Sources of Seasonal Variability in Tropical UT/LS Water Vapor and Ozone: Inferences from Ticosonde/Costa Rica*

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Ticosonde Background

Balloonsonde measurements of water vapor and ozone at San José, Costa Rica

- Water: Cryogenic Frostpoint Hygrometer (CFH; Vömel et al, JGR, 2007)
- Ozone: Electrochemical Concentration Cell (ECC; Komhyr et al., JGR, 1995)

Regular launches (~weekly) since July 2005 ***(Ticosonde is 10!)***

- ECC every 1 to 2 weeks, plus 4 intensive observation periods 2005-2007
- CFH/ECC once monthly
- Three Ticosonde sites in the 10-year record: Alajuela, Heredia, San Pedro, maximum separation 21 km

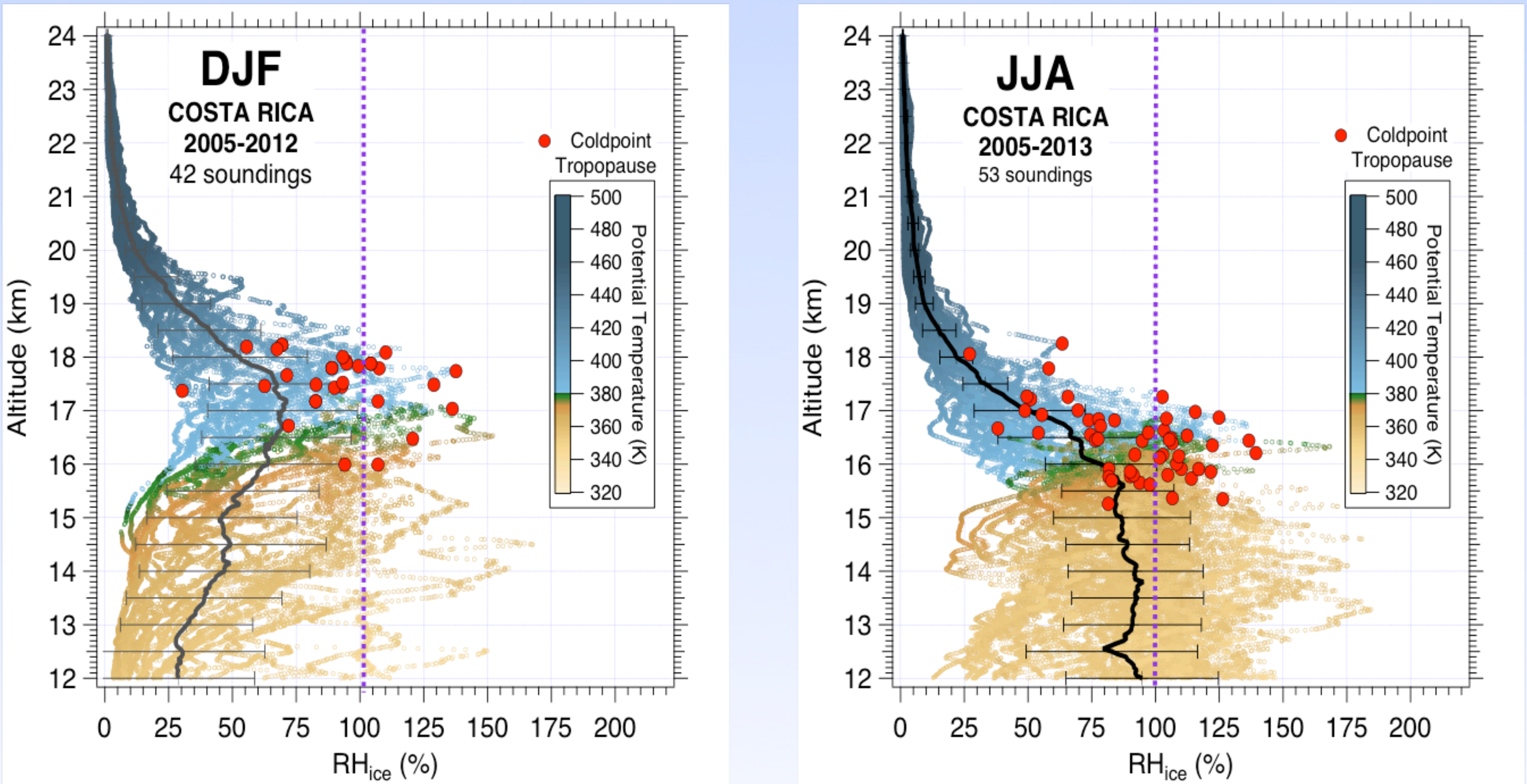
Longest running set of *in situ* measurements of tropical water vapor

- 186 CFH/ECC ascents, total of 451 ECC profiles (through last Friday)
- Data archived at the Aura Validation Data Center (http:/avdc.gsfc.nasa.gov)

Costa Rican Co-Investigators

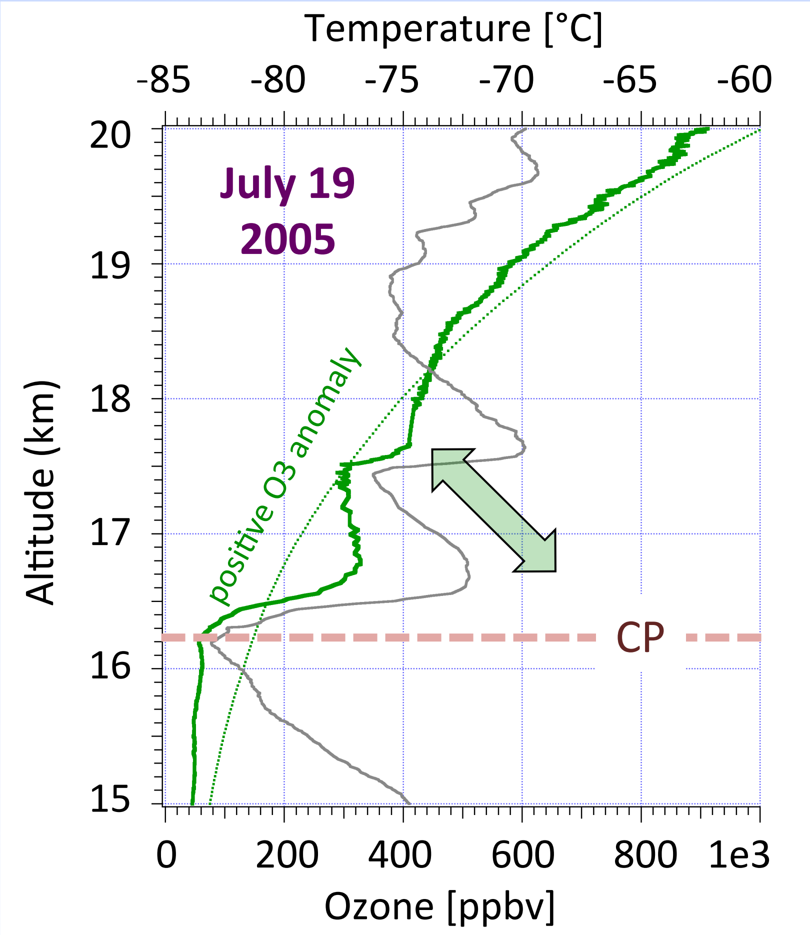
- Dr. Jorge Andrés Diaz, Universidad de Costa Rica, 2011-present
- Dra. Jessica Valverde, Universidad Nacional, 2005-2011

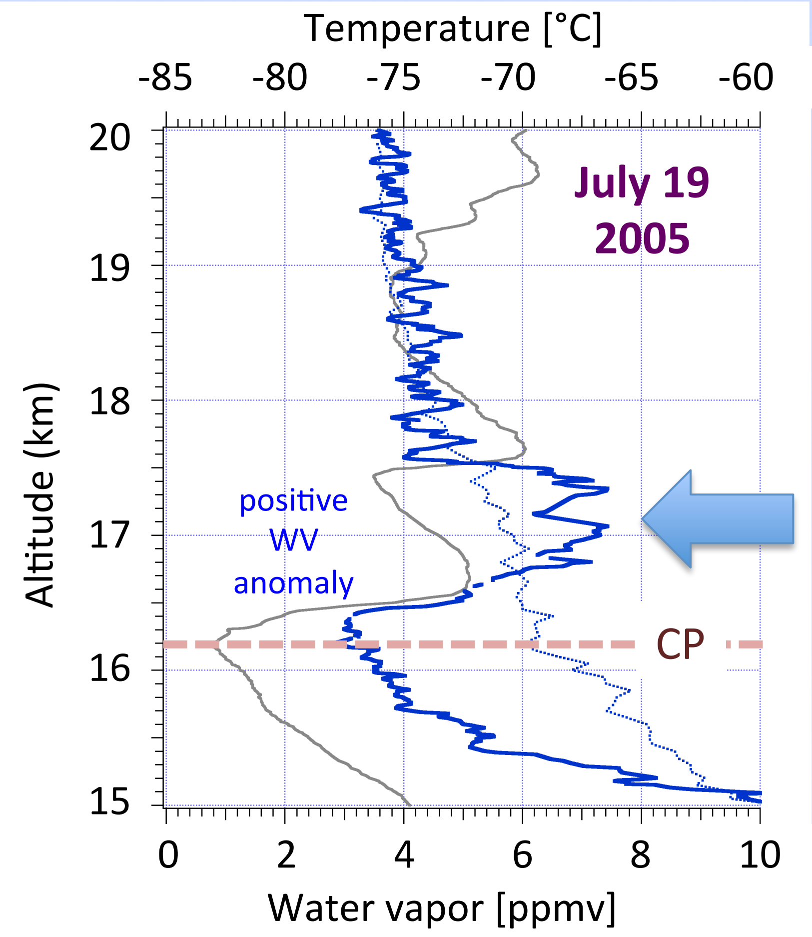
Motivation: What processes drive seasonal differences in UT/LS RH_{ice} and coldpoints



- UT/LS supersaturations occur in both boreal winter and summer, but in JJA CP tropopause more tightly clustered near 380 K

Motivation: What are the contributions to WV and O_3 anomalies from local versus remote processes?

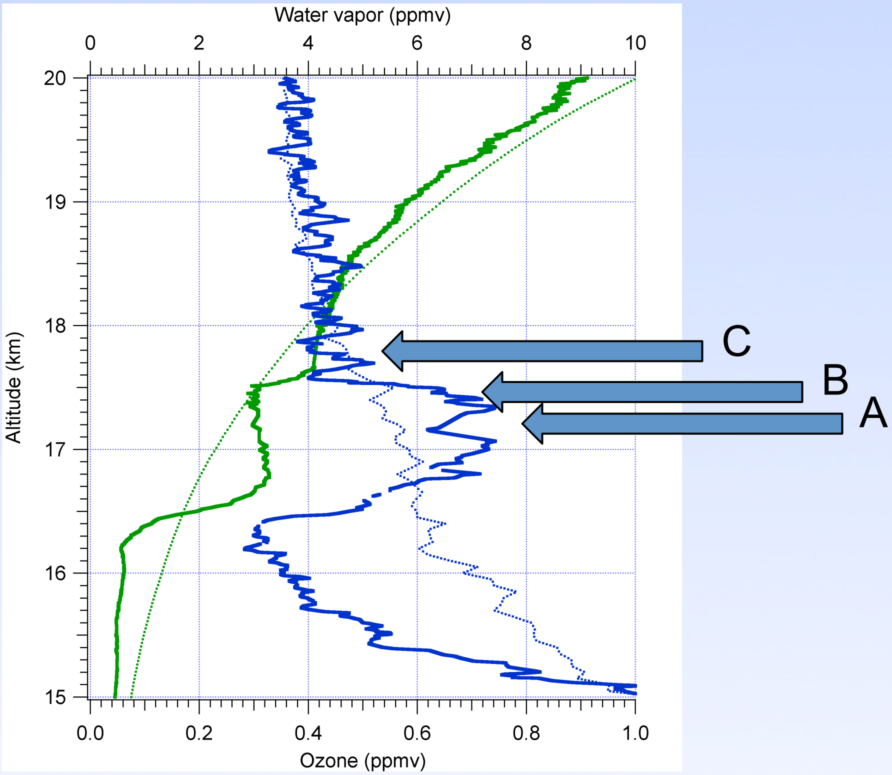


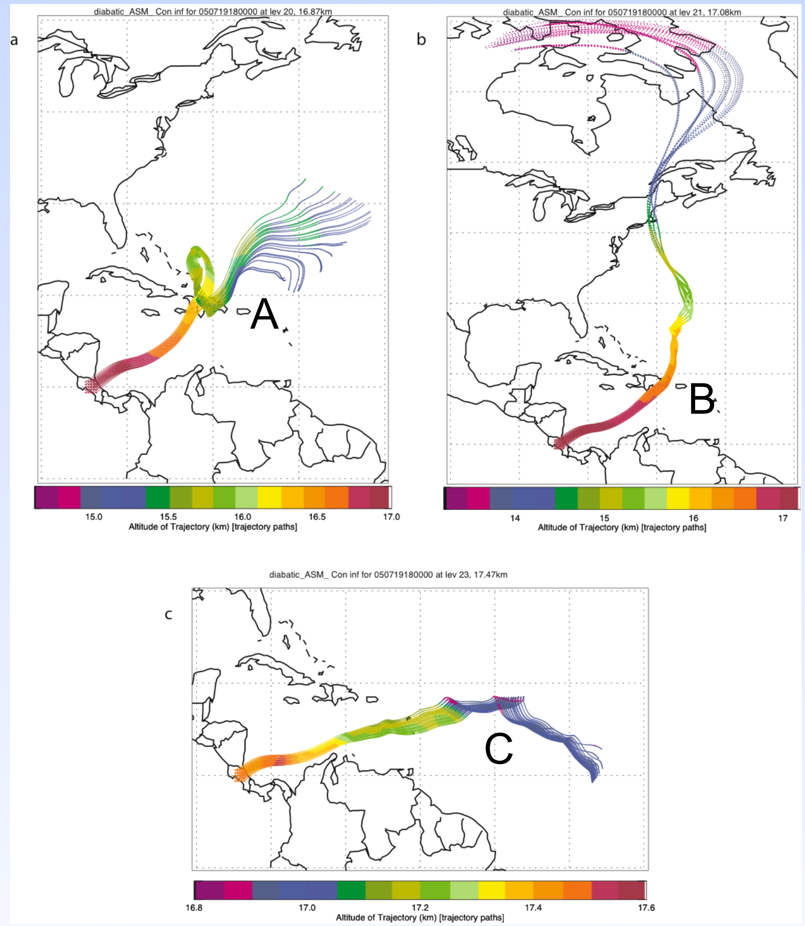


Gravity wave displacements modulate deep positive ozone anomaly in LMS

High ozone in water vapor anomaly requires non-local origin – transport from higher latitudes?

Trajectory analysis confirms role of horizontal transport in LMS for July 19, 2005 case





- *Advection of deep layer from subtropics*
- *Gravity wave-like (adiabatic) variations embedded*

10-day Back trajectories from Costa Rica (courtesy L. Pfister)

Distinguish three modes of variability displayed by WV and O_3 in UT/LS

WAVE VARIABILITY

- anomalies due to cross-gradient adiabatic displacements induced by equatorial inertio-gravity waves

SOURCE VARIABILITY

- anomalies due to quasi-horizontal transport from a remote region, *e.g.,* the tropical western Pacific, extra-tropical latitudes

PATH VARIABILITY

- anomalies due to physical processes occurring along the path of horizontal transport, *e. g.,* dehydration, convective mixing

➢ *These modes are sensitive to the structure and dynamics of the background atmosphere and therefore seasonally dependent*

OUTLINE OF TALK

A. SEASONAL MEAN STRUCTURE OF T, WATER VAPOR and OZONE – boreal winter (Nov-Mar) and summer (JJA)

B. SOUNDING EXAMPLES – from winter and summer

C. ESTIMATING WAVE VARIABILITY – adiabatic variance fraction

D. PROFILES OF O_3 and WV IN POTENTIAL TEMPERATURE COORDINATES

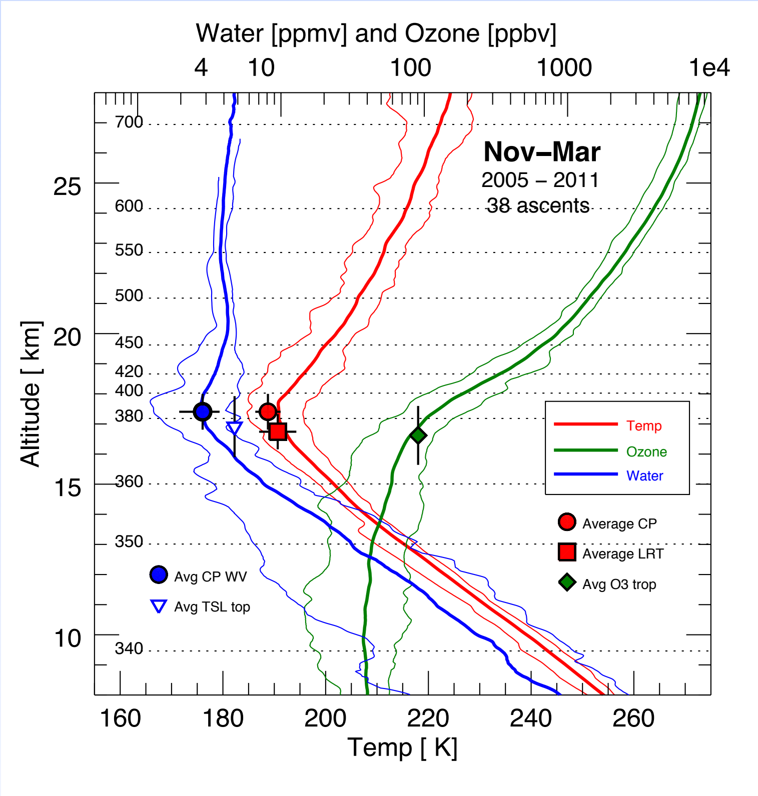
E. SEASONAL SCATTER DIAGRAMS

F. MLS RDF PROFILES and INFERENCES FROM COMPARISON TO SONDE SCATTER DIAGRAMS

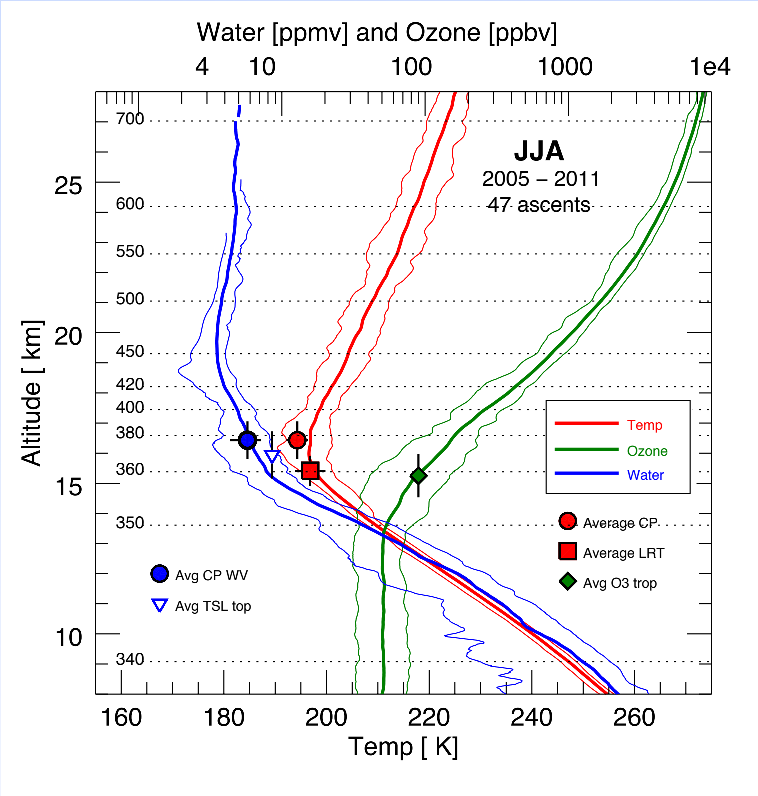
G. SUMMARY

Mean UT/LS profiles

Winter



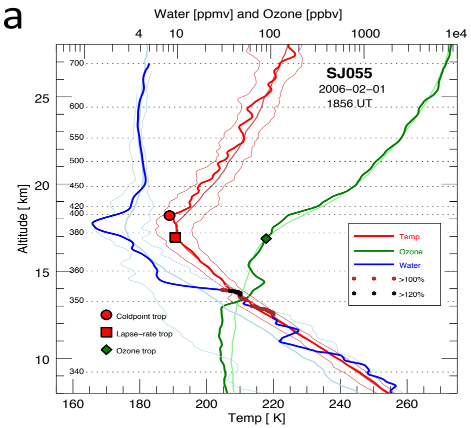
Summer



Selected profiles

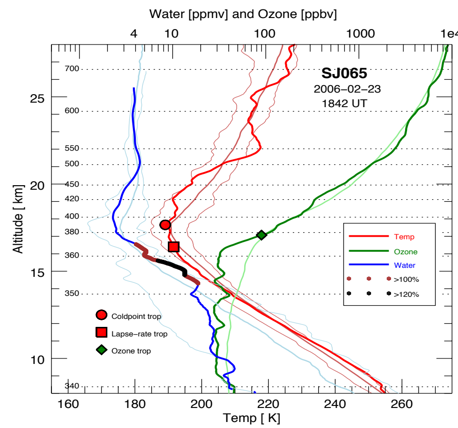
WINTER

a



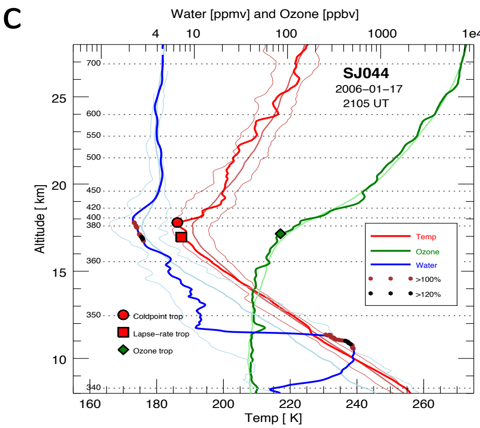
lo O_3 below 15 km
dry UT and LMS

b



deep waves in LS, lo UT O_3
saturated UT, lo WV in LS

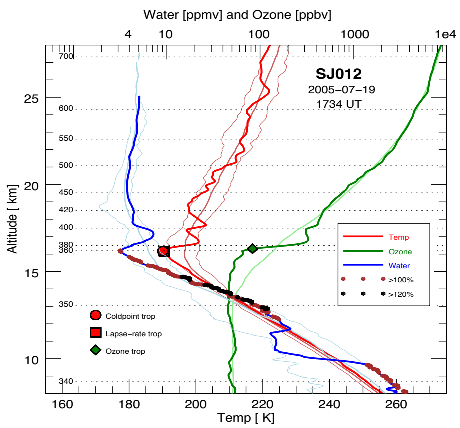
c



Cold CP, dry UT

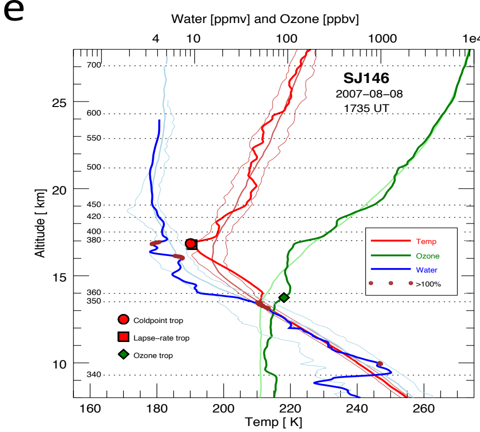
SUMMER

d



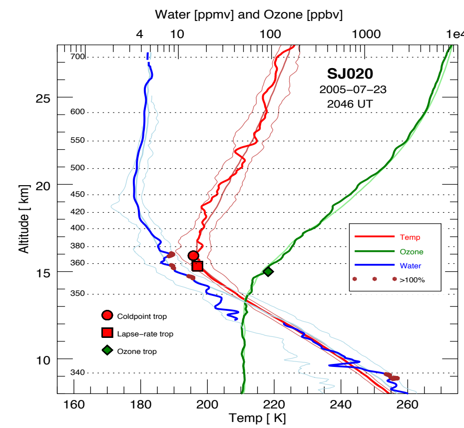
wavy LMS, very cold CP
lo UT O_3, hi LS O_3
saturated UT, hi WV in LMS

e



deep wave in UT, cold CP
hi/lo UT O_3, hi LS O_3
dry UT

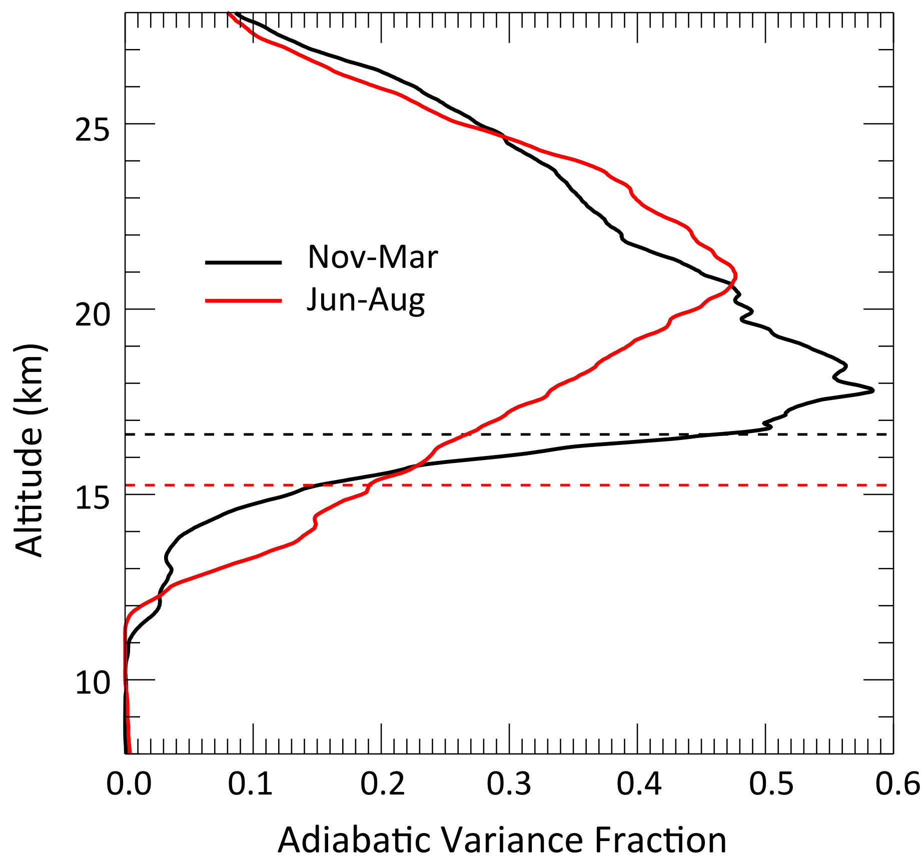
f



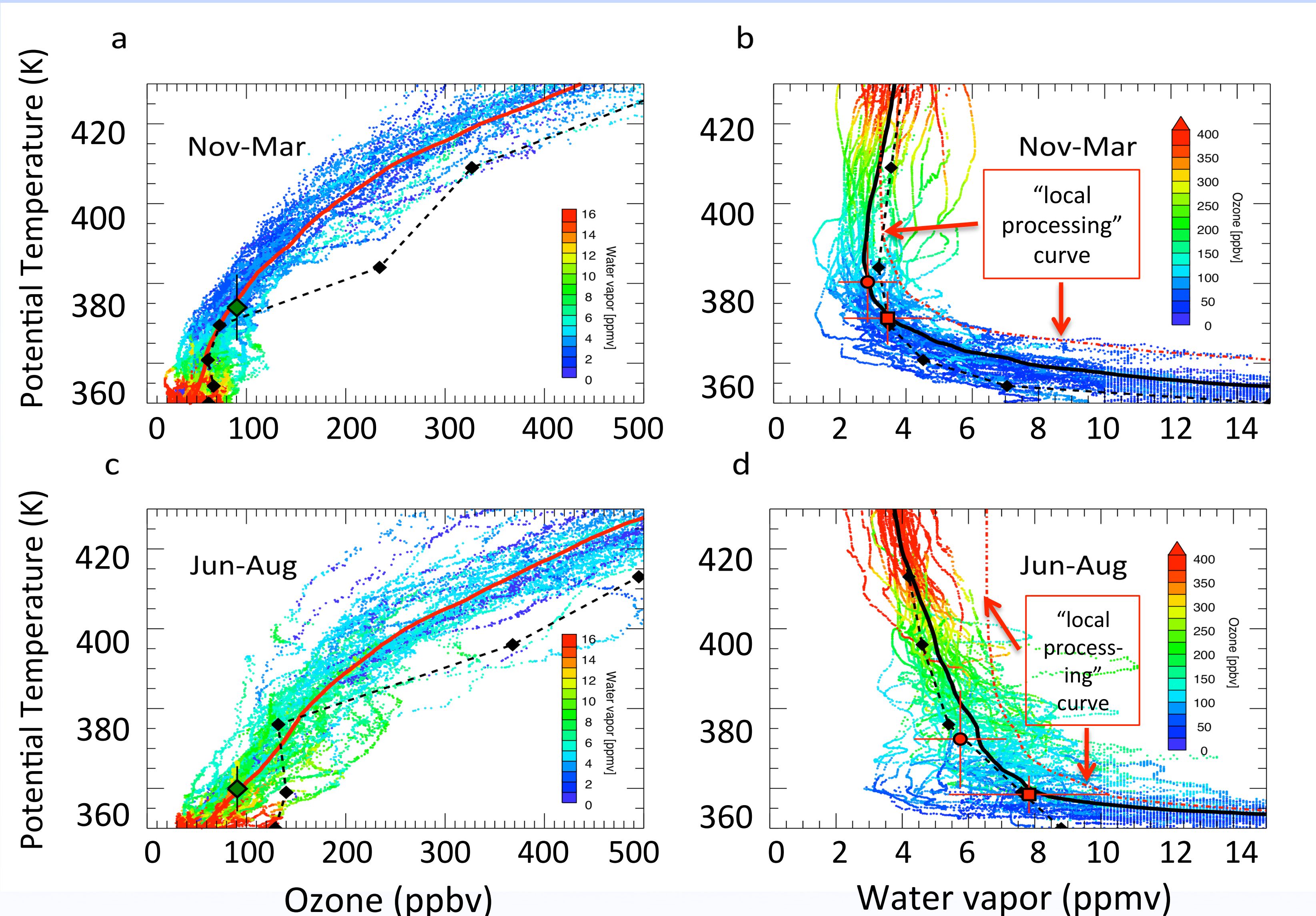
Adiabatic variance fraction

$$F_\theta = \left[\frac{\partial \overline{\mu}}{\partial z} \Big/ \frac{\partial \overline{\theta}}{\partial z} \right]^2 \frac{V_\theta}{V_\mu}$$

- F_θ expresses the fraction of a tracer's variance due to adiabatic displacements
- The lower the value of F_θ above the tropopause is indicative of more influence by horizontal transport
- For example, the LMS in the Jun-Aug period is thus relatively more affected by horizontal transport



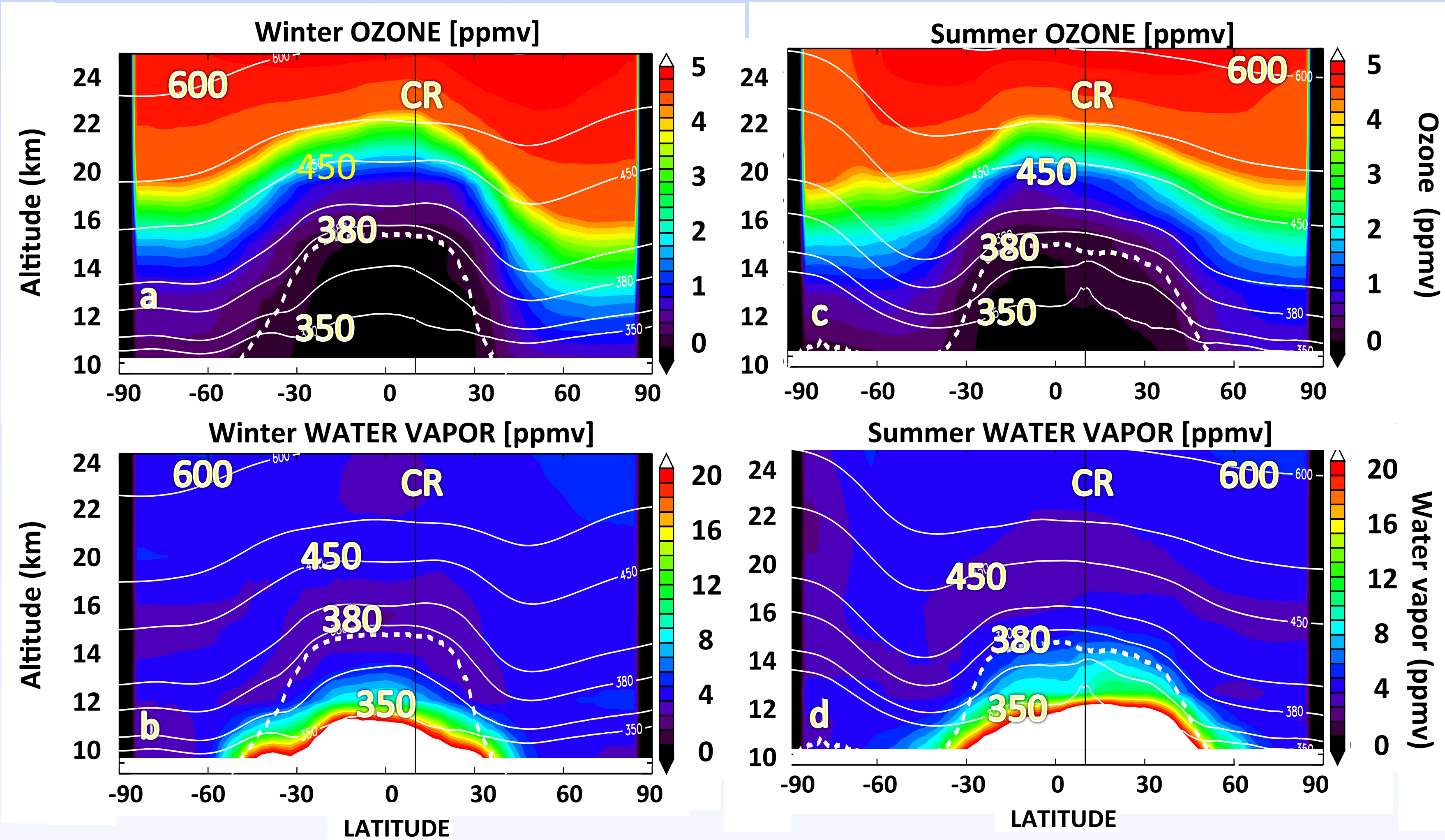
Ozone and Water Vapor vs. Theta



CT3LS Meeting
Boulder, CO

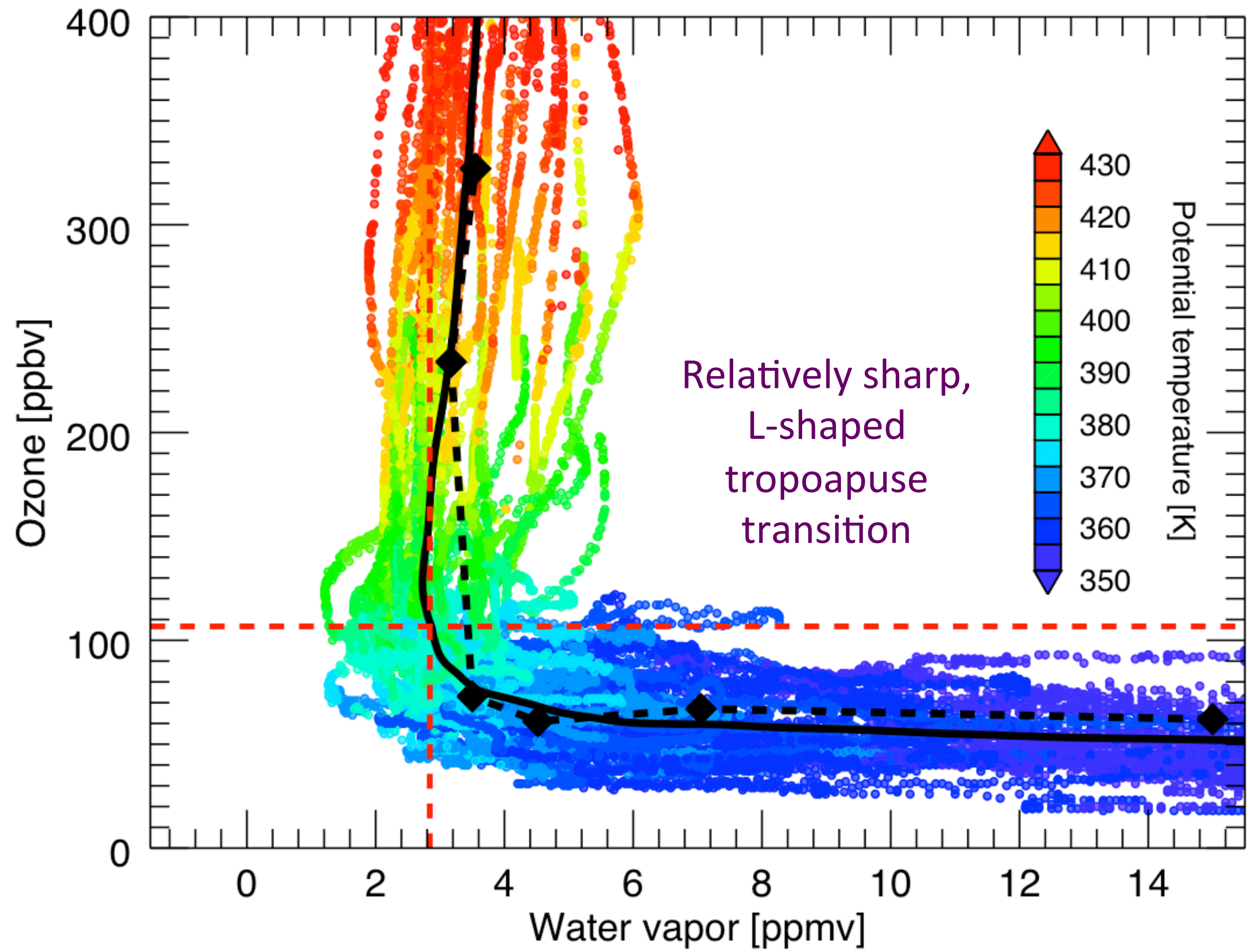
22 July 2015

MLS Ozone and Water Vapor

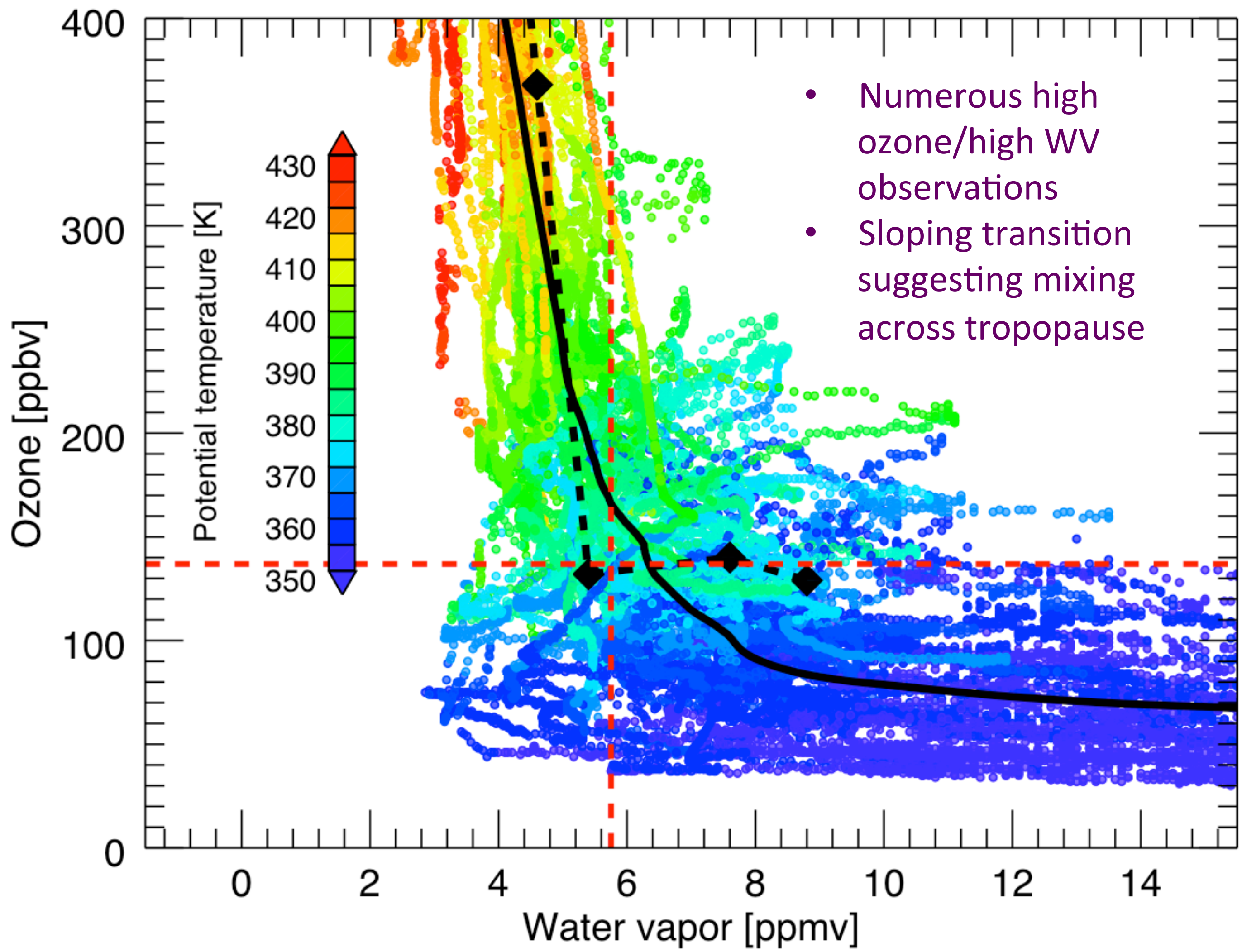


- *Isentropes 350 K and above connect the tropics and mid-latitudes so it is possible for mid-latitude ozone to move into the tropics isentropically*

Ozone-water vapor scatterplot: Winter

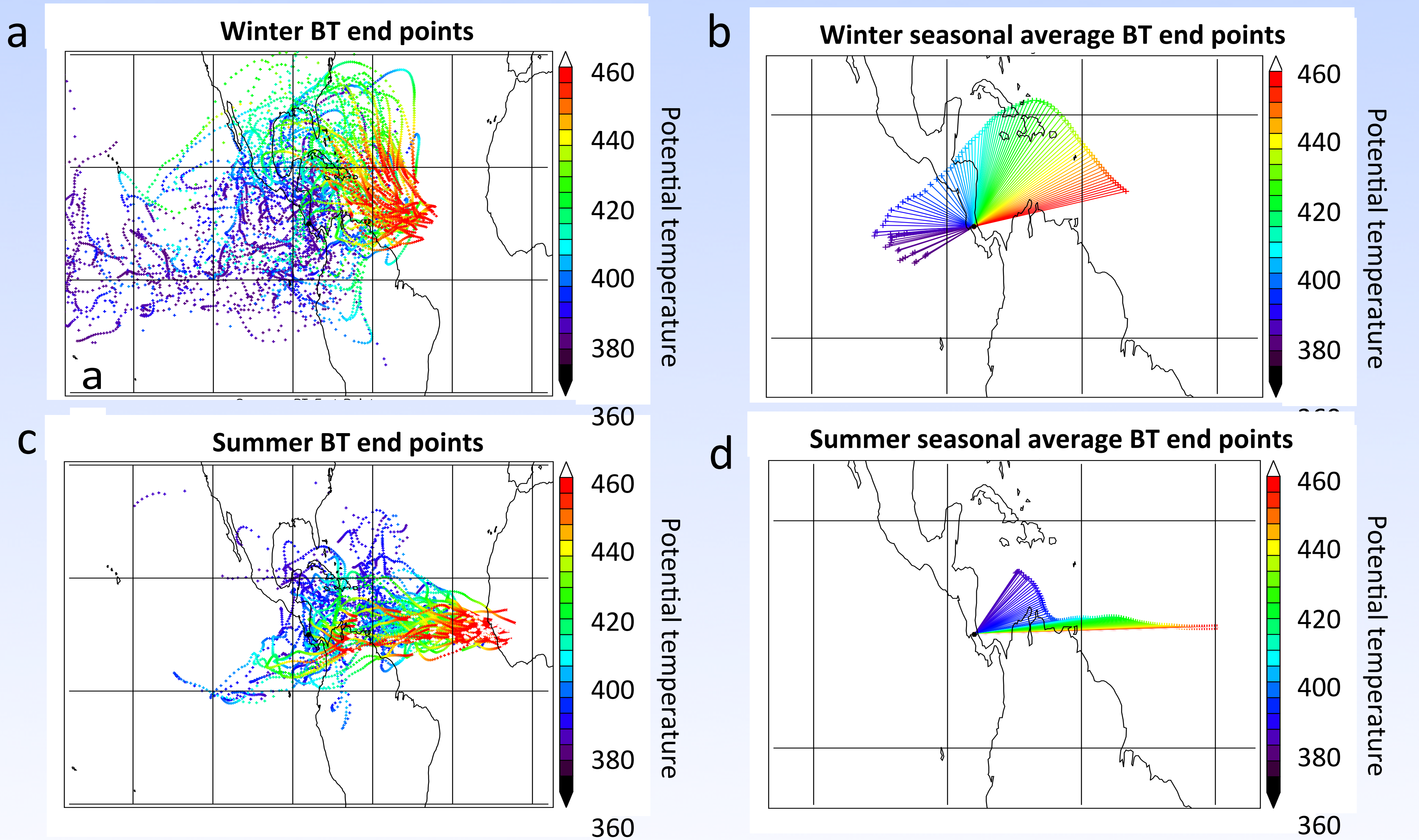


Ozone-water vapor scatterplot: Summer

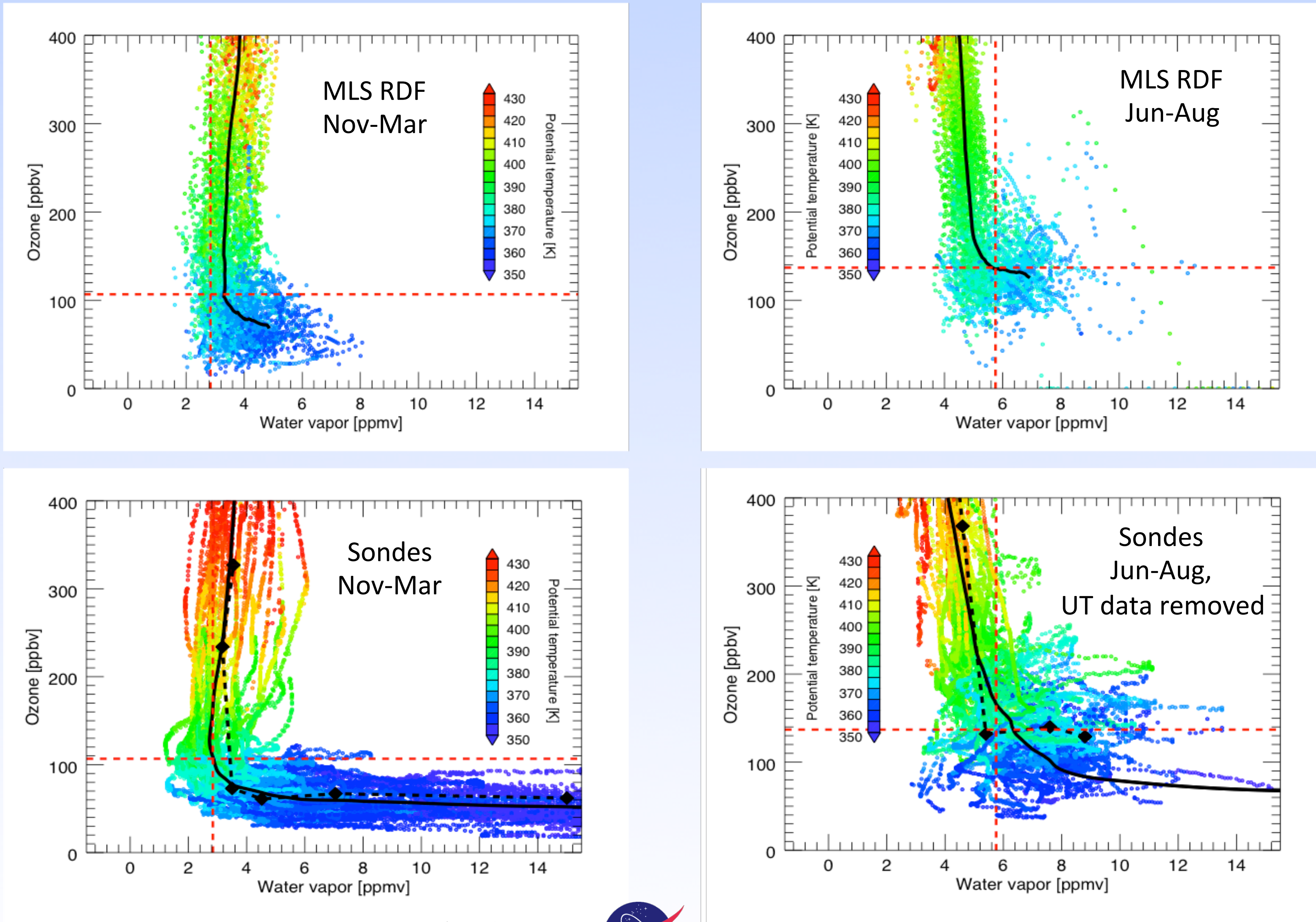


- Numerous high ozone/high WV observations
- Sloping transition suggesting mixing across tropopause

Back trajectories



MLS RDF vs sonde scatterplots



SUMMARY

- Useful to distinguish three modes of WV and ozone variability in the UT/LS: **wave, source** and **path**
- Relatively less **wave variability** in summer lowermost stratosphere – evidence of greater transport from extra-tropics compared to winter
- MLS data support isentropic flow into tropics to yield enhanced water vapor and ozone clearly seen in summer O_3-H_2O scatterplot – evidence of **source variability**
- "Local processing" curve in both seasons indicates that stratospheric dehydration occurred elsewhere – likely in TWP during winter
- MLS RDF profiles capture many features of sonde scatterplots – supports dominance of source variability in winter, but discrepancies in summer may be attributed to upstream injection of water vapor into LMS by deep convection – a form of **path variability**

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Ticosonde would not be possible without the close partnerships we have enjoyed with our Costa Rica Co-Investigators Dr. Jorge Andrés Diaz and Dra. Jessica Valverde and their launch teams.