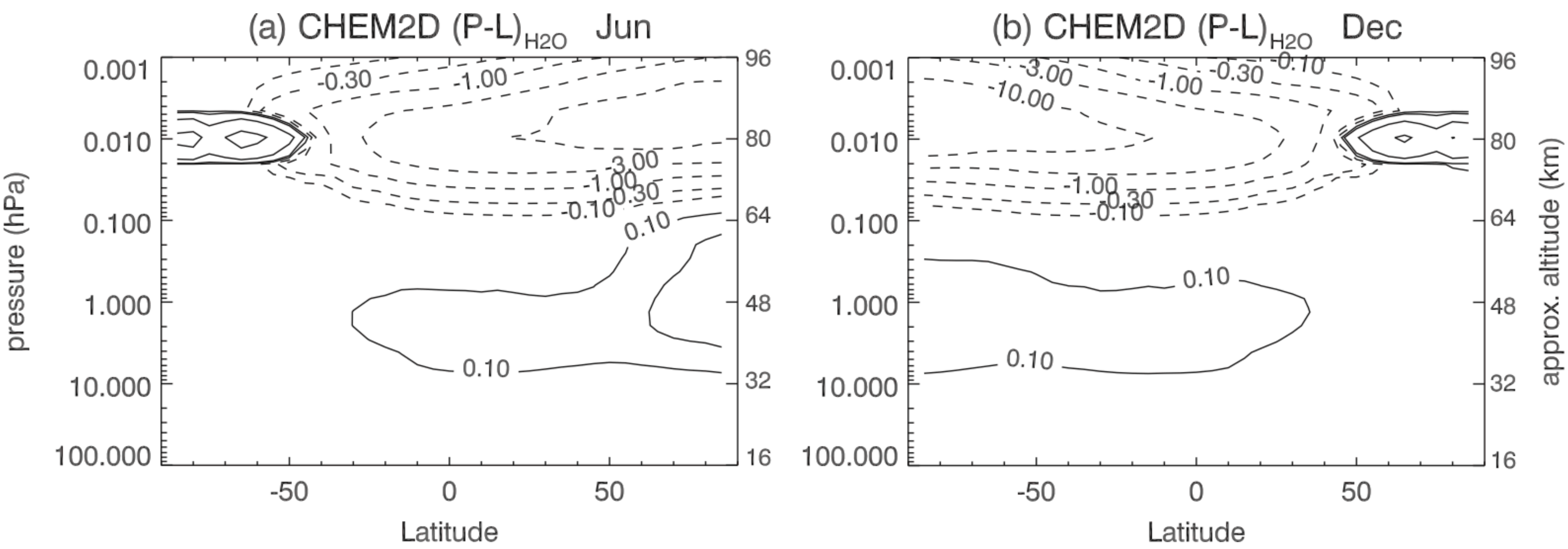
$$-\left[\frac{\partial(P-L)}{\partial q}\right]_0 = \tau_*^{-1} \, .$$

The $(P\text{-}L)_0$ and τ_* values are computed from perturbation experiments with the NRL two-dimensional photochemical model (CHEM2D). The equilibrium profile q_0 is specified using a climatology based on combination of reanalysis and satellite observations

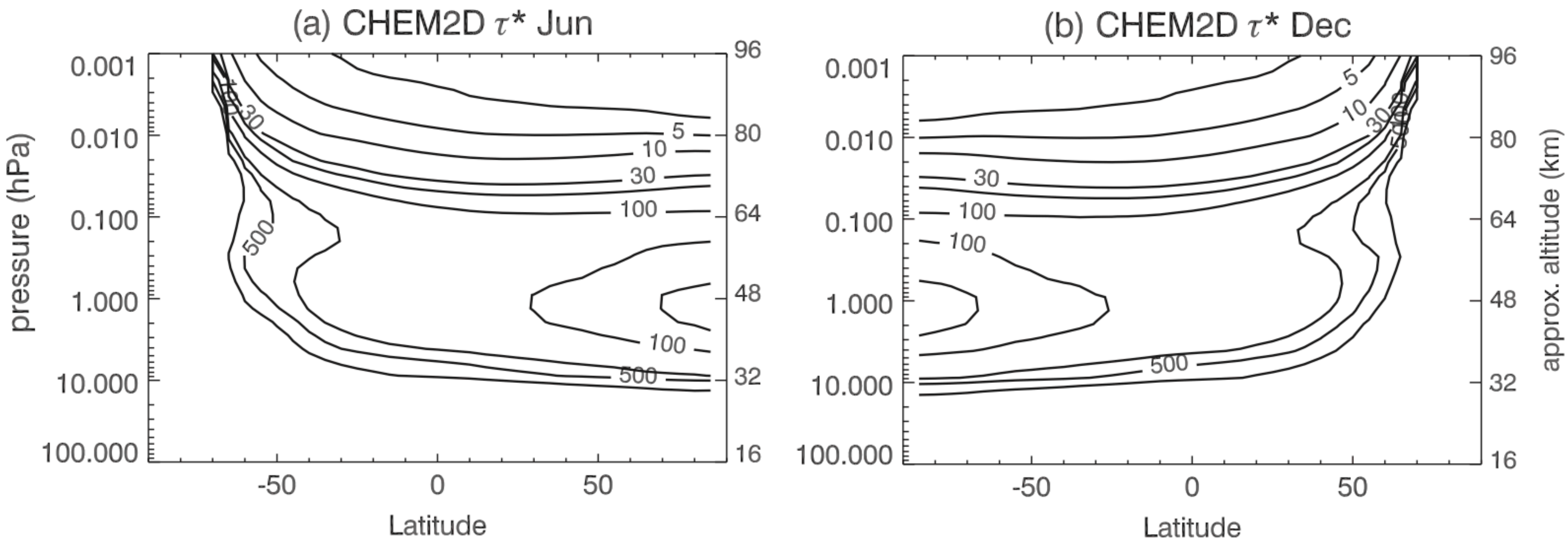
CHEM2D Production (P) and Loss (L)



CHEM2D Net Tendency (P-L)



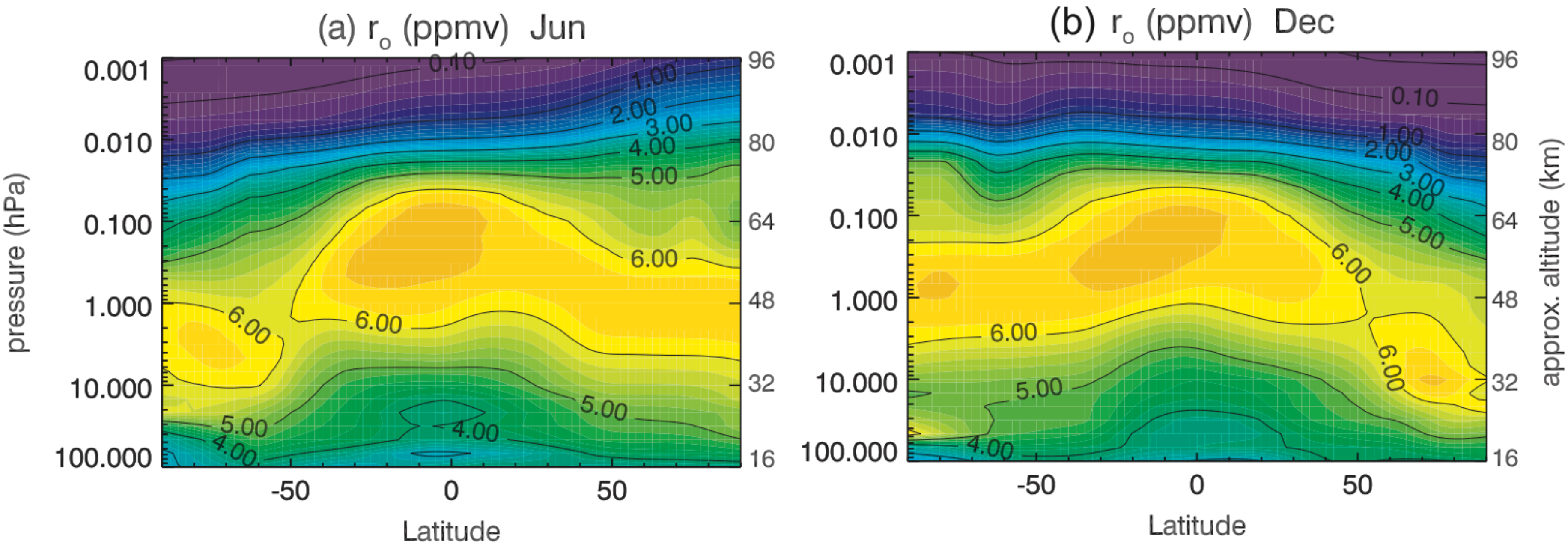
Effective Photochemical Lifetime



$$\tau^* = \frac{1}{\tau_{CH4}^{-1} + \tau_{H2O}^{-1}}$$

Effective photochemical lifetime includes effects of both production (via methane oxidation) and loss (via photolysis)

Background values q_o



Sources:
- 1000-200 hPa ERA40
- 146-10 hPa HALOE climatology
- 10-0.005 hPa Aura MLS
- 0.005 – 6.e5e-5 hPa CHEM2D

You can use whatever background climatology best fits your system!

Implementation

Adopting an approach similar to that for the CHEM2D ozone photochemistry parameterization, or CHEM2D-OPP (McCormack et al., 2006), the specific humidity photochemical tendency in NOGAPS-ALPHA is applied by first defining a photochemical steady state value for the water vapor mixing ratio

$$r^{ss} = r^{o} + (P - L)^{o}\tau^{*} \quad (10)$$

so that the H_2O mixing ratio tendency can be expressed as

$$\frac{\partial r}{\partial t} = \frac{-(r - r^{ss})}{\tau^{*}}. \quad (11)$$

The updated mixing ratio value is computed using a standard backward-Euler solution of the form

$$r(t + \Delta t) = r(t) + [r^{ss} - r(t)]\left[\frac{\frac{\Delta t}{\tau^{*}}}{1 + \frac{\Delta t}{\tau^{*}}}\right] \quad (12)$$

[McCormack et al., ACP. 2008]

r = model H2O mixing ratio

r_o = q_o = background zonal monthly mean climatology

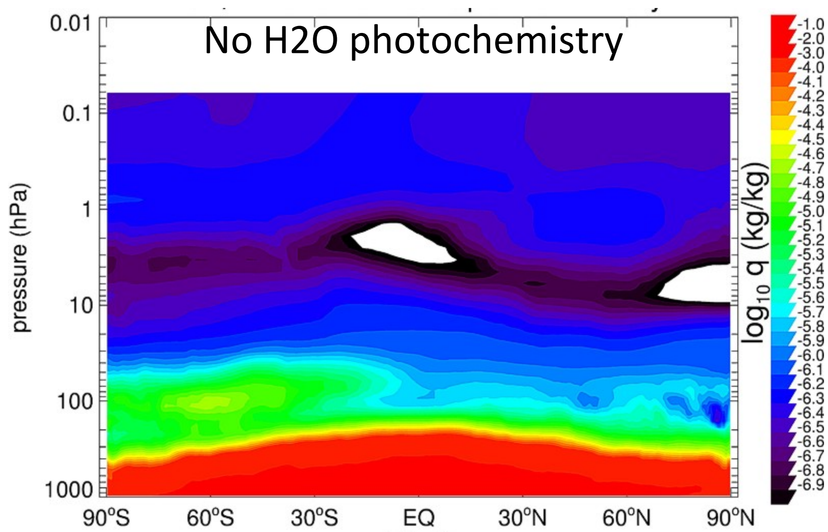
(P-L) = net photochemical tendency from CHEM2D model

τ^* = effective photochemical lifetime reflecting both CH4 oxidation and H2O photolysis effects

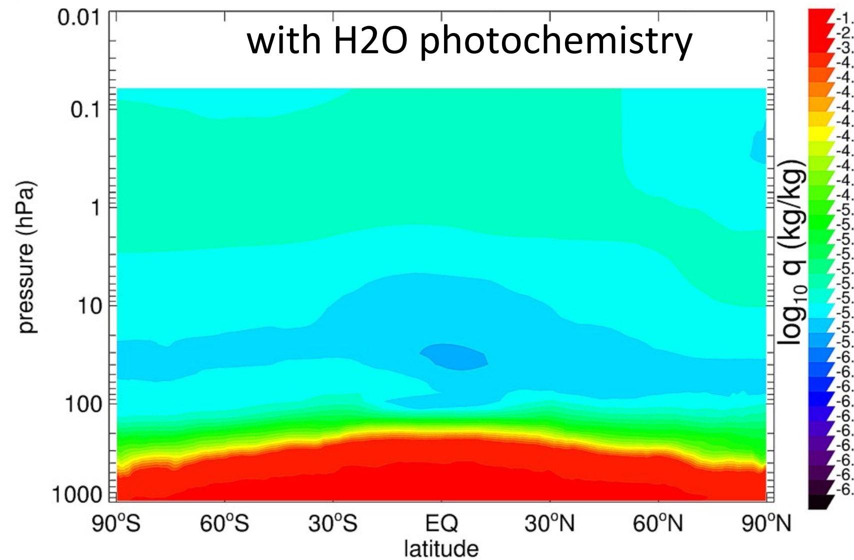
Δt = model time step

Parameterized H_2O Photochemistry in NAVGEM

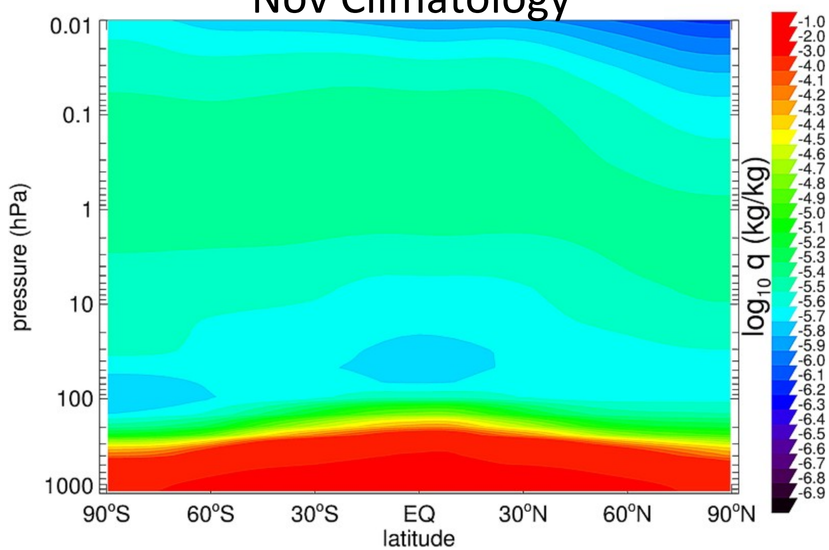
Spec. Humidity Analysis 15 Nov 2011

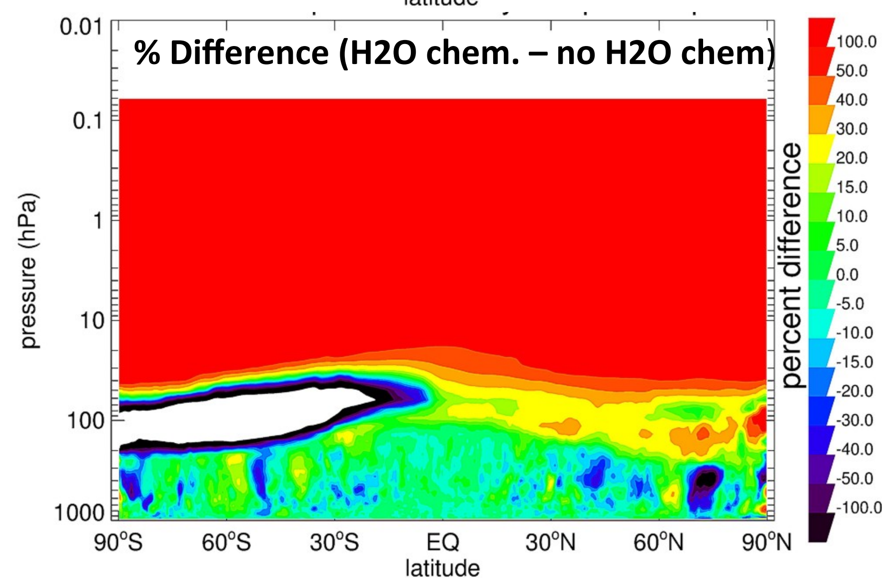


Spec. Humidity Analysis 15 Nov 2011



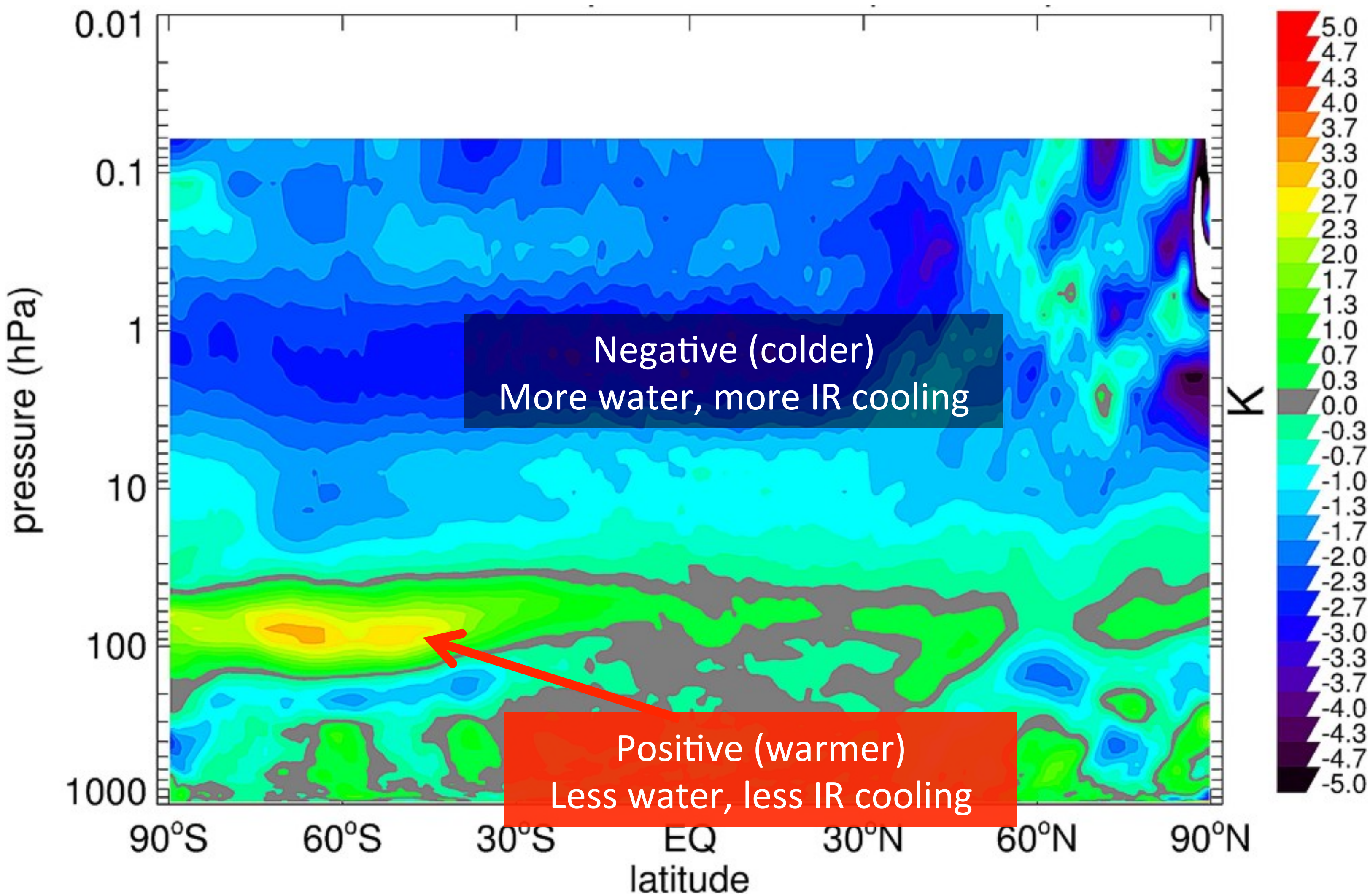
Nov Climatology





Parameterized H_2O Photochemistry: Reducing Forecast Temperature Bias

288-Hour Forecast Temperature Difference: (H2O chem) – (no H2O chem)



Summary

- Linearized water vapor photochemistry constrains model prognostic humidity variable in stratosphere/mesosphere to observed climatogical values while also capturing short-term transport effects
- Assumed background humidity field q_o allows for QC of prognostic humidity, particularly in UT/LS region
- Accurate prognostic humidity values in UT/LS can reduce forecast model biases

Acknowledgments

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