Transport Rates and Age of Air in the Tropical Tropopause Layer during Boreal Winter

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CT3LS Meeting
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Motivation

Assess the impact of increasing greenhouse gases (GHG) in the troposphere on the stratosphere

- *Stratospheric composition*: fate of stratospheric ozone recovery (e.g., lifetimes of Ozone Depleting Substances), distribution of ozone, water, and OH and their impact on radiative properties of the UT/LS.

- *Stratospheric circulation*: changes in the strength of the large-scale Brewer-Dobson circulation (BDC). Models forecast an increase in tropical upwelling and strengthening of the BDC resulting in faster transit times in the stratosphere. Faster transit (or shorter residence times) result in younger air masses in the stratosphere, a property that we can test with GHG measurements.

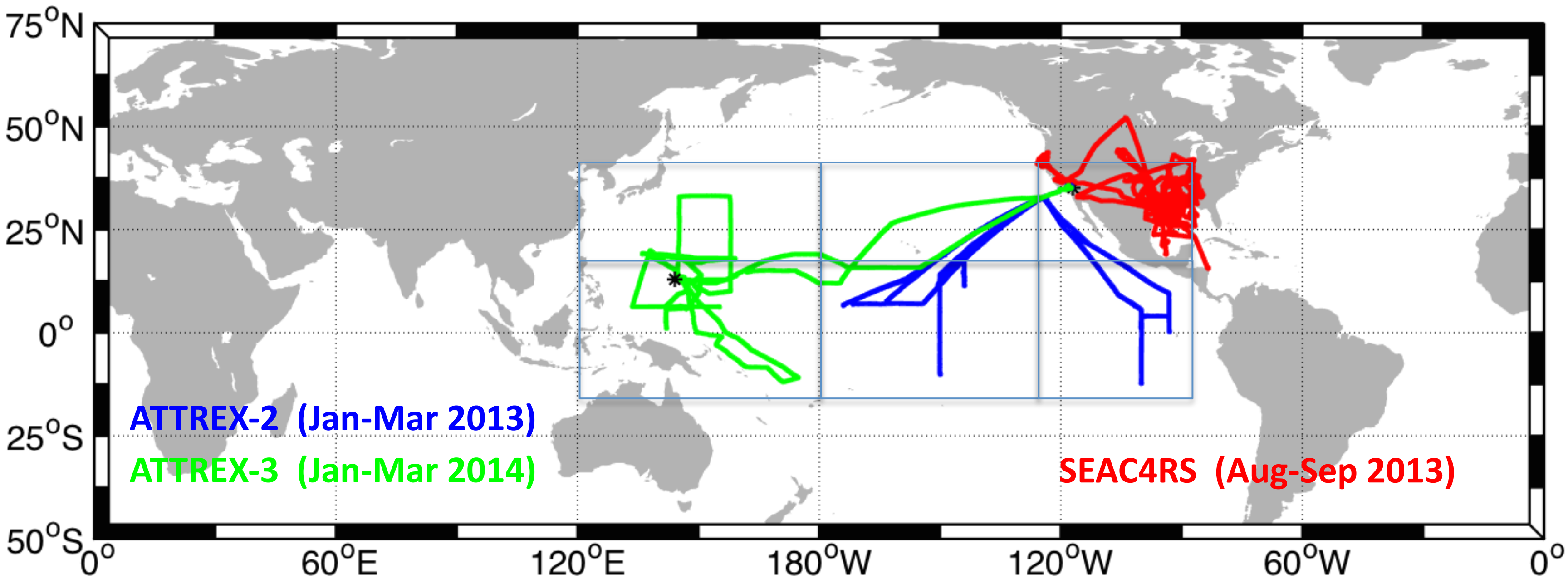
Scientific questions:

– What is the temporal and geographical variability of transport rates in the TTL?

– How well do models capture the variability in chemical composition and age of air in this region?

* GEOS-5 model   * TA&M Lagrangian trajectories

Aircraft Campaigns



Surface Measurements of CO_2

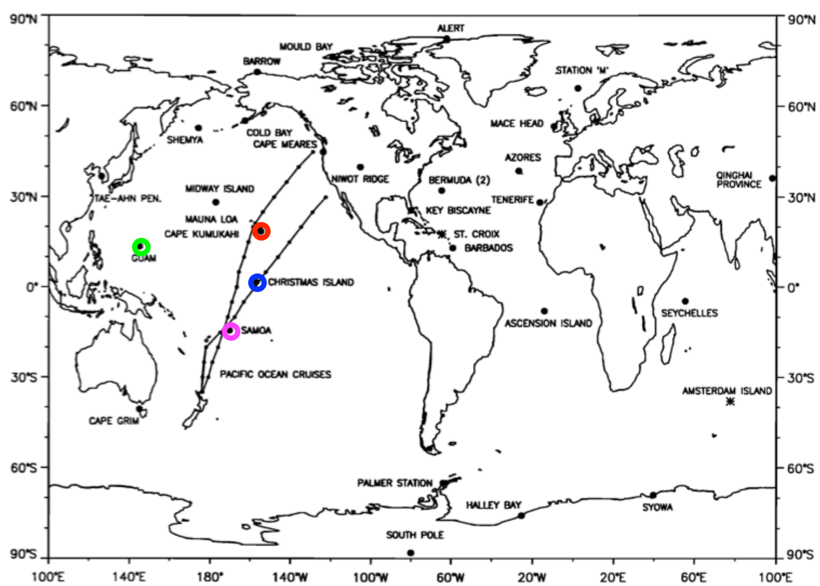
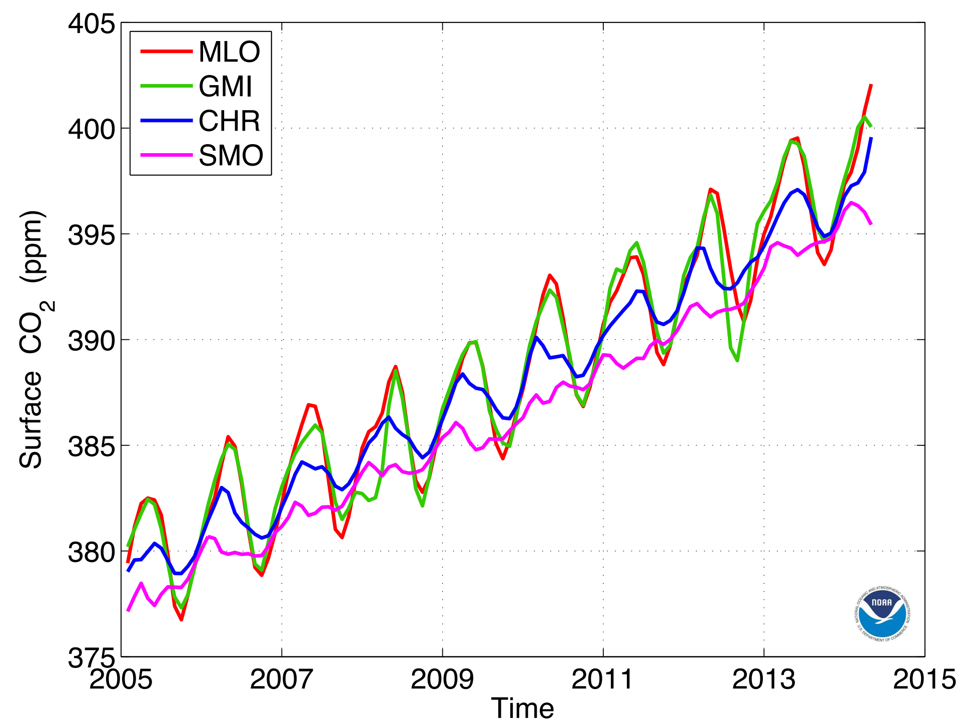
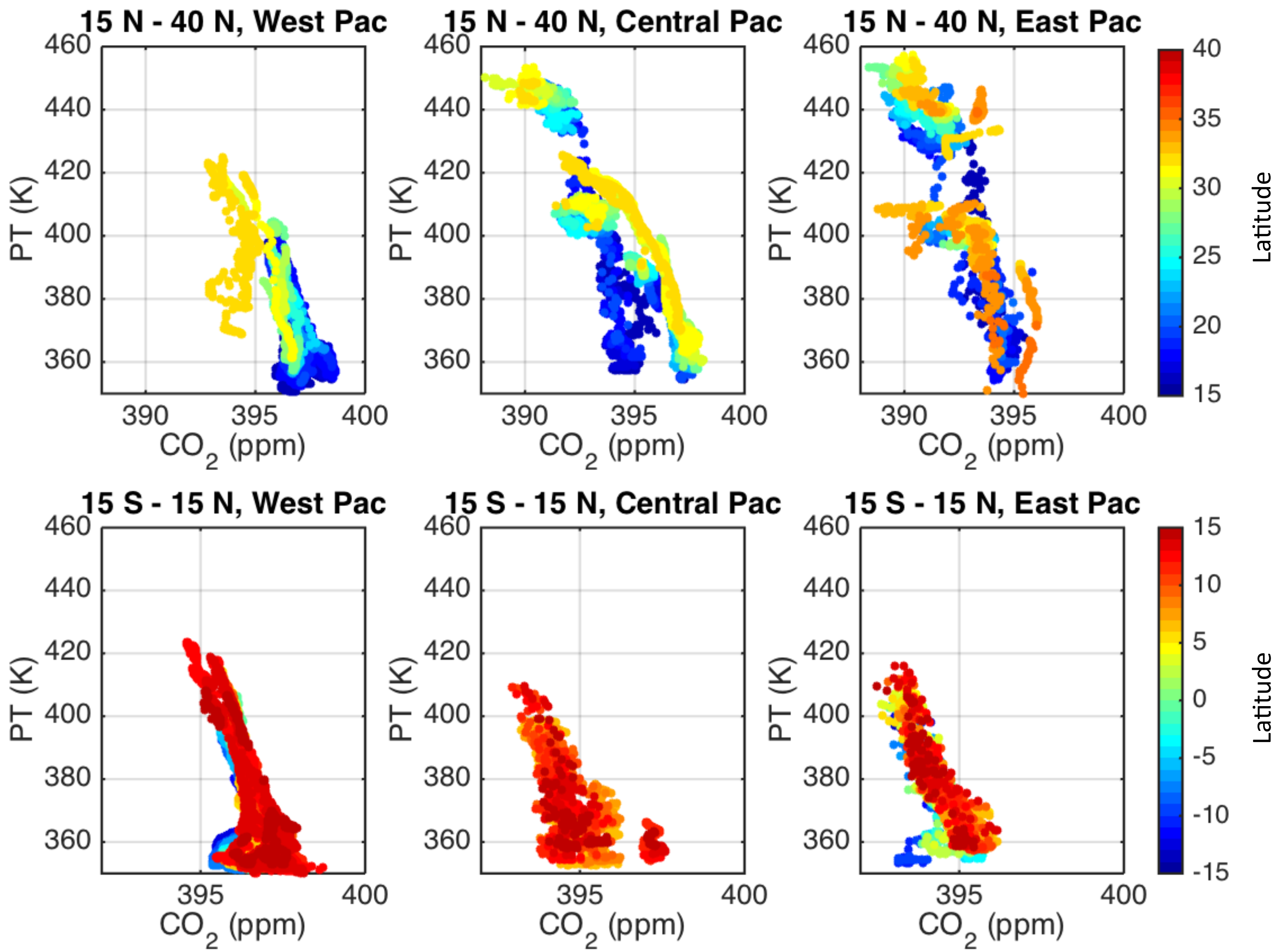


Figure 2. Map showing the locations of the Climate Monitoring and Diagnostic Laboratory (CMDL) cooperative flask-sampling network sites. The asterisks indicate sites where sampling has been discontinued.

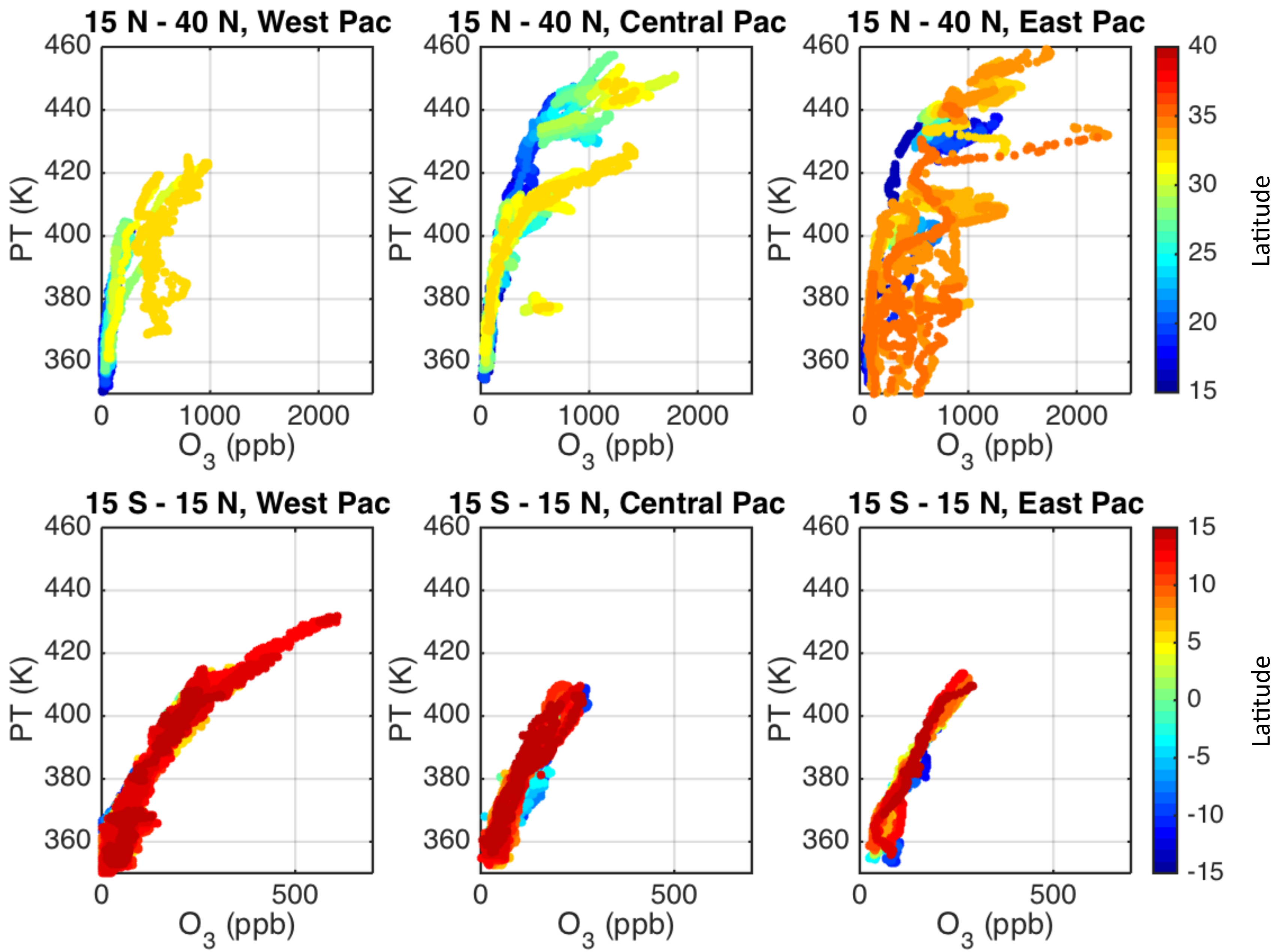
Conway et al., JGR, 1994

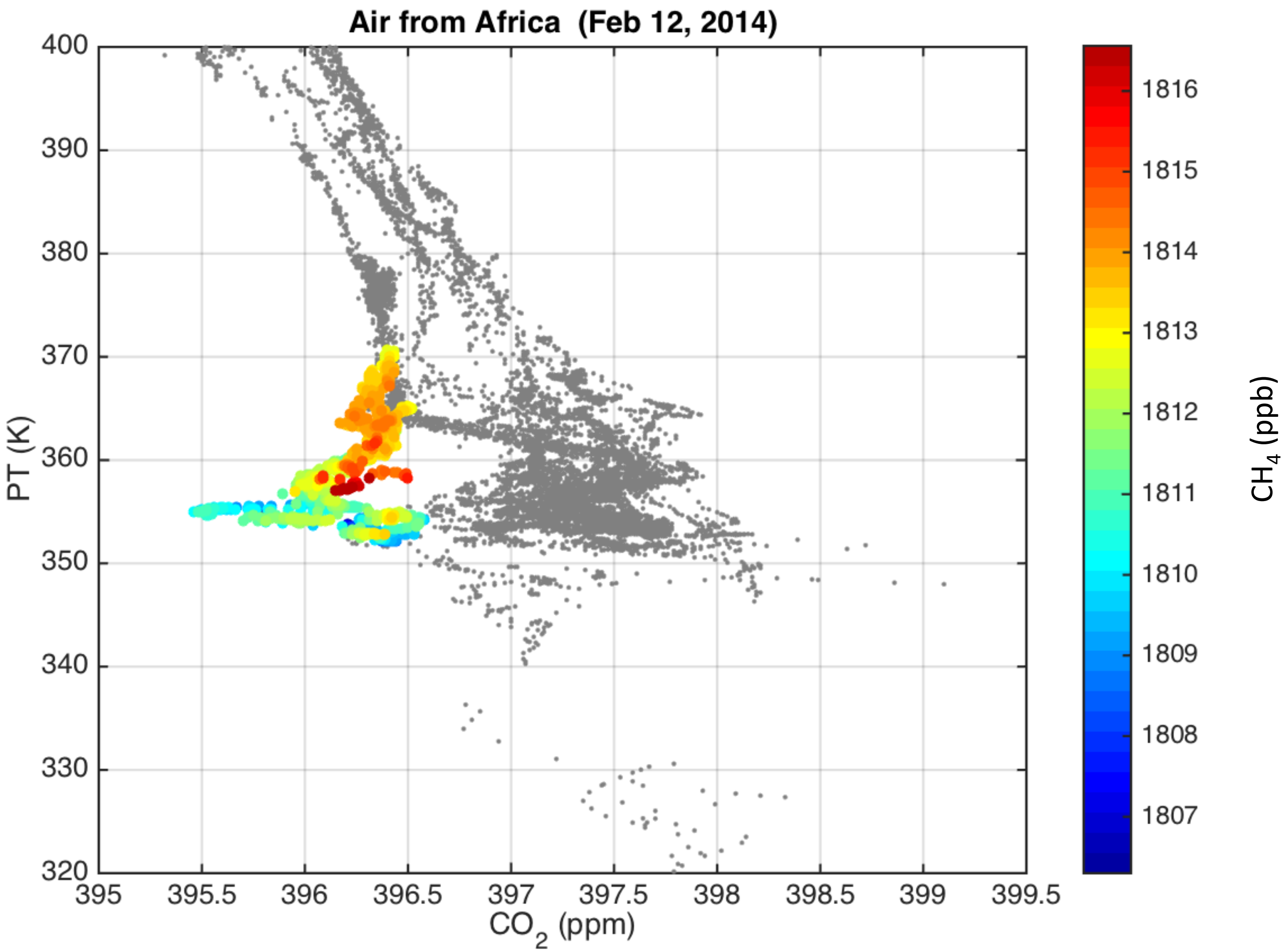


CO_2 Variability with Latitude, Longitude, and Altitude

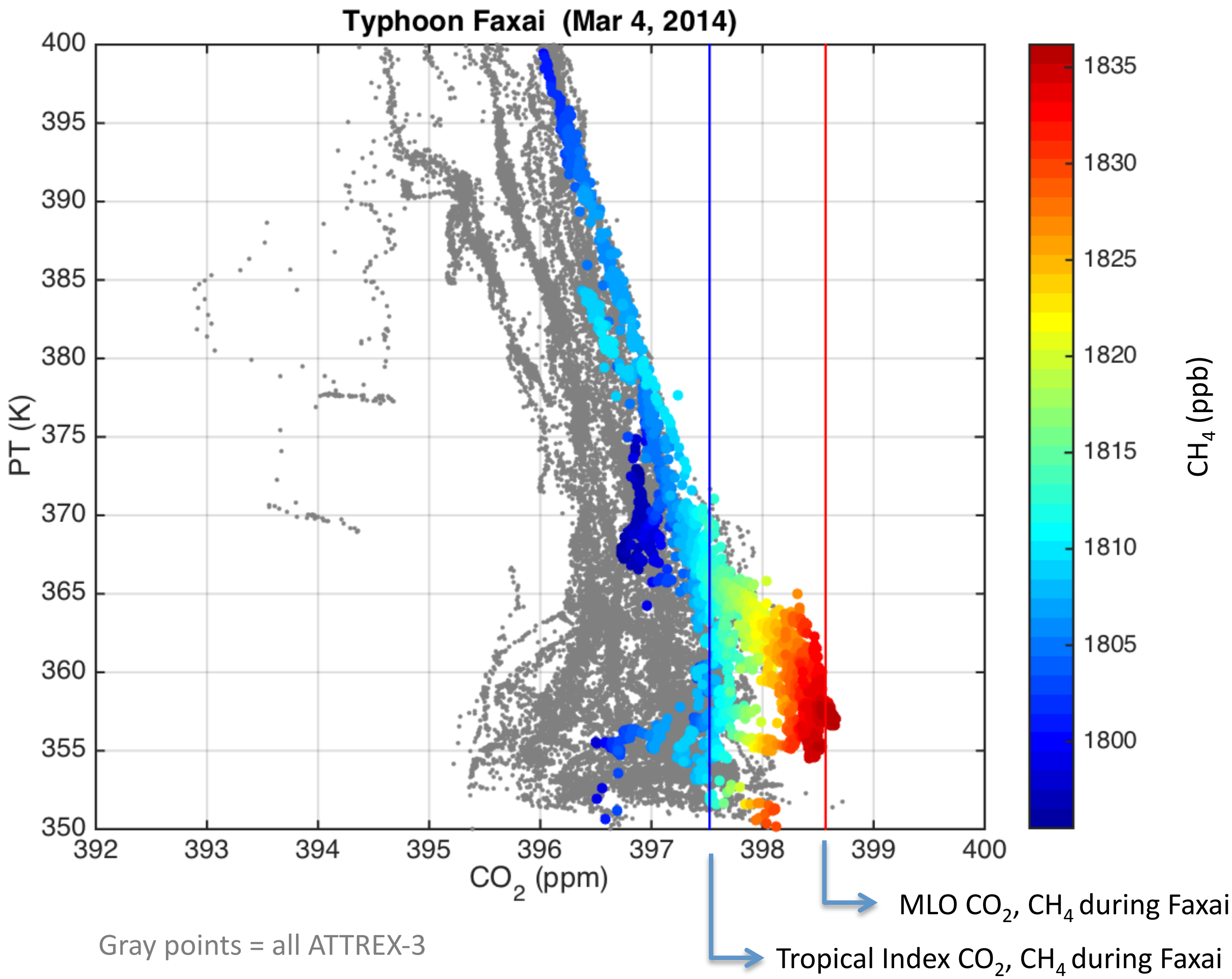


O_3 Variability with Latitude, Longitude, and Altitude



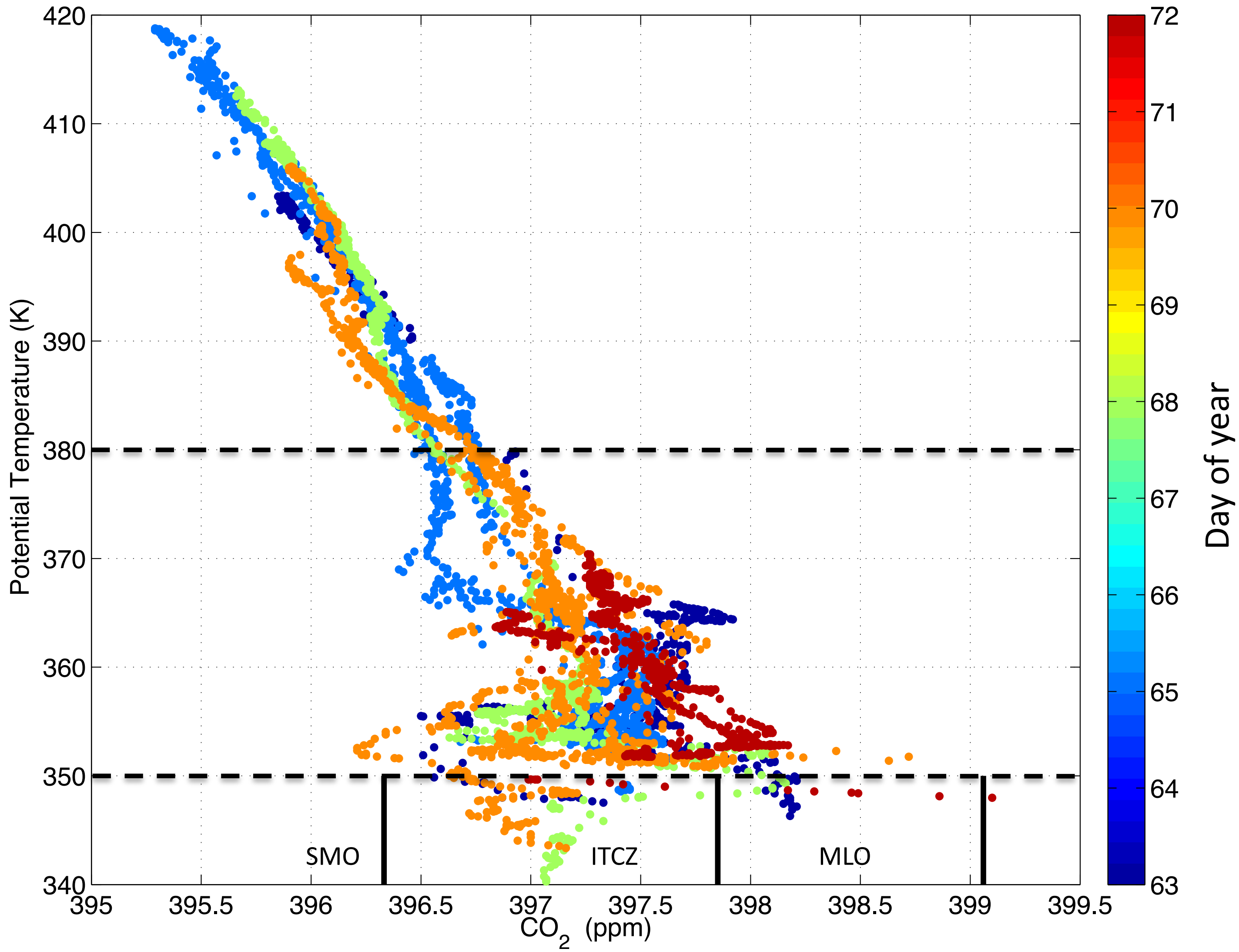


Gray points = data over Guam (10-15 N)


Typhoon Faxai (Mar 4, 2014)
PT (K)
400
395
390
385
380
375
370
365
360
355
350
392
393
394
395
396
397
398
399
400
CO_2 (ppm)
1835
1830
1825
1820
1815
1810
1805
1800
CH_4 (ppb)
MLO CO_2, CH_4 during Faxai
Tropical Index CO_2, CH_4 during Faxai
Gray points = all ATTREX-3

Vertical Profiles of CO_2 over Guam

Mar 4 – 13, 2014

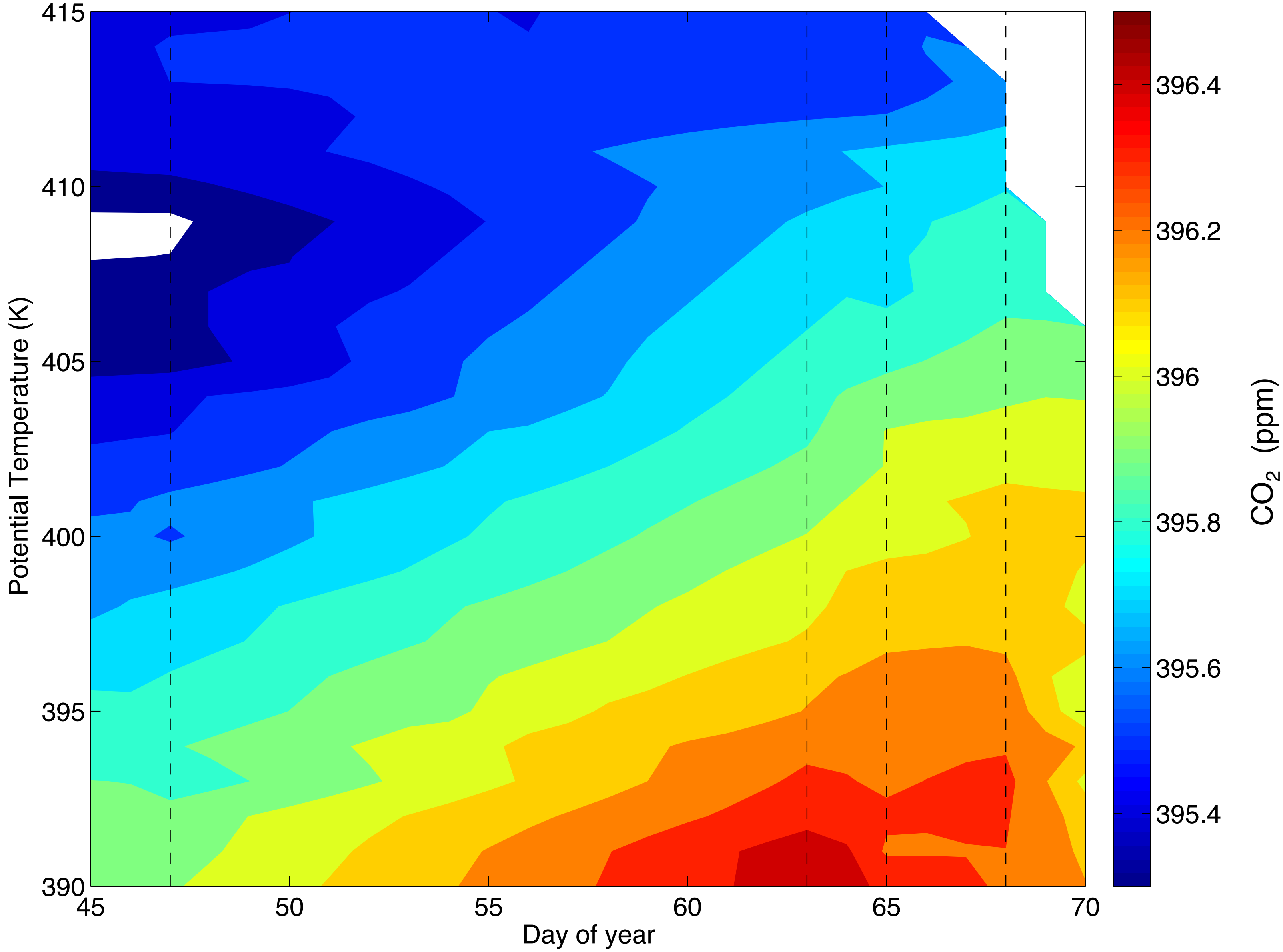


Tracer Variability: 1-D Tracer Continuity Equation

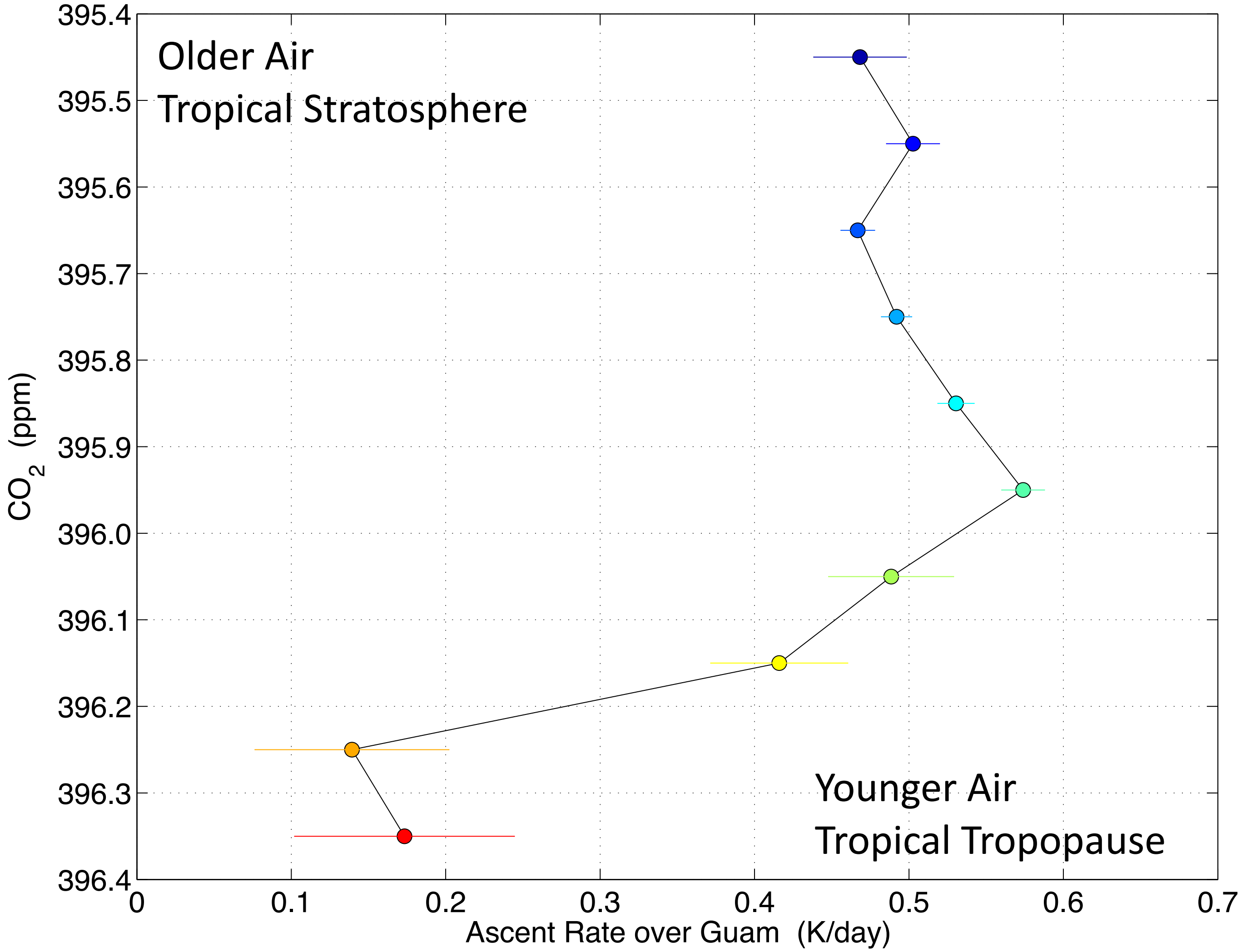
$$\frac{\partial \chi}{\partial t} = \underbrace{\frac{1}{\rho} K_\theta \frac{\partial}{\partial \theta}\left(\rho \frac{\partial \chi}{\partial \theta}\right)}_{\text{Vertical Diffusion}} - \underbrace{Q \frac{\partial \chi}{\partial \theta}}_{\text{Vertical Advection}} - \underbrace{\frac{1}{\tau}(\chi - \chi_e)}_{\text{Horizontal Mixing}} + \underbrace{(P - L)}_{\text{Net Photochemical Rate}}$$

χ	tracer mixing ratio
χ_e	tracer mixing ratio in the extra-tropics
K_θ	coefficient of vertical diffusion
Q	vertical velocity
τ	relaxation time
ρ	air density
θ	Potential Temperature above the tropical tropopause (390 K)
$P - L$	net photochemical rate (=0 for CO_2)

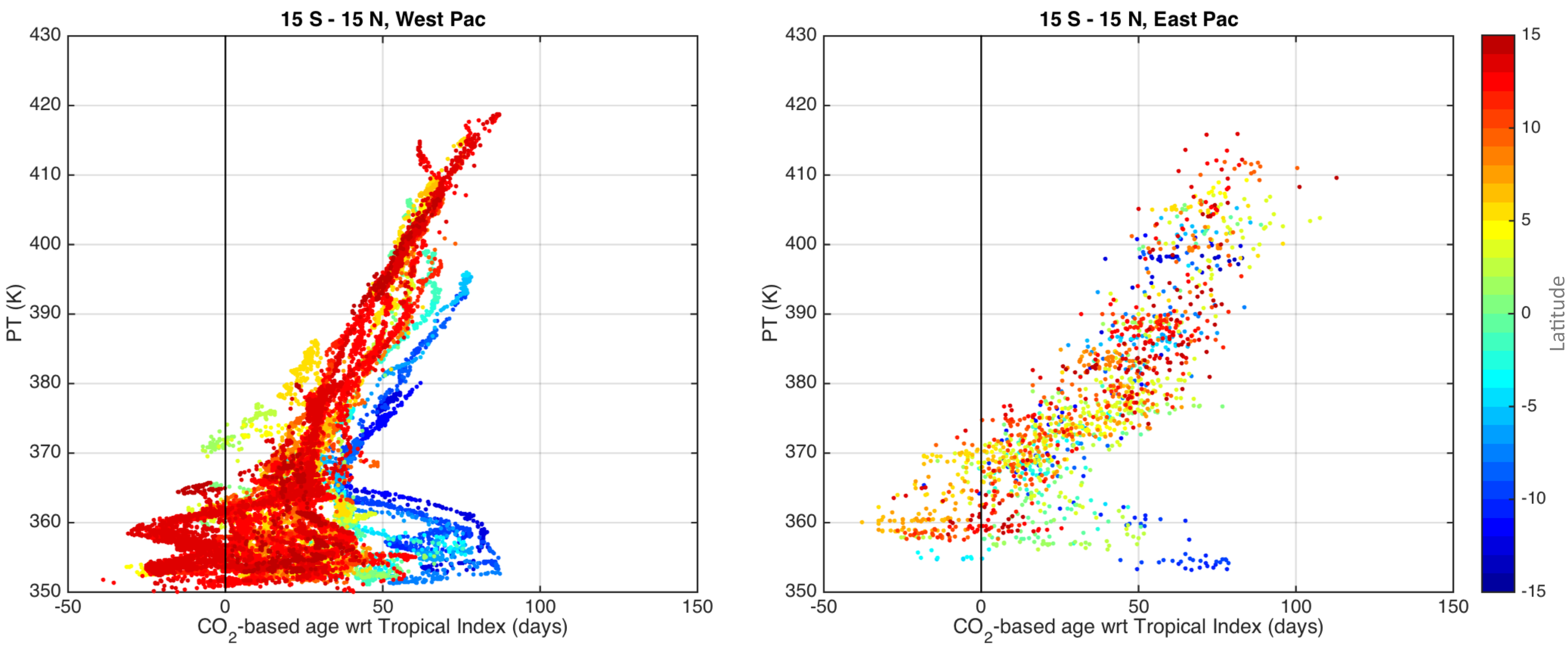
CO_2 Evolution in the Lower Stratosphere over Guam



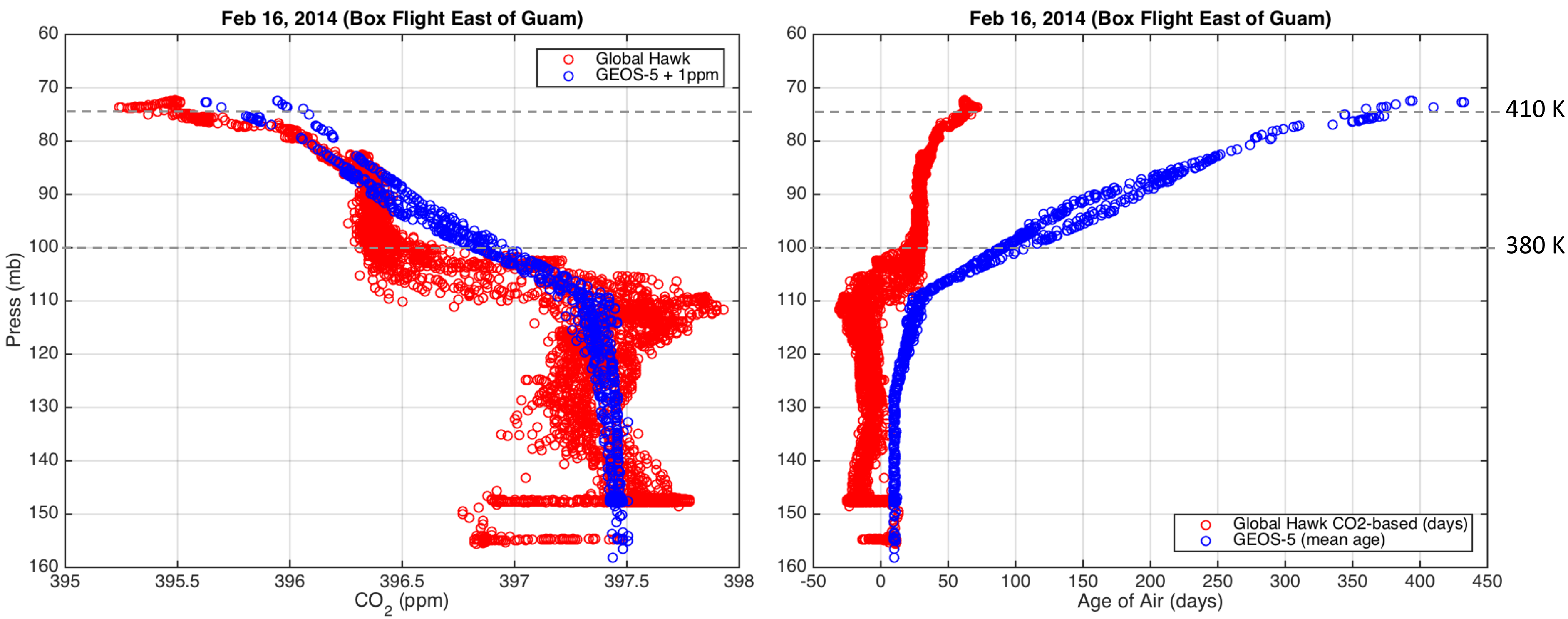
CO_2 Evolution in the Lower Stratosphere over Guam –> Vertical Advection only



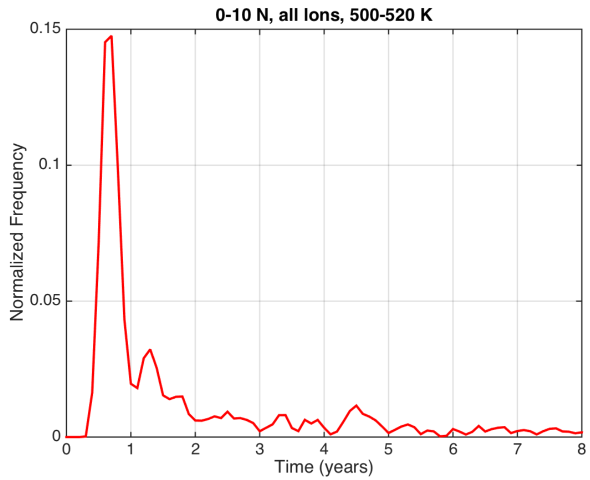
CO_2- based Age of Air with respect to Tropical Index: Western vs Eastern Pacific, Northern vs Southern Hemisphere

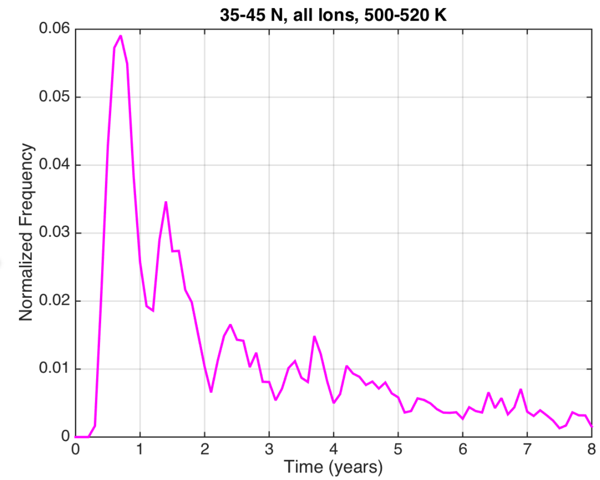


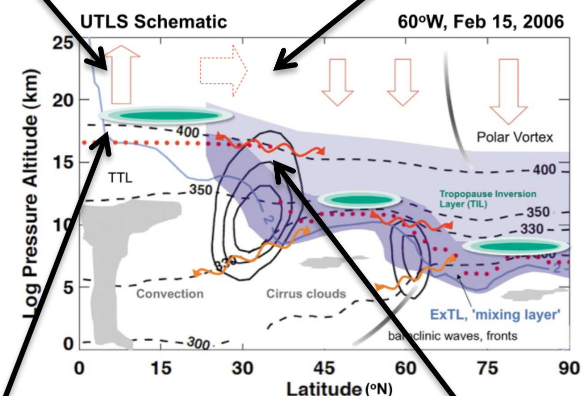
Model vs Observations: CO_2 and Age of Air



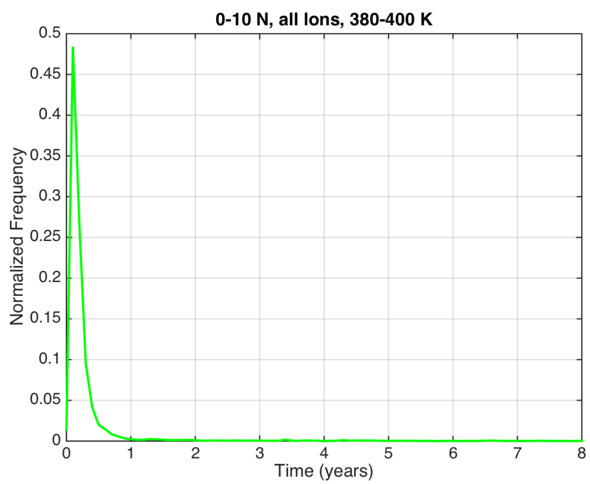
Age Spectra

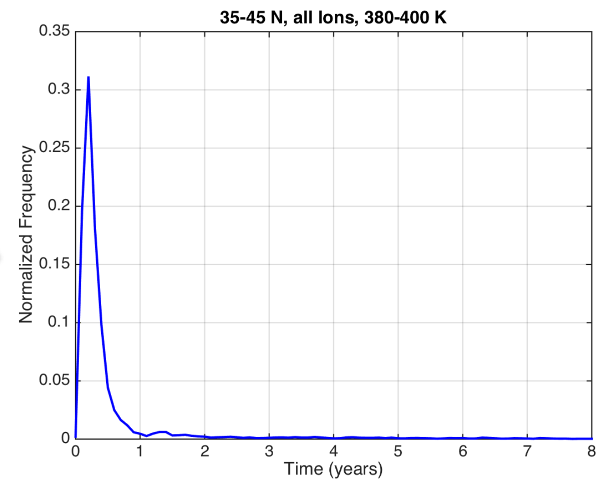


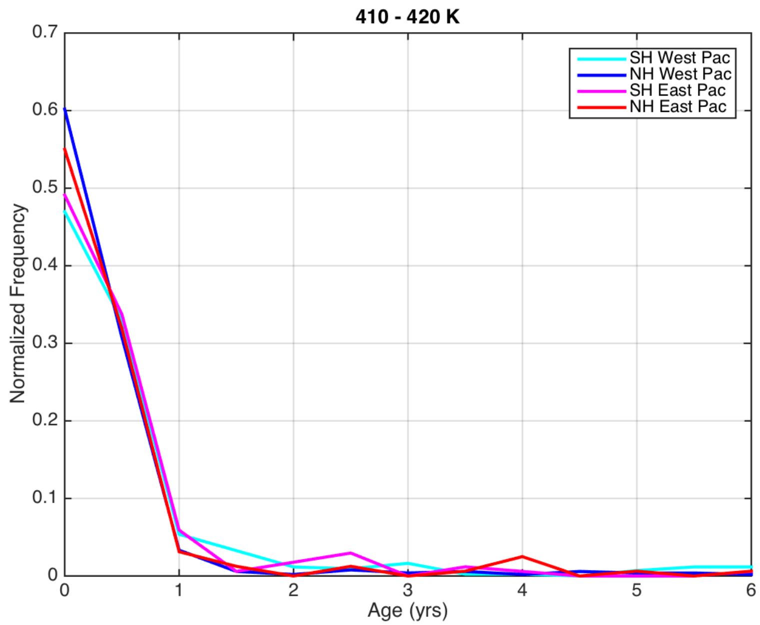


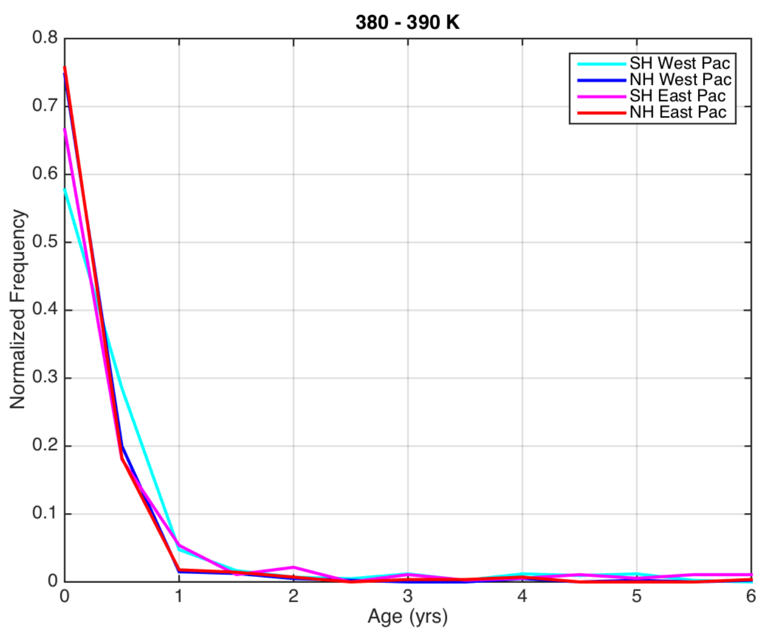


Gettelman et al., Rev. Geophys., 2011

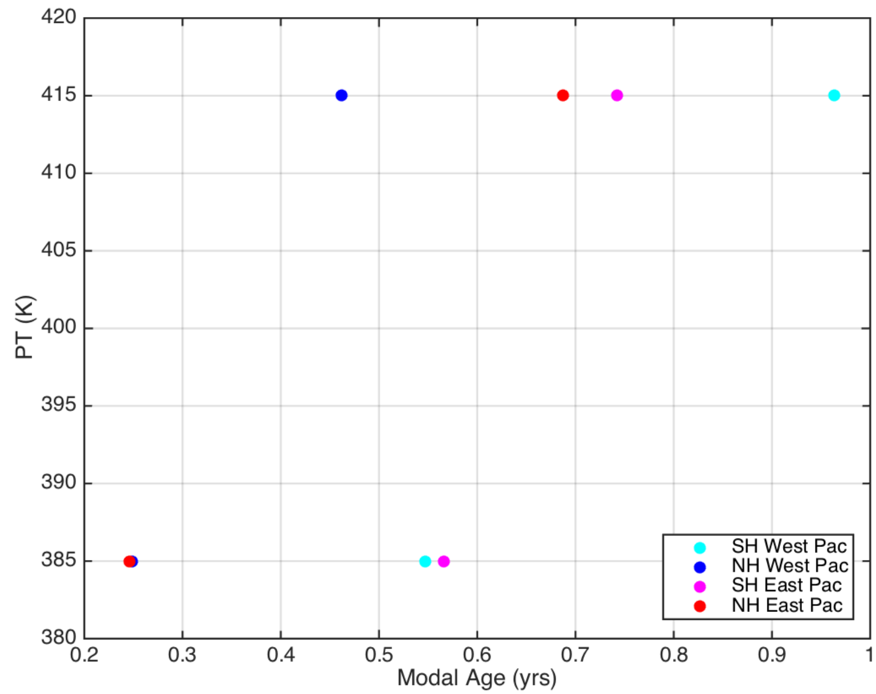




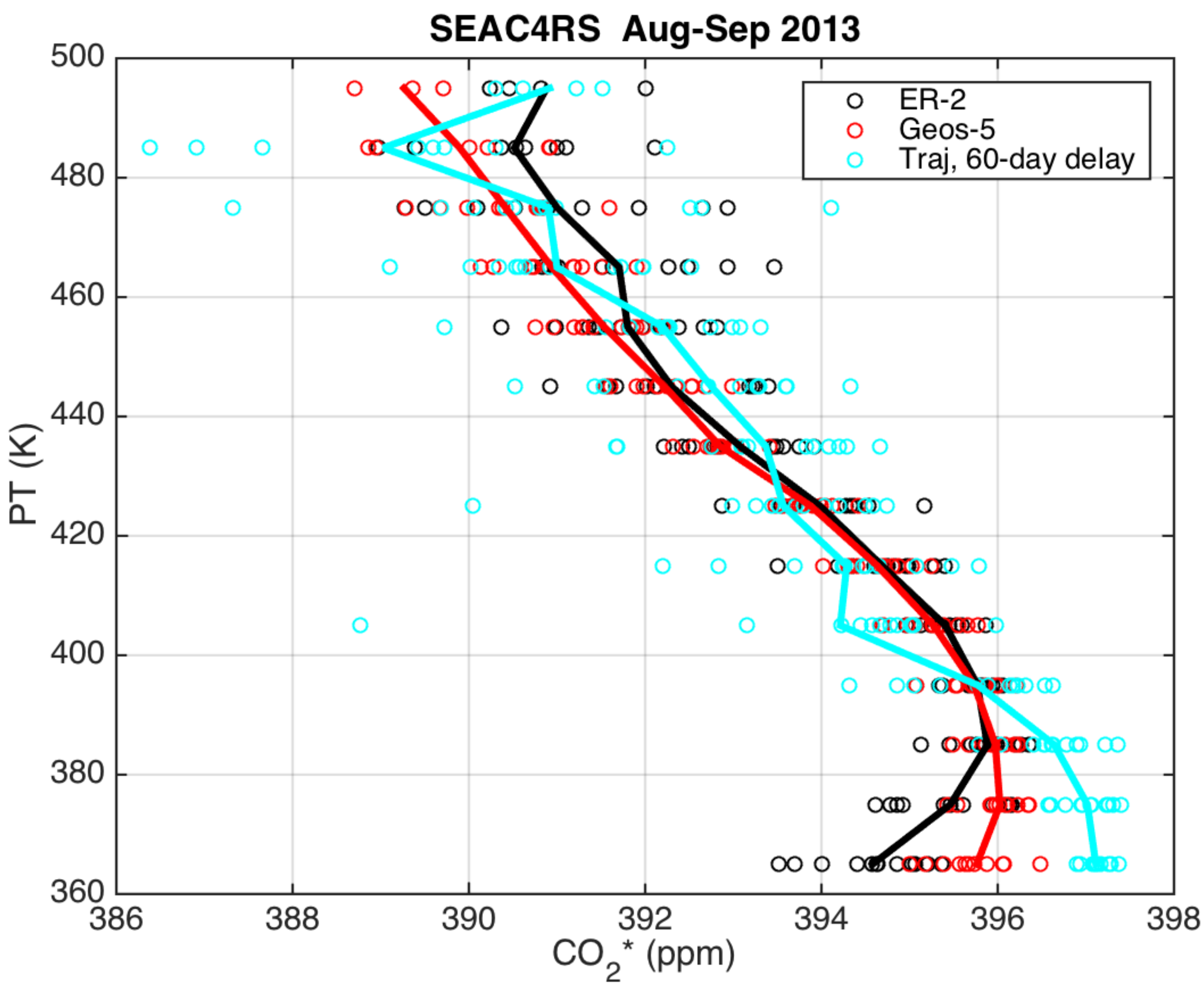




Age Spectra and Mean Age in the TTL



Reconstructing CO_2 profiles with models



Summary

- Temporal and geographical variability in tracer distribution are evident in the aircraft observations, even though they can be small in magnitude.
- Events such as long-range transport of biomass burning from Africa and typhoons modify the chemical composition of the bottom of the TTL over the Western Pacific.
- CO_2 observations can be used to determine ascent rates in the deep tropics (assuming vertical advection only) and are comparable to previous studies.
- ATTREX measurements and models (GCM, trajectories) should provide a powerful combination to dissect and evaluate processes responsible for the observed chemical signatures in the TTL.


THANKS!