Structures of Tropical Tropospheric Ozone Profiles

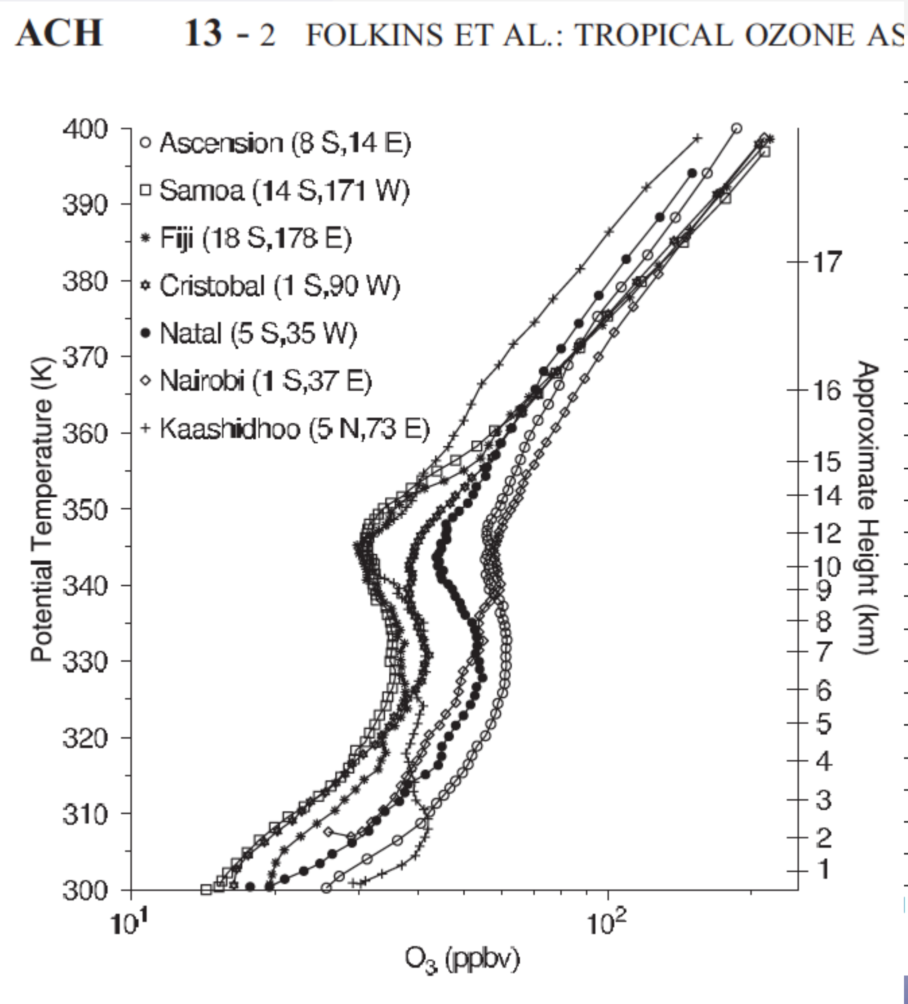
Observed in CONTRAST and

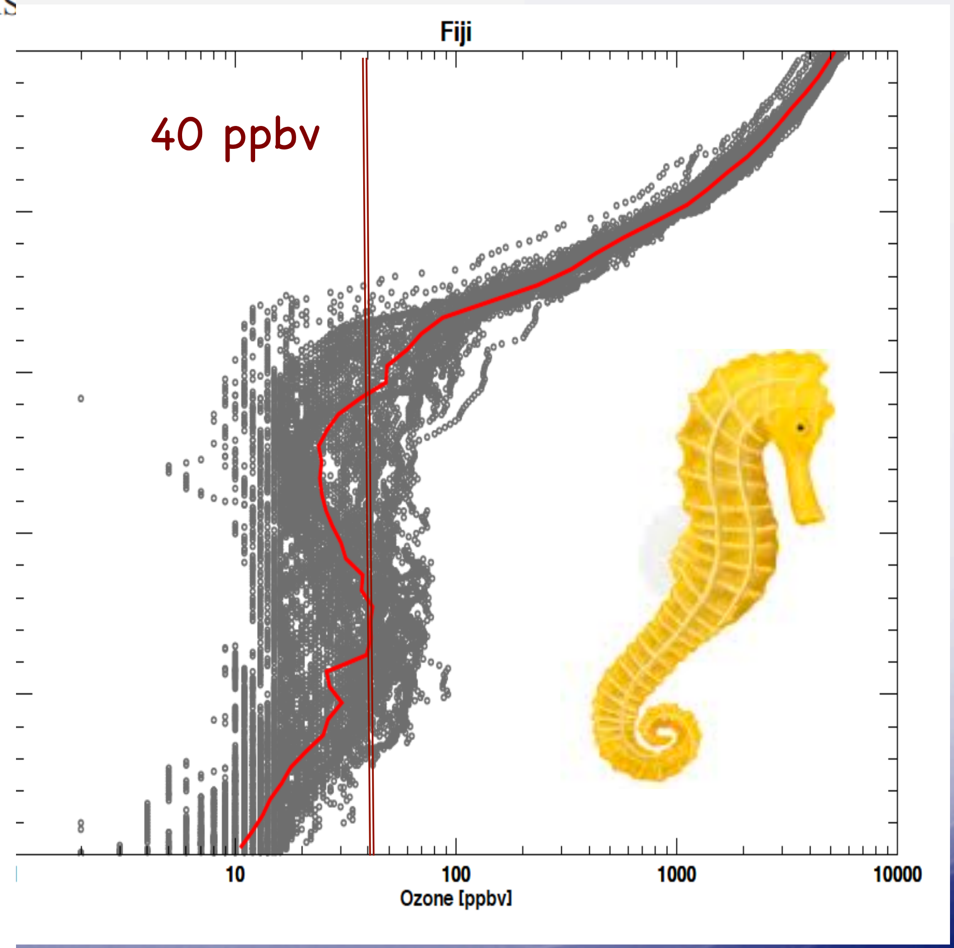
Analyses of the Controlling Mechanisms

Laura Pan and Shawn Honomichl

With Contributions from
Elliot Atlas, Bill Randel, Jim Bresch, Doug Kinnison, Eric Apel, Becky Hornbrook, Andy Weinheimer, and Teresa Campos

The "Conventional View" of the Tropical Ozone Profile:
"seahorse shaped"





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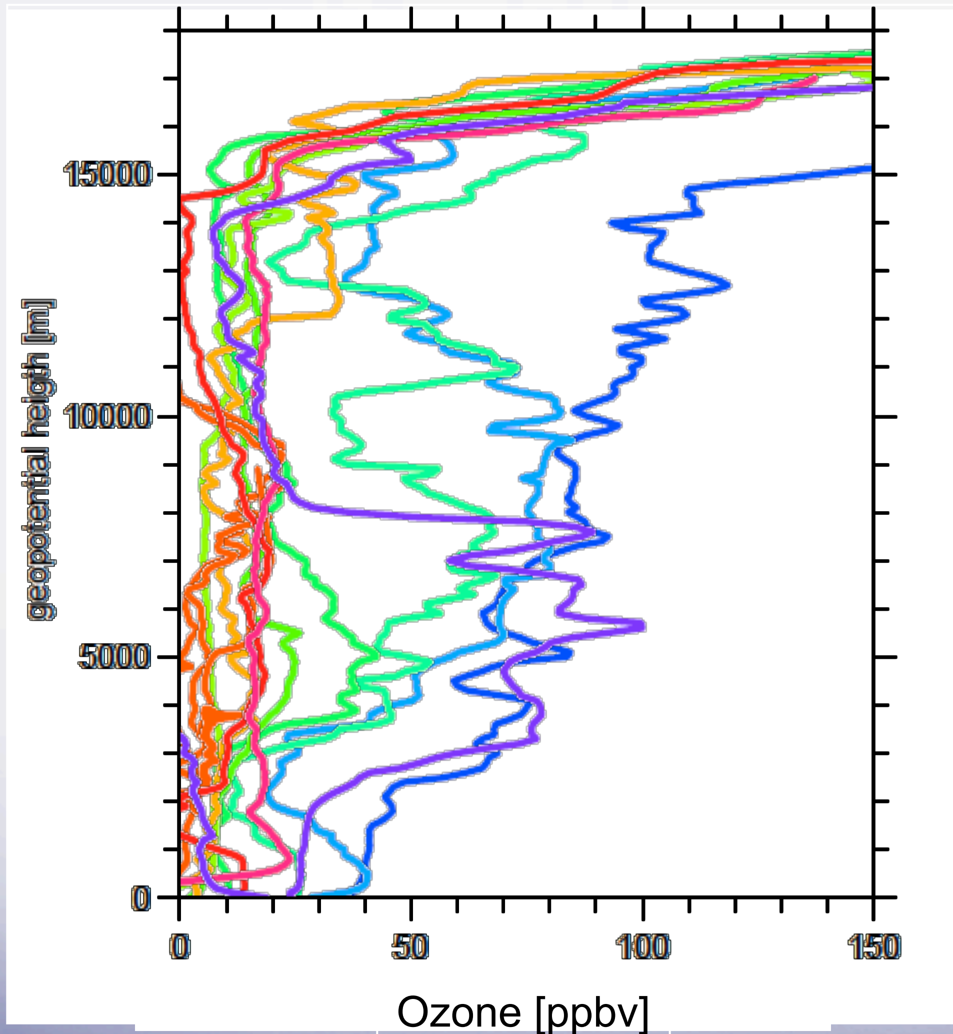
"near zero ozone?"

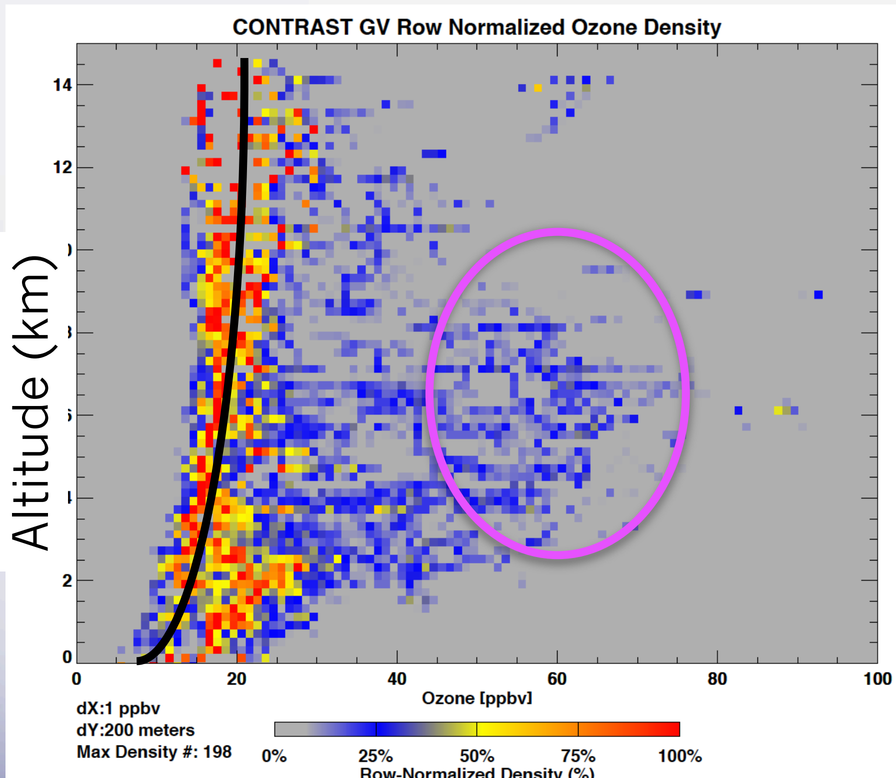
Ozone profile measurements in the West Pacific

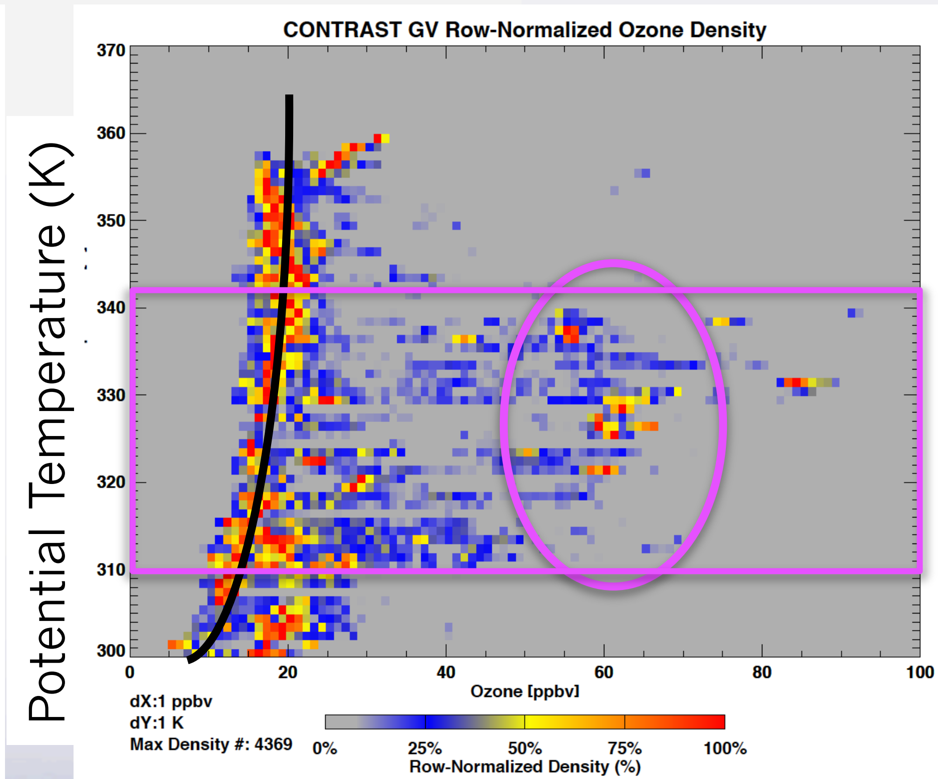


091011: 33.5°N
091012: 26.2°N
091013: 23.1°N
091014: 18.8°N
091015: 14.9°N
091016: 10.5°N
091017: 6.2°N
091018: 1.1°N
091019: 3.1°S
091020: 7.2°S
091021: 11.8°S
091022: 14.4°S

Rex, M., Wohltmann, I., Ridder, T., Lehmann, R., Rosenlof, K., Wennberg, P., Weisenstein, D., Notholt, J., Krüger, K., Mohr, V., and Tegtmeier, S.: A tropical West Pacific OH minimum and implications for stratospheric composition, Atmos. Chem. Phys., 14, 4827-4841, doi:10.5194/acp-14-4827-2014, 2014.

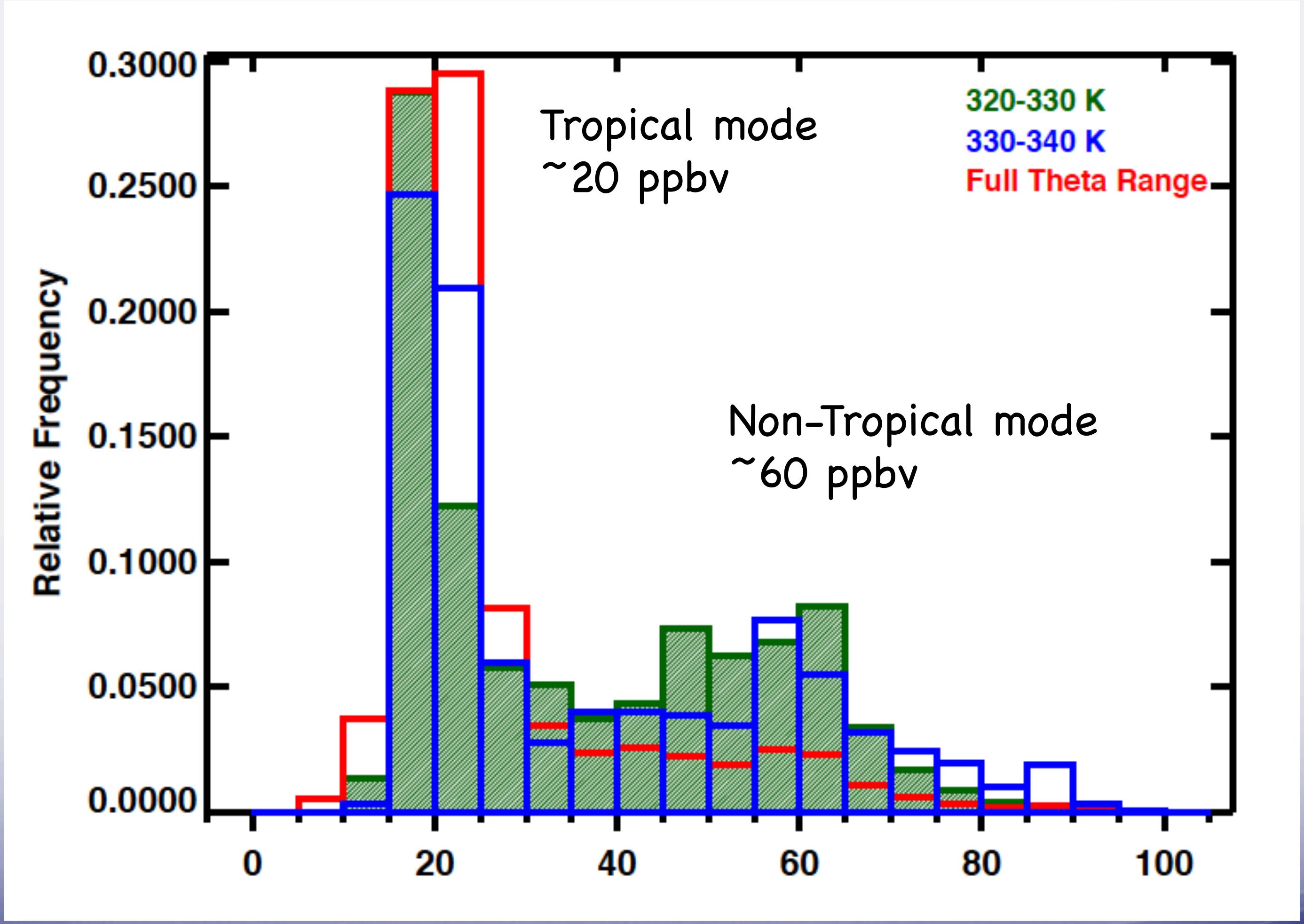
WP Tropospheric O_3 – a Bi-modal Distribution





"Tropical mode" "Non-Tropical mode"

The Bi-modal distribution is most pronounced In 320-340 K range



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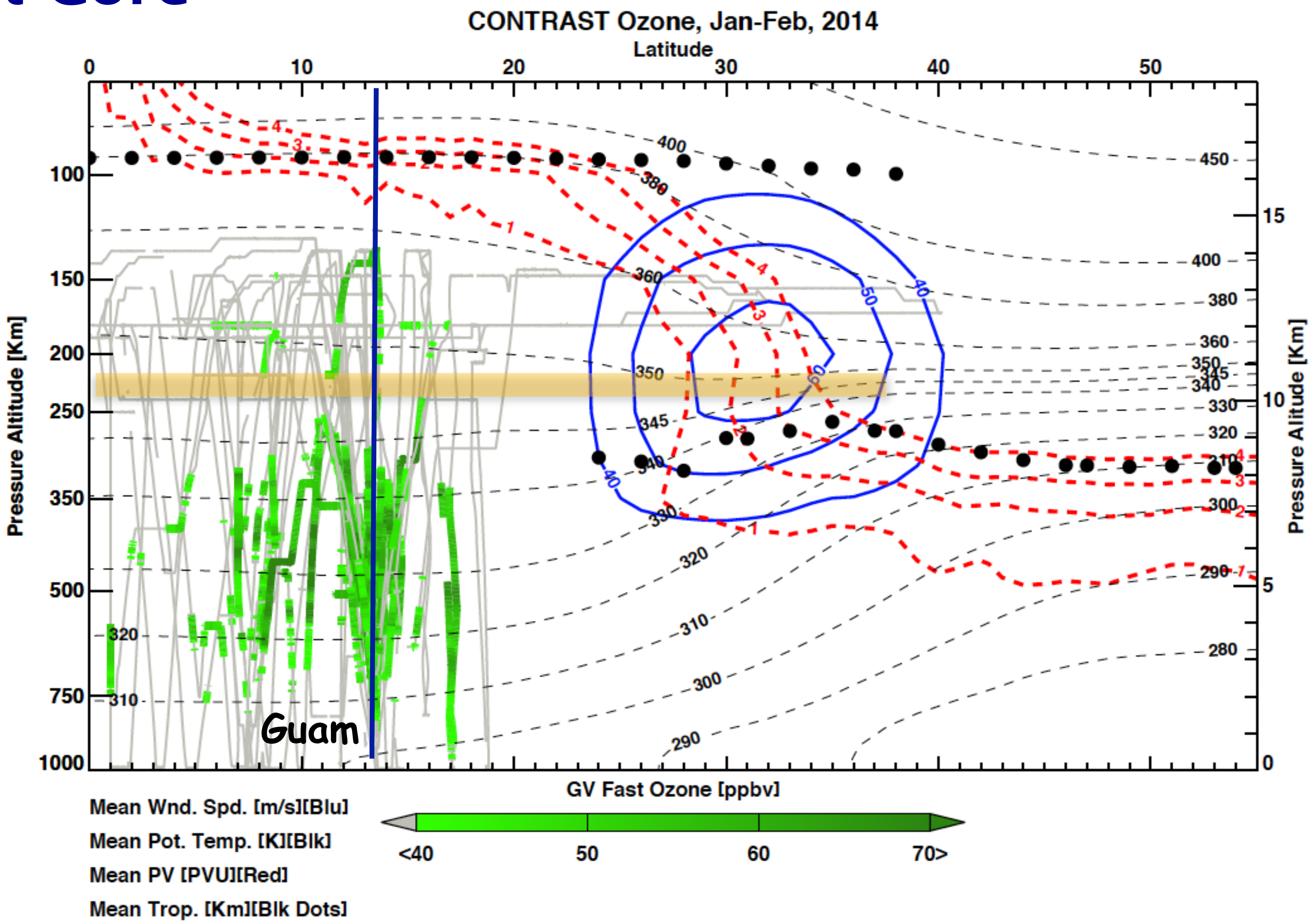
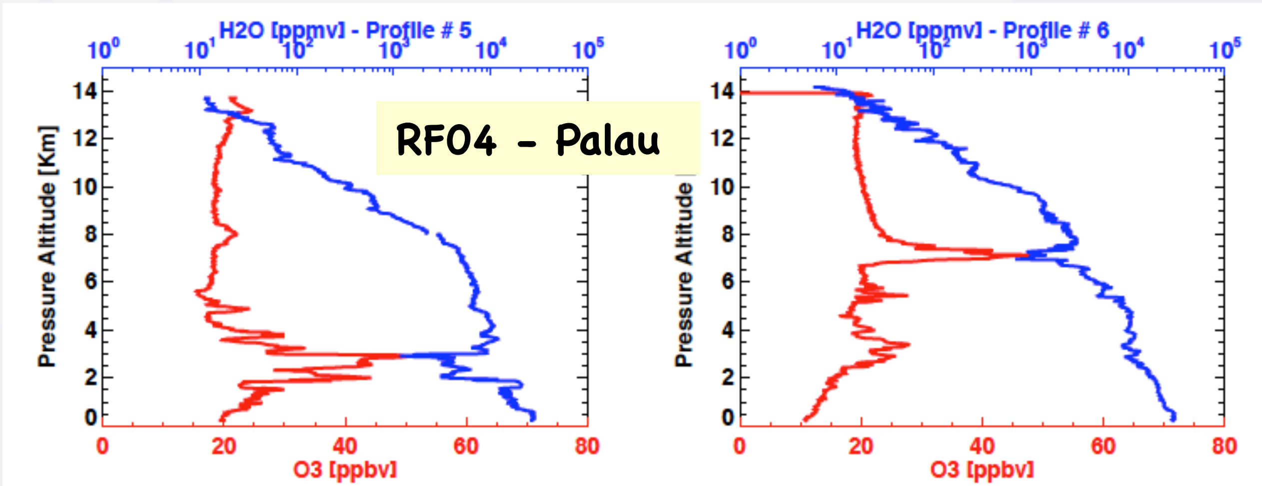
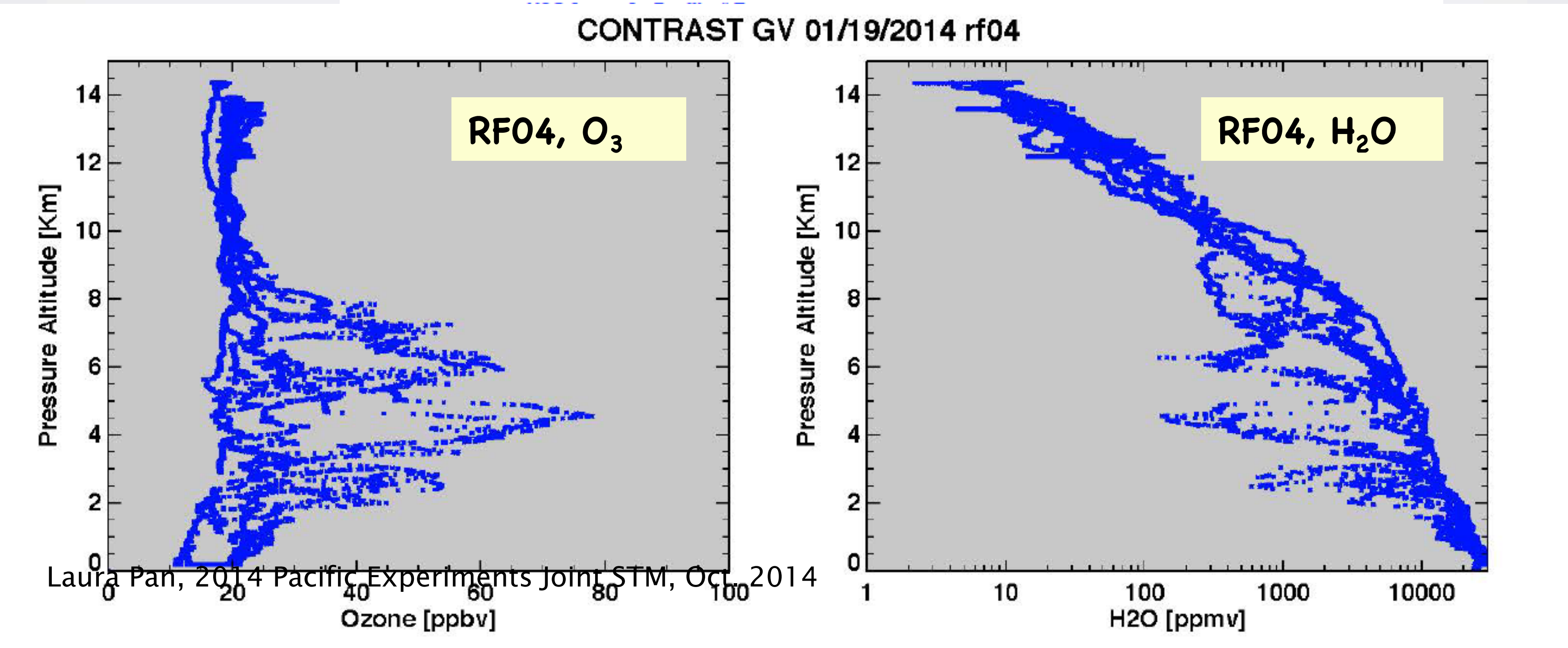
Relationship of O_3 Enhanced Layer and the Jet Core

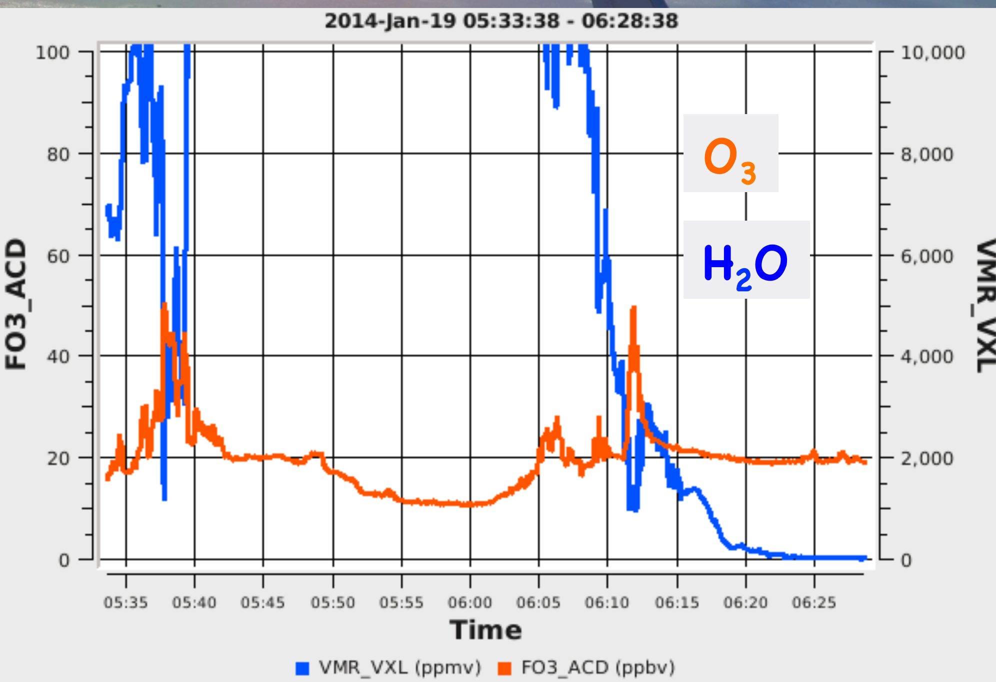


Persistent presence of layers of anti-correlated O_3 & H_2O





Where we measured thin filaments of O_3 layers that are anti-correlated with H_2O



GV was at ~ 500 ft between approximately 05:45 → 06:00. The ozone- water vapor anti-correlation structure was near 20-25 Kft.

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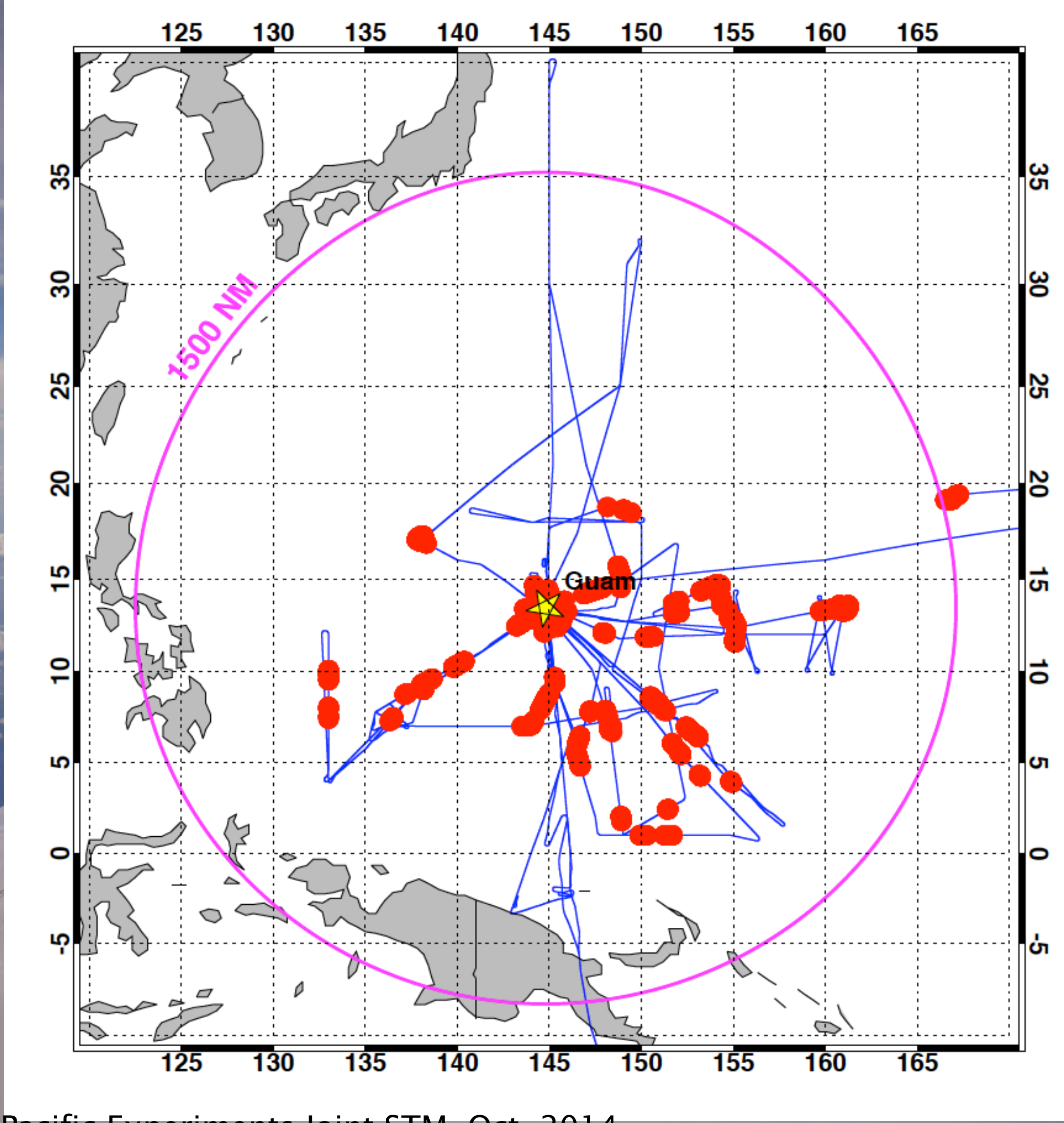
Locations of the anti-correlated layers



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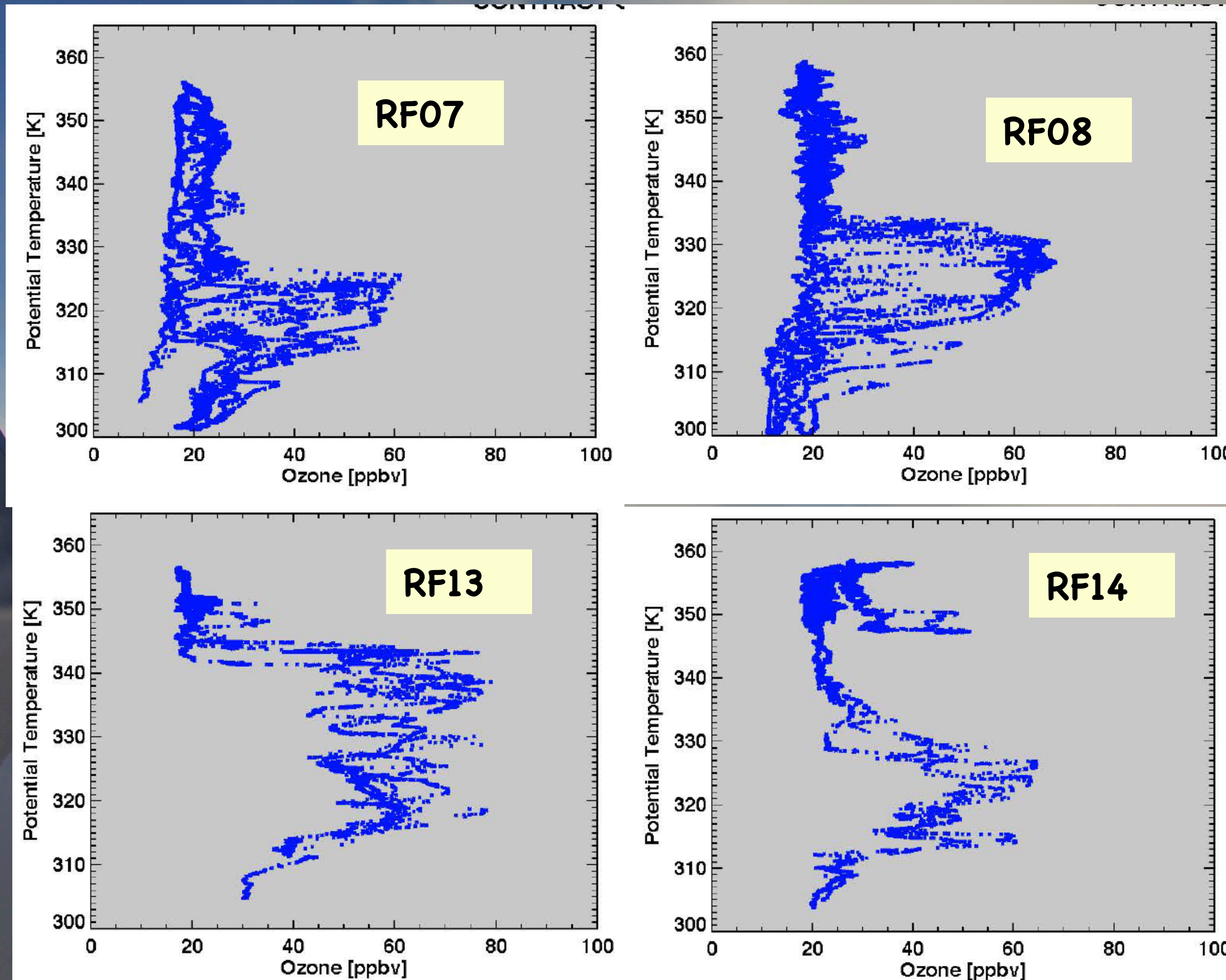
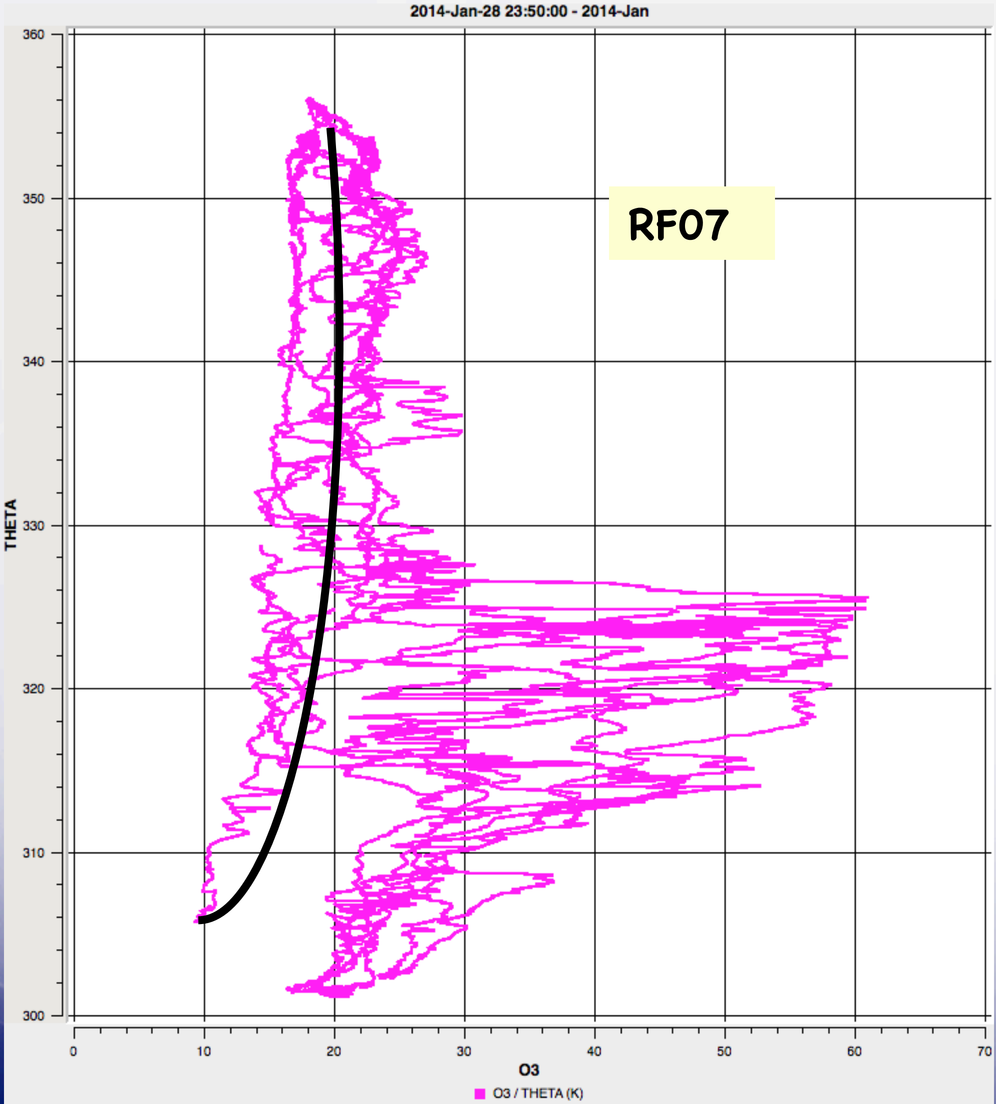

RF07
RF08
RF13
RF14
Potential Temperature [K]
360
350
340
330
320
310
300
Ozone [ppbv]
0
20
40
60
80
100

"Goose-Shaped" profiles?



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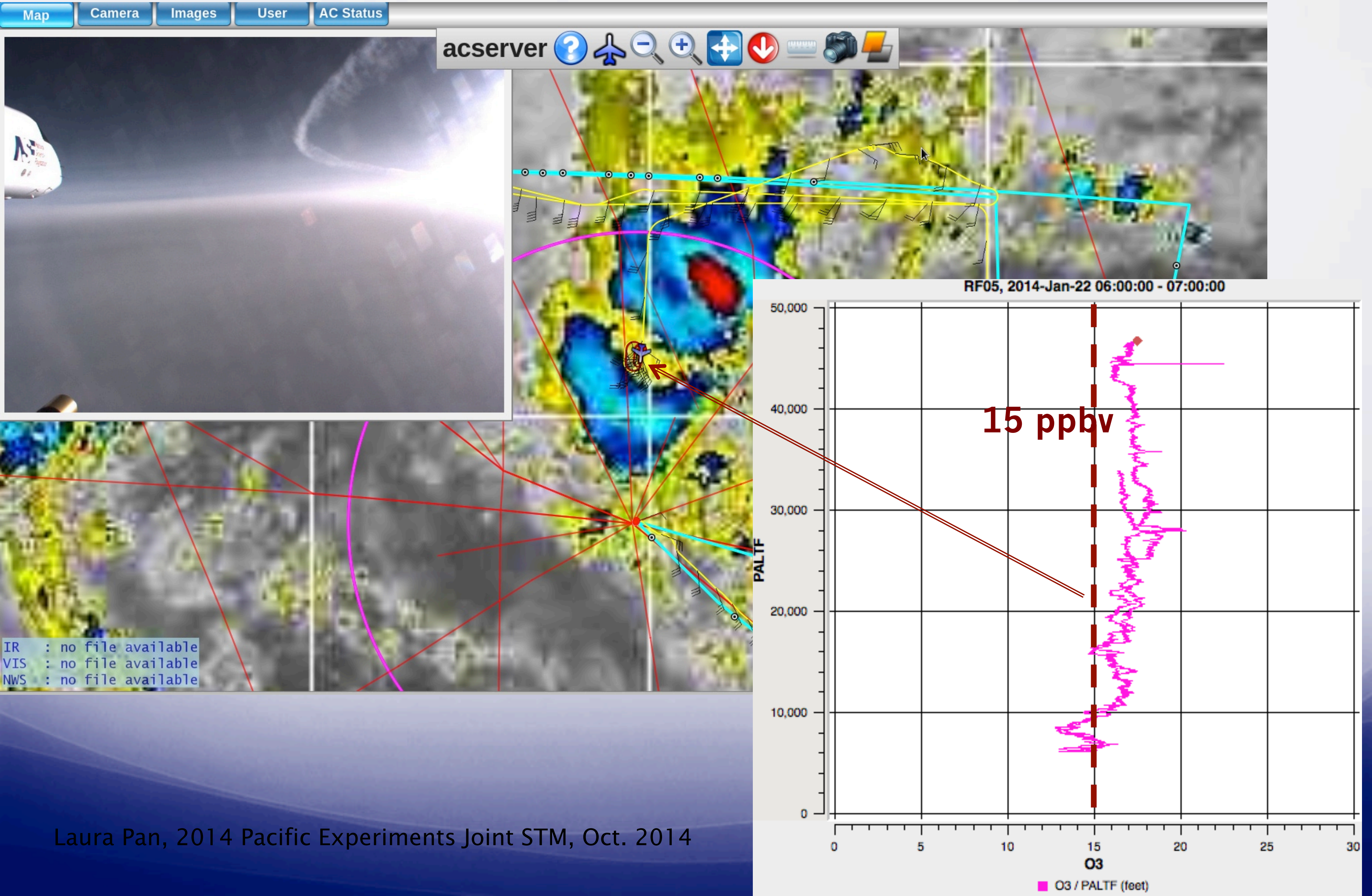
The convectively controlled O_3 profile: between two towers (no enhanced ozone layer here…)



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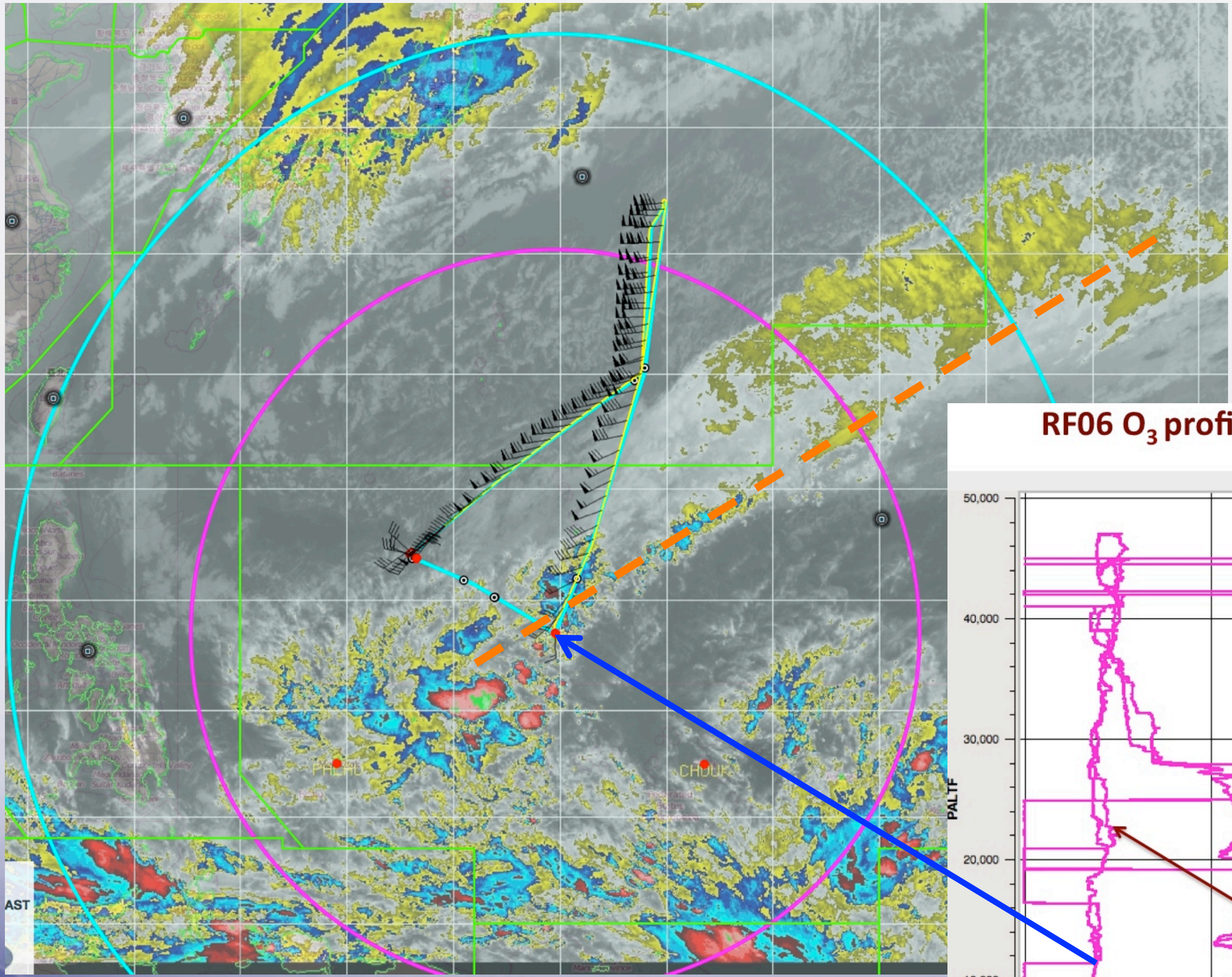
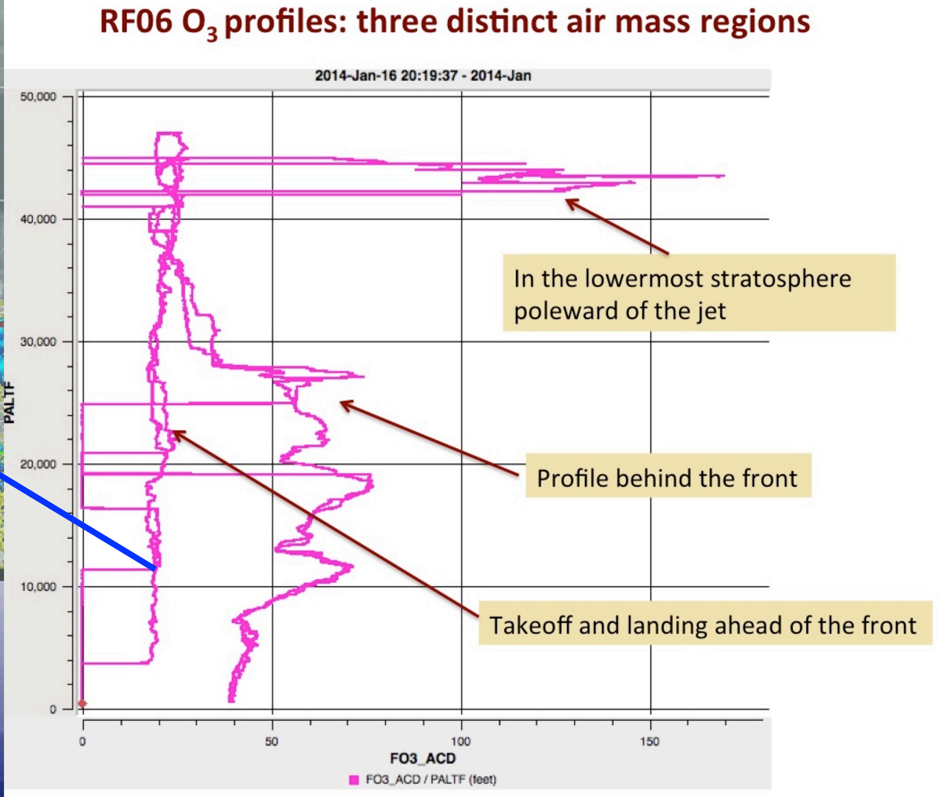
The convectively controlled O_3 profile: Ahead of a front/shear line (no enhanced ozone layer here…)





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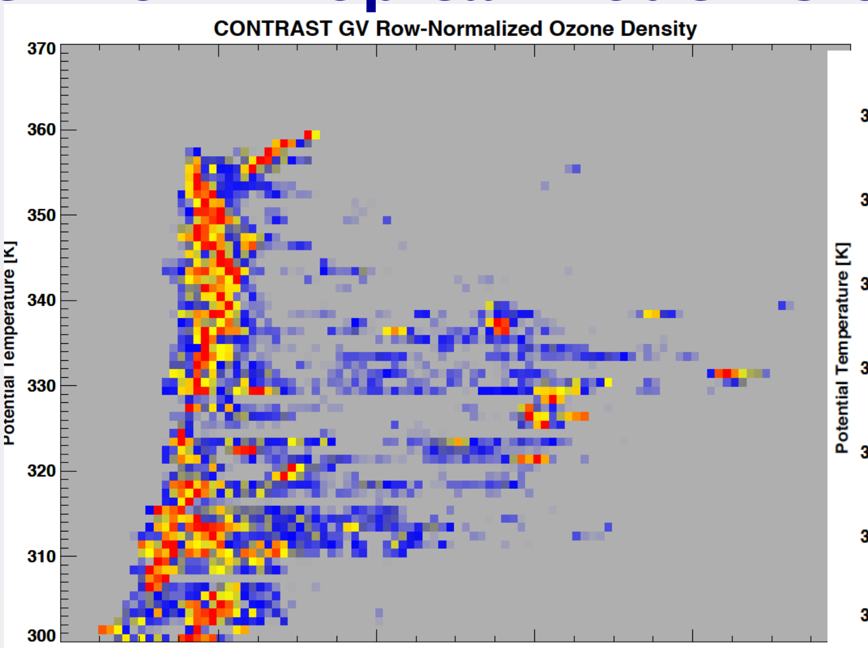
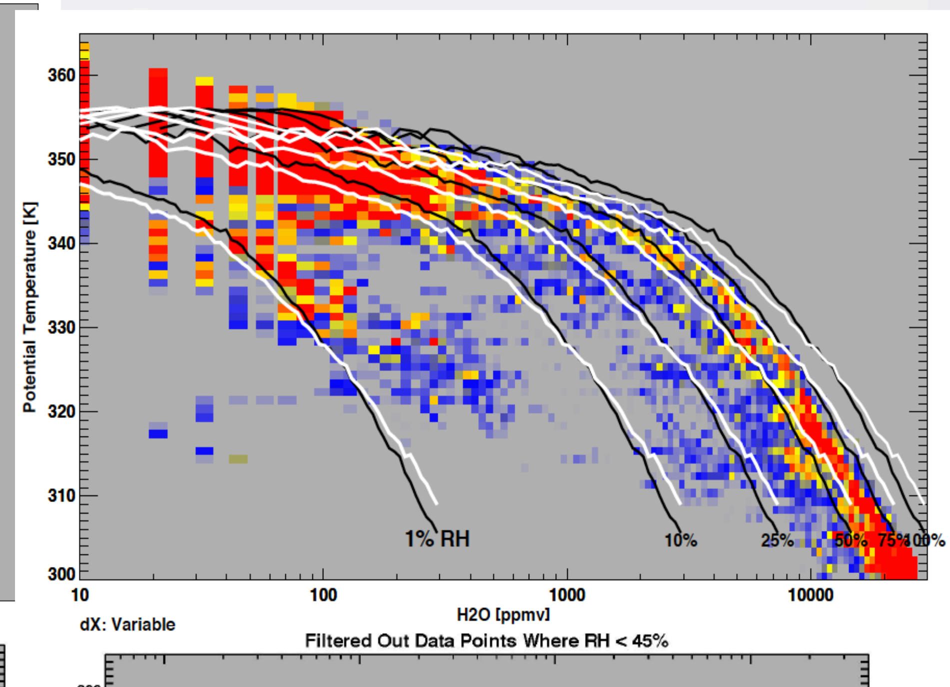
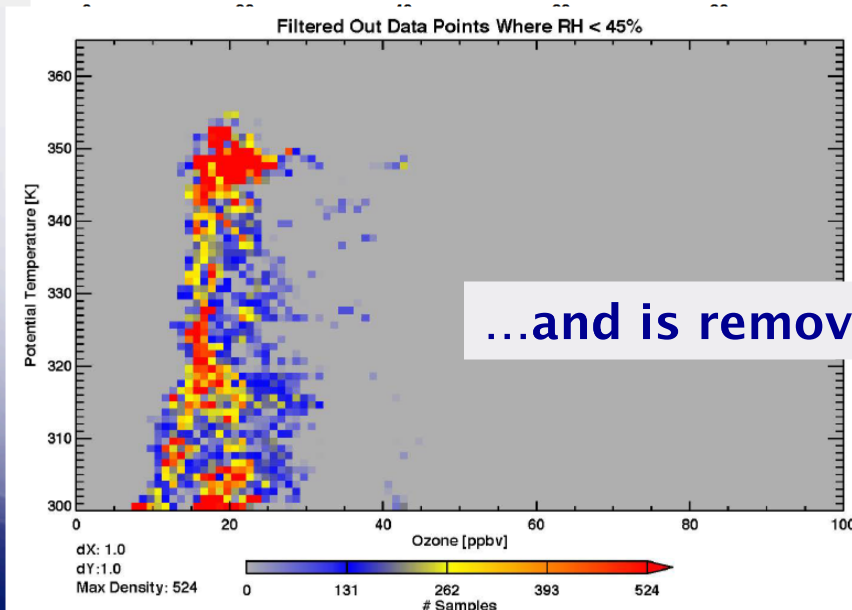
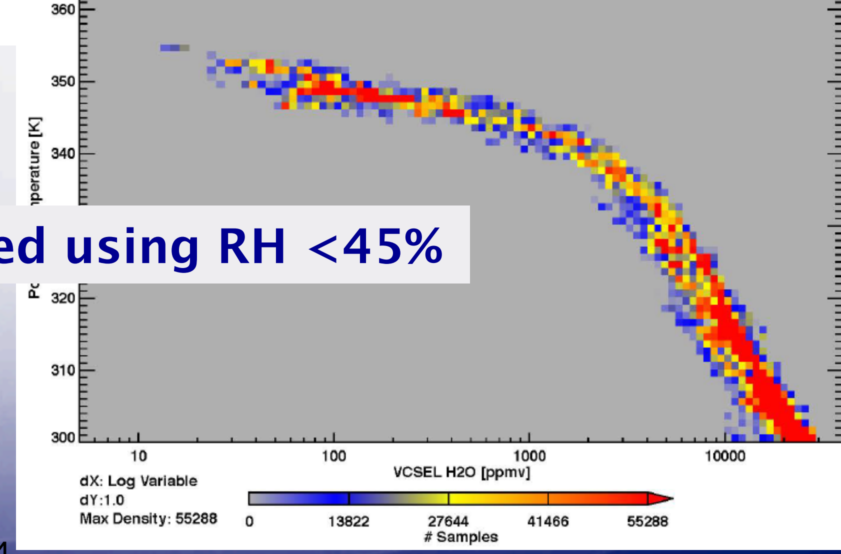
The “Non-Tropical Mode” is correlated with dry air mass









…and is removed using RH <45%

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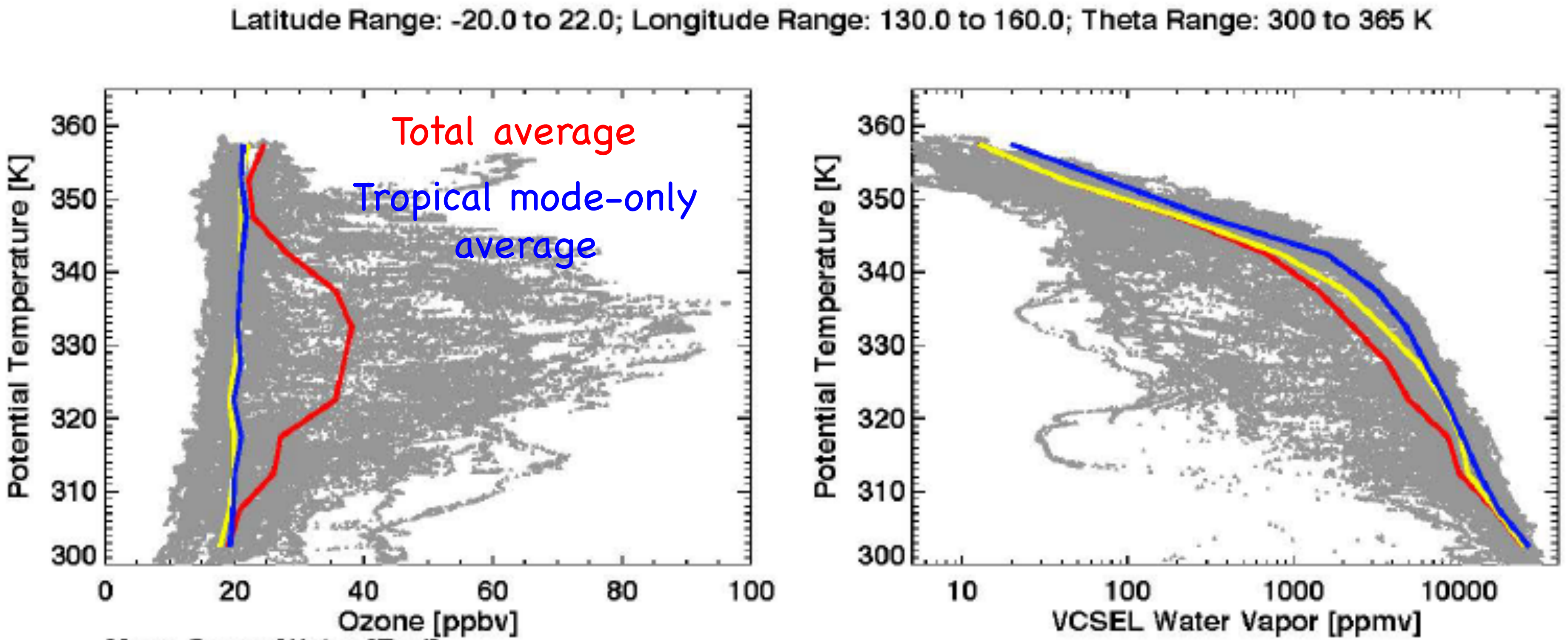
The “truth” revealed by CONTRAST measurements:

the “belly of the seahorse” is a result of averaging two modes



Mean Ozone/Water [Red]
Mean Ozone/Water (Ozone < 30 ppbv) [Yellow]
Mean Ozone/Water (RH > 45%) [Blue]


Q:
What processes control the non-tropical mode?
Laura Pan, 2014 Pacific Experiments Joint STM, Oct. 2014

TOGA COARE: "Dry Intrusions"

A Proposed Mechanism for the Intrusion of Dry Air into the Tropical Western Pacific Region

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Japan Marine Science and Technology Center, Yokosuka, Japan

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(Manuscript received 20 October 1997, in final form 27 May 1998)

ABSTRACT

Recent studies using data from the Tropical Ocean and Global Atmosphere program's Coupled Ocean–Atmosphere Response Experiment (TOGA COARE) have shown that synoptic-scale areas of extremely dry air can occur in the troposphere over the equatorial western Pacific. These layers of extremely dry air modify convective activity and the vertical profile of radiation in clear air. At the present time there is some disagreement as to the dynamic mechanism responsible for these events and a number of their characteristics are relatively unknown. In this study, the origin and characteristics of the dry air events were investigated through analysis of TOGA COARE rawinsonde data and examination of global analyses from two different forecast centers. These drying events were found to be very common and evidence was presented that their intensity was underestimated in the global analyses. These dry events were shown to most often originate in the Northern (winter) Hemisphere as troughs associated with baroclinic waves intensified and expanded equatorward, leading to a process analogous to Rossby wave breaking. In these cases, the dry air at the edge of the westerlies at upper levels was incorporated into the equatorward extension of thin NE–SW tropospheric troughs, where it subsided and was subsequently advected equatorward. If sufficient subsidence took place, the dry air continued flowing equatorward on the eastern edge of well-defined anticyclones in the lower troposphere. The dry air in one case originated in a Southern (summer) Hemisphere trough that was associated with midlatitude baroclinic waves that propagated equatorward and developed into a series of distinct disturbances along a subtropical jet. In both the Northern and Southern Hemisphere events, the subsiding dry air in the midtroposphere was injected into the fringes of the Tropics, where it was able to reach equatorial regions if it interacted with favorable meridional flow in the Tropics. Past studies have proposed that these intrusions of dry air could induce droughts in the Tropics through decreasing deep convective activity. The implication of this study is that these droughts are actually induced by midlatitude processes.

PEM–Tropics A, B: ozone layers

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 104, NO. D5, PAGES 5745–5764, MARCH 20, 1999

Measurements of atmospheric layers from the NASA DC-8 and P-3B aircraft during PEM-Tropics A

P. Stoller,[1] J. Y. N. Cho,[1] R. E. Newell,[1] V. Thouret,[1,2] Y. Zhu,[1] M. A. Carroll,[3] G. M. Albercook,[3] B. E. Anderson,[4] J. D. W. Barrick,[4] E. V. Browell,[4] G. L. Gregory,[4] G. W. Sachse,[4] S. Vay,[4] J. D. Bradshaw,[5,6] and S. Sandholm[5]

Abstract. Tropospheric vertical structure was analyzed using in situ measurements of O_3, CO, CH_4, and H_2O taken on board the NASA DC-8 aircraft during three Pacific Exploratory Missions (PEMs): PEM-West A, September-October 1991 in the western Pacific; PEM-West B, February-March 1994 in the western Pacific; and PEM-Tropics A, September-October 1996 in the central and eastern Pacific. PEM-Tropics A added measurements from the NASA P3-B aircraft. We used a new mode-based method to define a background against which to find layers. Using only O_3 and H_2O, we found 472 layers in PEM-Tropics A (0.72 layers per vertical kilometer profiled), 237 layers in PEM-West A (0.54 layers/km), and 158 layers in PEM-West B (0.41 layers/km). Using all constituents, we found 187 layers in PEM-Tropics A (0.43 layers/km), 128 layers in PEM-West A (0.29 layers/km), and 80 layers in PEM-West B (0.21 layers/km). Stratospheric air, sometimes mixed with trapped pollution, was the dominant layer source in all three missions. The larger number of layers per kilometer in PEM-Tropics A was probably due to repeated profiling of several "superlayers" visible in many of the mission lidar and potential vorticity profiles. The thickness of the superlayers was of order 1 km, and the horizontal extent was of order 1000 km. We found that layers have an important effect on the thermal structure. An example based on ozonesonde data from Tahiti is shown, where a dry, subsiding layer was stabilized by much greater radiative cooling at the base than at the top. The stabilized layer can trap pollution and force vertical plumes to spread into horizontal layers.

SHADOZ ozone layers

Atmos. Chem. Phys., 8, 2609–2621, 2008
www.atmos-chem-phys.net/8/2609/2008/

Atmospheric Chemistry and Physics

Ozone-enhanced layers in the troposphere over the equatorial Pacific Ocean and the influence of transport of midlatitude UT/LS air

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[1]Department of Environmental Sciences, College of Science, Ibaraki University, Mito, Japan
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Received: 12 October 2007 – Published in Atmos. Chem. Phys. Discuss.: 26 November 2007
Revised: 22 April 2008 – Accepted: 29 April 2008 – Published: 19 May 2008

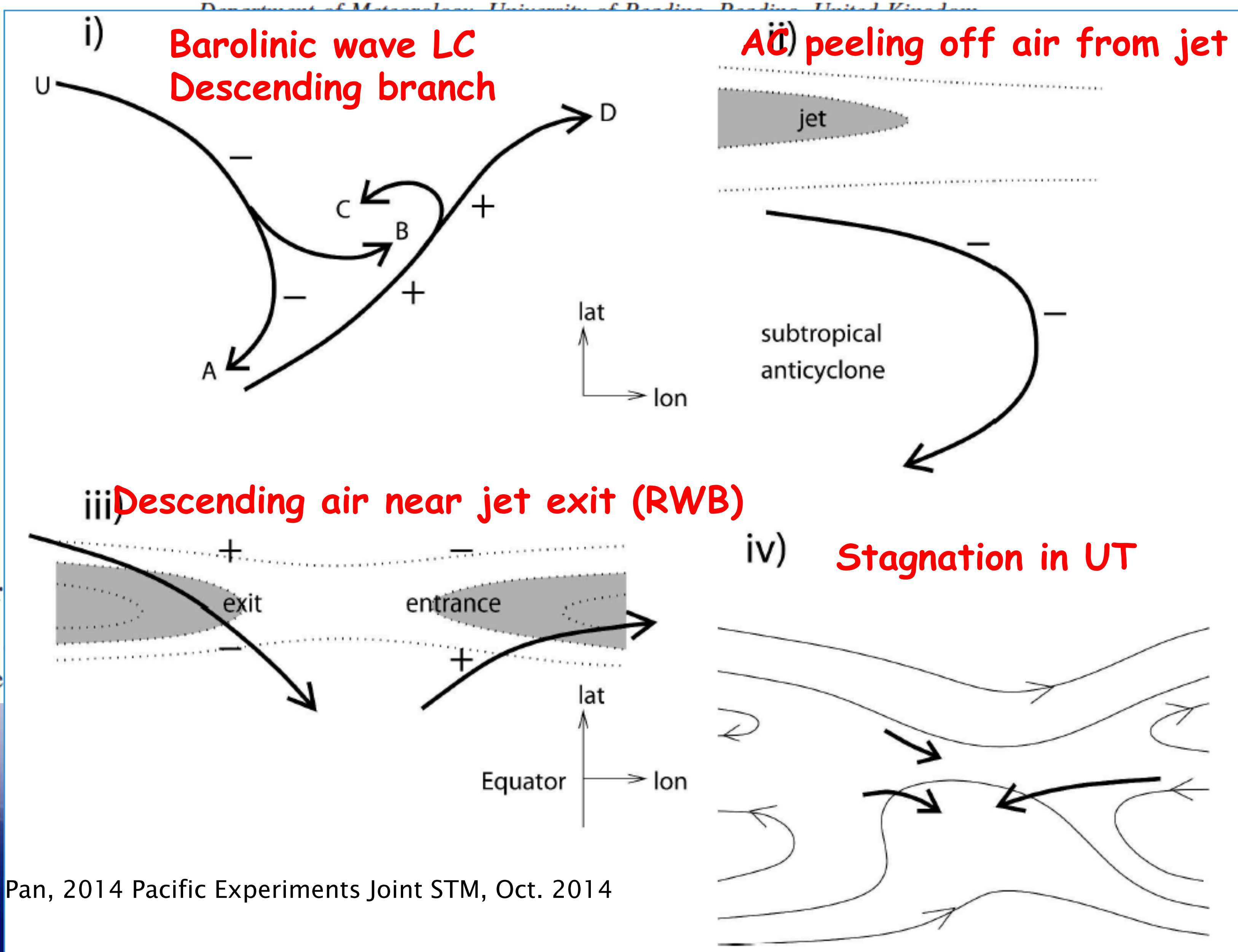
Abstract. Occurrence of ozone (O_3)-enhanced layers in the troposphere over the equatorial Pacific Ocean and their seasonal variation were investigated based on ozonesonde data obtained at three Southern Hemisphere ADditional OZonesondes (SHADOZ) sites, Watukosek, American Samoa and San Cristobal, for 6 years between 1998 and 2003. O_3-enhanced layers were found in about 50% of observed O_3 profiles at the three sites. The formation processes of O_3-enhanced layers were investigated by meteorological analyses including backward trajectories. On numerous occasions, O_3-enhanced layers resulted from the transport of air masses affected by biomass burning. The contribution of this process was about 30% at San Cristobal during the periods from February to March and from August to September, while it was relatively low, about 10%, at Watukosek and Samoa. A significant number of the O_3-enhanced layers were attributed to the transport of midlatitude upper-troposphere and lower-stratosphere (UT/LS) air. Meteorological analyses indicated that these layers originated from equatorward and downward transport of the midlatitude UT/LS air masses

1 Introduction

The tropospheric ozone (O_3) concentration in the tropics is generally low, especially over the Pacific Ocean, in comparison with that in the midlatitude (e.g., Fishman et al., 1990; Brasseur et al., 1999; Kondo et al., 2002). However, O_3-enhanced layers are often observed in the tropics (e.g., Newell et al., 1996; Stoller et al., 1999; Thouret et al., 2001). Photochemical production from the O_3 precursor gases emitted from biomass burning is considered to increase O_3 concentrations in the tropical troposphere. Increases in O_3 associated with biomass burning over the tropical Pacific Ocean have been repeatedly reported. Oltmans et al. (2001) suggested that the O_3-enhanced layers observed at Fiji (18.1° S, 178.2° E), Samoa (14.3° S, 189.4° E), Tahiti (18.0° S, 211.0° E), and Galapagos (0.9° S, 270.4° E) with ozonesondes were attributable to the transport of air masses affected by biomass burning in Australia and South America. In Indonesia, during the local late dry season between September and November, enhancements of tropospheric O_3

Origins of Dry Air in the Tropics and Subtropics

PIERO CAU, JOHN METHVEN, AND BRIAN HOSKINS



1. Intr

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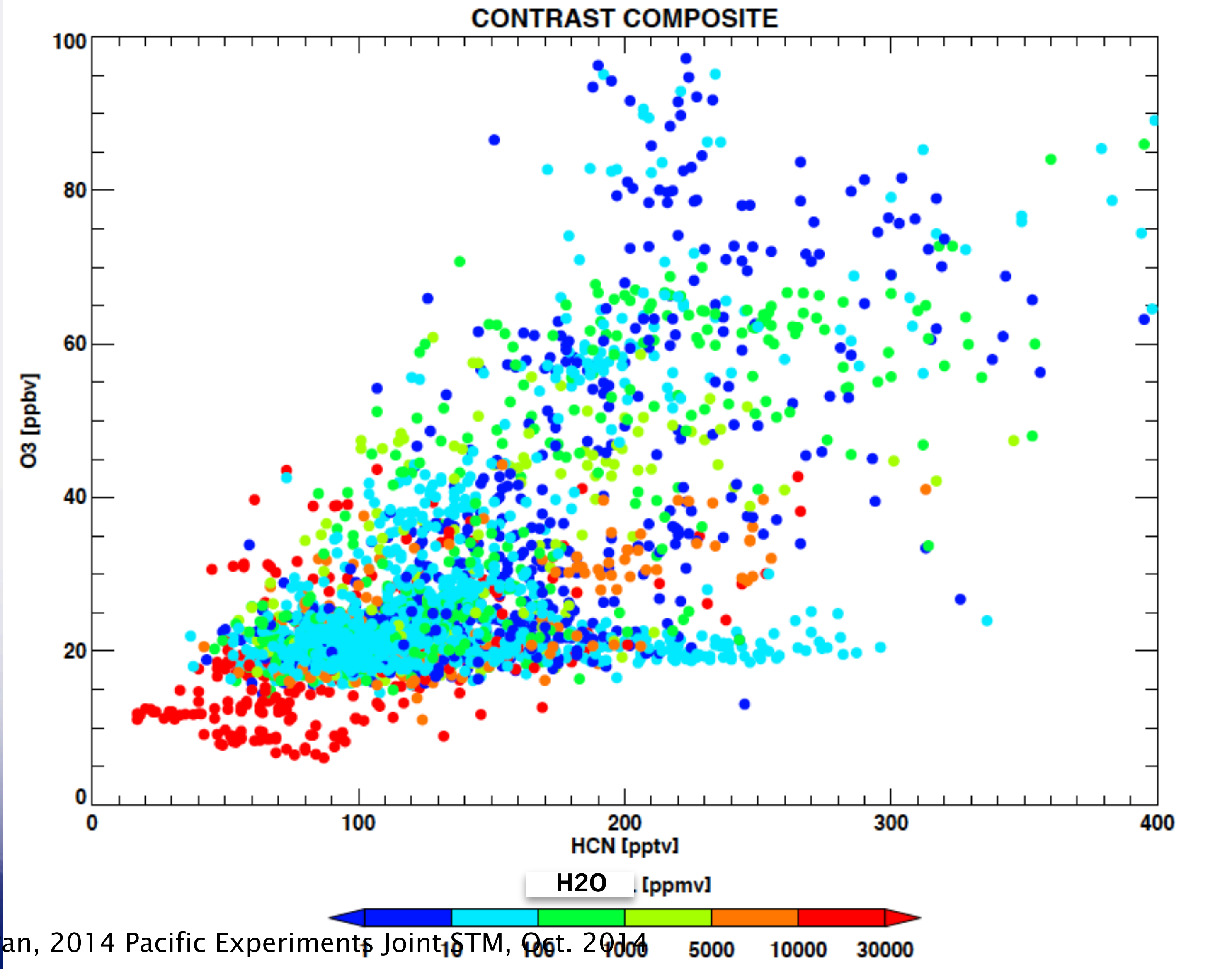
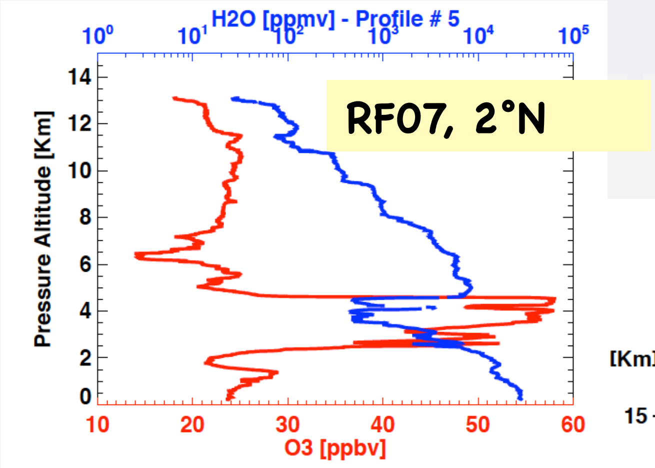
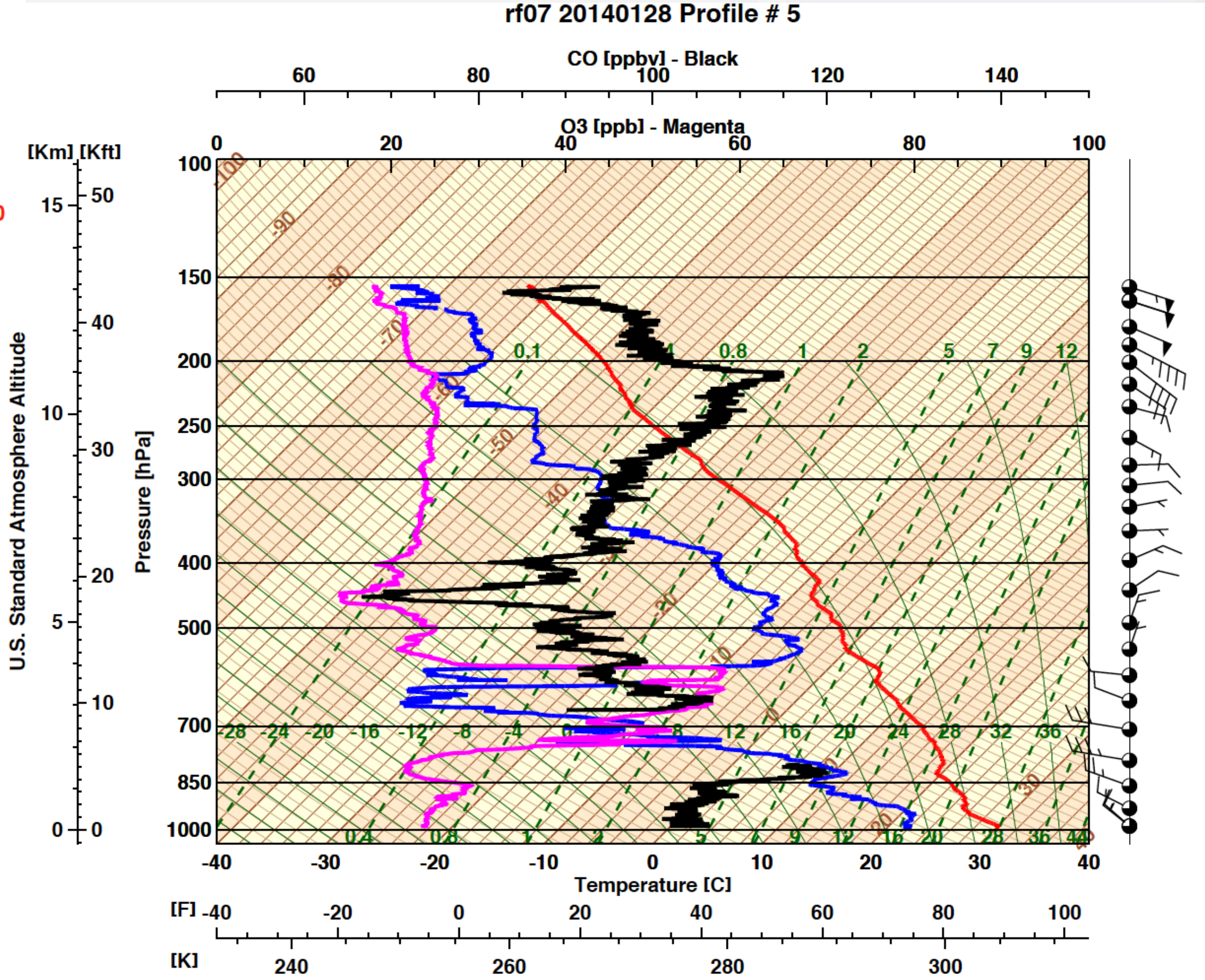
Significant correlation of ozone and HCN:
-Role of Biomass Burning (BB)?



O_3 Layer structure negatively correlates with H_2O also found positively correlates with CO in some cases





Q:

If both the transport from mid-lat UTLS and the BB contribute to the non-tropical mode, how do we quantify the relative contributions?

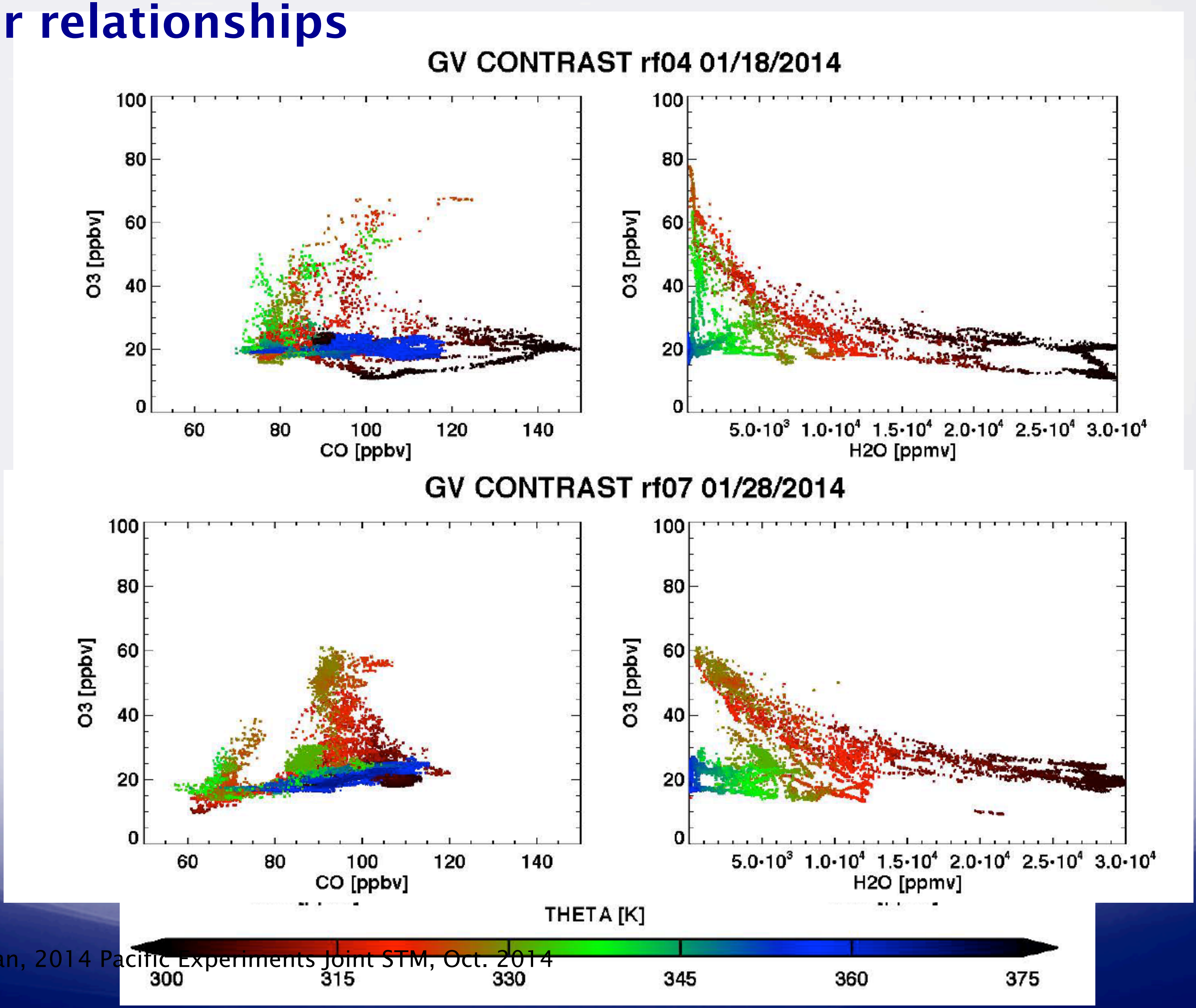
- **Tracer relationships**
- **Trajectories/RDF**
- **CAM-chem**
- **Box models**

On going effort of many:

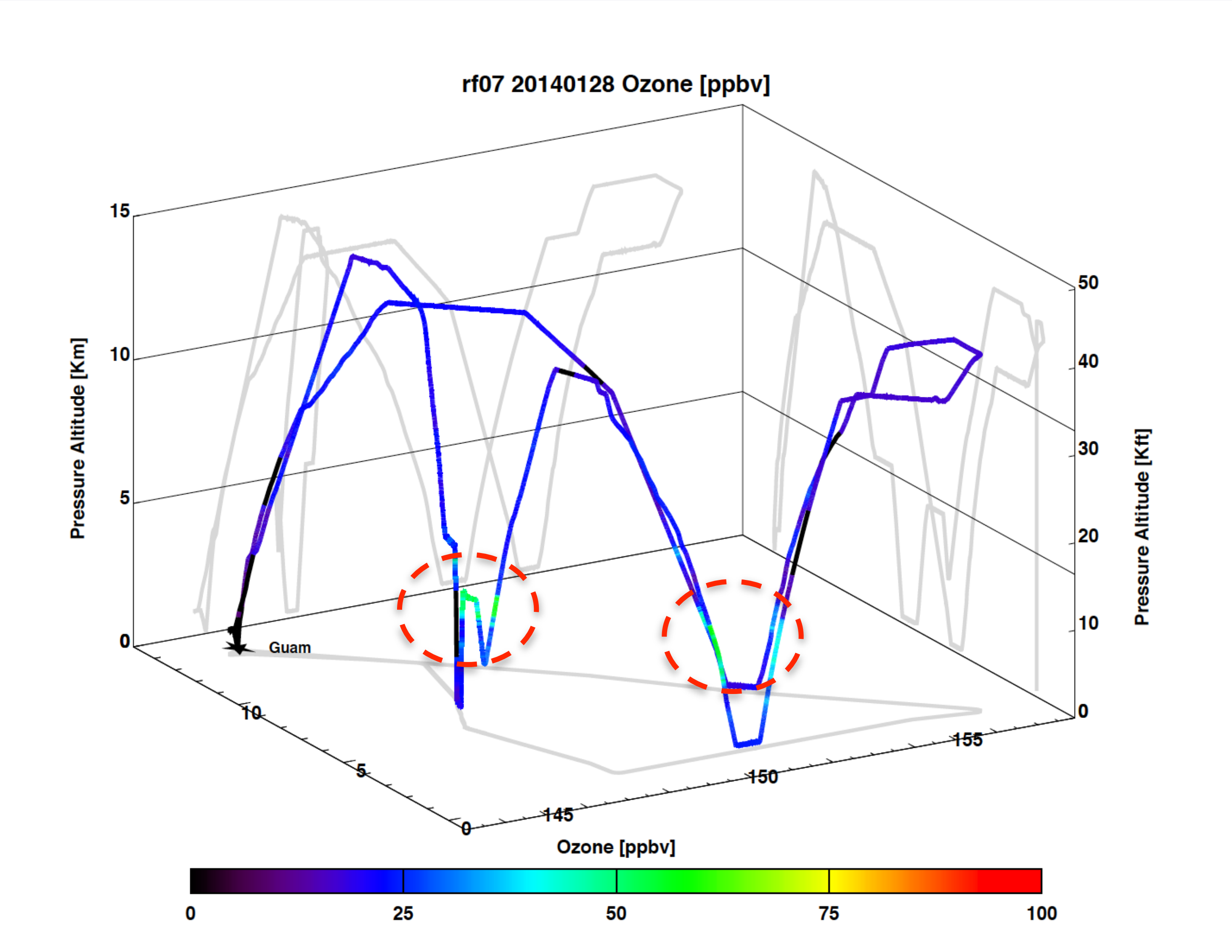
Laura Pan, Bill Randel, Becky Hornbrook, Eric Apel, Doug Kinnison…

Ross Salawitch, Dan Anderson, Brad Pierce …

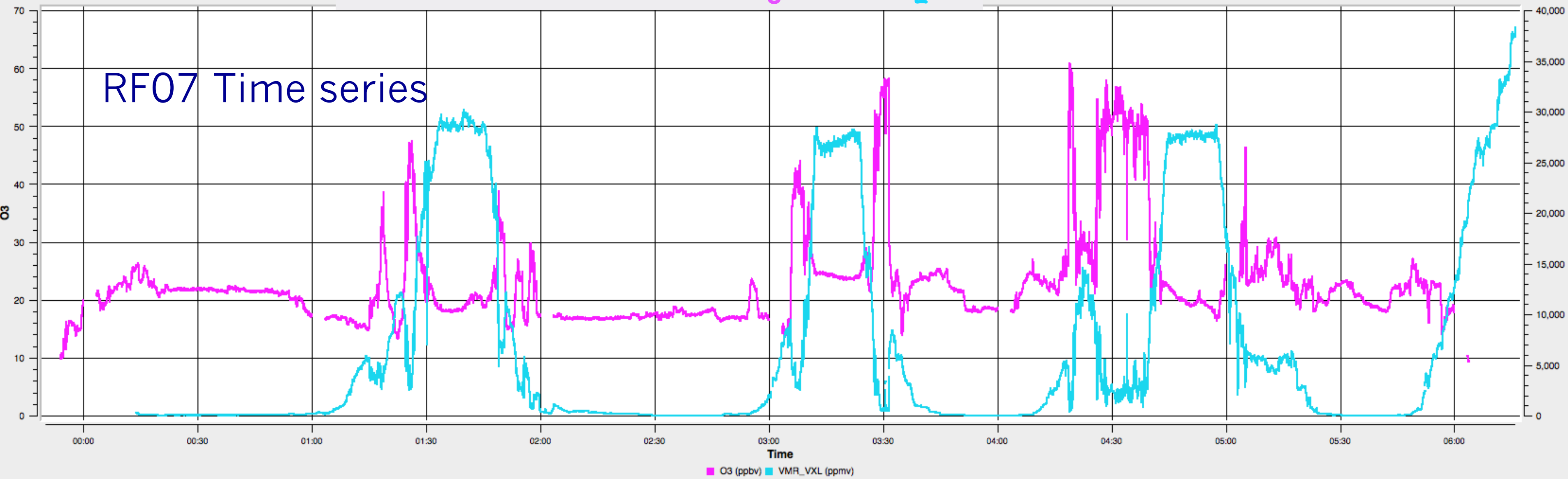
Tracer relationships



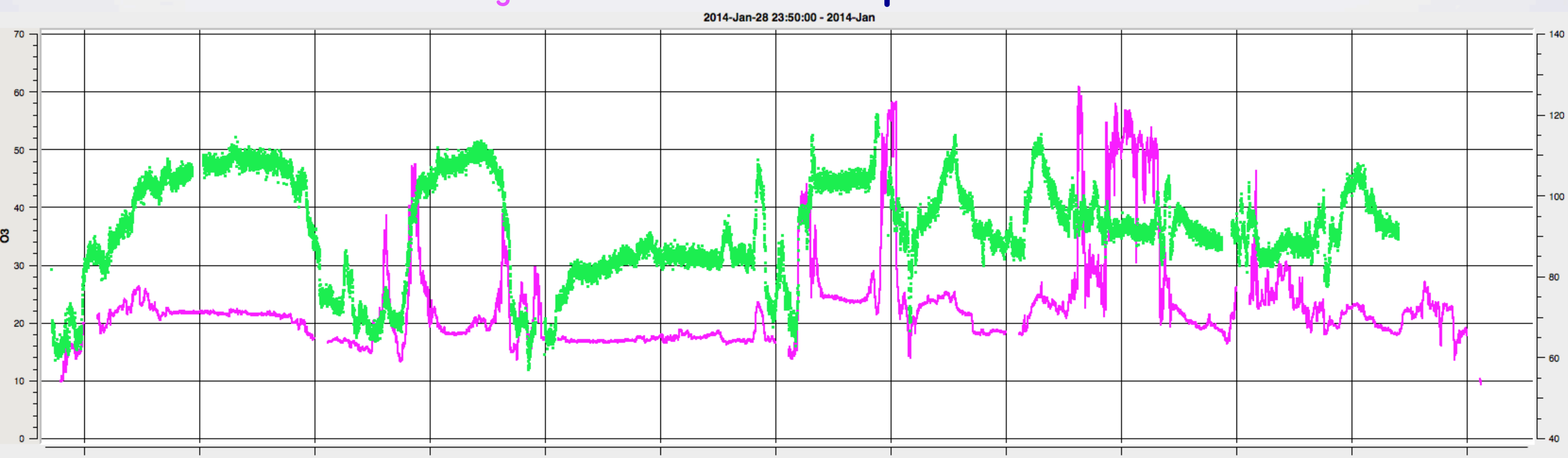
Case study of RF07



Anti-correlation of O_3 and H_2O



O_3 and CO relationship is mixed



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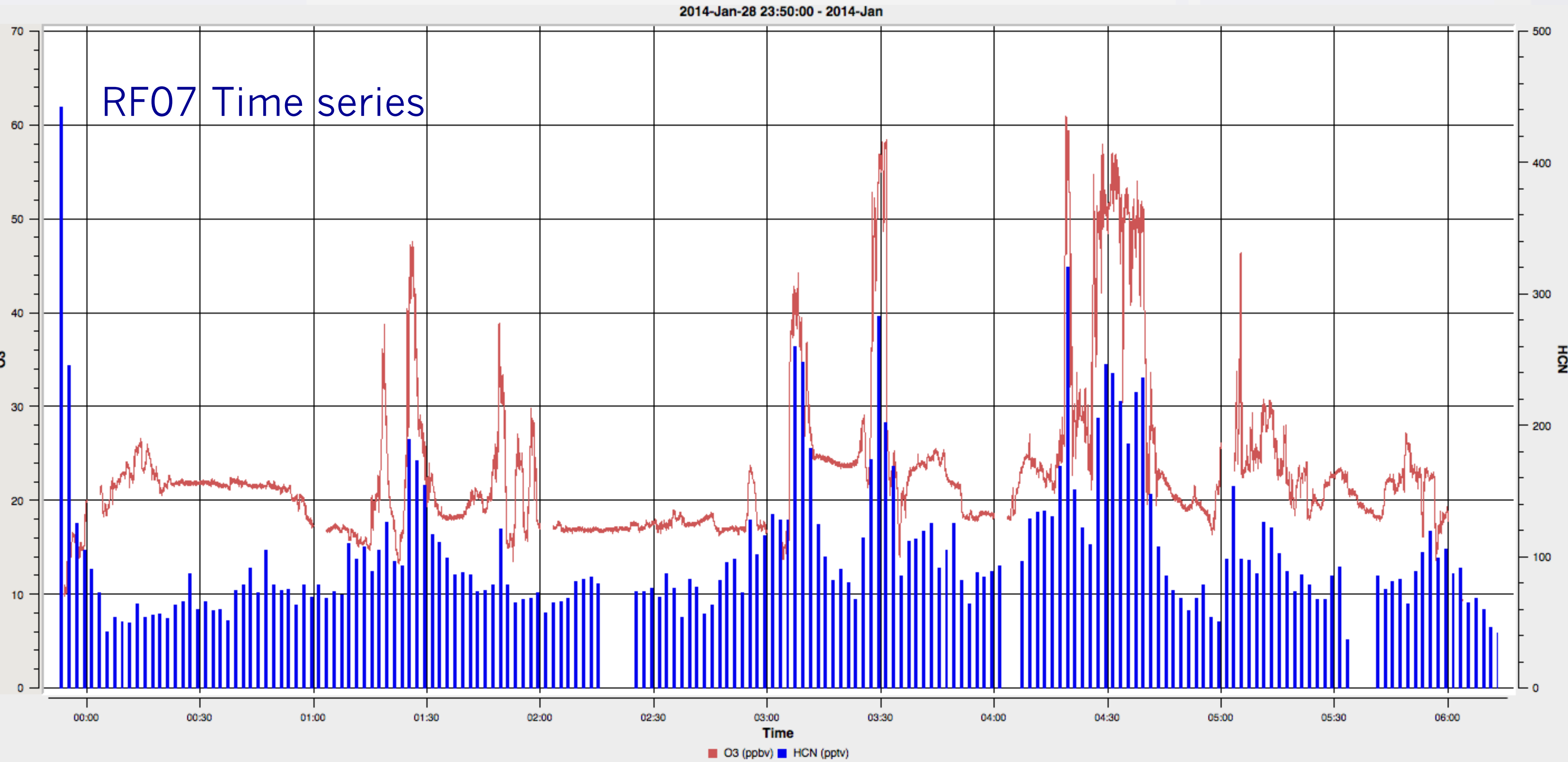
Significant correlation between O_3 and HCN



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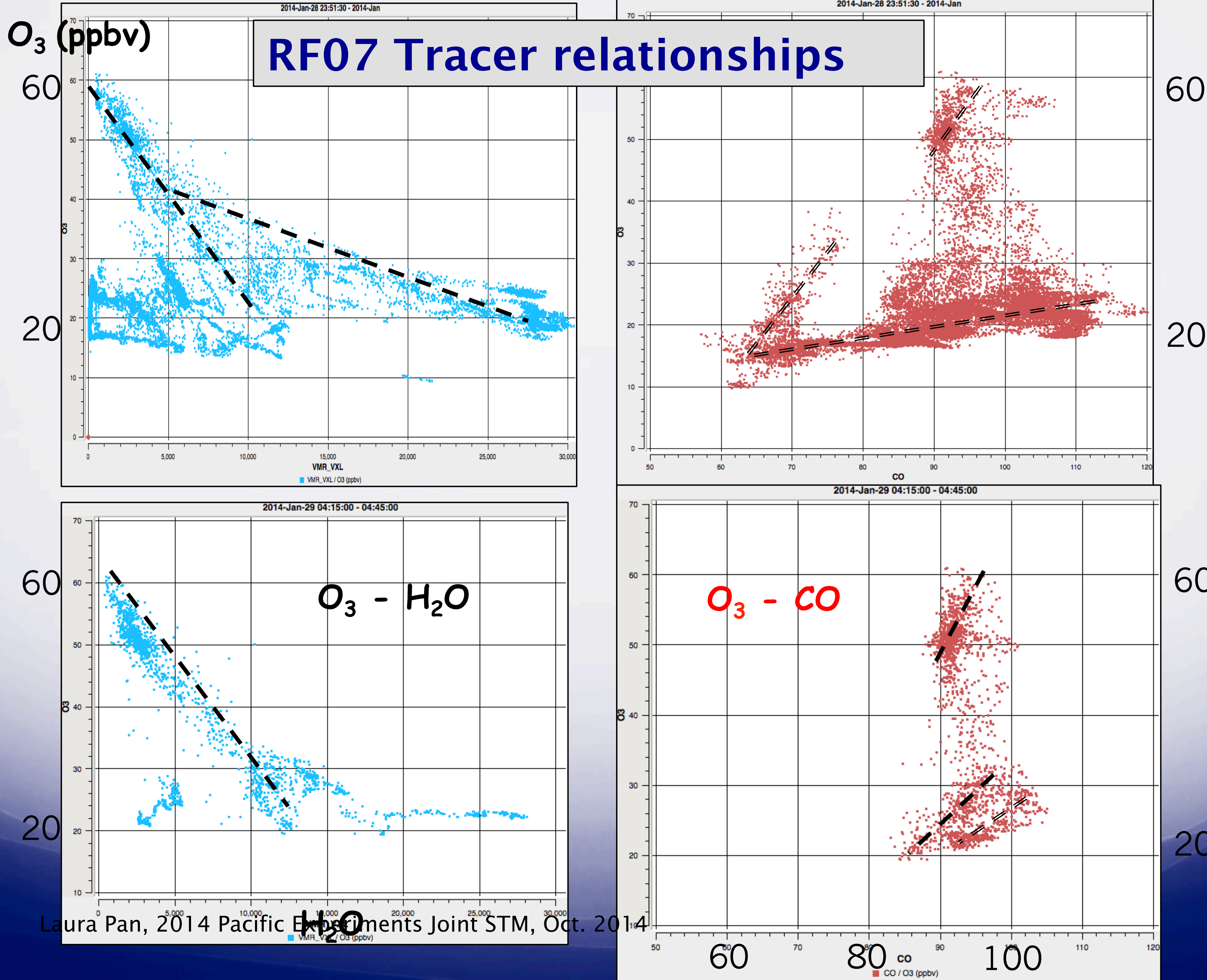
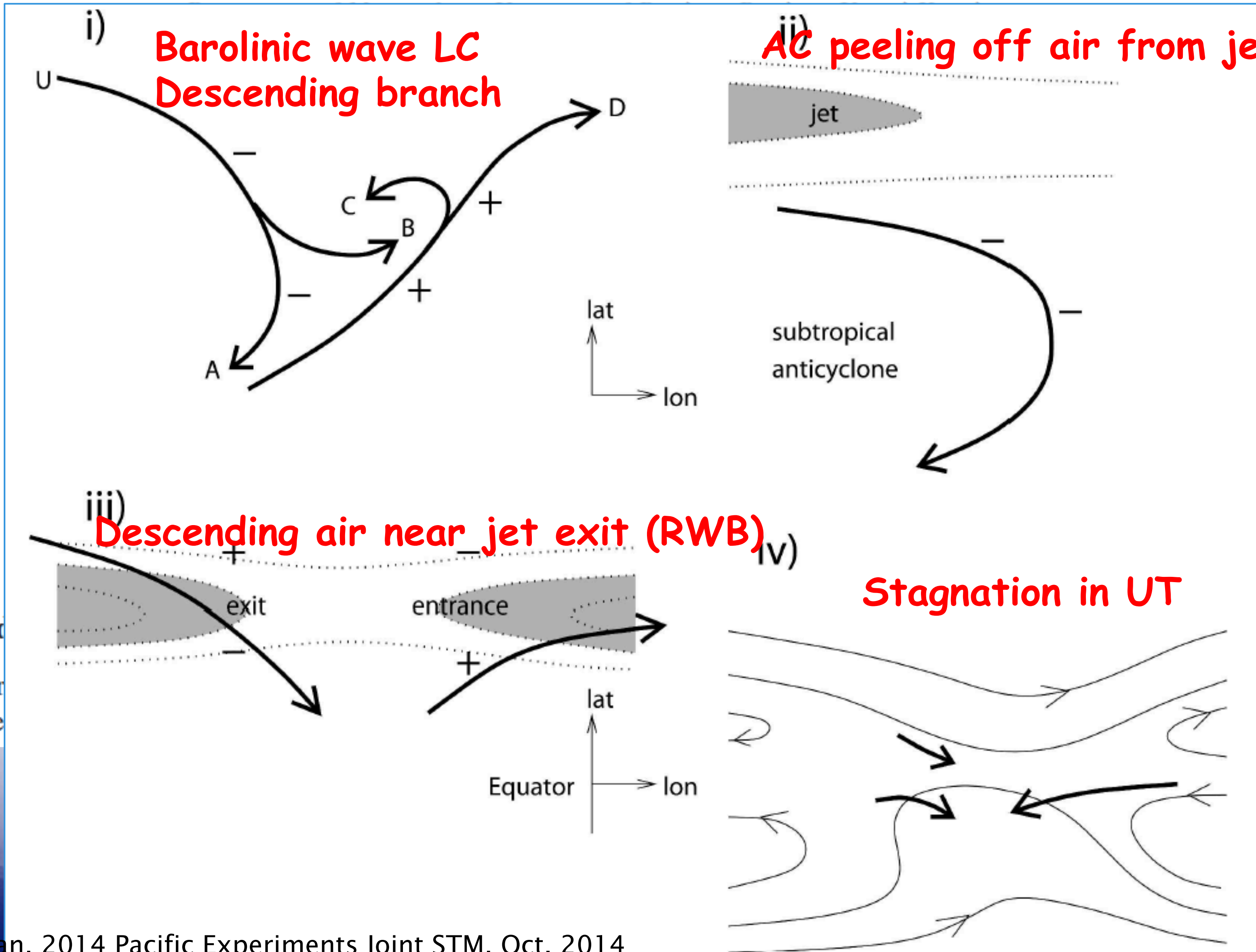
RF07 Tracer relationships



Origins of Dry Air in the Tropics and Subtropics

Piero Cau, John Methven, and Brian Hoskins



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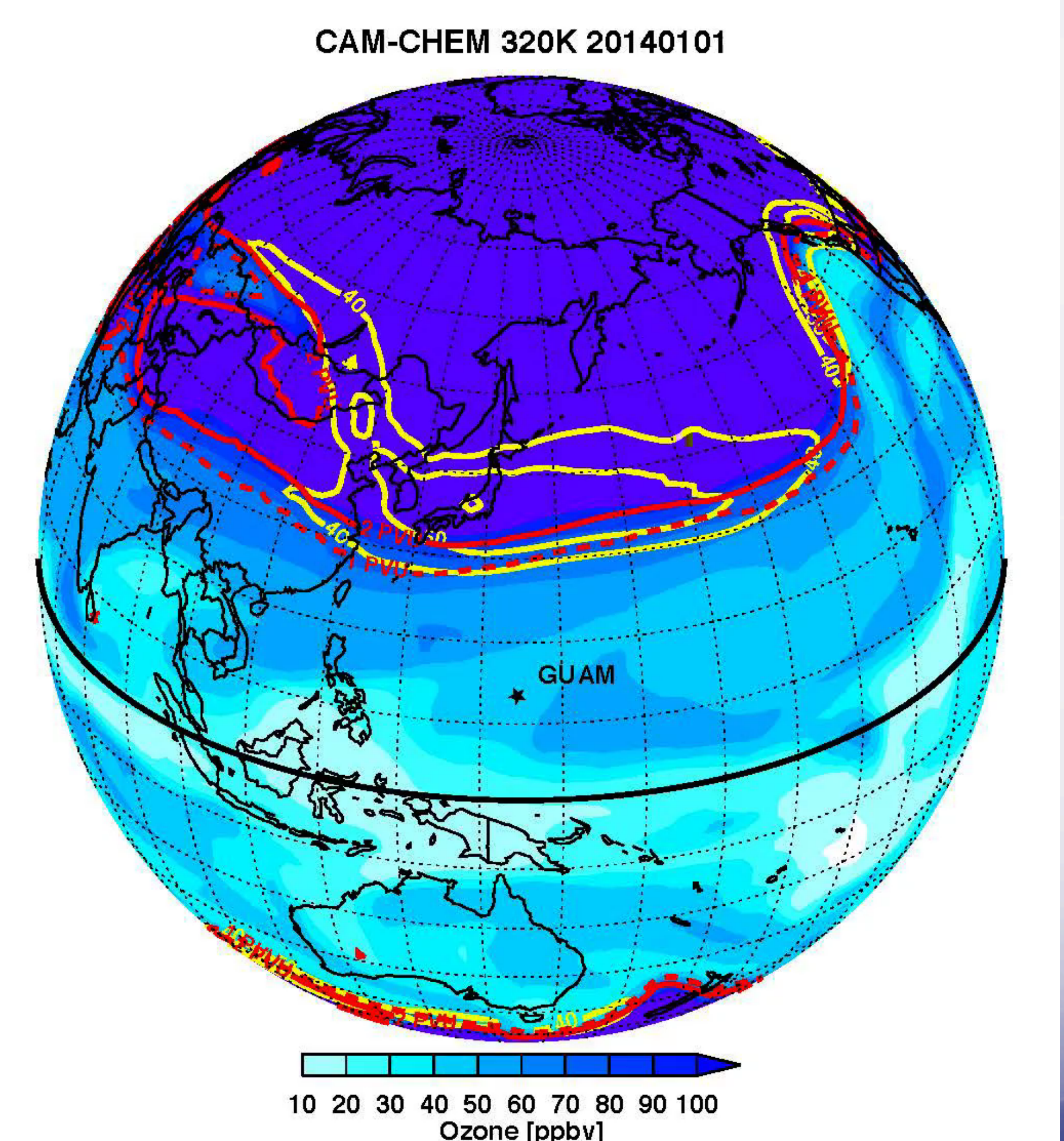
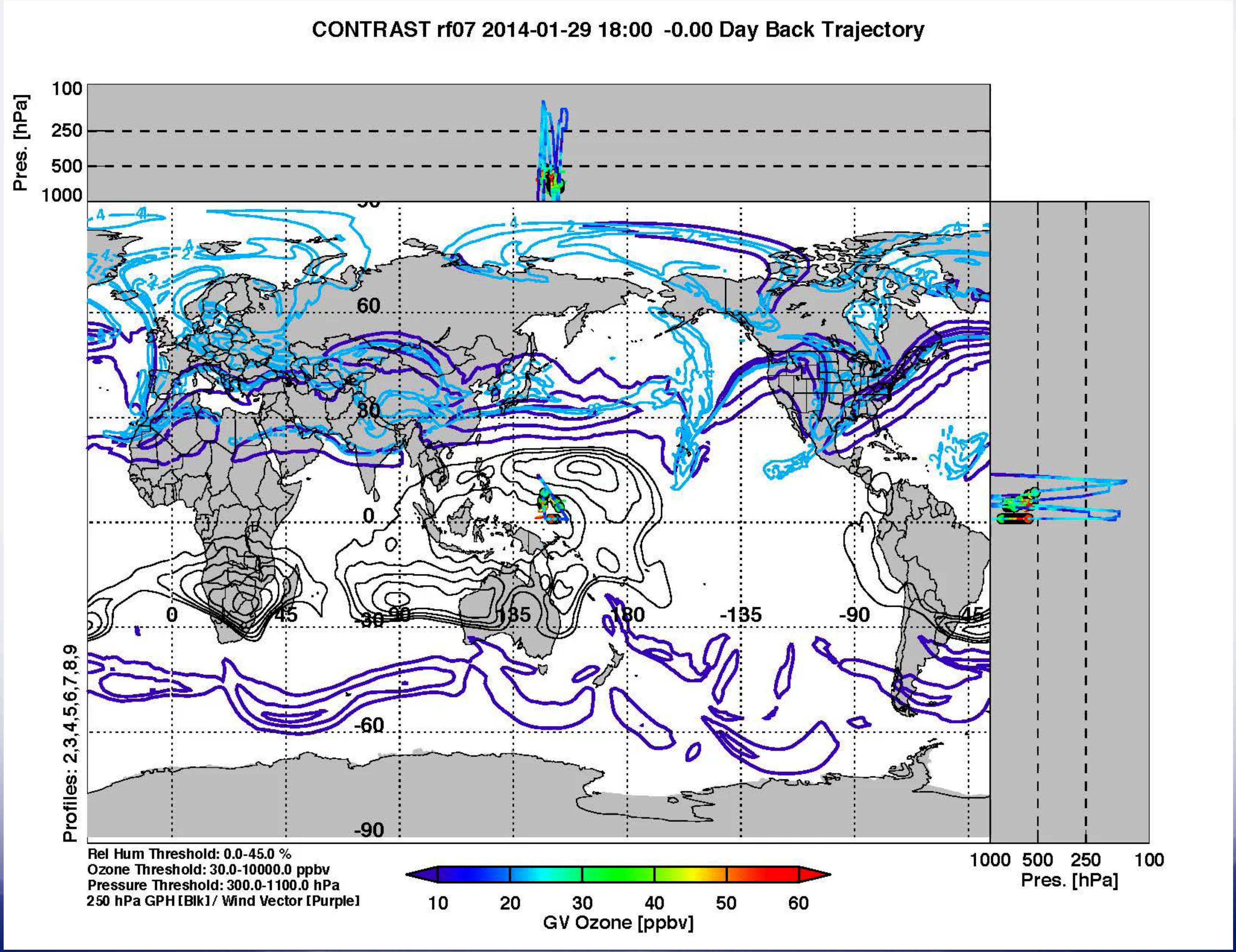
CAM-chem SD run for CONTRAST period



Doug Kinnison

Laura Pan, 2014 Pacific Experiments Joint STM, Oct. 2014

(animation not converted to PDF)



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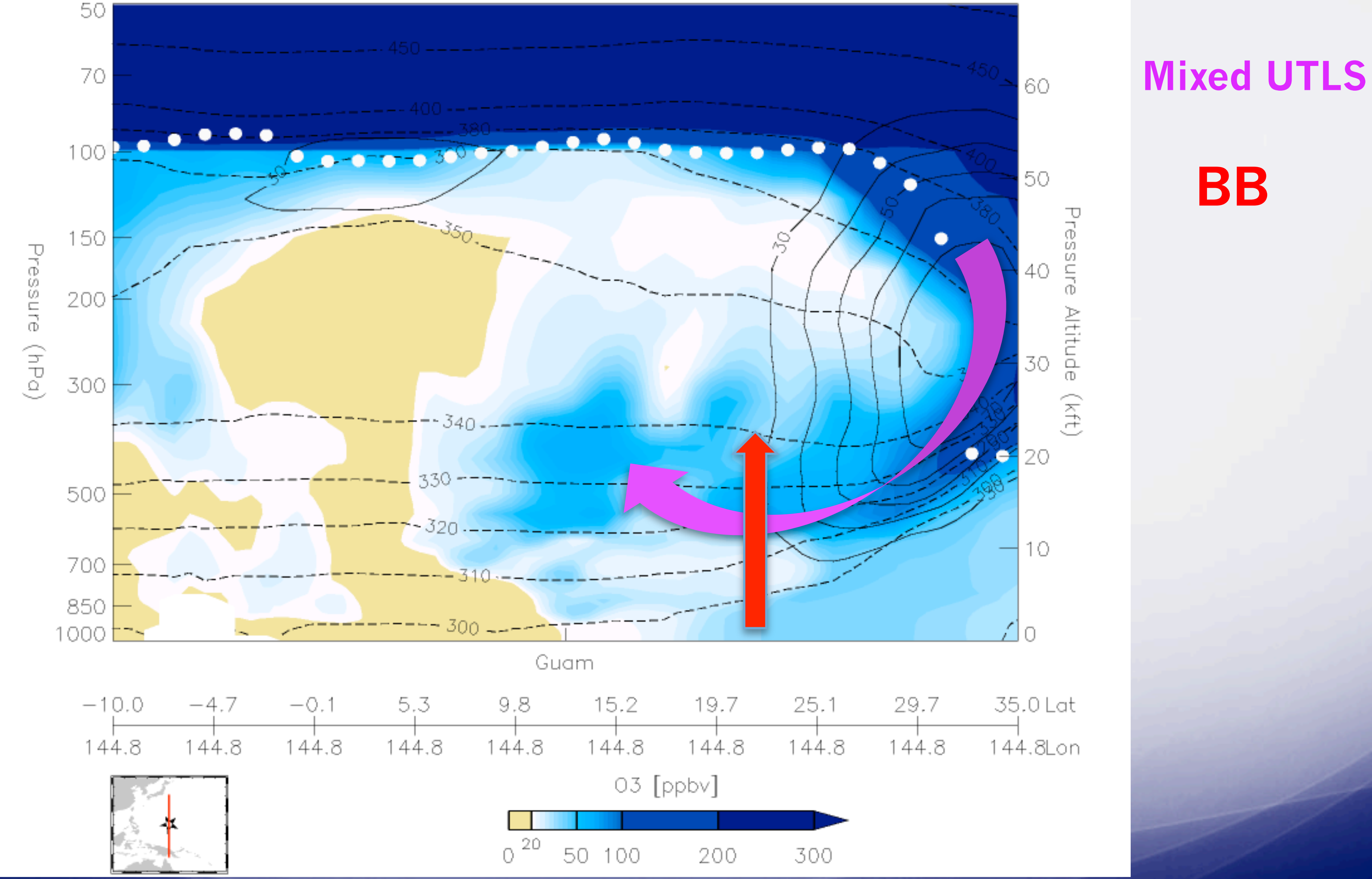
(animation not converted to PDF)

A working conceptual model:

CAM-Chem in Forecast Mode –



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A working conceptual model:

Prados et al., 1999 (AEROCE)

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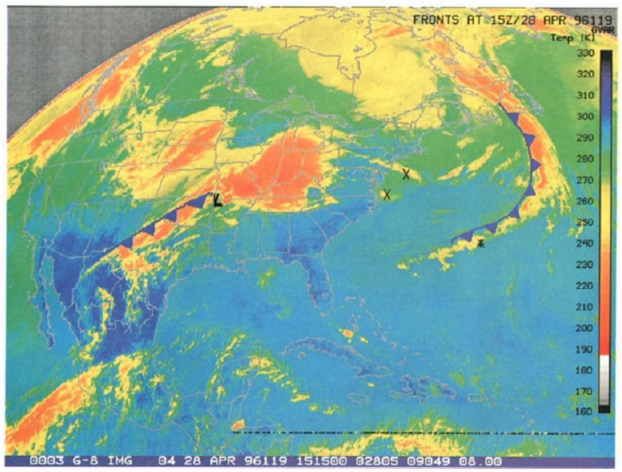

Plate 1a. GOES 8 IR image for April 28, 1996, at 1515 UTC as the aircraft was taking off from Bermuda. The temperature scale is located to the right (K). The star indicates the location of Bermuda. There is a new storm system developing over the midwestern and central United States associated with a large area of convection. Crosses represent the location of the two clouds used to trace air moving toward Bermuda. Also note the primary front located near Bermuda.

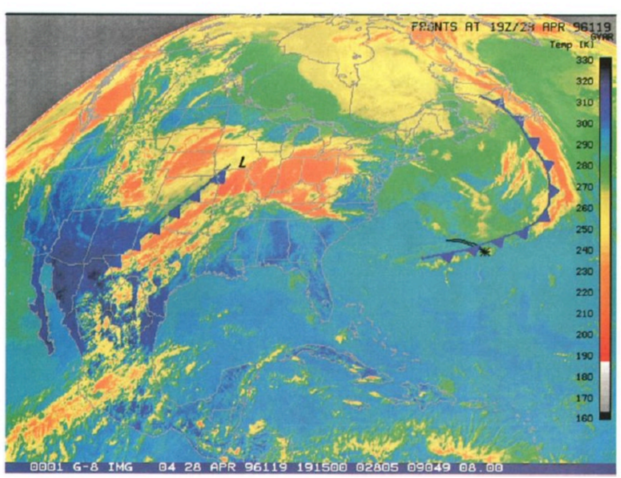

Plate 1b. GOES 8 IR image from April 28, 1996, at 1915 UTC. The aircraft has traveled its maximum distance west of Bermuda. Also shown is the flight track and the location of Bermuda (star). Fragments of cloud from the area of convection over the Midwest have warmed and subsided (relative to Plate 1a) as the air mass moved out toward Bermuda.

Homeyer et al., 2011 (START08 case study)

D23304 HOMEYER ET AL.: CON

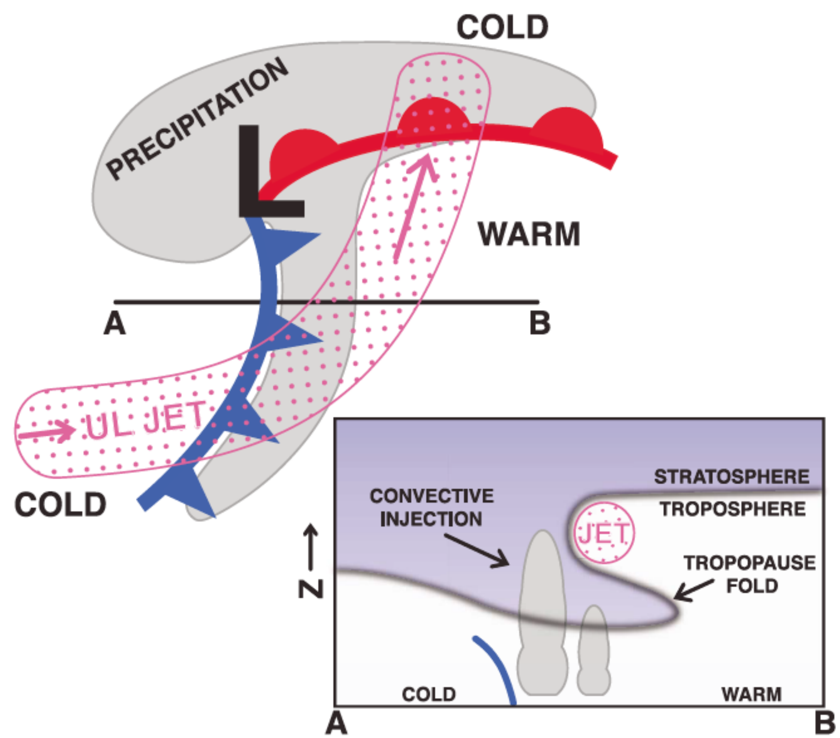

Figure 14. Conceptual model of the synoptic meteorological conditions conducive to convective injection in stratospheric intrusions. The upper left is a representation of the associated surface and upper-level meteorological conditions. The vertical section, along line A–B, shows the stratospheric intrusion ahead of the surface cold front (a "split front") and location of convective injection.

It is only a beginning…