Chemical Tracers as Indicators of Transport Time Scales and Source Regions of Air in the UTLS

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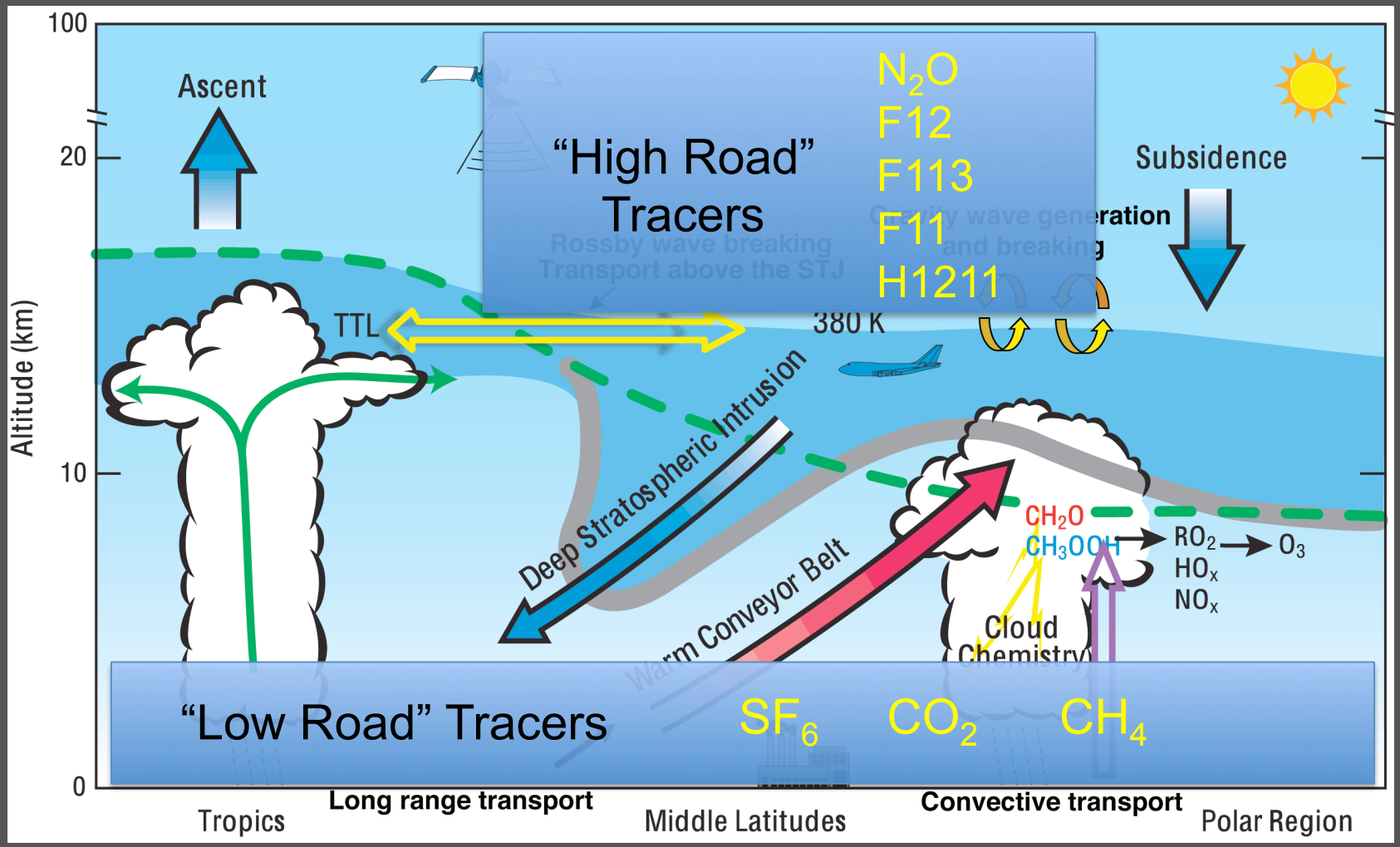
Motivation

- The UTLS is a challenging region for models to simulate accurately due to the variety of transport processes that affect radiatively important trace gas distributions.

- How can we better use *in situ* trace gas measurements to make model independent estimates of the contributions of various transport processes to UTLS trace gas distributions?

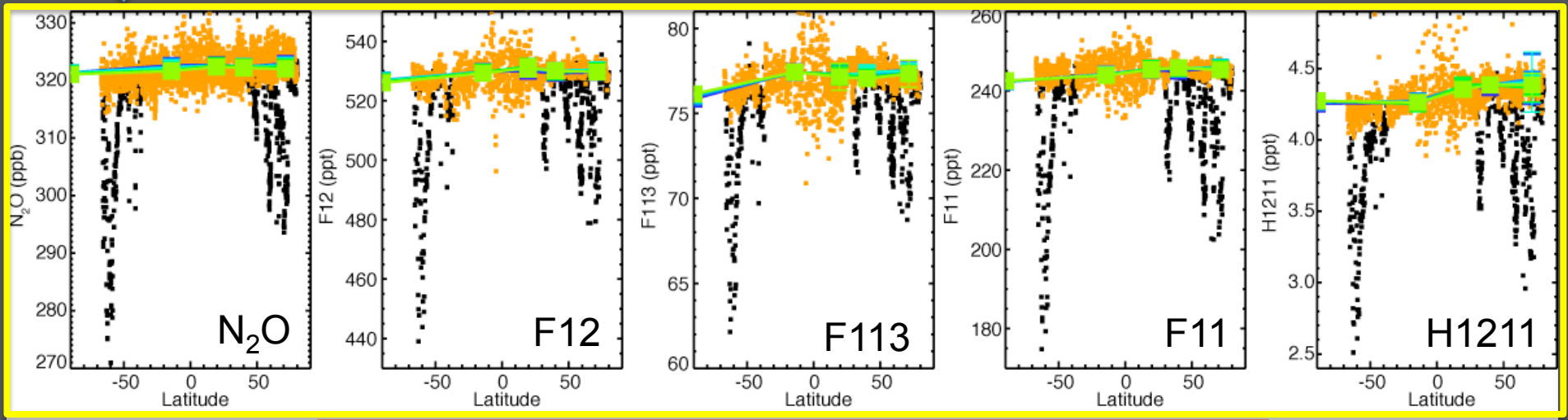
UTLS Transport and Mixing Pathways



From *Stohl et al., 2003* and *Pan et al., 2010*

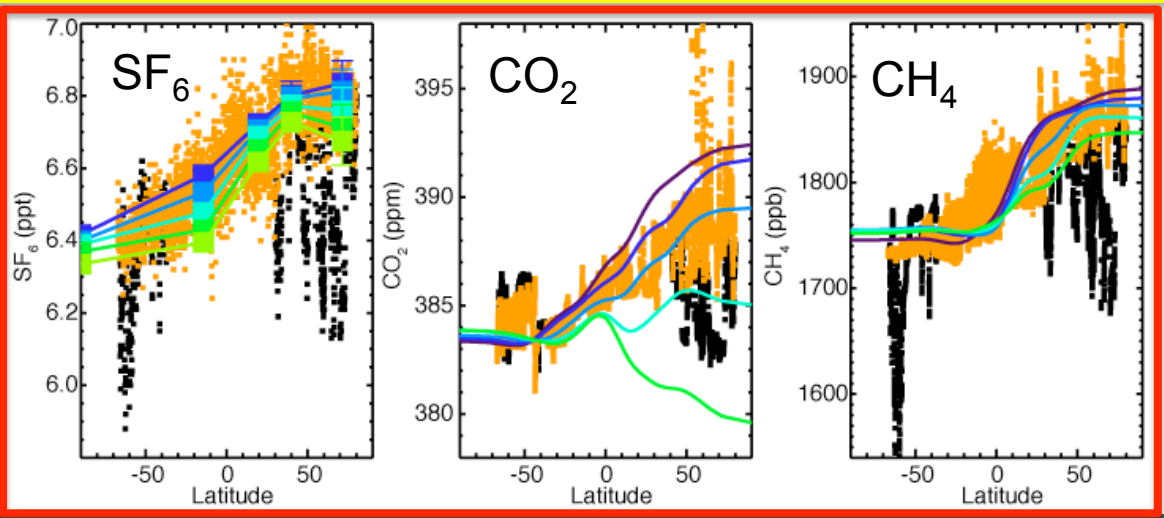
Boundary Layer and HIPPO 1 UT/LS Tracer Gradients

Photolytic tracers – only destroyed above certain levels in the stratosphere.



Colored symbols are HIPPO 1 measurements.

Orange = Trop.
Black = Strat.



Colored lines are NOAA GMD boundary layer measurements.

Globalview dataset in the case of CO_2 and CH_4.

Large boundary layer spatial and/or temporal gradient tracers

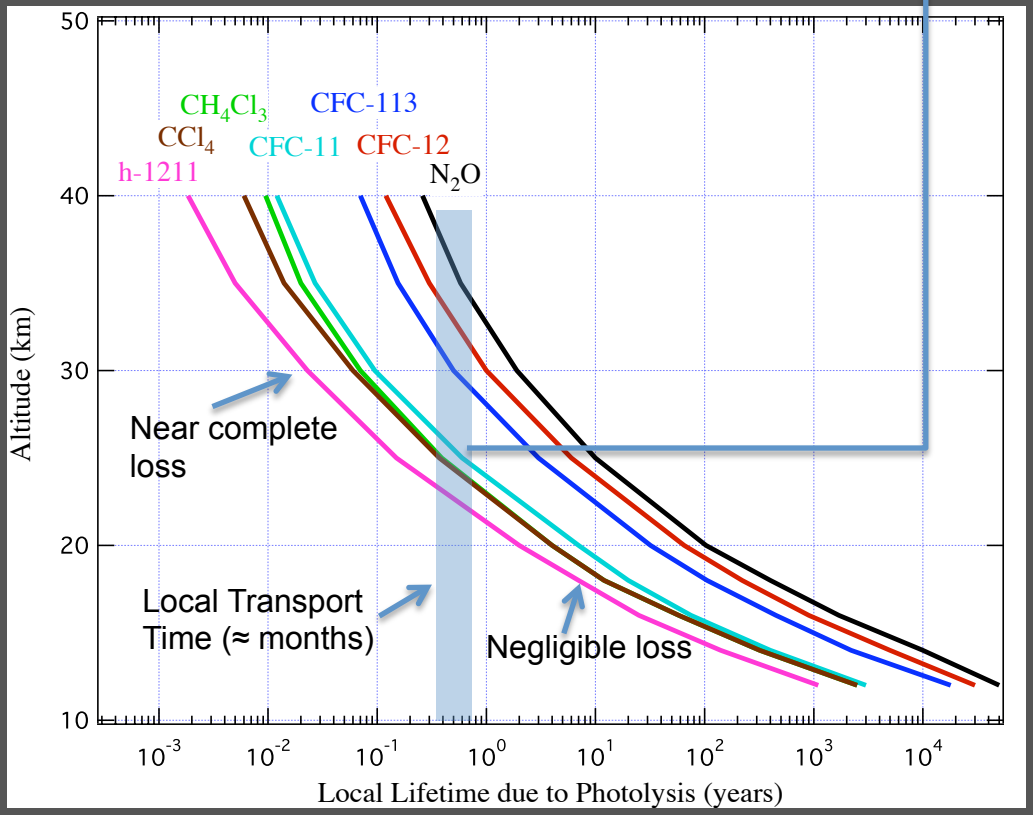
Method

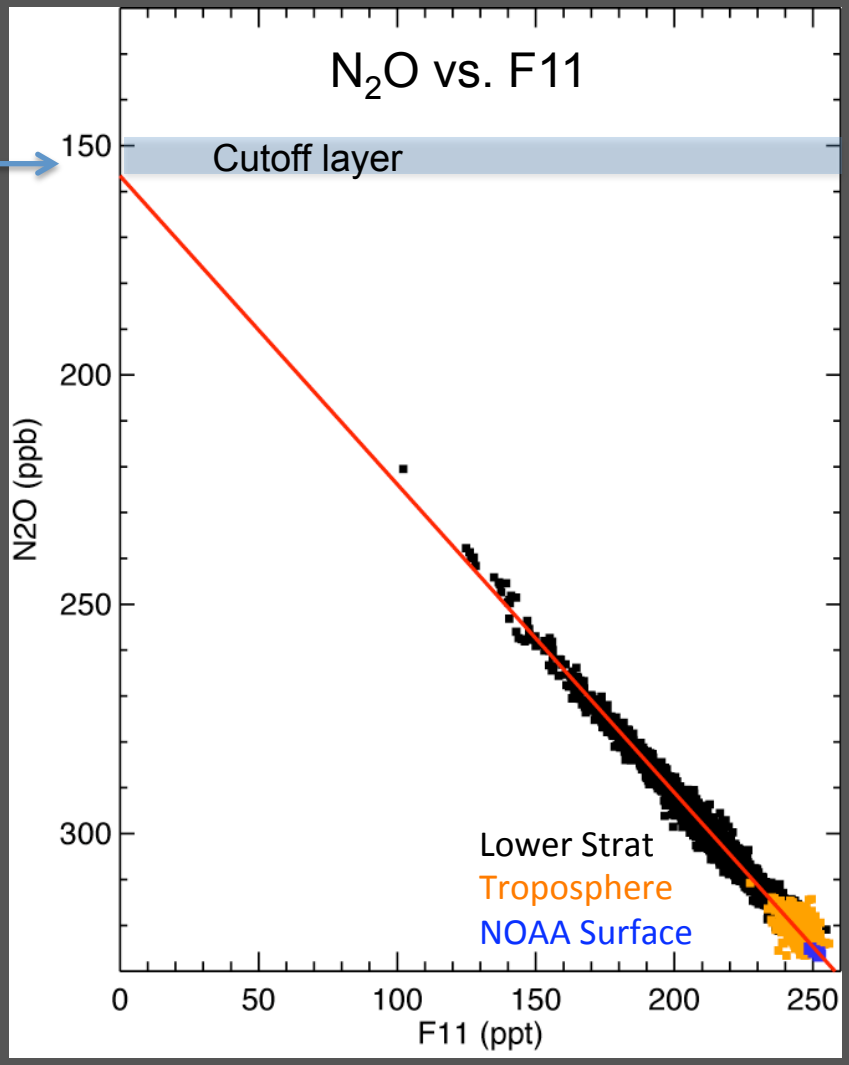
- Estimate the portion of UTLS tracer mixing ratio gradients due to “high road” transport using photolytic tracer correlations.
- Remove measured tracer gradients due to high road transport.
- Identify “low road” transport time scales and boundary layer latitudinal origins.

Stratospheric Fractions From Photolytic Tracer Correlations

Any decrease in a photolytic tracer is due to mixing from above the cutoff layer, where the mixing ratio is nearly zero, with surface values.

Midlatitude Photolytic Lifetime Profiles

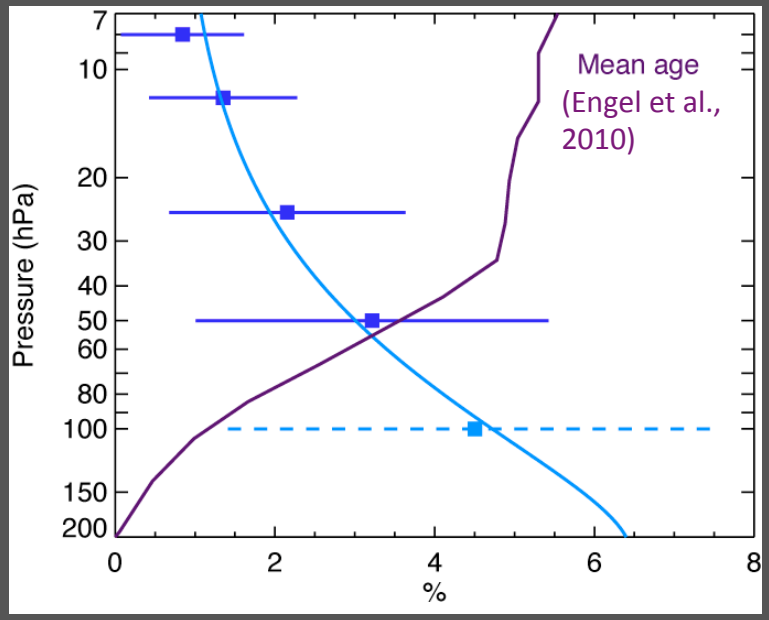




Each measurement will have a profile of fractions of air from above each cutoff layer.

Removing “High Road” Piece of UTLS Measurements

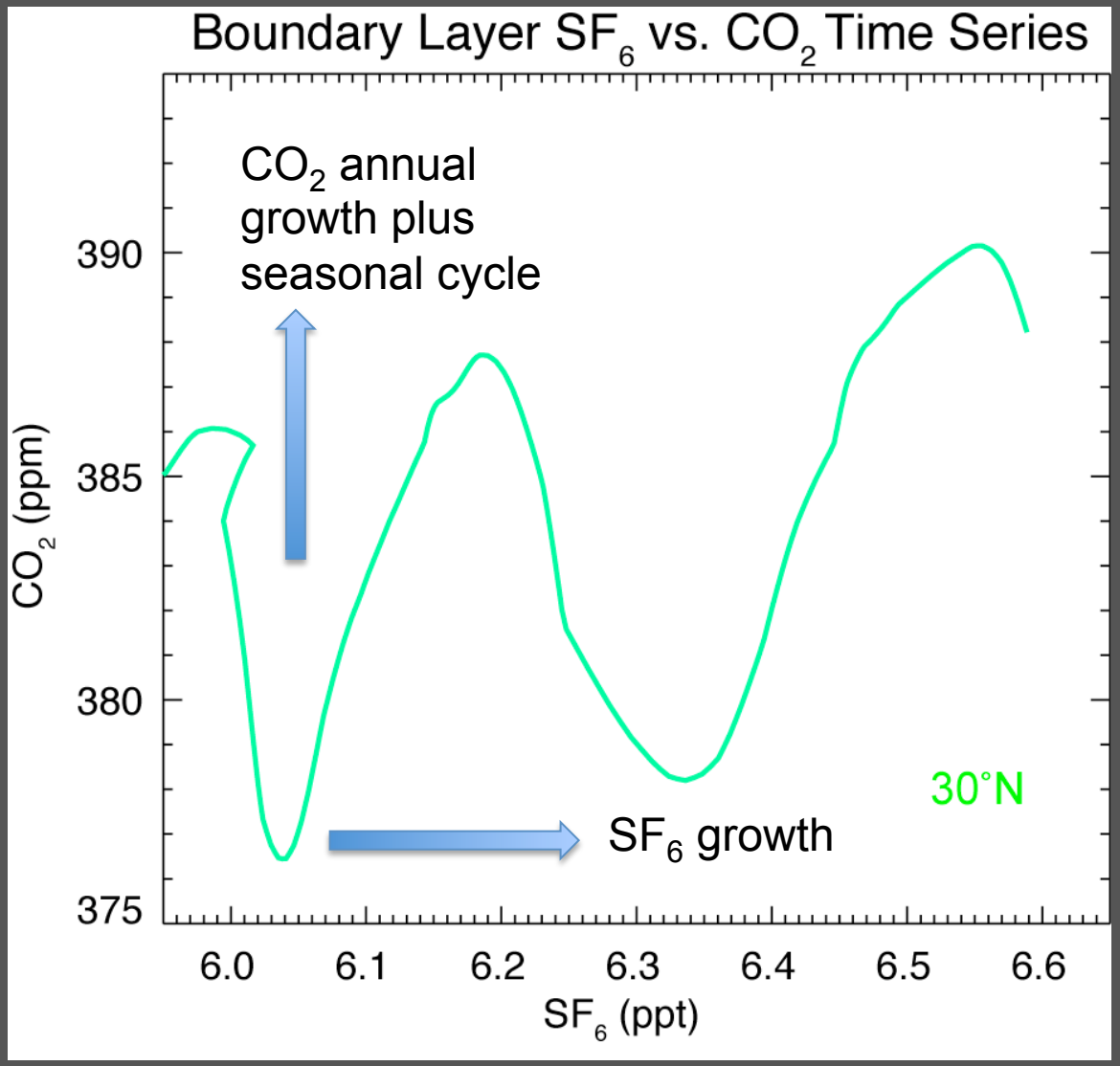
For “age” tracers, use midlatitude stratospheric age profile and fractions of air from above the photolytic cutoff layers (blue line in plot at right) to adjust the measured mixing ratios.



For CH_4, use ACE H_2O, CH_4 and N_2O measurements to estimate the CH_4 loss between photolytic cutoff layers and combine with the stratospheric fraction profile to adjust the measured CH_4 mixing ratios.

The resulting adjusted SF_6, CO_2 and CH_4 mixing ratio gradients are ideally due only to “low road” transport.

“Low Road” Transport Times and Boundary Layer Origins From the Age Tracers



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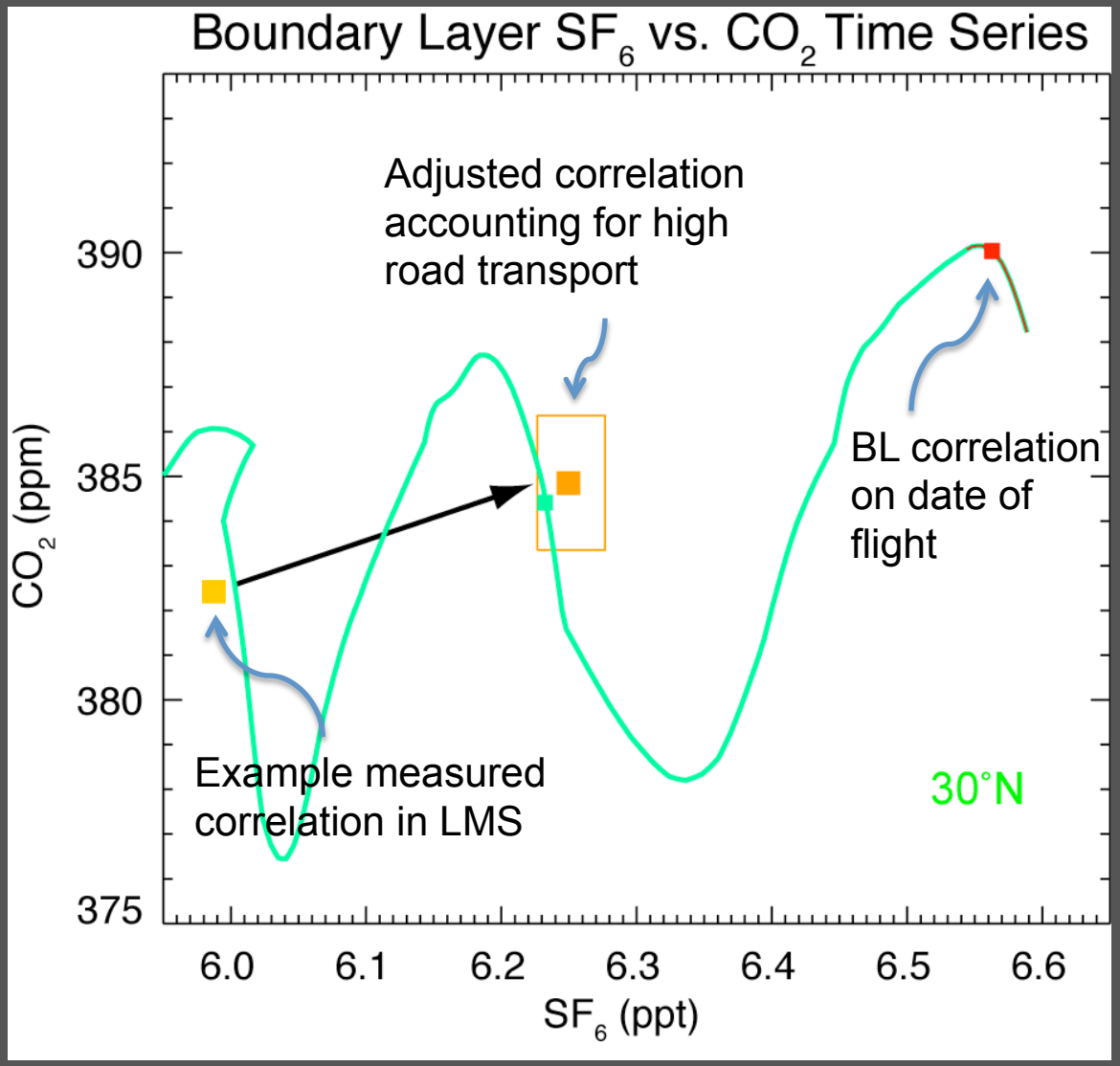
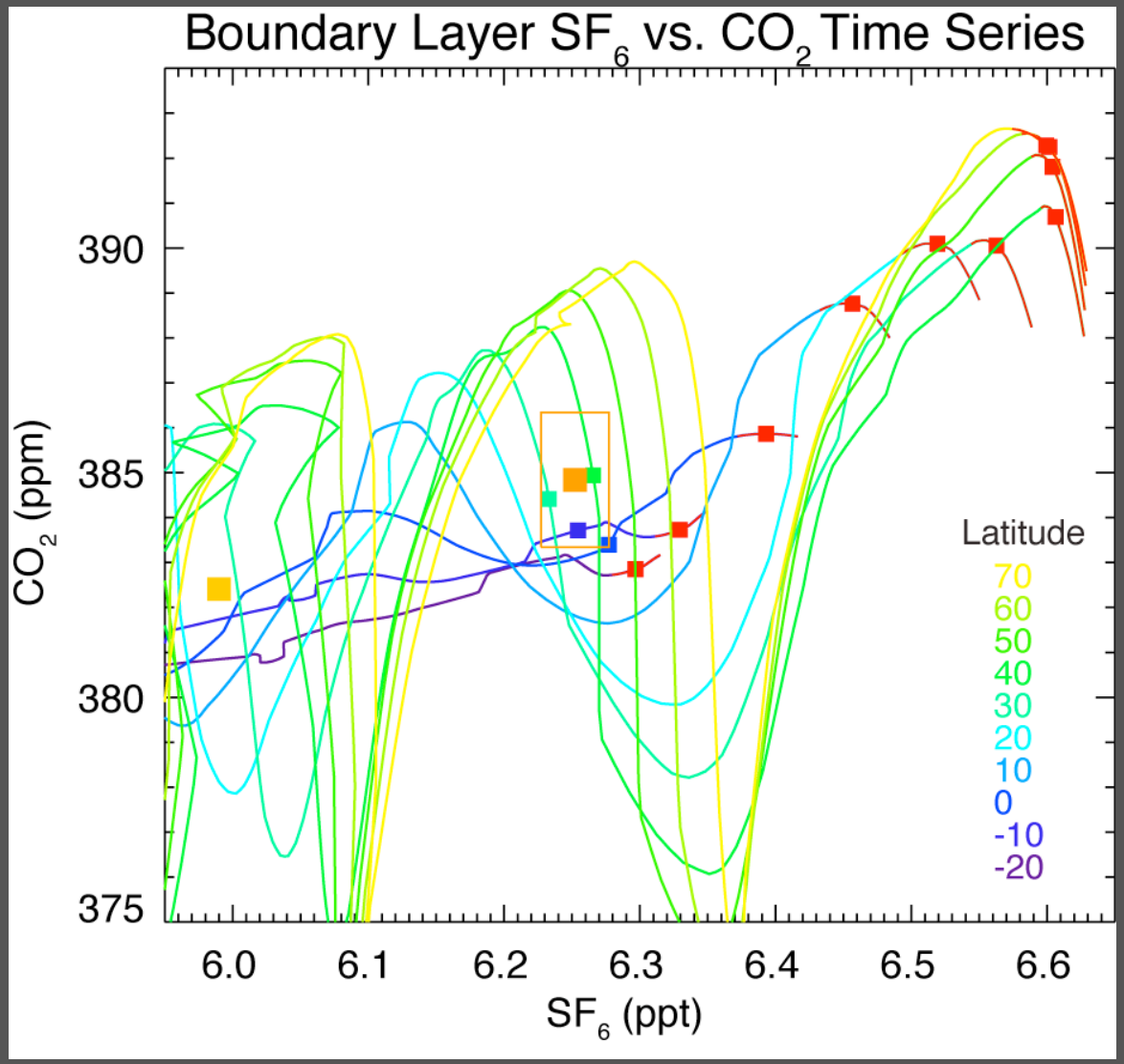
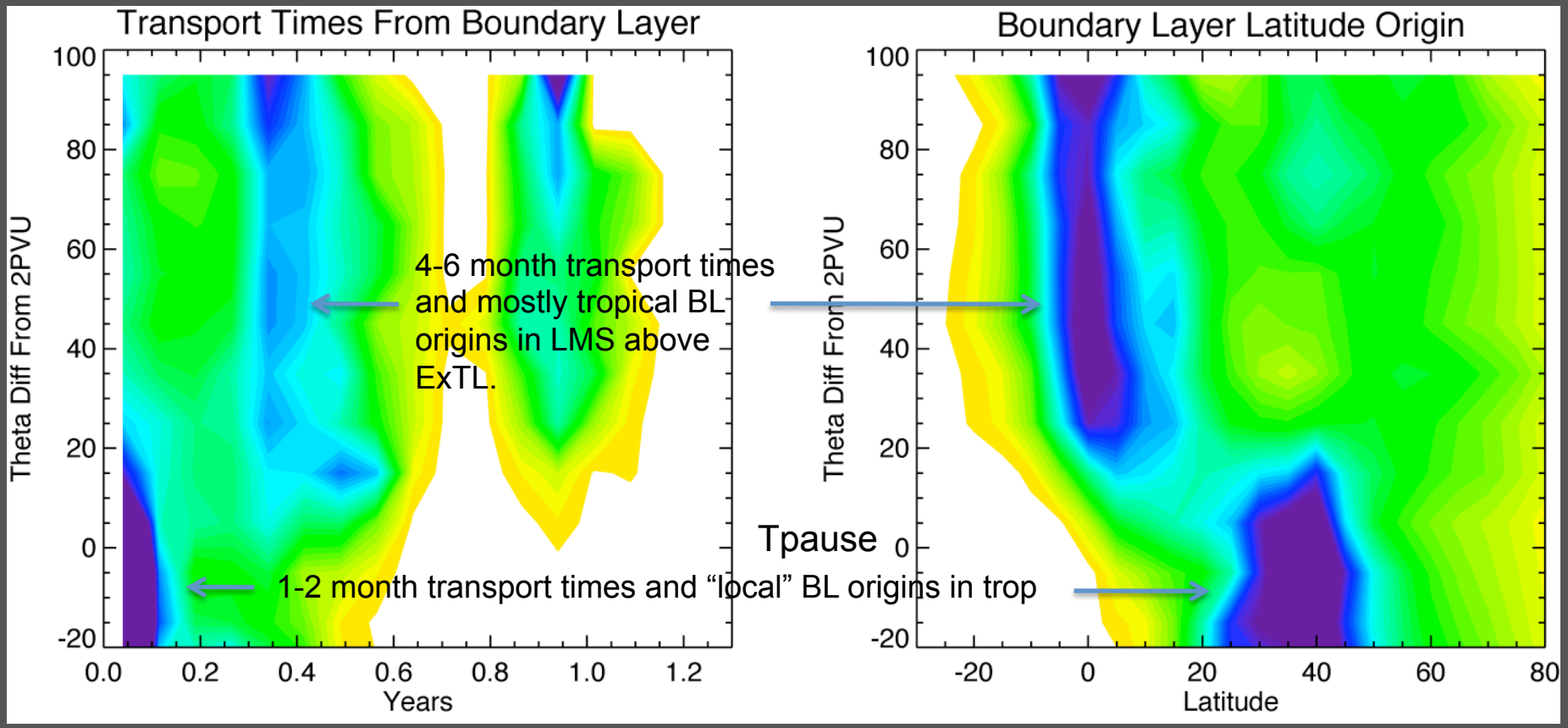


“Low Road” Transport Times and Boundary Layer Origins From the Age Tracers

- Adjusted example correlation matches within uncertainty the 30-40N and 10S-Eq curves.
- Green and blue squares represent closest match of boundary layer correlations to adjusted LMS correlation.
- Probability is assigned based on distance in correlation space between observed and BL correlations within the uncertainty box.
- Large difference in transport time if parcel originated at 30-40N (≈ 1 year) vs. 10S-Eq (several months).

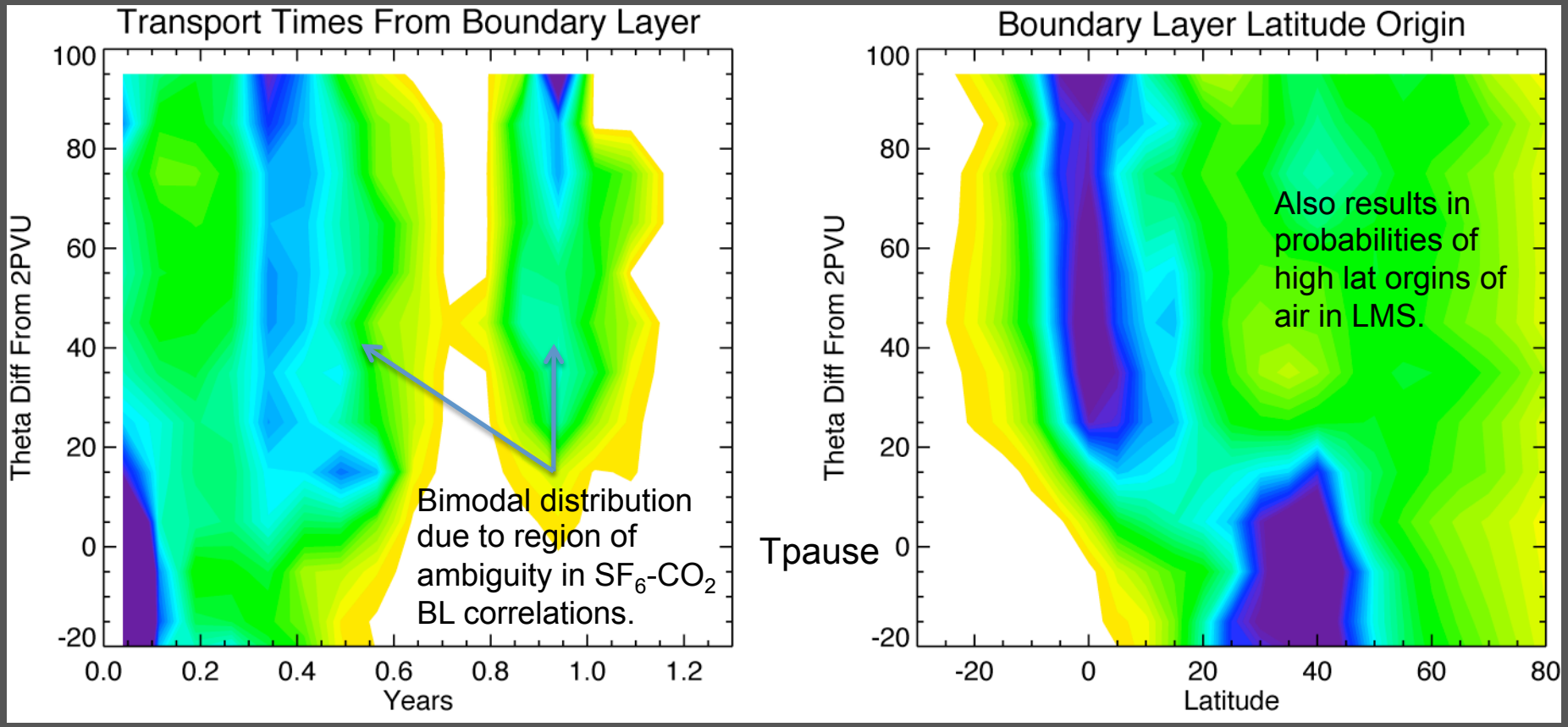


Probability Distribution Profiles From SF_6-CO_2 Correlations



- Purple and blue = higher probabilities, green and yellow = lower probabilities
- The total probability at each theta level is normalized to one.

Probability Distribution Profiles From SF_6-CO_2 Correlations



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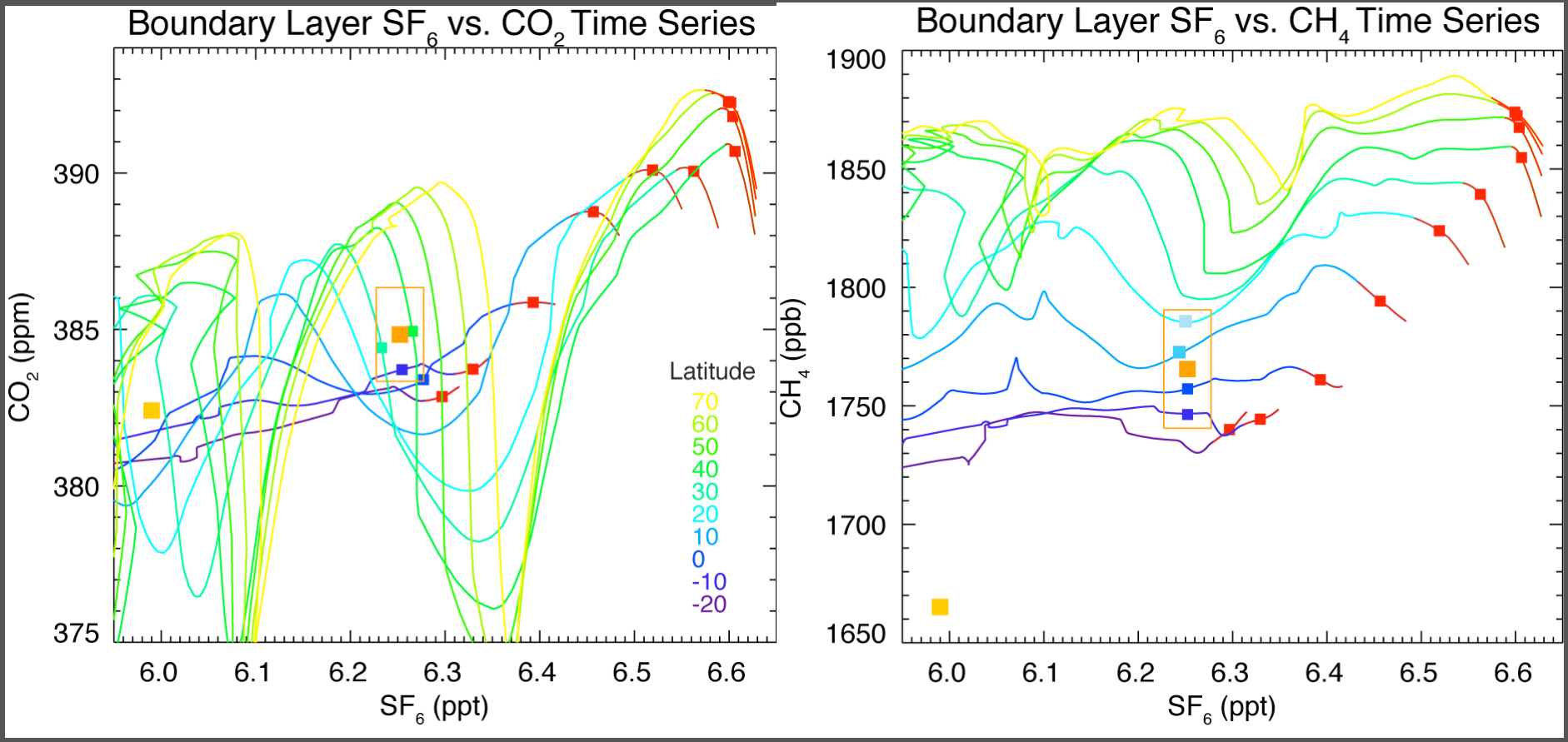
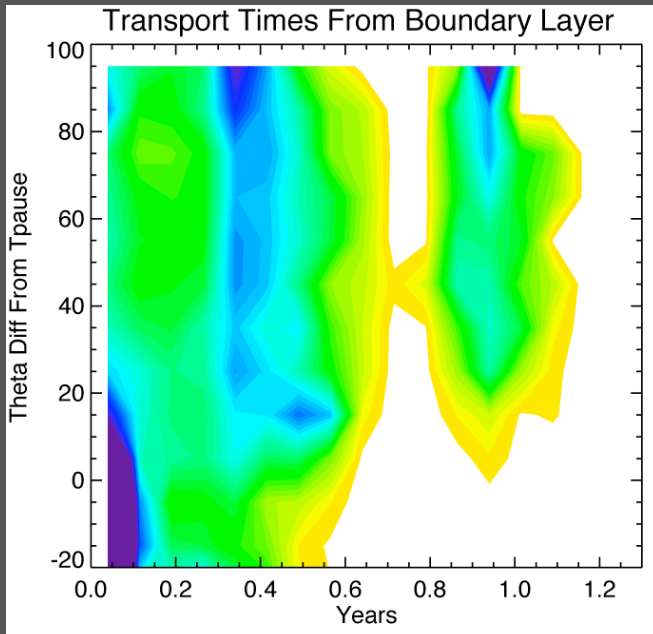
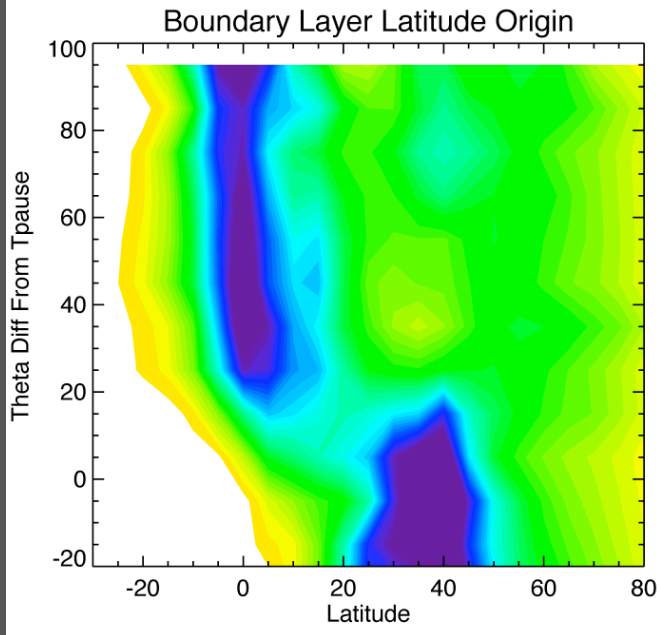
Add CH_4 to the Picture…



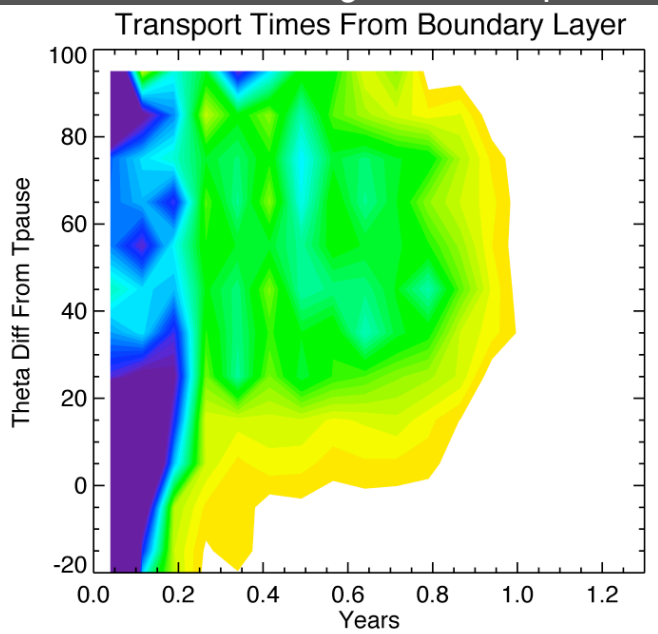
Reduces most of the ambiguity in boundary layer latitude origin, still working on merging the analysis using all three tracers.

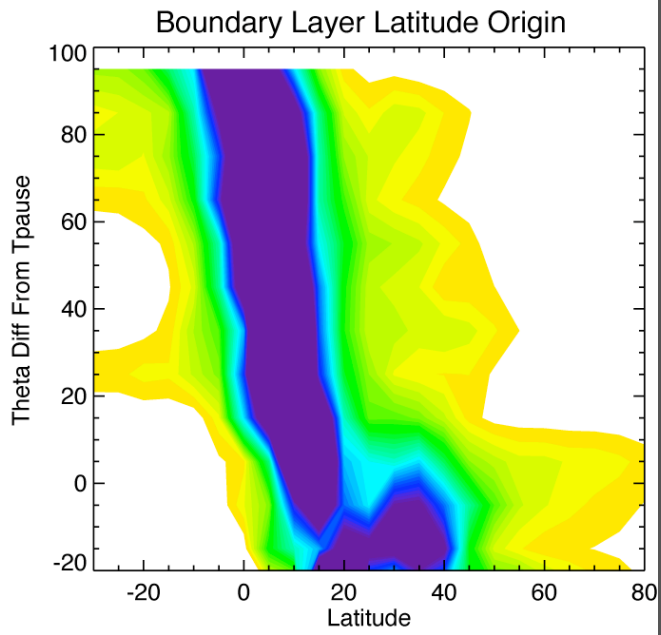
From SF_6 vs. CO_2



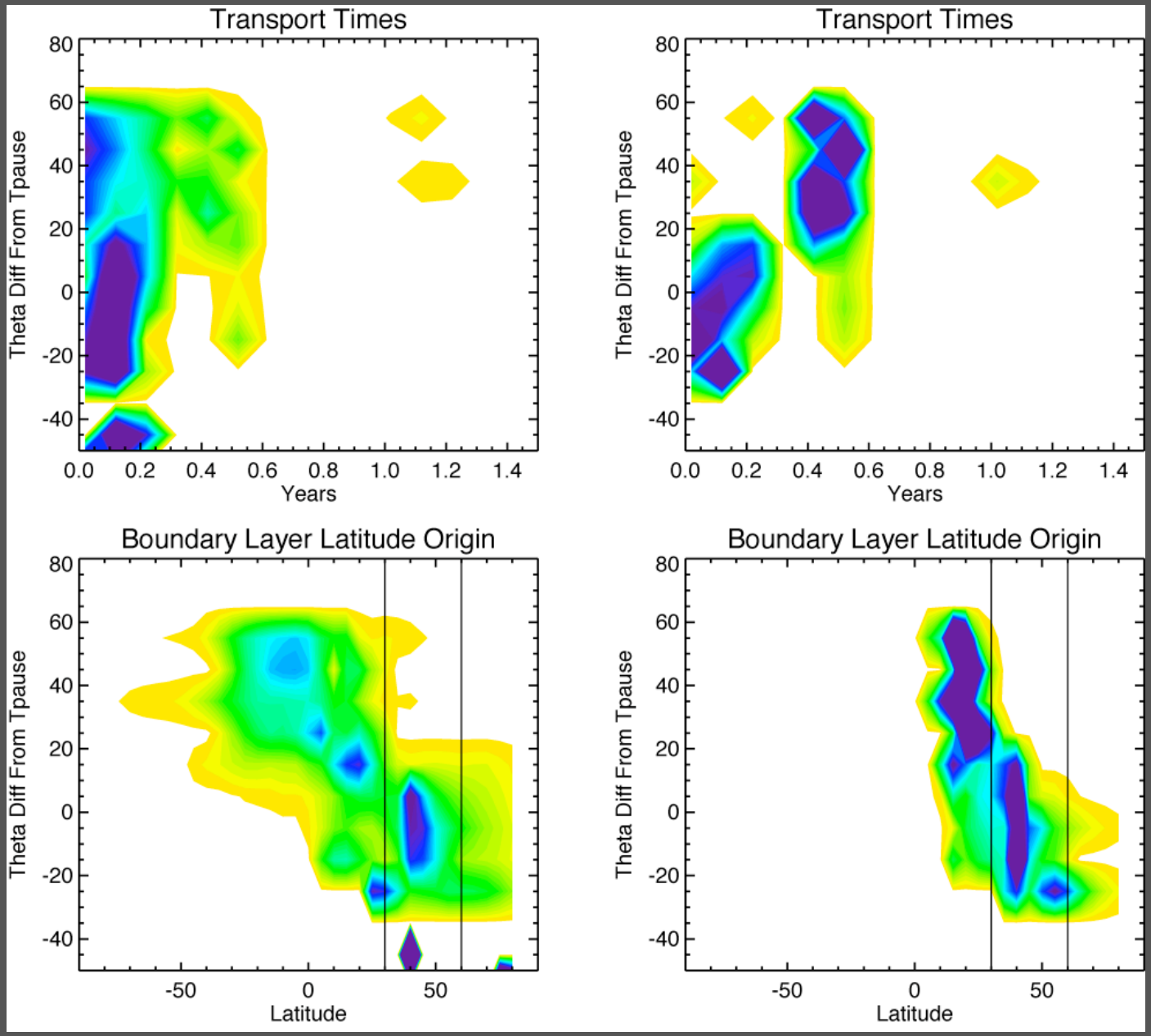


From SF_6 vs. CH_4

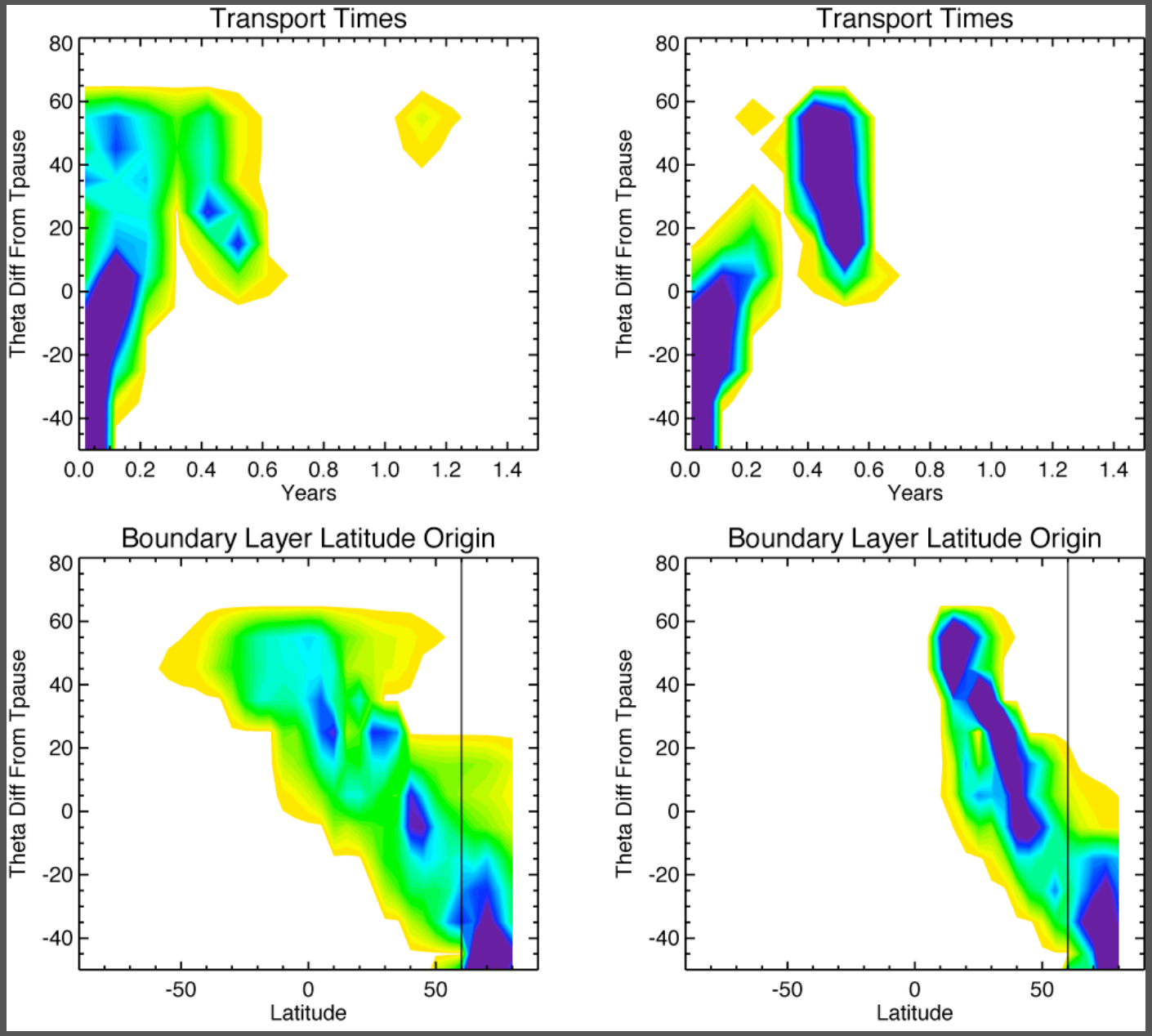




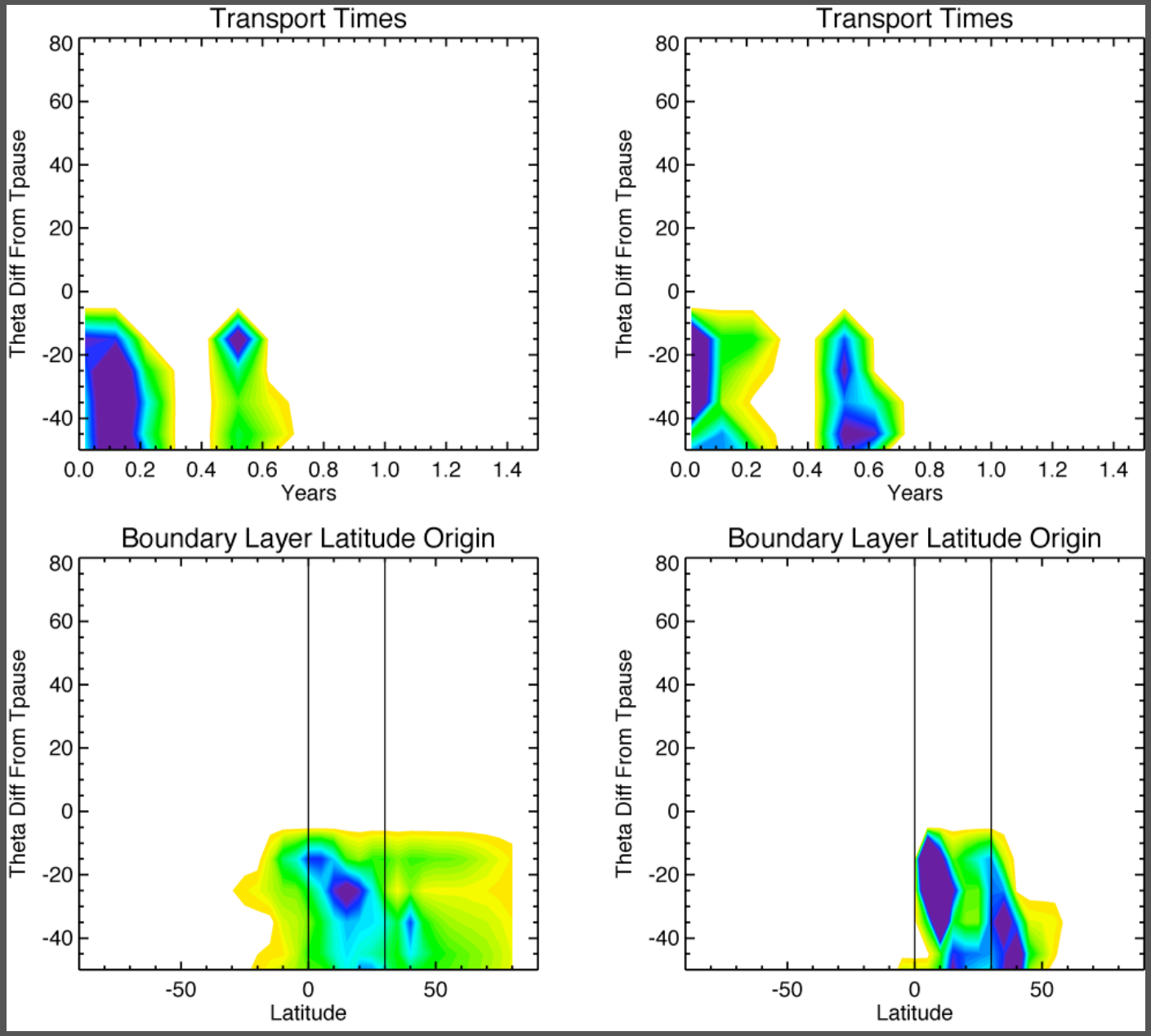
HIPPO 1 30-60N



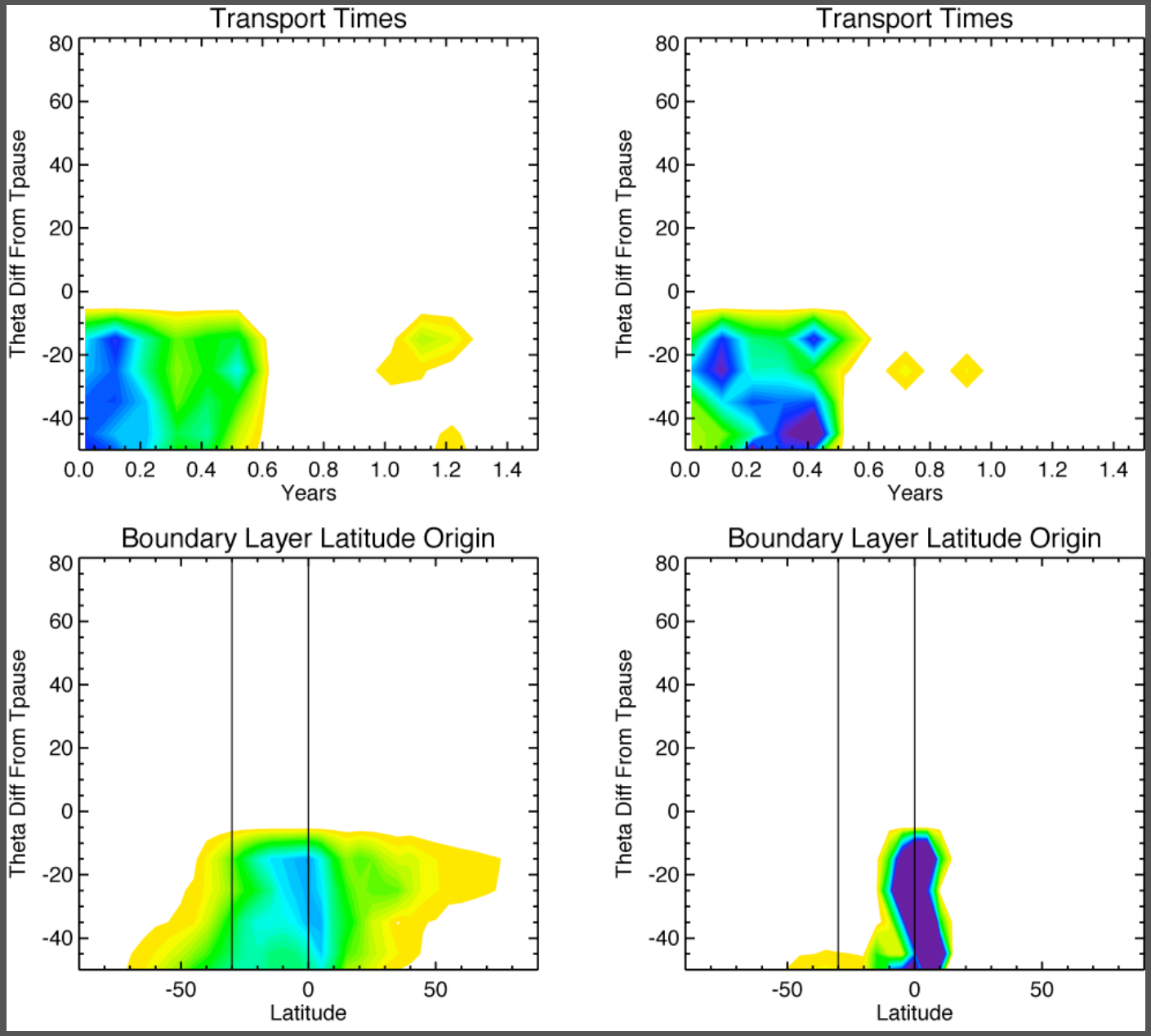
HIPPO 1 60-90N



HIPPO 1 0-30N


Transport Times
Theta Diff From Tpause
80
60
40
20
0
-20
-40
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Years
Transport Times
Theta Diff From Tpause
Years
Boundary Layer Latitude Origin
Theta Diff From Tpause
-50
0
50
Latitude
Boundary Layer Latitude Origin
Theta Diff From Tpause
Latitude

HIPPO 1 0-30S


Transport Times
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80
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Latitude
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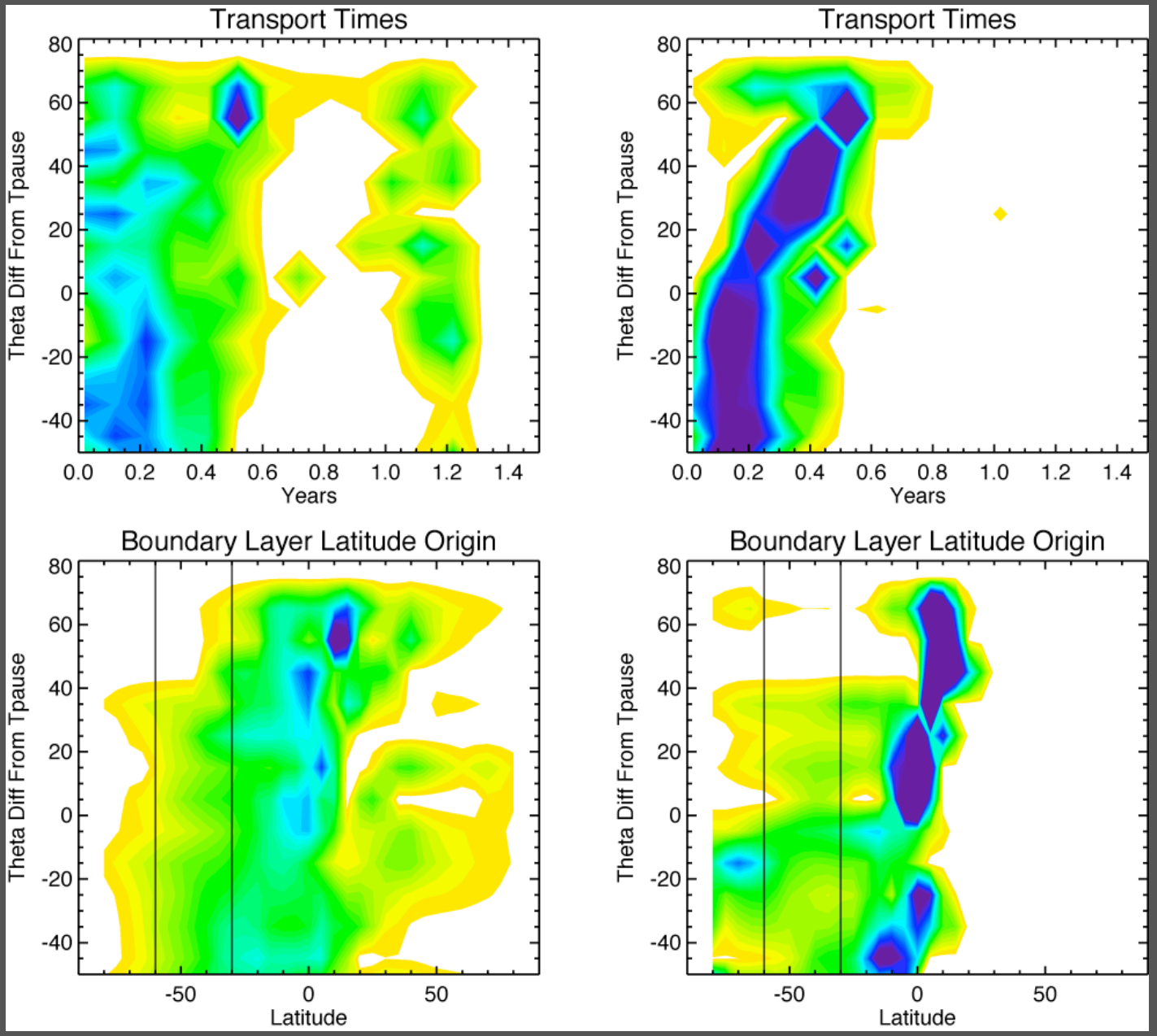
HIPPO 1 30-60S



Summary

- HIPPO dataset is unique and highly valuable for studying transport in the UTLS.
- A new technique was demonstrated using photolytic tracer correlations to estimate the “high road” transport.
- SF_6, CO_2 and CH_4 measurements with the high road transport removed allow the calculation of “low road” transport times from the boundary layer into the UTLS as well as boundary layer latitudinal origins.
- Further work will include more species and subsequent HIPPO campaign measurements.