On the Permeability of the Extratropical Tropopause: A view from Aura/MLS observations

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Aura Science Team meeting, Helsinki, Finland

September 13, 2011

A climatological view of the PV, CO, and O_3 horizontal cross-tropopause gradients in the extratropics

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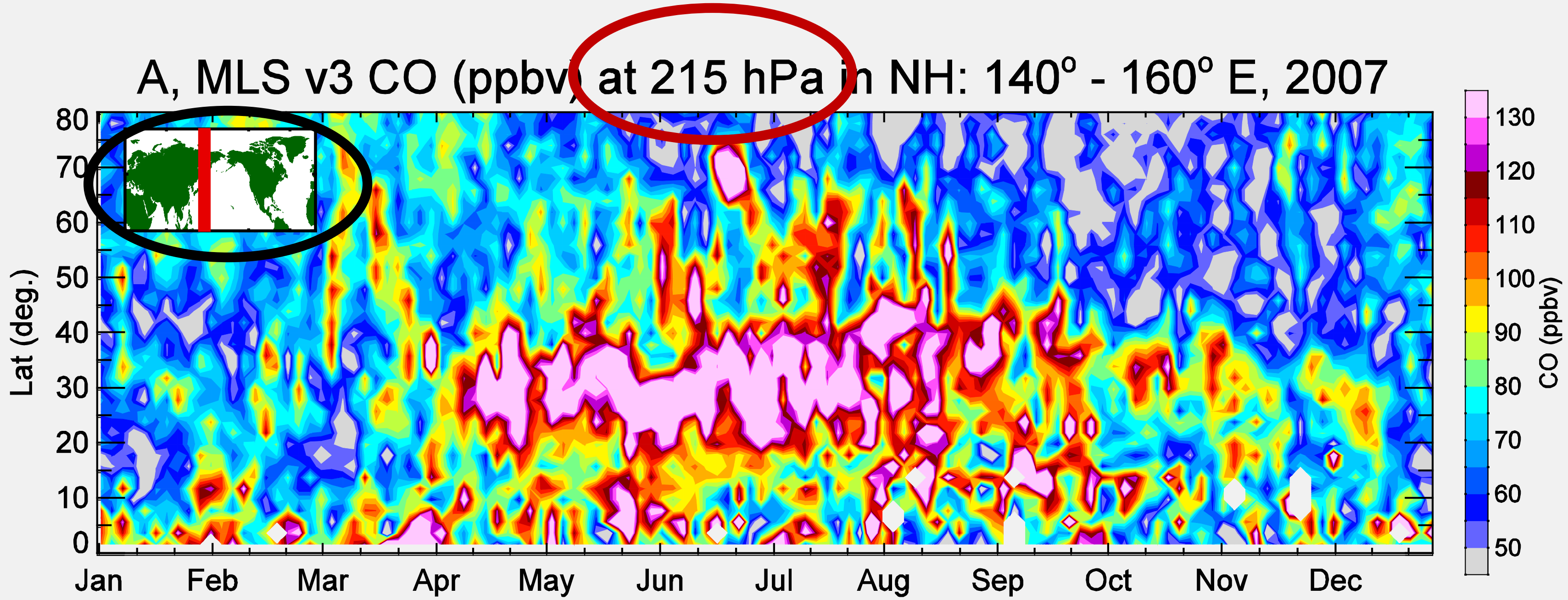
Introduction

- Many previous studies have shown the sharp transition in potential vorticity (PV) and chemical tracer abundances (e.g., carbon monoxide, CO, and ozone, O_3) at the extratropical tropopause in a synoptical scale.
- A few studies have shown seasonal mean features, e.g., small diffusivity *(Haynes and Shuckburgh, 2000; Shuckburgh et al., 2009),* at the extratoprical tropopause, using equivalent latitude coordinates (EqLat).
- The location of the tropopause varies largely (> 15 degrees) within a season, even in EqLat coordinates. Therefore, the sharp transition at the tropopause is blurred in calculated seasonal means.
- How can we get the "precise" tropopause features in a climatological view? Or, how do we extract the tropopause features in large space-borne datasets?

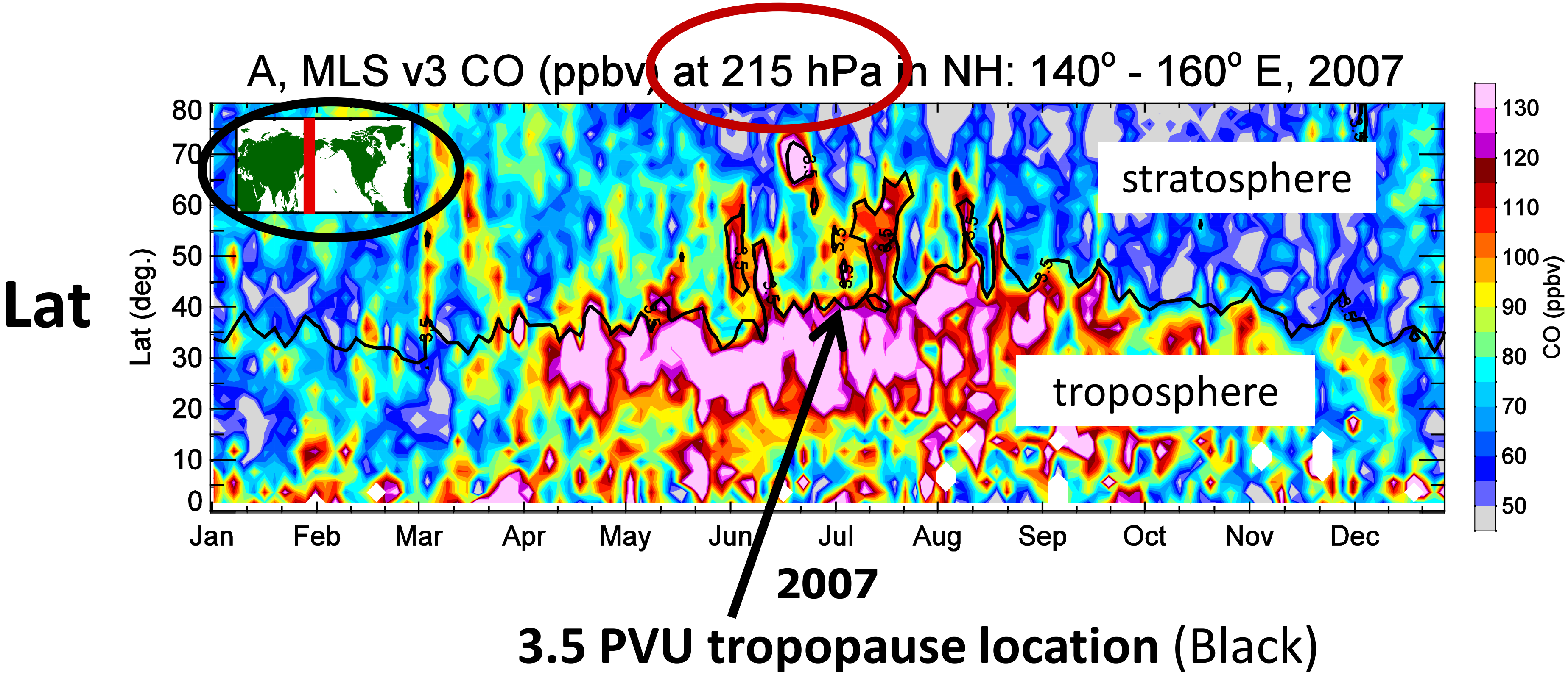
MLS CO time-latitude cross-section at 215 hPa

Lat

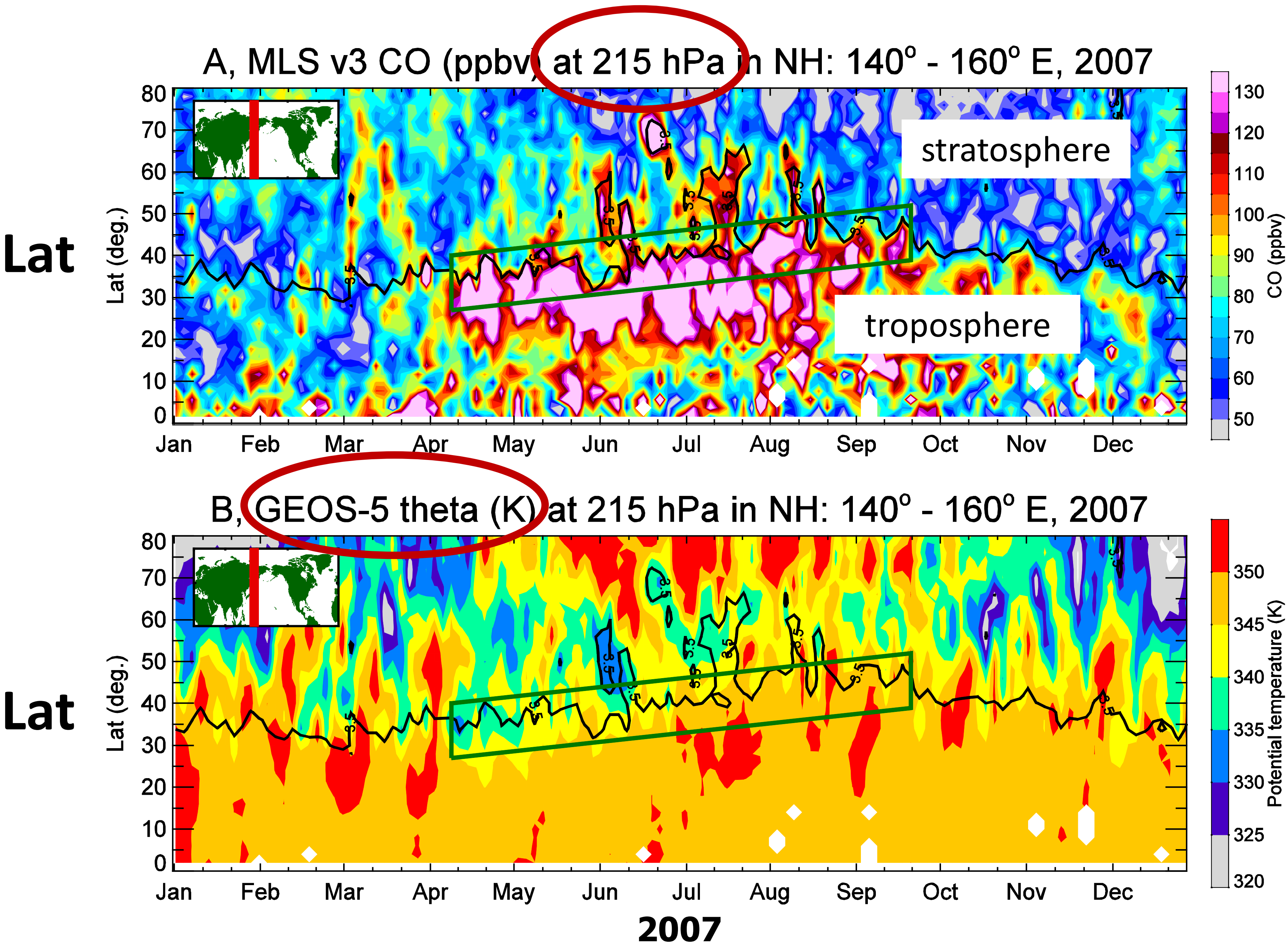


2007

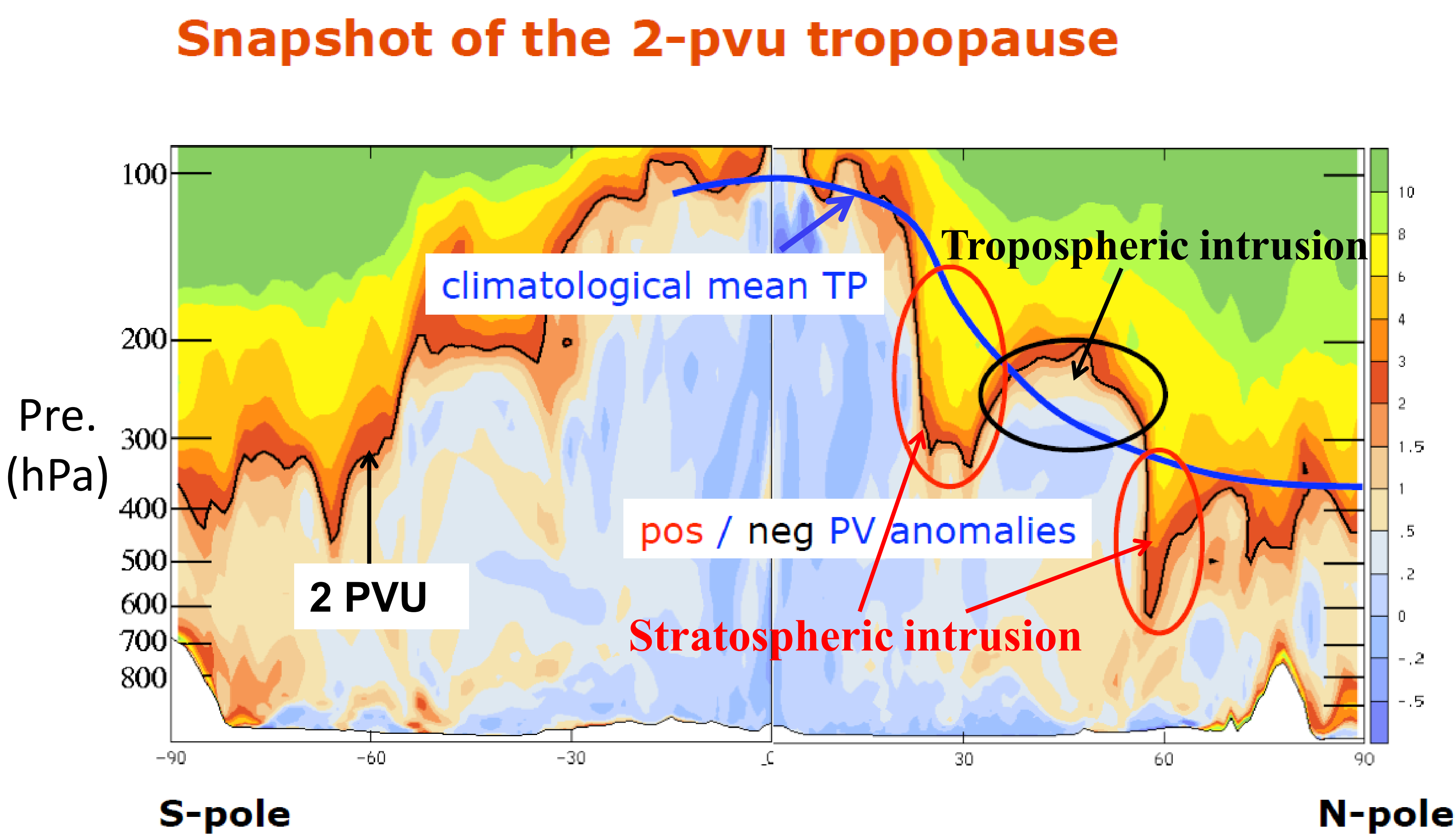
MLS CO time-latitude cross-section at 215 hPa



MLS CO time-latitude cross-section at 215 hPa



PV and tropopause

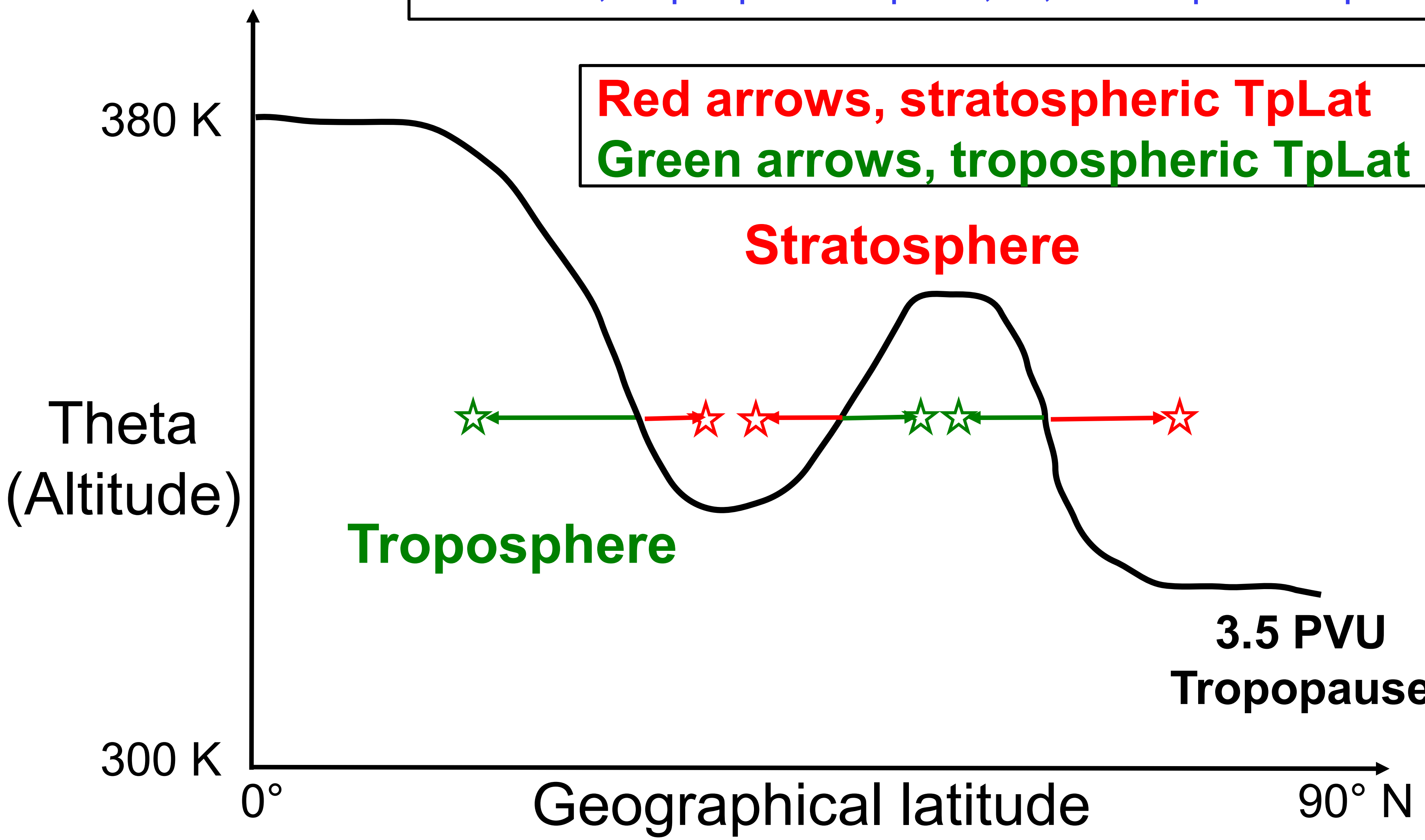


(Courtesy of Heini Wernli, ETH, 2005 Cargese UTLS Summer School lecture note)

Tropopause Latitude coordinates (TpLat)

— Latitudinal distances from the nearest tropopause on an isentropic surface.

In the NH, tropospheric TpLat , – ; stratospheric TpLat , + .
In the SH, tropospheric TpLat , + ; stratospheric TpLat , – .

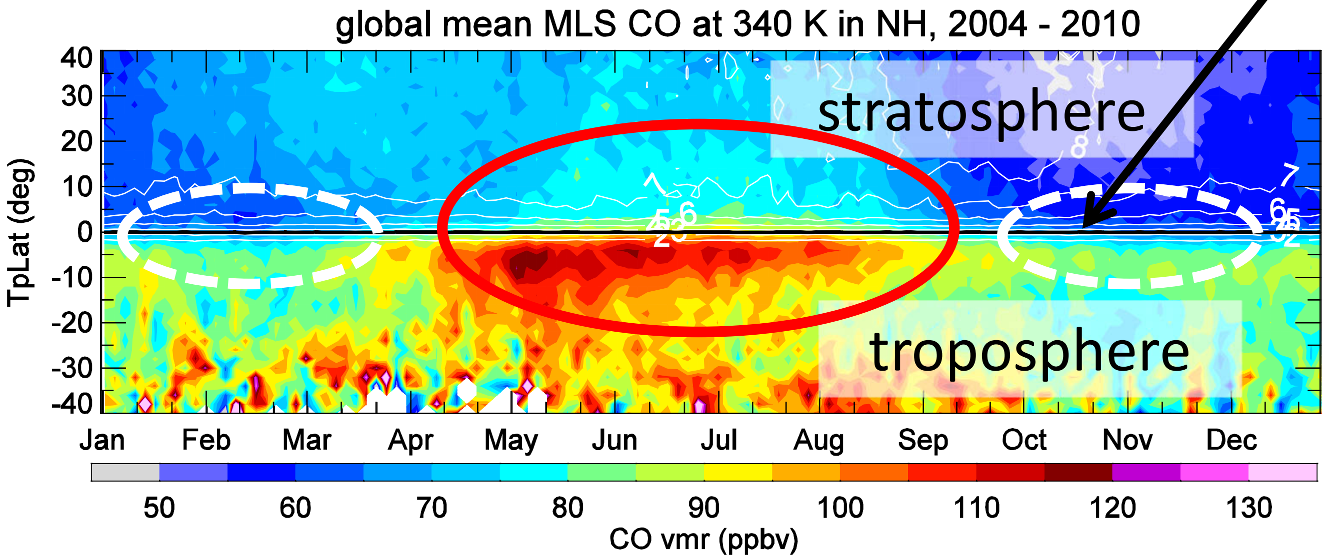


Multi-year (2004-2010) NH global mean CO at ~340 K

in the new TpLat coordinates

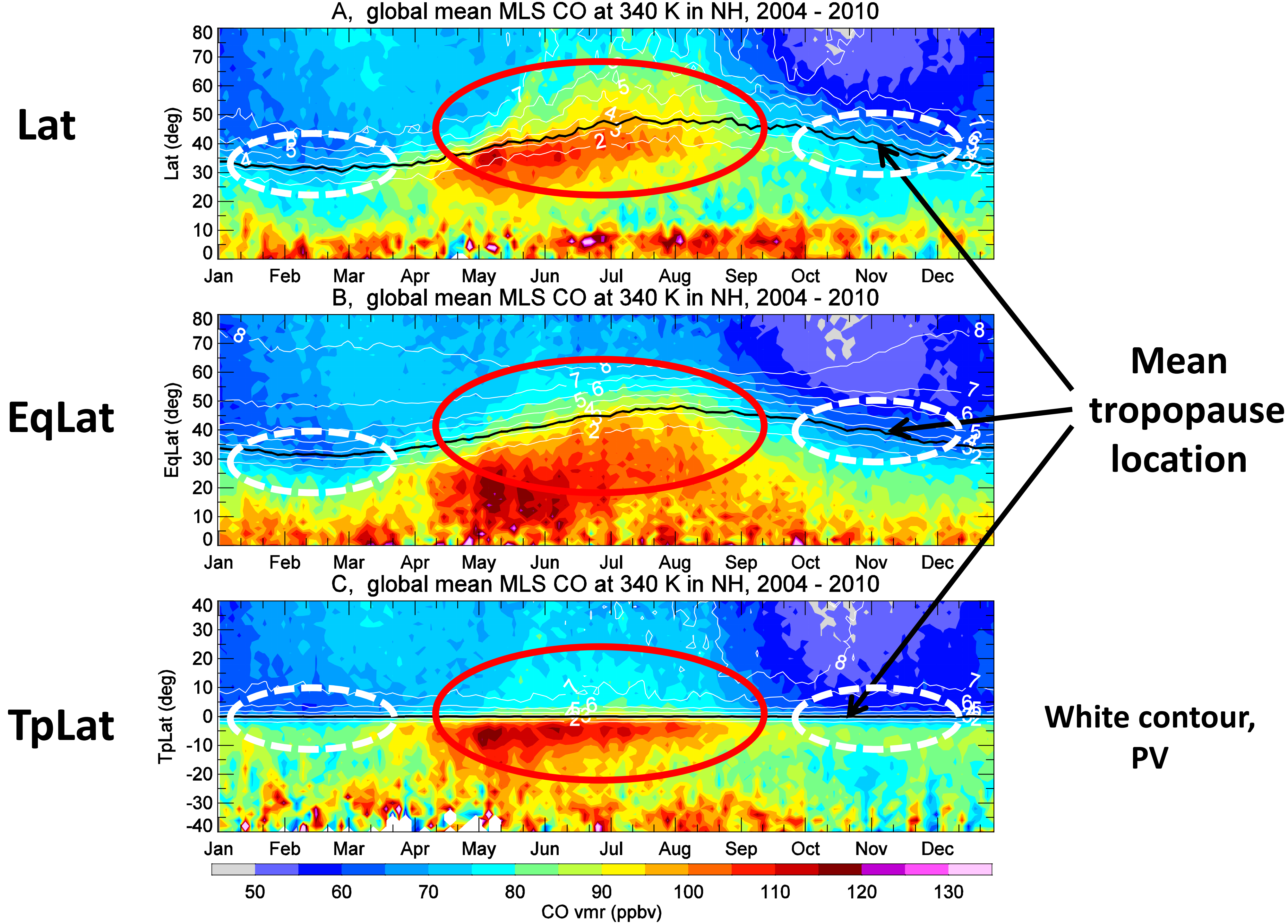
tropopause location

TpLat



White contour, PV

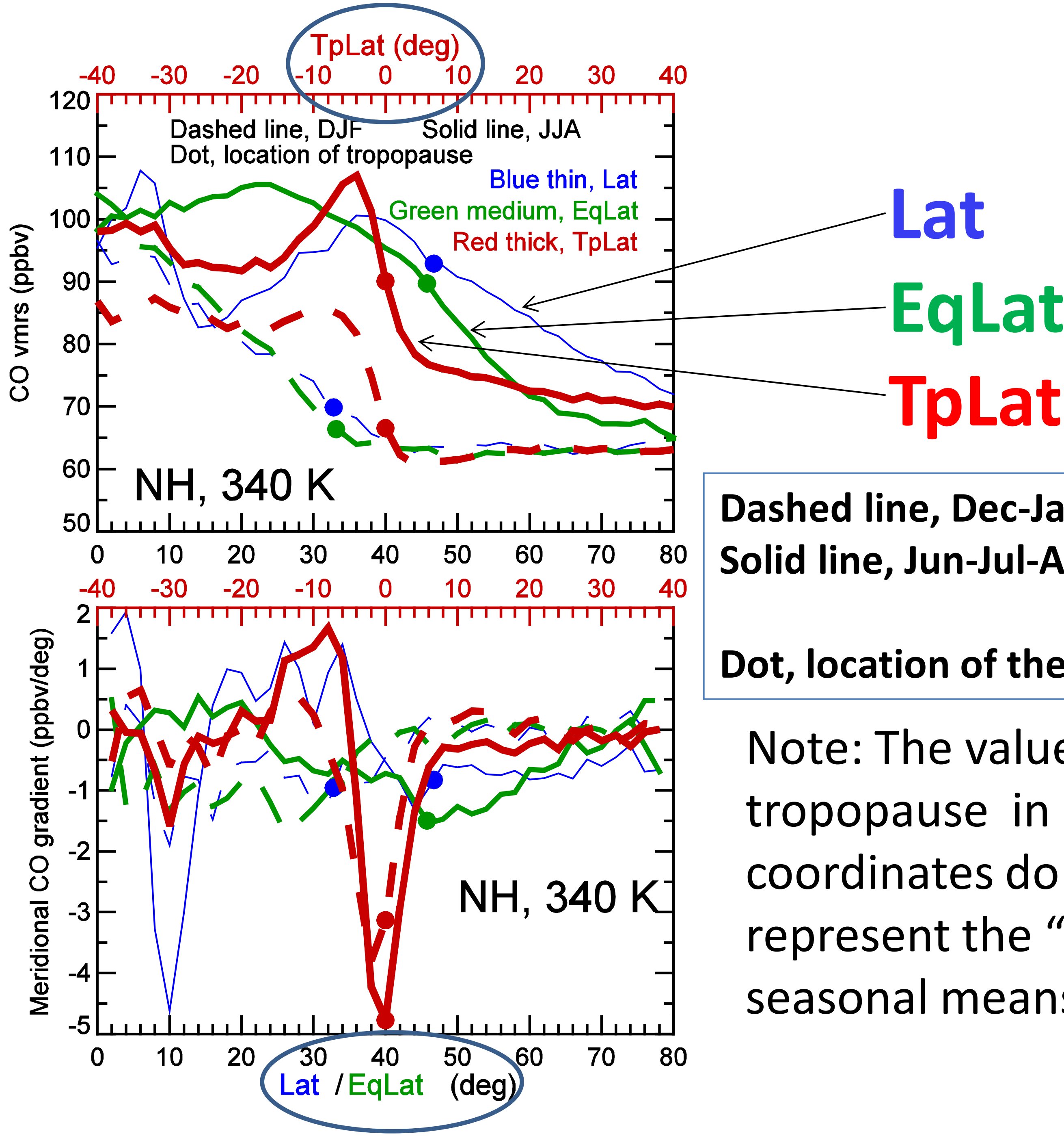
Multi-year (2004-2010) NH global mean CO at ~340 K



Seasonal mean CO vmrs and gradients in the NH

Mean CO

CO gradients



Dashed line, Dec-Jan-Feb
Solid line, Jun-Jul-Aug

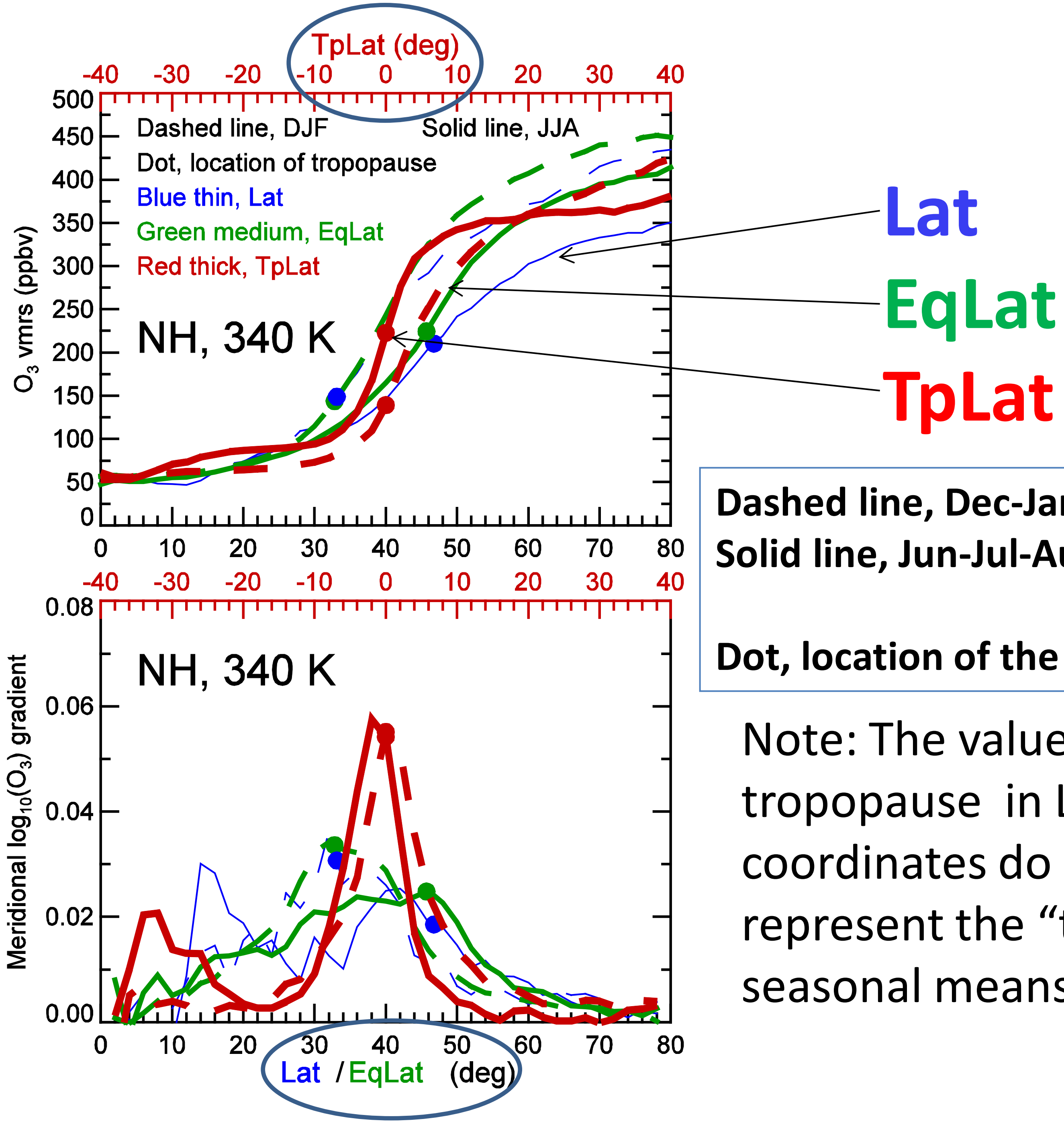
Dot, location of the tropopause

Note: The values at tropopause in Lat/EqLat coordinates do not represent the "true" seasonal means.

Seasonal mean O_3 vmrs and gradients in the NH

Mean O_3

O_3 gradients



Dashed line, Dec-Jan-Feb
Solid line, Jun-Jul-Aug

Dot, location of the tropopause

Note: The values at tropopause in Lat/EqLat coordinates do not represent the “true” seasonal means.

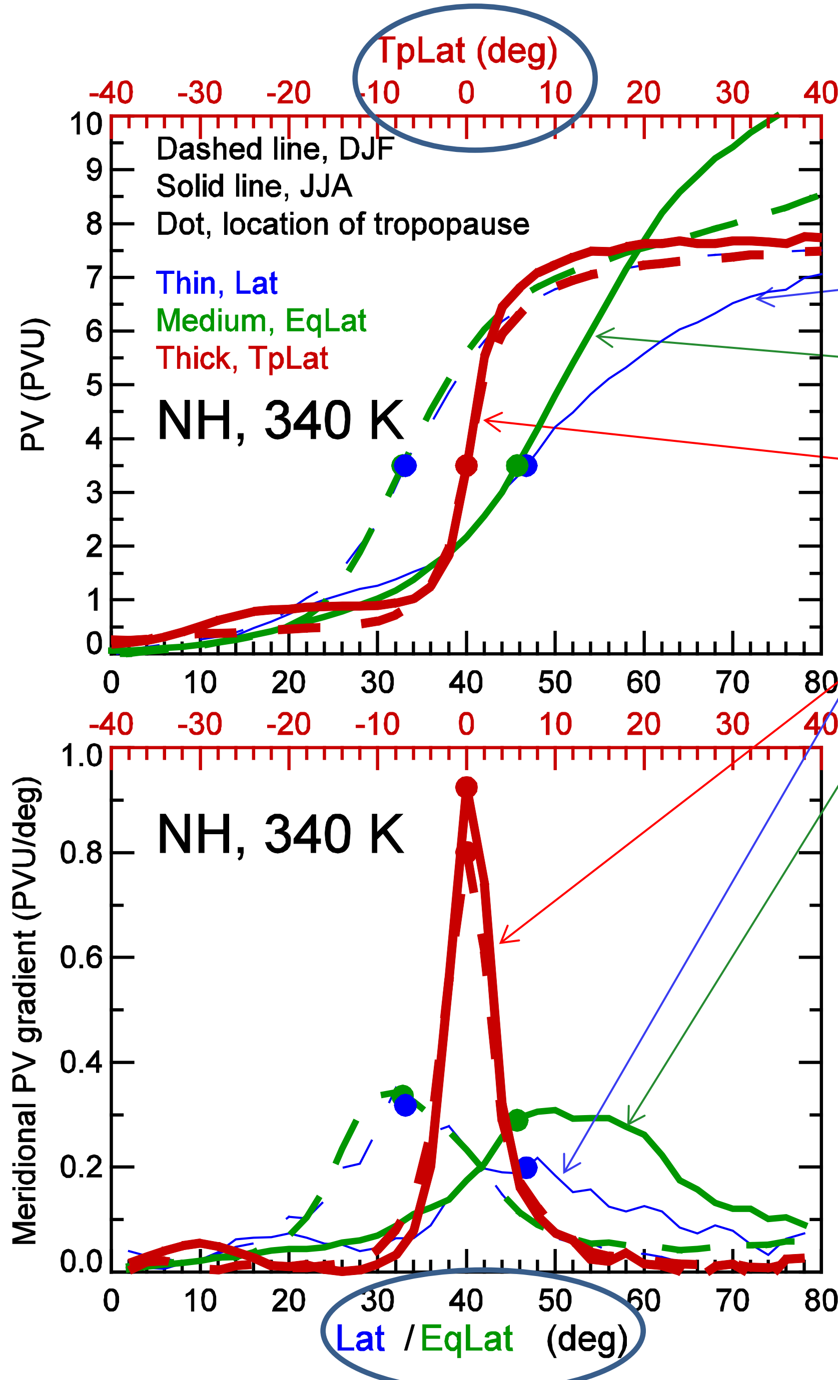
General view about the seasonal variation in PV gradients at the extratropical tropopause

- *…… It is well known that the jet stream is weaker in summer than in winter. Consequently, the transition region of enhanced PV gradients spans a larger region, which has a similar extent around the globe, indicating a less sharp tropopause in the summer months. It reflects the larger permeability between the troposphere and the stratosphere in summer……* (Kunz et al., 2011, JGR)

Seasonal mean PV values/gradients in the NH

Mean PV

PV gradients



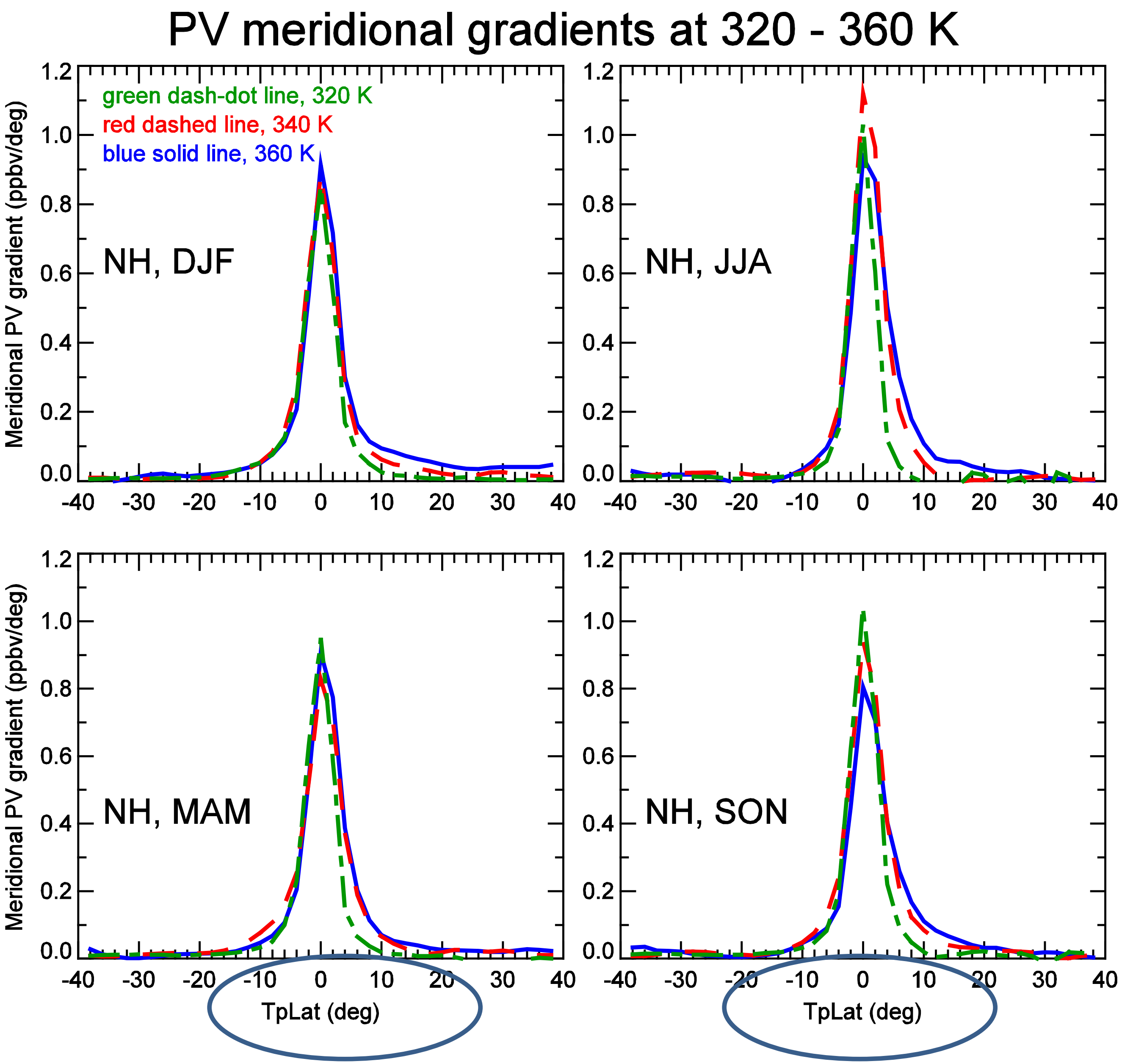
Dashed line, Dec-Jan-Feb
Solid line, Jun-Jul-Aug

Dot, location of the tropopause

Note: The values at tropopause in Lat/EqLat coordinates do not represent the "true" seasonal means.

Seasonal mean PV values/gradients at **320 K, 340 K, and 360 K** in the NH

(Whole GEOS-5 data in 2007, not sampled at MLS locations)

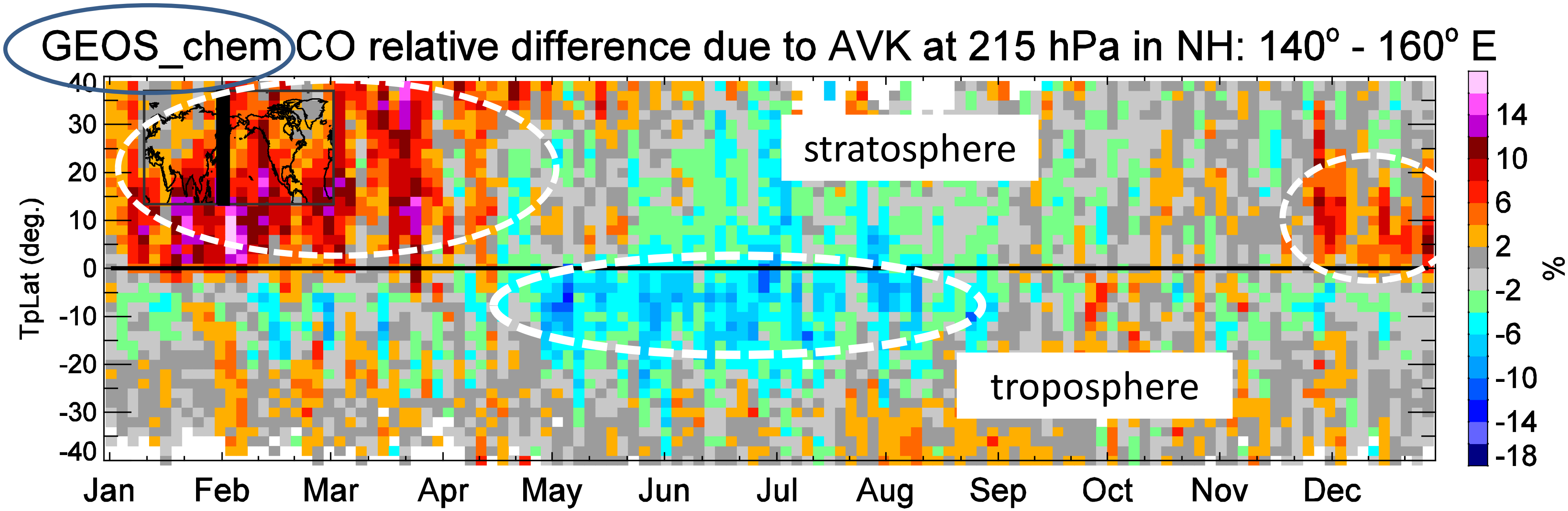


Green dash-dot line, 320 K

Red dashed line, 340 K

Blue solid line, 360 K

Averaging Kernel effect



- CO abundances are generally increased in the LS, and are generally decreased in the UT by AVK.
- If no AVK effect, the CO meridional gradients would have been larger in MLS measurements than shown in previous slides.

Summary

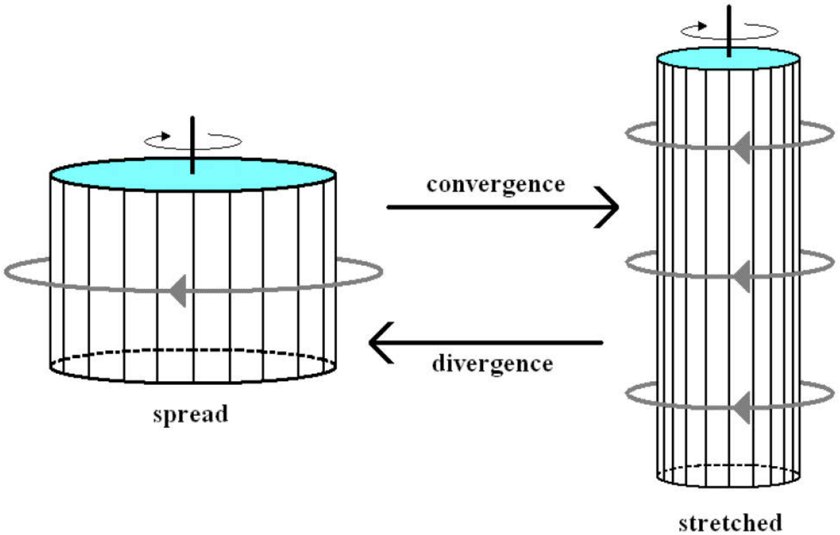
- MLS sees the distinctions in CO and O_3 abundances between the UT and the LS, showing MLS retrievals are useful in UTLS studies.
- The new TpLat coordinate is much better than Lat/EqLat coordinates in bringing out the sharp gradients at the tropopause in large model/space-borne datasets.
- In a climatological view, the extratropical tropopause is an equally effective "transport barrier", indicated by the large gradients, in both winter and summer.

Thank you.

PV and Equivalent Latitudes

Potential Vorticity (PV), conserved in adiabatic and frictionless process.

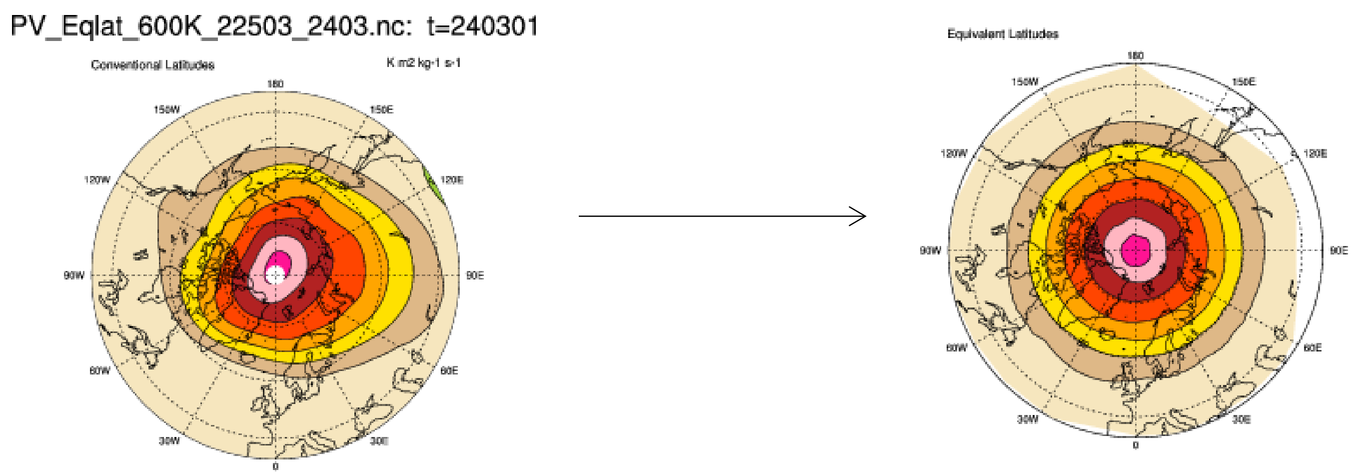
$$\mathrm{PV} = \frac{1}{\rho}\zeta^{a} \cdot \nabla\theta$$



(From Wiki)

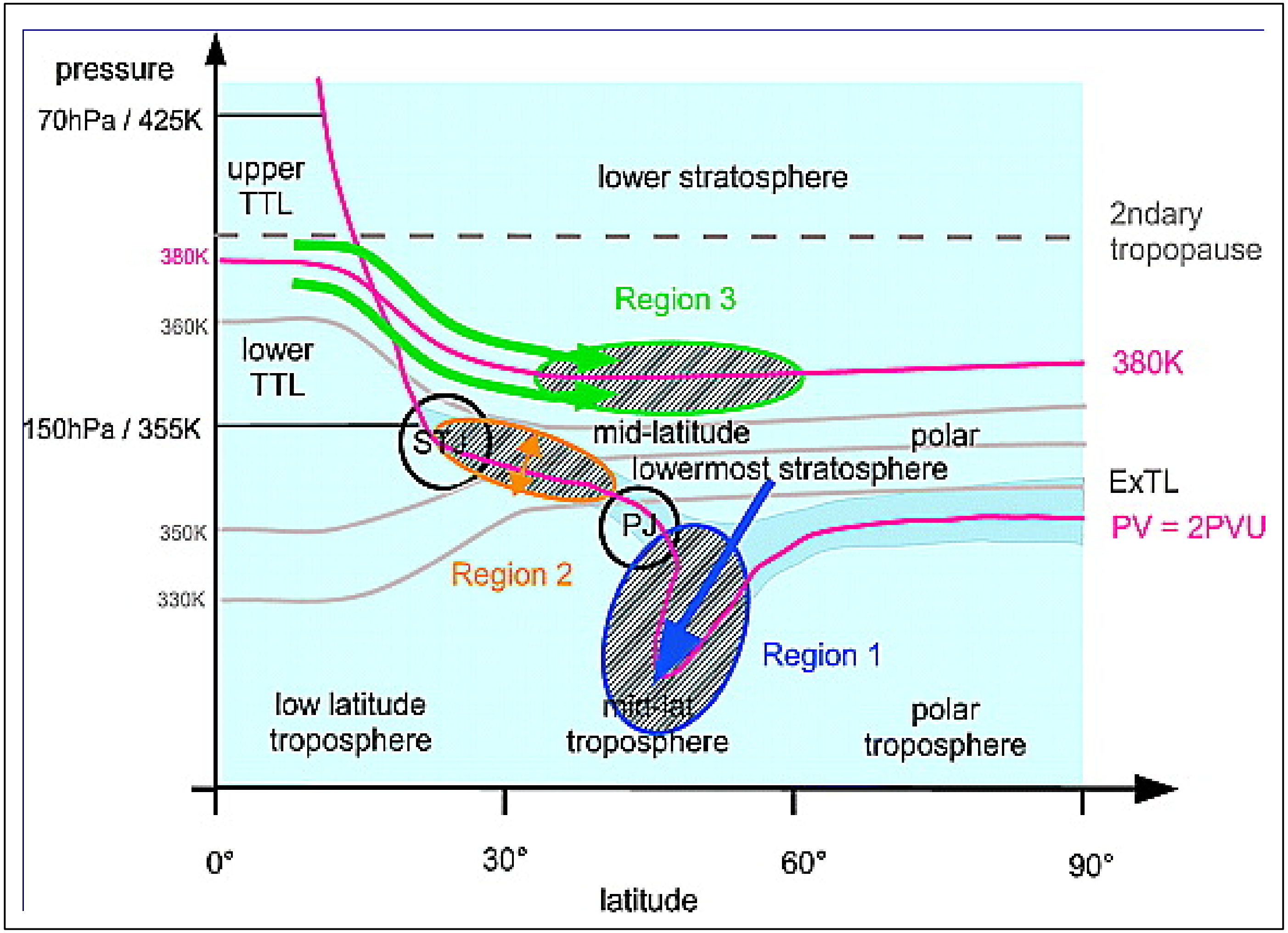
PV in geographical Lat at 600 K.

PV in Equivalent Lat (EqLat) at 600 K



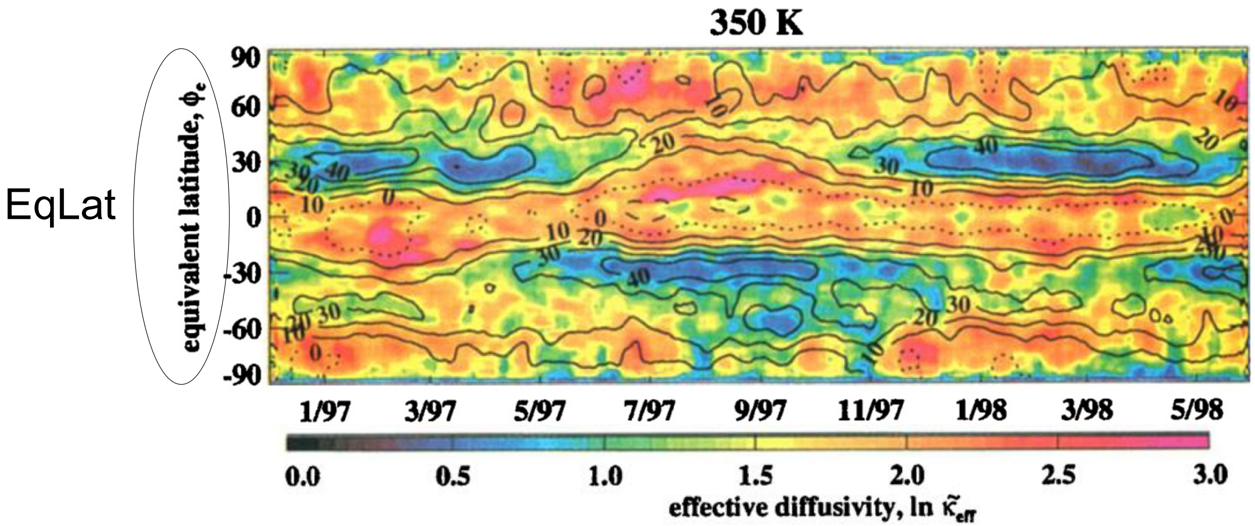
(http://www.ncl.ucar.edu/Applications/equiv_lat.shtml)

Introduction: STE processes



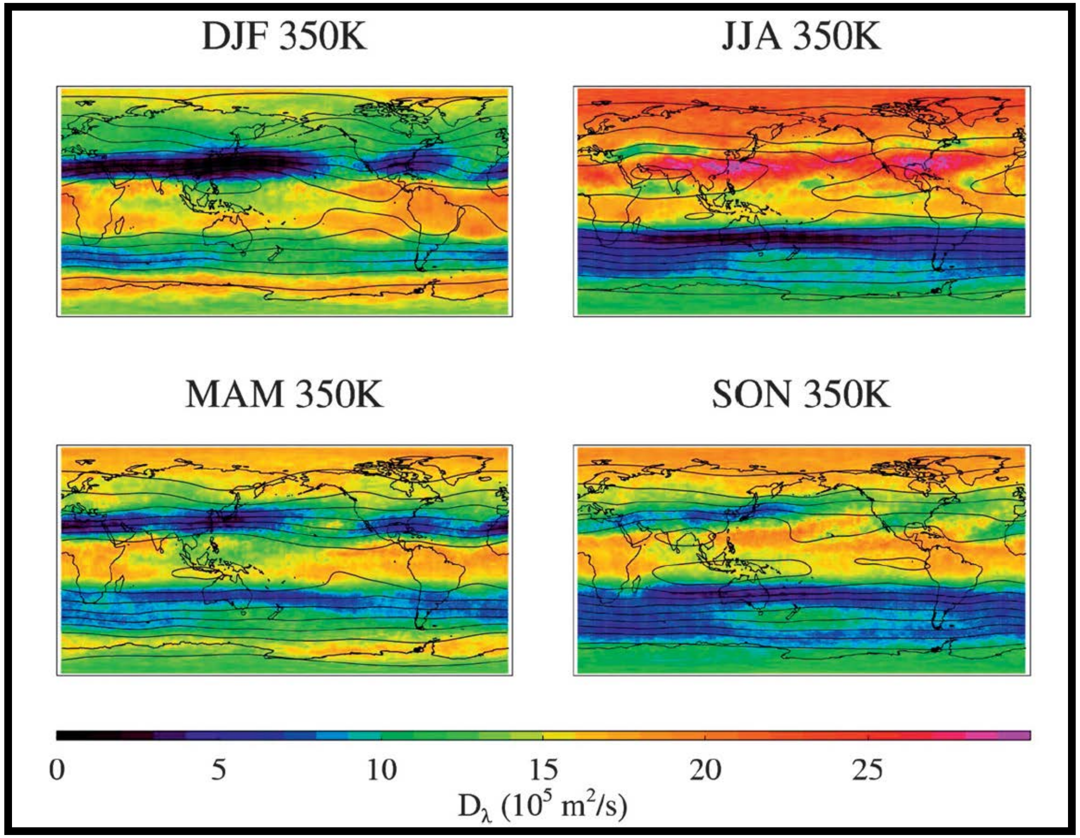
(Vogel, B., et al., 2011, JGR)

Previous studies, generally based on EqLat.



Effective diffusivity and U wind

(Haynes and Shuckburgh, 2000, JGR)



Seasonal cycle of the Lyapunov diffusivity (color), with time-mean streamlines overplotted as black contours. (Shuckburgh et al., 2009, JAS)

Subtropical Jet

Vertical distribution of U velocity at 215 – 178 – 147 hPa

0 – 360 E (zonal mean)

Black contours, PV

Strong seasonal variation of U, but always maximum U wind at the tropopause.

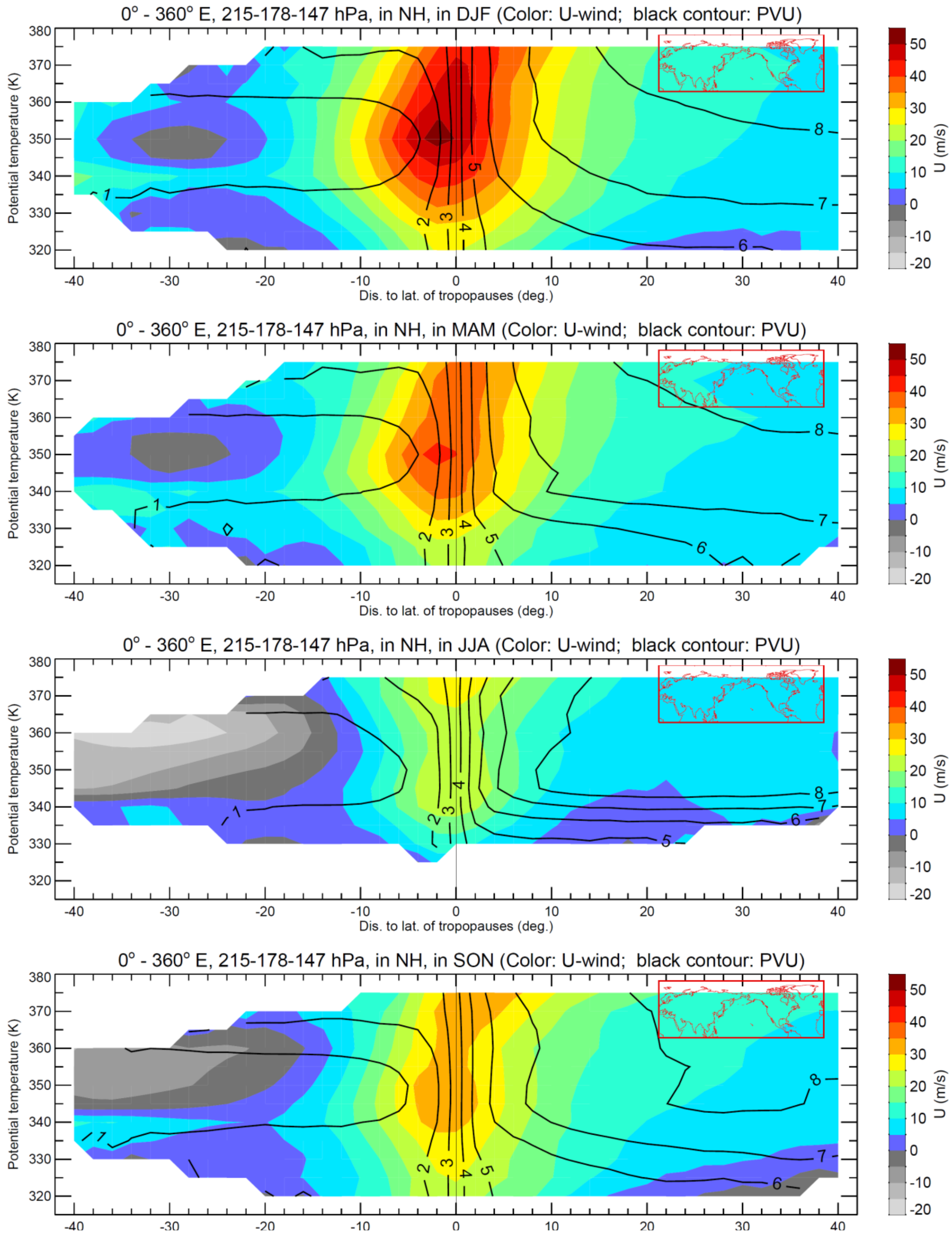
Potential Temperature (K)

DJF

MAM

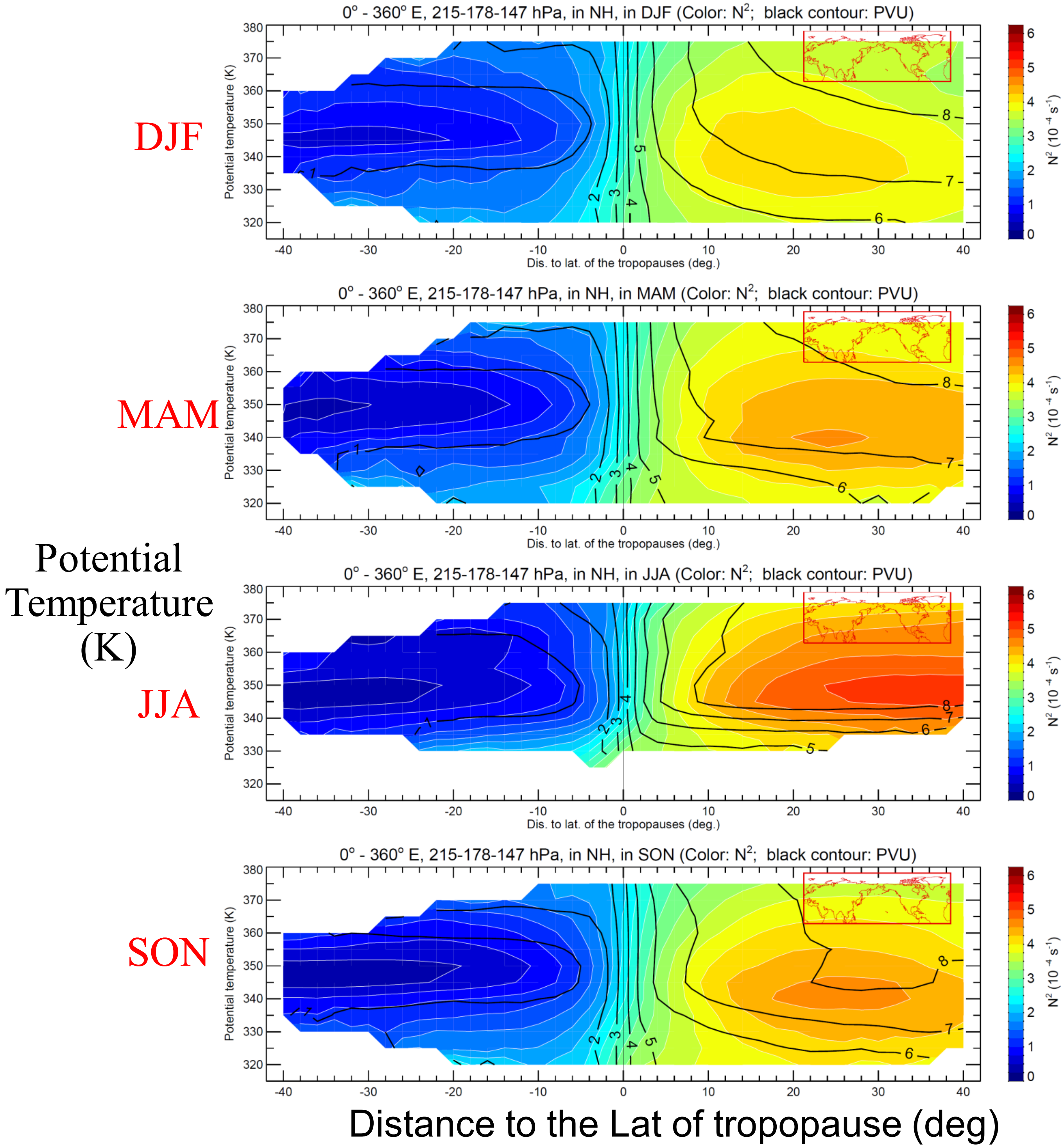
JJA

SON



Distance to the Lat of tropopause (deg)

Static stability at 215–178–147 hPa



The static stability is larger in the LS than in the UT;

It is the largest in JJA and the smallest in DJF.