Eastern margin variability of the South Pacific Convergence Zone: Supplement

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1. Janury SPCZ region climatology

Figure S1 illustrates climatologies of CMAP precipitation [*Xie and Arkin*, 1997] and NCEP Reanalysis [*Kalnay et al.*, 1996] 850 mb specific humidity and 925 mb horizontal winds for January. Note the low-level, predominantly easterly trade wind inflow into the eastern portion of the SPCZ and the relatively low values of specific humidity in the southeast Pacific dry descent region.

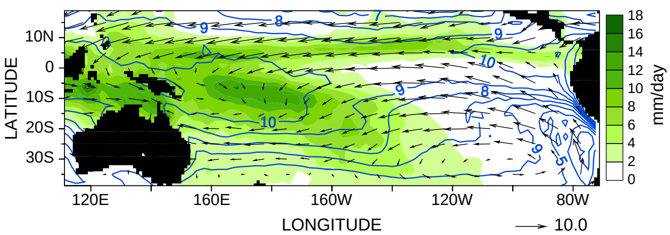

FIGURE S 1: January climatology of the South Pacific Convergence Zone region. Shown are the CMAP precipitation (shading; in units of mm day^{-1}) and the NCEP Reanalysis specific humidity at 850 mb (line contours; in units of g kg^{-1}) and 925 mb winds (vectors). The values plotted are averages over 1979-2006.

2. Overview of the idealized SPCZ prototype

The vertically-integrated, steady-state temperature (T) and moisture (q) equations are:

$$0 = M_s \nabla \cdot \mathbf{v} + P + R_{net} + H \qquad \text{(S-1)}$$

and

$$0 = E - P + M_{qp} q \nabla \cdot \mathbf{v} - (u_q \partial_x + v_q \partial_y) q \qquad \text{(S-2)}$$

Here, P is precipitation; R_{net}, H, and E are, respectively, the total column (shortwave and longwave) radiative heating, sensible heating, and latent heating; $\nabla \cdot \mathbf{v}$ is vertical convergence; and u_q and v_q are, respectively, the projections of zonal and meridional winds onto the vertical structure of the moisture profile. Equations (S-1) and (S-2) have been cast in a moist static energy formulation: M_s is related to the vertical structure of dry static energy, $s = gz + c_p T$, where c_p is the specific heat capacity at constant pressure, while M_{qp} is related to the change of q in the vertical.

Equation (S-1) can be used to eliminate $\nabla \cdot \mathbf{v}$ from (S-2). The parameters E (= 110 W m^{-2}), H (= 0 W m^{-2}), and Ms (= 3.3 K) are prescribed as constants over the domain of interest, 160°W-100°W and 30°S-10°N, with values estimated from the NCEP Reanalysis for the southeast Pacific descent region. Similarly, u_q and v_q are set to -5.0 m s^{-1} and 2.5 m s^{-1}, in approximate agreement with the observed low-level values in the southeast Pacific trade wind region. R_{net} is separated into clear-sky (R_{net}^{clear}) and cloudy-sky (R_{net}^{cloud}) components, with R_{net}^{clear} = -130 W m^{-2} and $R_{net}^{cloud} = c_s P$, where $c_s = 0.2$ following *Bretherton and Sobel* [2002].

P is represented using a *Betts and Miller* [1986] formulation, $P = (c_P \Delta p/g)\tau_c^{-1}(q - q_c) = \epsilon_c(q - q_c)$, i.e., convection relaxes tropospheric moisture toward a reference profile q_c over an adjustment timescale τ_c. Recent empirical work [*Bretherton et al.*, 2004; *Peters and Neelin*, 2006] appears to demonstrate the existence of critical values of column-integrated water vapor governing the transition between nonconvecting and strongly convecting conditions in the Tropics. This critical threshold, q_c, depends principally on T [*Neelin et al.*, 2008], as in the Betts and Miller case, although the functional dependence of P on q and q_c appears to be a nonlinear power law rather than a simple linear function. Within the convecting region, $M_{q_c} = M_{qp} q_c$, is prescribed constant.

The general solution of (S-2) is:

$$q_i^j(x, y) = [q_0^j(x, y) + q_i^*] e^{\lambda_i z^j(x,y)} f_i^j(x, y) - q_i^* \qquad \text{(S-3)}$$

The subscript i refers to either the nonconvecting region ($i = 1$) or the convecting region ($i = 2$), while the superscript j refers to the portion of the domain for which $y > \kappa x$ ($j = 1$) or $y \le \kappa x$ ($j = 2$), where $\kappa = v_q/u_q$. Definitions of the parameters in (S-3) are: $\lambda_1 = M_{qp} M_s^{-1} R_{net}^{clear}$, $\lambda_2 = -M_c M_s^{-1} \epsilon_c (1 - M_{q_c} M_c^{-1} c_s)$, $q_1^* = \lambda_1^{-1} E$, and $q_2^* = \lambda_2^{-1}[E + M_{q_c} M_s^{-1} R_{net}^{clear} + \epsilon_c q_c M_s^{-1}(M_c - M_{q_c} c_s)]$, where $M_c = M_s - M_{q_c}$ is the gross moist stability of the convecting region. The function $z^j(x, y)$ equals $u_q^{-1} x$ or $v_q^{-1} y$ for $j = 1$ or $j = 2$, while $q_0^j(x, y)$ equals $q_{0y}(y - \kappa x)$ or $q_{0x}(x - \kappa^{-1} y)$, with $q_{0y} = q(0, y)$ and $q_{0x} = q(x, 0)$ representing the values of q along the eastern and southern domain boundaries, respectively. Finally, $f_1^j(x, y) = 1$, while $f_2^j(x, y) = (\frac{q_c + q_1^*}{q_0^j(x,y) + q_1^*})^{-\lambda_2/\lambda_1}$.

In the absence of horizontal advection for the selected values of E and $\nabla \cdot \mathbf{v}$, $q_1^* > q_c$, which means that the entire domain would convect. For the convecting region in the "strict quasi-equilibrium" limit of $\tau_c \to 0$ [*Emanuel et al.*, 1994], $q_2^j(x, y) \to q_c$ in (S-3), yielding convecting region precipitation that is spatially homogeneous and

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equal to

$$P = \frac{M_s E + M_{q_c} R_{net}^{clear}}{M_c - M_{q_c} c_s} \quad \text{(S-4)}$$

We further note that the factors controlling the position of the convective margin and the width of the anomalies are closely related. For example, for $x < \kappa y$, the location of the convective margin is $x_c = u_q \lambda_1^{-1} \ln[(1 + q_c \lambda_1/E)/(1 + \lambda_1 q_{0x}/E)]$ while the width of the anomalous region, which is related to the standard deviation of x_c, σ_{x_c}, has u_q replaced by the standard deviation of the wind variations, σ_{u_q}. Expanding for small $q\lambda_1/E$ gives $\{x_c, \sigma_{x_c}\} = \{u_q, \sigma_{u_q}\}(q_c - q_{0x})/E$.

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