A method to foresee the 22nd century-state of the Low-Level Caribbean Jet and the SST difference between the Eastern Pacific and Western Atlantic Tropical Oceans from 21st century RegCM4 simulations

E. G. Pavia[1*], F. Graef[1], R. Fuentes-Franco[2], I. Villanueva[1]
[1]CICESE, Ensenada, Mexico. [2]ICTP, Trieste, Italy
*epavia@cicese.mx

1. Climatological projections reported by the IPCC indicate that towards the end of the 21st century the Northeastern Tropical Pacific Ocean (PACIFIC) and Northwestern Tropical Atlantic Ocean (ATLANTIC) will warm up. But, this warming is expected to be greater in the PACIFIC than in the ATLANTIC (Leloup and Clement, 2009). This differential warming could induce a significant strengthening of the westward Low-Level Caribbean Jet, and a decrease in precipitation in southern Mexico and Central America (SMCA) (see, e.g. Fuentes-Franco et al., 2014) (Figures 1-2).

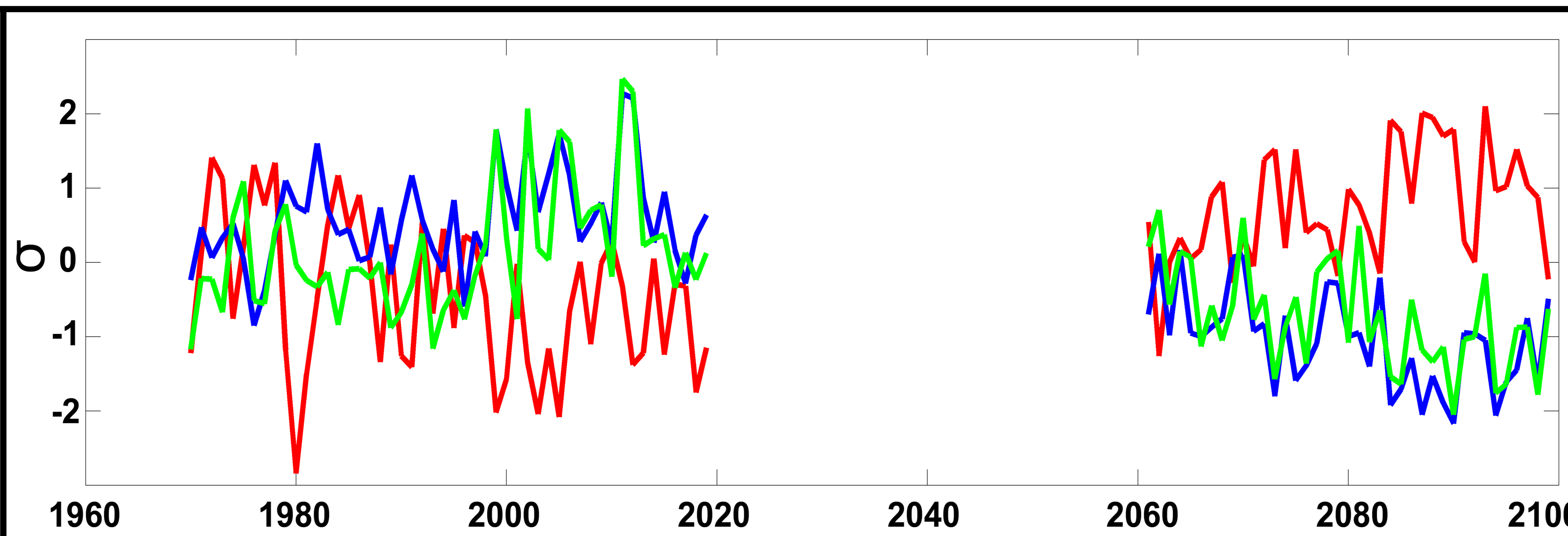

Figure 1. Annual anomalies of sea surface temperature (SST) difference (PACIFIC-ATLANTIC) (red line), zonal wind (blue line) and RegCM-simulated continental precipitation (green line). (Adapted from Fuentes-Franco et al., 2014).

2. Several simulations with global climate models (e.g. HadGEM) and regional climate models (e.g. RegCM) suggest that in the SMCA region (Figure 2.a), the mean decadal difference in SST (θ = PACIFIC-ATLANTIC) and mean decadal zonal wind (U) will remain, at least during the 21st century, highly and inversely correlated: *r* = -0.9 (see Figure 2.b).

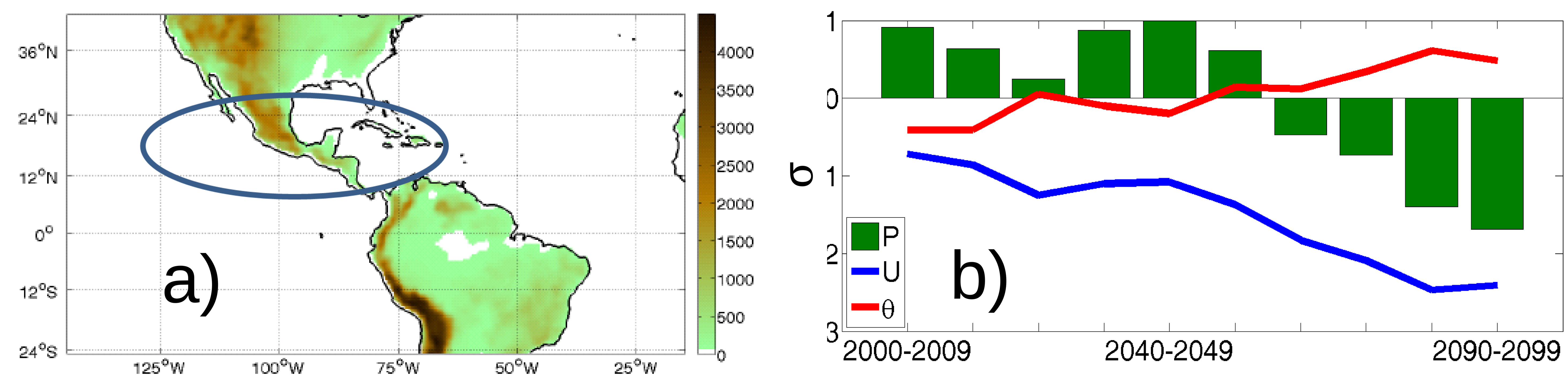

Figure 2. a) Central America CORDEX domain (color bar indicates meters above mean sea level). A blue ellipse indicates approximately the SMCA region where θ was calculated from HadGEM; and precipitation (P) and U from RegCM4 (Em-CLM, HadGEM forced, RCP 8.5). b) Standardized mean decadal θ, P and U.

3. Drought scenarios as the one projected towards the end of the 21st century have been recorded in the SMCA region (see Figure 3), although the physical causes may have been different.

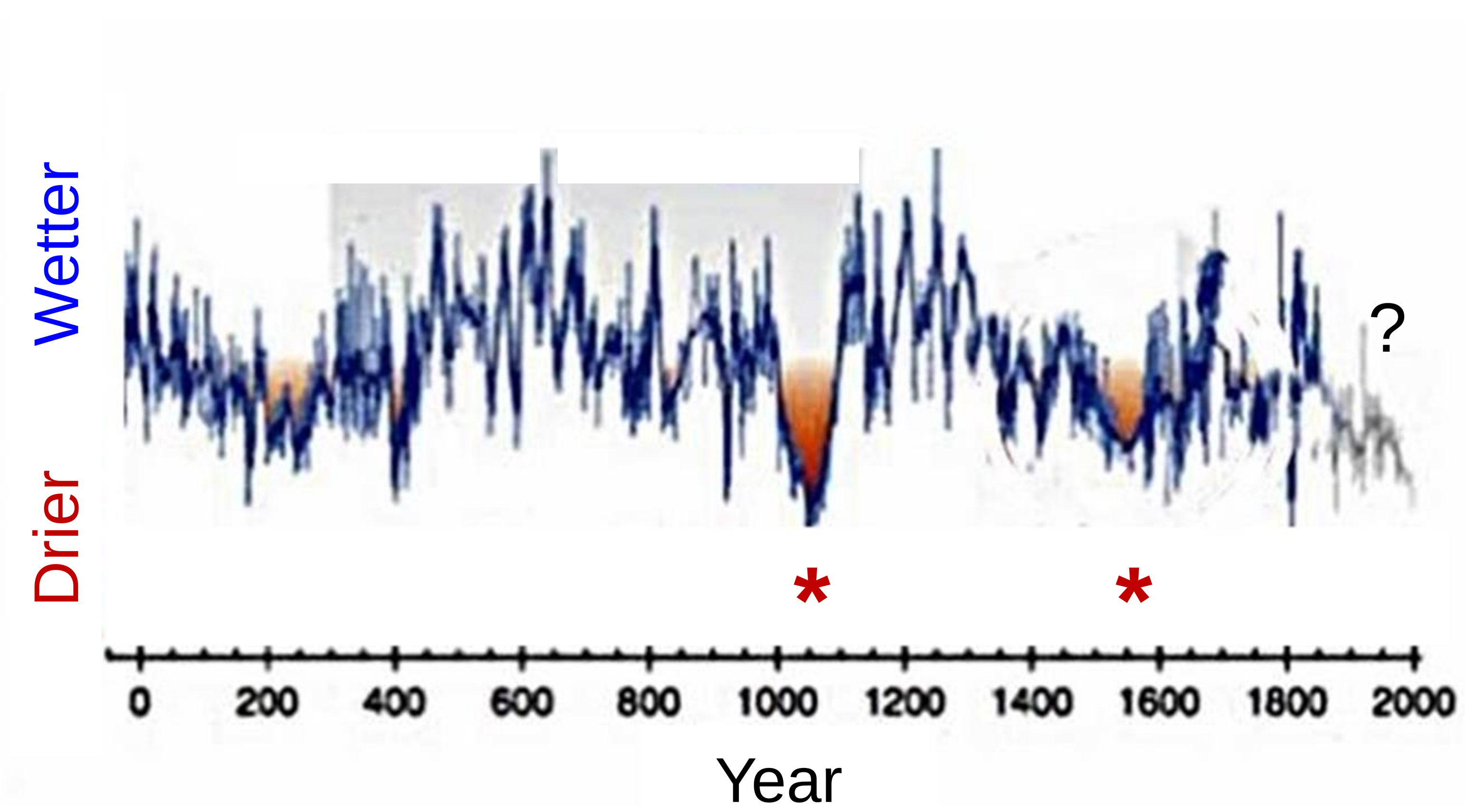

Figure 3. Climatological reconstruction from oxygen isotopes $\delta^{18}O$ collected at the Yok Balum Cave, Belize (16° 12' 31'' N, 89° 04' 24'' W). Red Asterisks (*) indicate the historic droughts of the 11th and 16th centuries. A question mark (?) indicates a period of uncertainty on the data. (Adapted from Kennett et al., 2012).

Vienna | Austria | 12-17 April 2015

< 1 of 2. See right >

4. Therefore, from initial and final conditions in the normalized U-θ space (Figure 4.a), we look for a periodic component in order to suggest a return period. The solution (Figure 4.b) is found with the method proposed in this work (points 5-7 ahead).

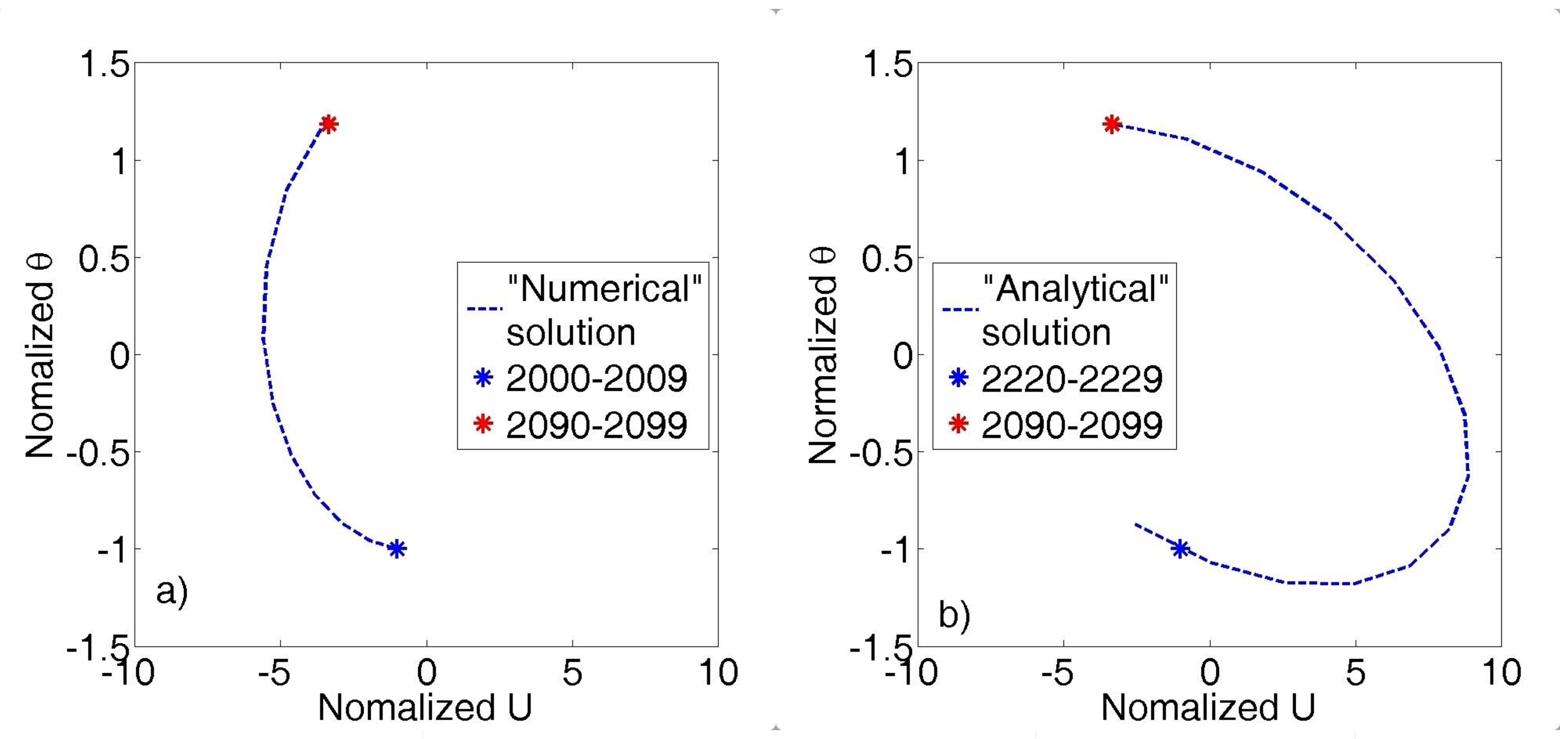

Figure 4. a) "Numerical" solution obtained with (5) and (6), it goes from (-1, -1) in 2000-2009 to (-3.4, 1.2) in 2090-2099. b) "Analytical" solution, obtained with (3) and (4), it goes from (-3.4, 1.2) in 2090-2099 to approximately (-1, -1) in 2220-2229 (see point (7) below).

5. We begin by assuming that:

$$\frac{dU}{dt} = \alpha \times \theta \qquad (1)$$

$$\frac{d\theta}{dt} = \beta \times U. \qquad (2)$$

Time derivatives of (1) and (2), and substituting yields:

$$\frac{d^2U}{dt^2} = \alpha\beta \times U \qquad (3)$$

$$\frac{d^2\theta}{dt^2} = \beta\alpha \times \theta. \qquad (4)$$

6. If $\alpha\beta < 0$ then (3) and (4) will have periodic solutions. To find α and β we discretize the coupled system [(1) and (2)] and solve it numerically:

$$U^{n+1} = U^n + \alpha\, \Delta t\, \theta^n \qquad (5)$$

$$\theta^{n+1} = \theta^n + \beta\, \Delta t\, U^n. \qquad (6)$$

We use mean decadal normalized data: $U = U/|U(1)|$, $\theta = \theta/|\theta(1)|$, $\Delta t \equiv 1$ (one decade!), iteratively (varying α and β) until

$$\epsilon = \left[\left(U^{10} - \left(\frac{U(10)}{|U(1)|}\right)\right)^2 + \left(\theta^{10} - \left(\frac{\theta(10)}{|\theta(1)|}\right)\right)^2\right]^{1/2}$$

is arbitrarily small or zero.

7. Knowing $\alpha = 1.72$ and $\beta = -0.05$ solutions of (3) and (4) are:

$$U = A\cos(\lambda t) + B\sin(\lambda t) \qquad (7)$$

$$\theta = C\cos(\lambda t) + D\sin(\lambda t), \qquad (8)$$

where $\lambda = (-\alpha\beta)^{1/2} = 0.29$. And from initial and final conditions we get:

$A = -1.0$, $B = -8.84$,
$C = -1.0$, $D = 0.64$.

(See Figure 4.b).

8. Preliminarily we compare our results. The solution of the system [(5) and (6)] is compared with data from RegCM4 in Figure 5; recall that here the coupled system only "knows" initial and final data. The "analytical" U from (7) is compared with data from two GCMs in Figure 6; and the "analytical" θ from (8) is compared with data from the same GCMs in Figure 7. Recall that (7) and (8) "do not know" anything about the GCMs.

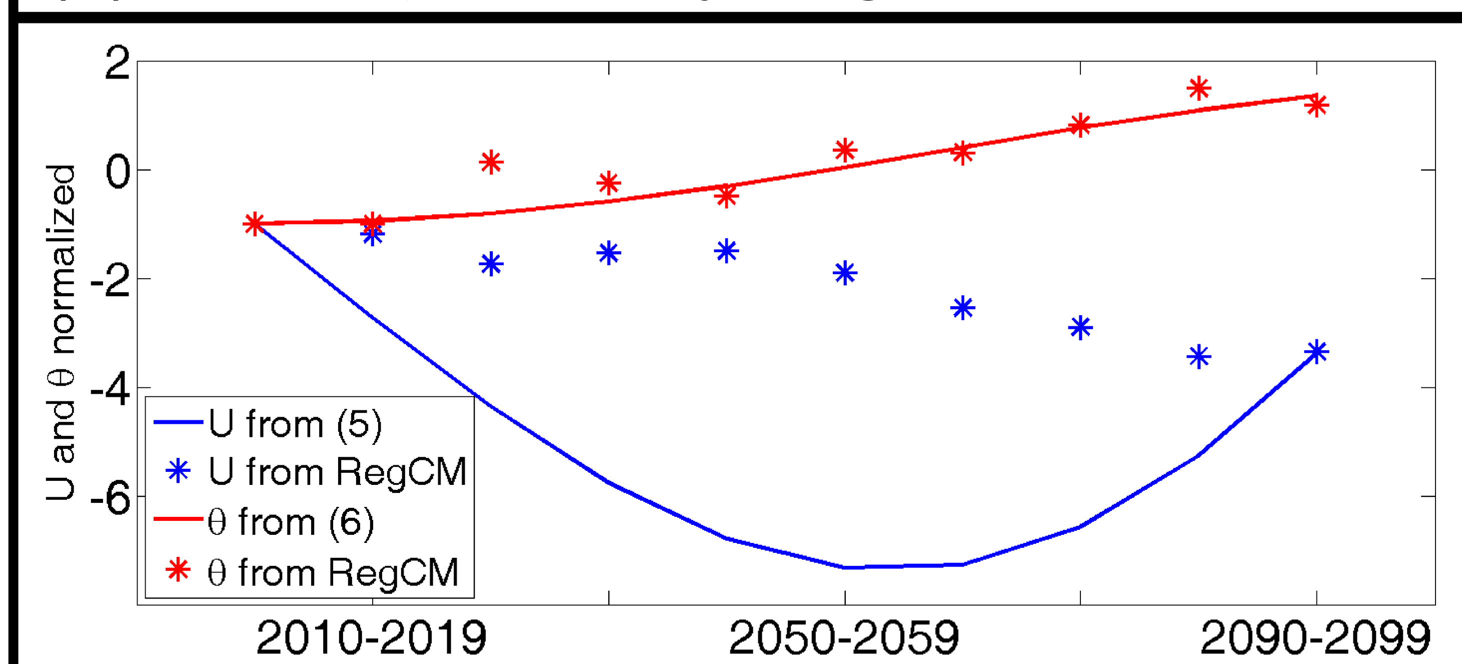

Figure 5. Normalized RegCM-data used to find α and β and the "numerical" solution of the coupled system [(5) and (6)].

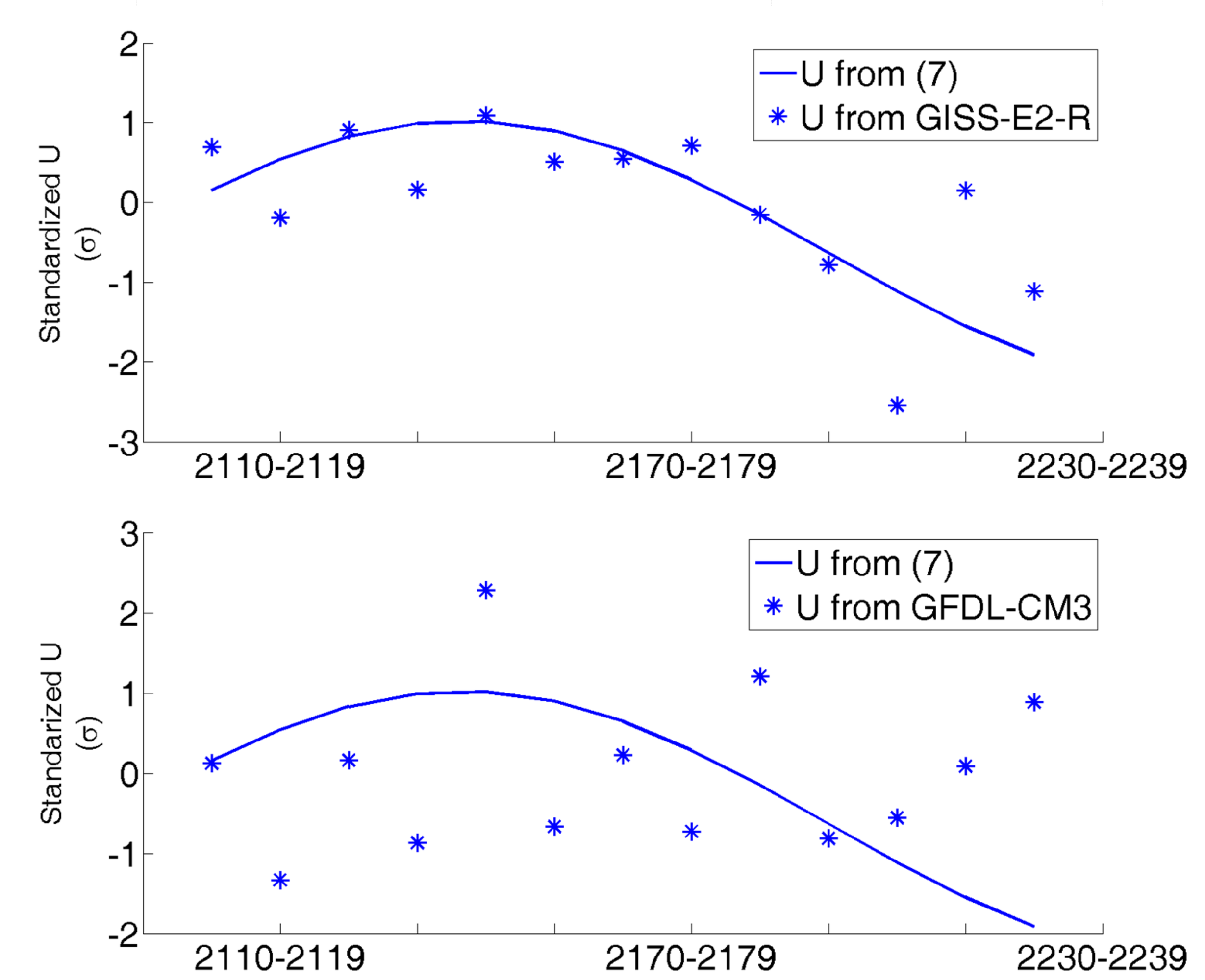

Figure 6. Standardized U for the SMCA region from (7) and from two GCMs. GISS-E2-R (RCP 2.6) compares better than GFDL-CM3 (RCP 4.5).

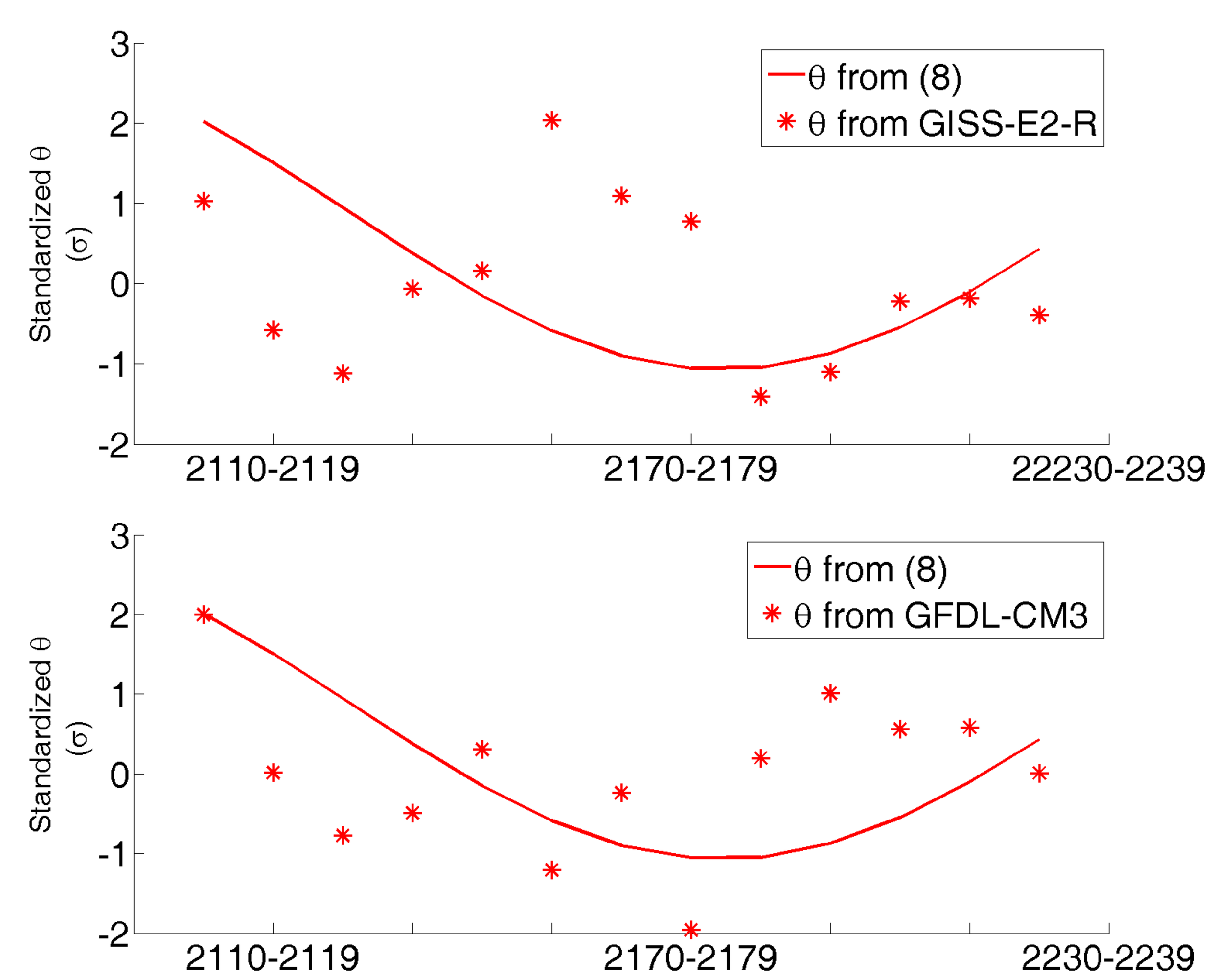

Figure 7. Standardized θ for the SMCA region from (8) and from two GCMs. GFDL-CM3 (RCP 4.5) compares better than GISS-E2-R (RCP 2.6).

9. We conclude that the system [(3) and (4)] may have periodic solutions. These solutions provide a "return period" of about one century. Comparisons with regional and global climate models give mixed results.

References

Fuentes-Franco et al., 2014, *Clim. Dyn.*, (On line).
Kennett et al., 2012, *Science*.
Leloup and Clement, 2009, *GRL*.