The Role of Convection in Tropical Ozone Variability Inferred from Profiles at NOAA's SHADOZ (Southern Hemisphere Additional Ozonesondes) Stations (1998-2017)

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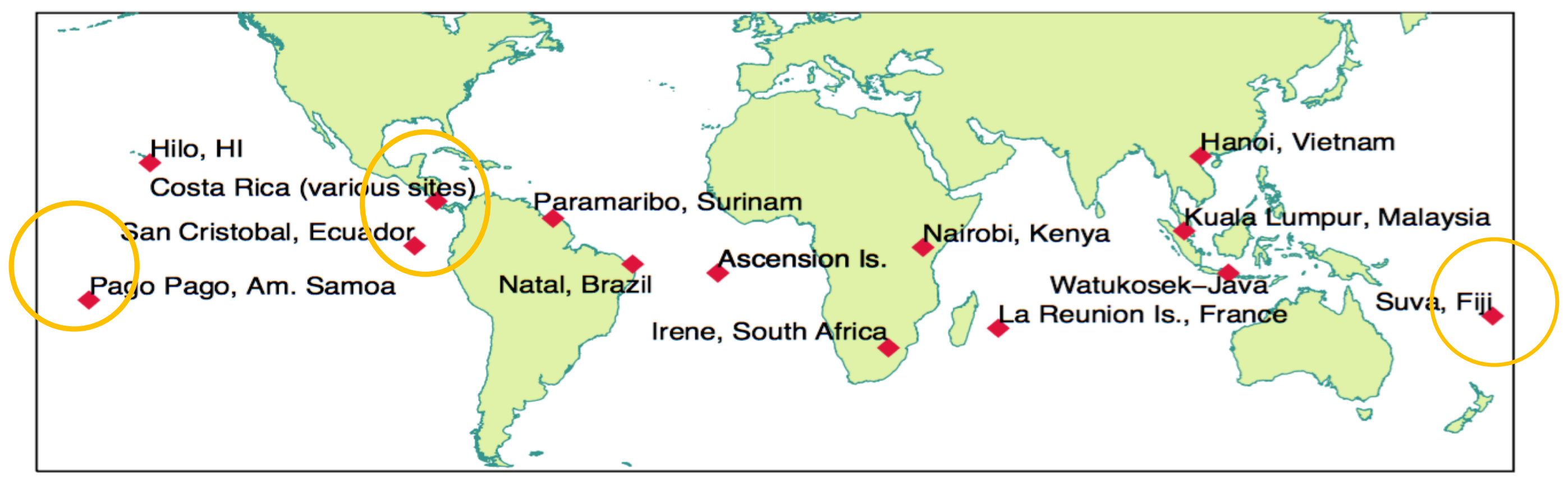
INTRODUCTION

The tropical free troposphere (FT) and Tropopause Transition Layer (TTL) are critical regions in changing atmospheric composition. Tropical ozonesonde data are isolated in fewer than 10 dozen stations but their superior vertical resolution is ideal for studying structure throughout the FT and TTL. Here we use the reprocessed 1998-2017 SHADOZ data (> 7500 profiles, Sterling et al., 2018; Thompson et al., 2017; Witte et al., 2017, 2018) to analyze the role of deep convection in seasonal and interannual variability in FT and TTL ozone at 4 Pacific stations that have been supported by NOAA: Fiji, Samoa, Costa Rica, San Cristóbal. **Convective Influence (CI)** is identified by 3 statistical methods: Gravity-wave identification (Thompson et al, 2010); Self-Organizing Maps and associated meteorological parameters (Stauffer et al., 2018); analysis of the 20-yr time series of TTL ozone with a multi-linear regression model that accounts for seasonal cycles, QBO, MJO, and ENSO. Results vary by site location. Contrasts in CI between NOAA Pacific sites and the Atlantic SHADOZ site, Ascension, are displayed. Variability observed in SHADOZ data constitutes an independent reference for models and satellite data that are used to interpret tropical ozone oscillations and trends.

SHADOZ MAP WITH NOAA'S SITES

Data are publicly available at https://tropo.gsfc.nasa.gov/shadoz

Figure 1



NOAA has supported ozone soundings at the 4 circled stations and at subtropical Hilo (since 1980s). The Atlantic sites supported by NASA/Goddard are Natal and Ascension.

CONVECTIVE INFLUENCE (CI) IN OZONE CLIMATOLOGY

Figure 2 below displays mean monthly ozone at 3 tropical Pacific NOAA stations and Ascension in the Atlantic. Low ozone in the upper FT signifies convective influence (CI) as near-surface clean marine air is redistributed vertically. Seasonally high ozone in the FT is from pollution, typically biomass fires in the tropics. Seasonal transitions in the apparent ratio of CI vs pollution influences varies from station to station. Samoa and Fiji are similar in timing of deepest convection (Jan.-March/April) and pollution Sept. to November. At Costa Rica the greatest CI is in November to January; pollution in June-October coincides with the cloudy rainy season studied in TC4 (Thompson et al., 2010). The Atlantic Ascension Island presents a distinct contrast with a short season of CI in March-May and extensive pollution from June through November.

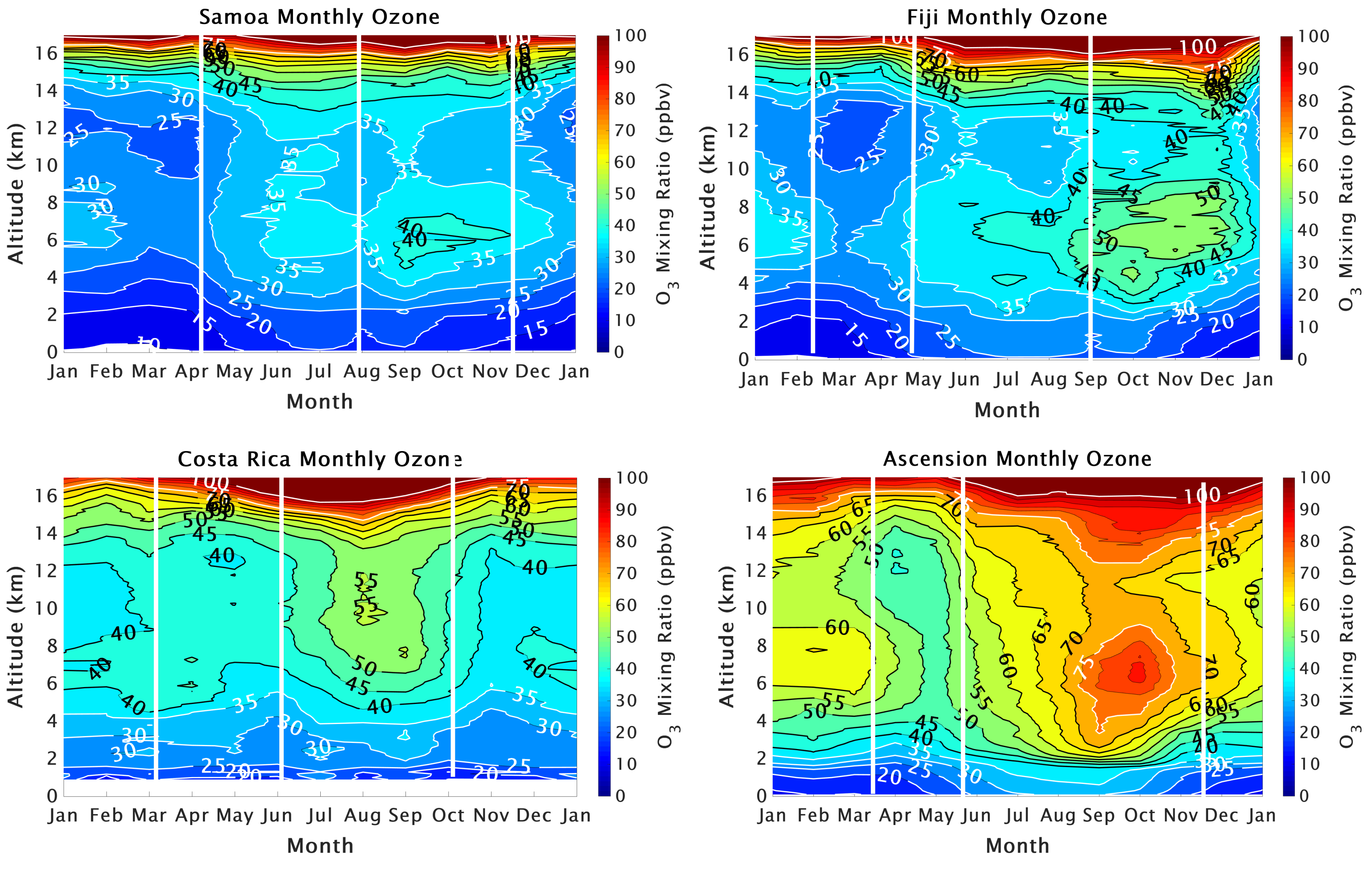


Figure 2

CI IDENTIFIED BY GRAVITY WAVE FREQUENCY

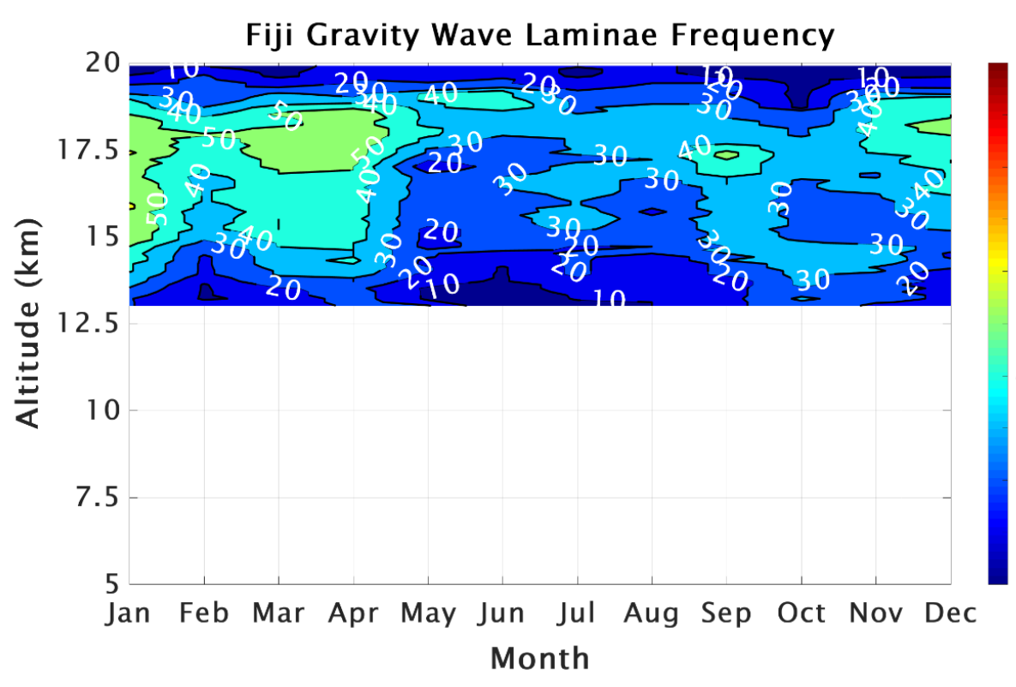


Figure 3a

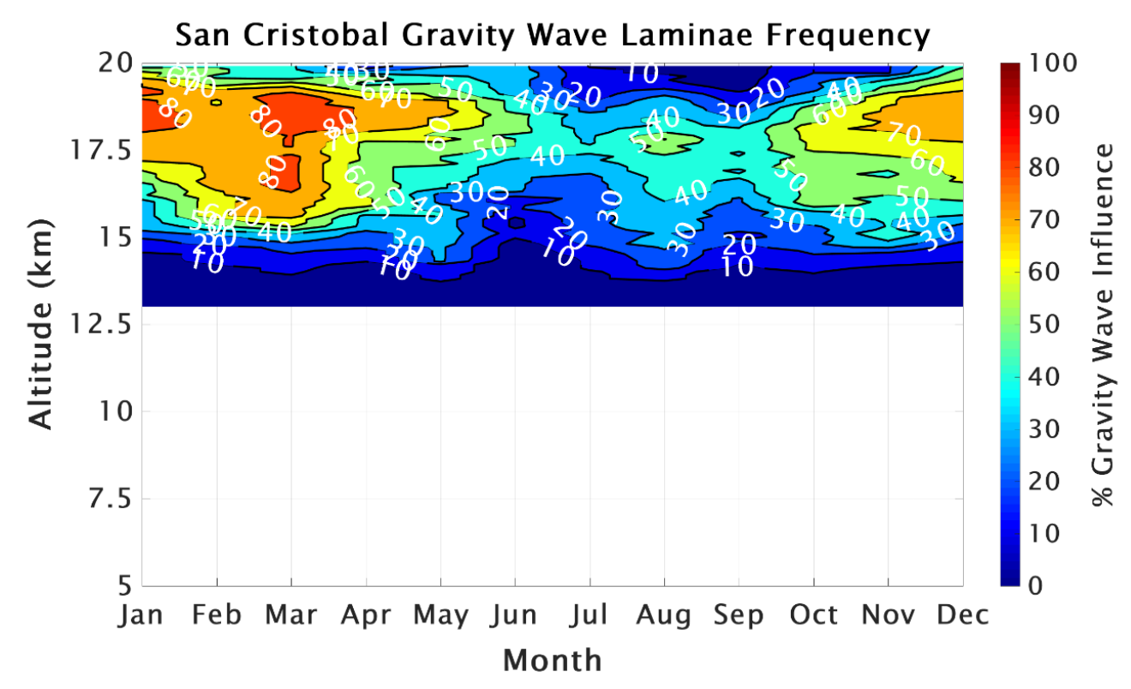


Figure 3b

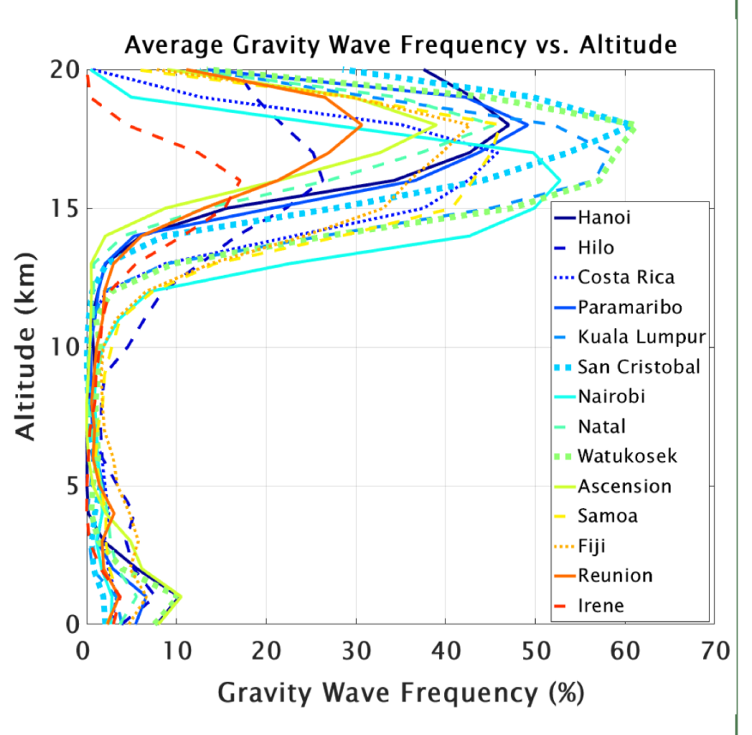


Figure 4

In **Figure 3** the greatest frequency of gravity waves (GW), associated with convection and inferred from ozone laminae over each station (Thompson et al., 2010), corresponds to CI variability seen in **Figure 2.** The greatest annually averaged GW is closer to the Equator (San Cristóbal at 1S vs Fiji at 18S); GW frequency is less at Ascension (**Figure 4**).

CI IDENTIFIED WITH OZONE PROFILE SOM

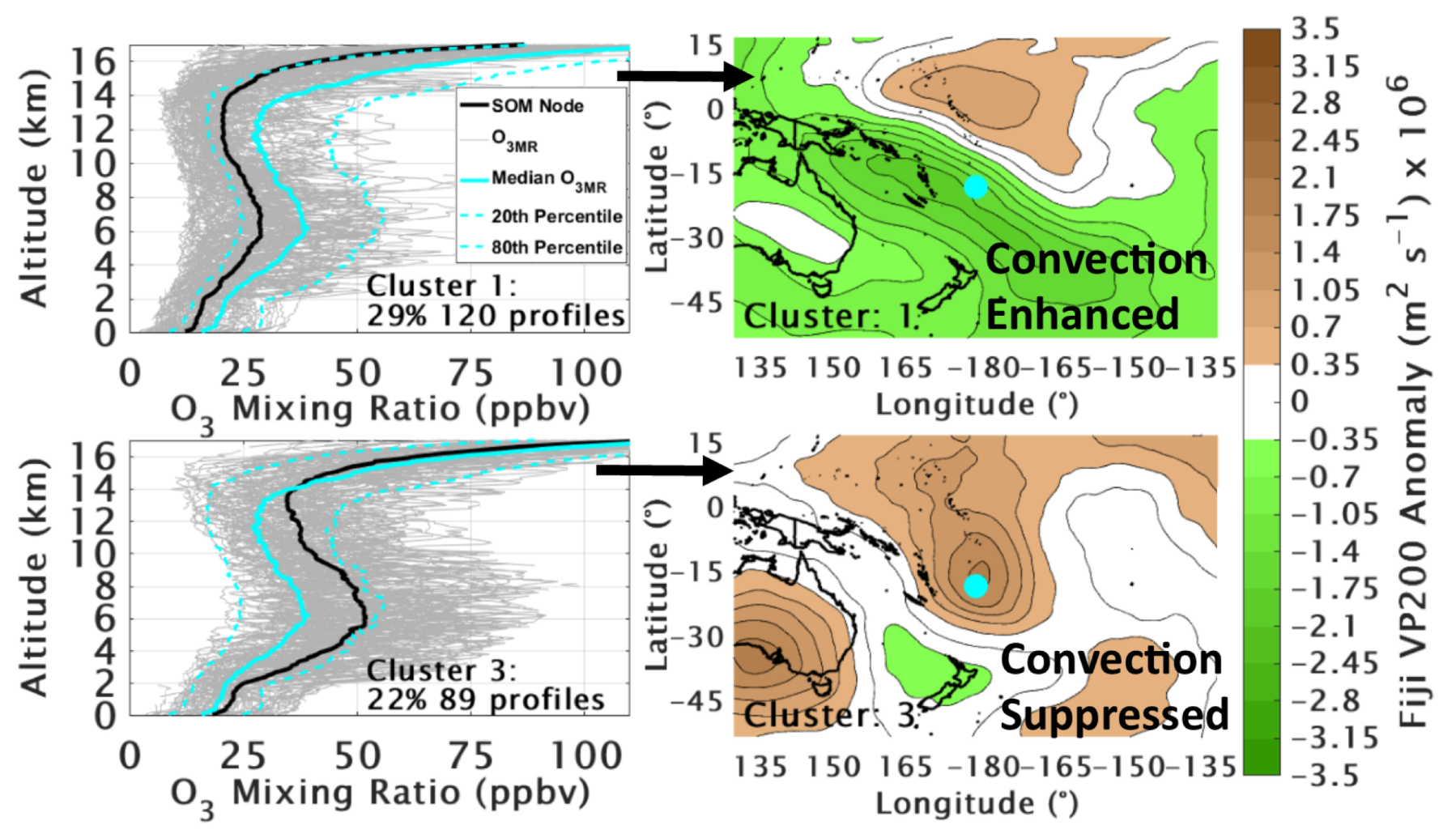


Figure 5a

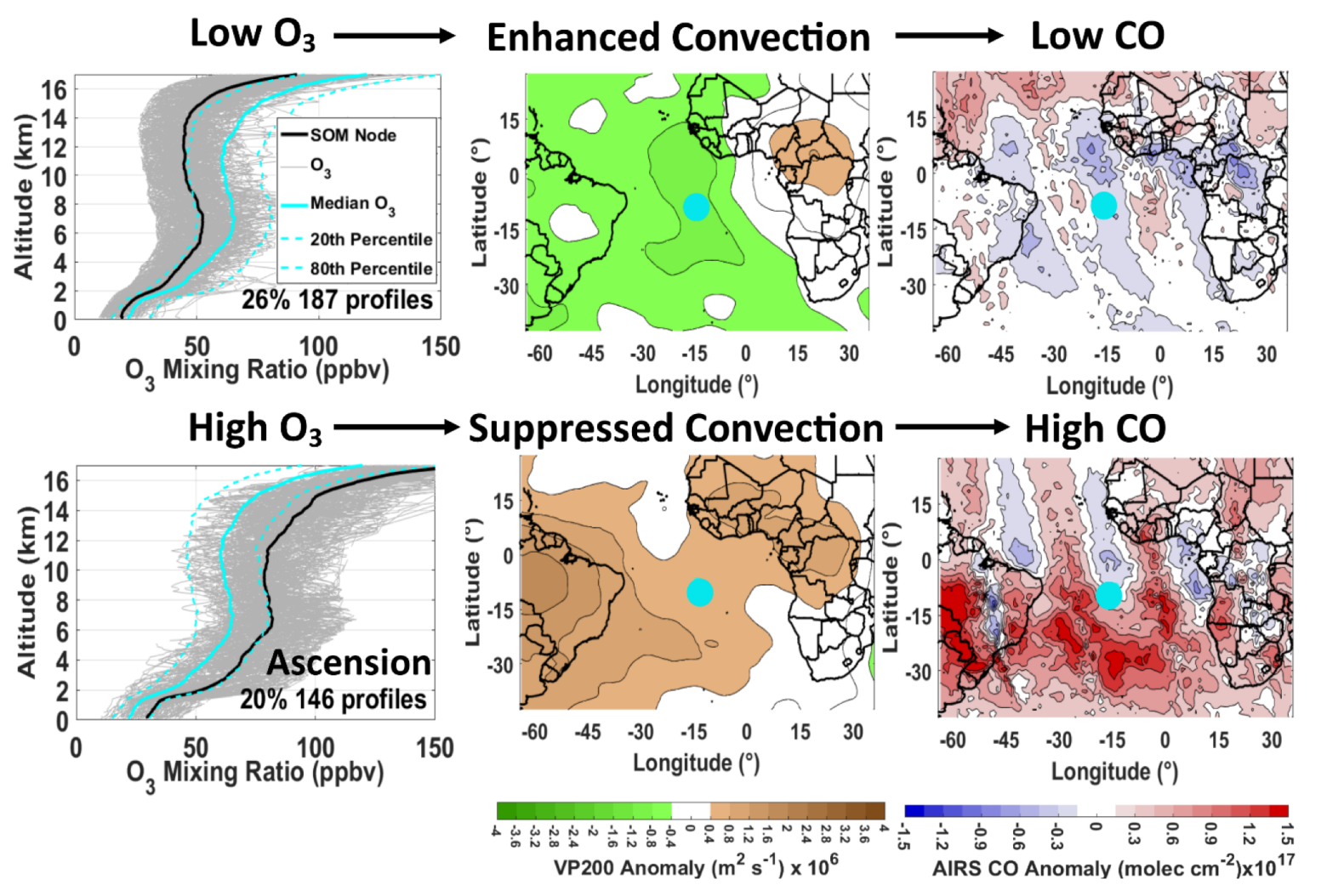


Figure 5b

Self-Organizing Maps (2x2 SOM) classify ozone profiles at SHADOZ sites with the lowest mixing ratio cluster representing profiles most affected by CI (upper row in **Figure 5a,b**) and high-ozone profiles linked to signatures of less convection & more pollution, denoted, respectively, in MERRA-2 velocity potential & AIRS CO (Stauffer et al, 2018).

CI INFERRED FROM MLRM OF OZONE TIME-SERIES

The black line and squares in **Figure 6** display monthly mean O_3 for the TTL, defined as the tropopause + 2 km, for 1999-2017. Note: TTL in Dobson Units (DU). For robust sample numbers, profiles for Costa Rica and San Cristóbal (east Pacific) are combined as are those for Ascension and Natal. NOAA's Samoa sampling is weekly without gaps. The GSFC Multi-Linear Regression Model (MLRM) is used to analyze $O_3(t)$, with terms for the seasonal cycle, ENSO and QBO, the most significant source of variability for these stations. Model fit (dashed red) and residual (green) are also shown.

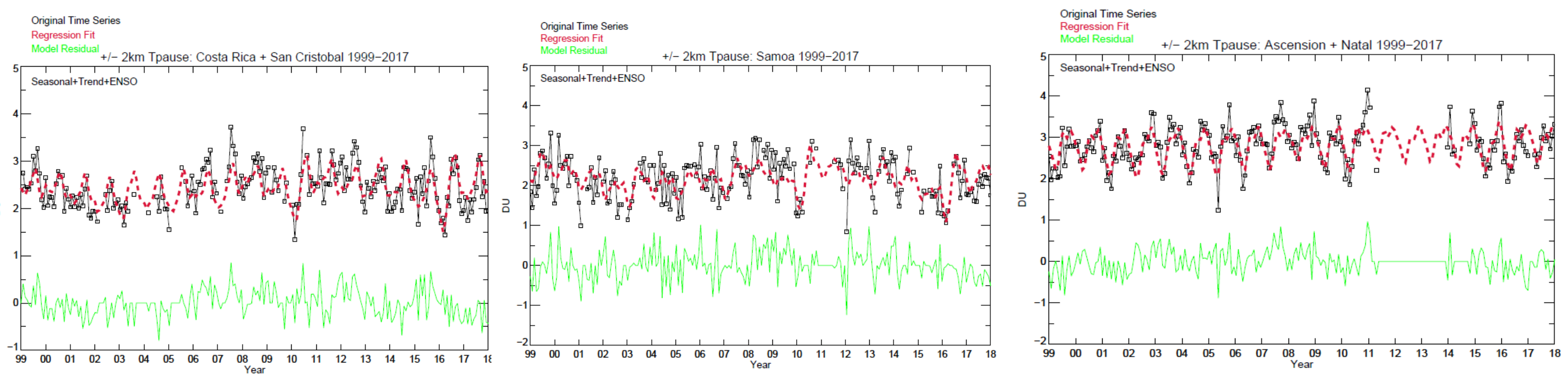
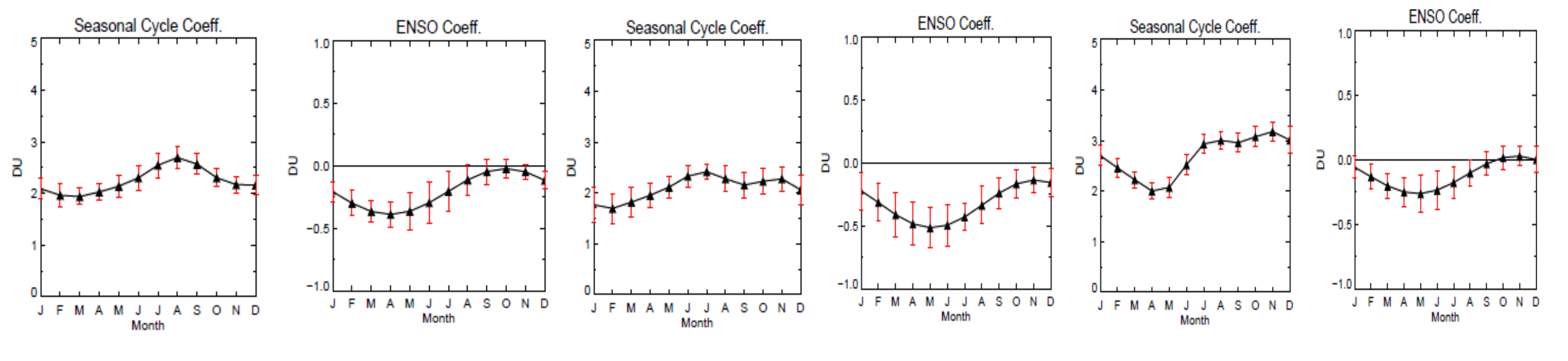


Figure 6

In **Figure 7** the seasonal cycles for the three time-series are given to + 2σ, along with the ENSO impact, reflecting the link to CI. We will focus on trends and their uncertainties at all tropical SHADOZ sites, defined here as within + 19°. Early results for the stations below point to trends only in the first, convectively active, time of year. However, ozone amount in the TTL is <10% of the typical FT and TTL tropical column.



Costa Rica – San Cris **Samoa** **Ascension-Natal**

Figure 7

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