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Supporting Information for

**Impacts of Shifting Subtropical Highs on the California and Canary Current Systems**

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**Introduction**

The text below describes the differences between the model and reanalysis representations of the climatological mean positions of the subtropical highs, followed by a discussion of the correlations among the four upwelling-related variables described in the main text. The figures include a schematic representation of the relationships among upwelling-related variables, a figure analogous to Figure 2 but for reanalysis, and a figure analogous to Figure 4 but for Hadley cell indices. The three tables show correlations among variables referenced in the text.

Comparison of Modeled vs. Observed Climatology

The NPSH, as defined here, has a JJA-season climatological mean position of 150.8˚W, 37.4˚N according to the CESM coupled control run. By comparison, the mean NPSH position in the ERA-Interim reanalysis for the period 1980-2016 is 151.2˚W, 35.9˚N. Similarly, the mean position of the NASH is 44.6˚W, 34.1˚N in CESM and 39.7˚W, 33.4˚N in ERA-Interim.

Hence, the model appears to have a good representation of the climatological mean state of the NPSH, though the modeled NASH is too far to the west. This is unlikely to change the conclusions however: the patterns in the bottom row of Figure 2 miss the Canary current not because they are too far west, but because they are too far north.

On the other hand, the mean JJA-season Hadley cell edge in CESM is at 38.5˚N, whereas in ERA-Interim it is found at only 32.7˚N. This is a notable discrepancy, and could imply that the pattern of anomalies in SLP or other variables associated with shifts in the Hadley cell edge are also displaced poleward compared to the real atmosphere. Once again though, this displacement is unlikely to affect the conclusions of this study, as those SLP anomalies are weak at any latitude (see Figure 5 of Schmidt & Grise, 2019).

**Correlations Between Upwelling-Related Variables**

As described in the main text, there are four variables related to upwelling in the eastern boundary current regions: (1) surface wind stress, (2) surface ocean current, (3) upwelling, and (4) chlorophyll. We define surface currents in terms of the highest model level, we use upwelling in the model layer spanning depths 50-60 meters, and we use chlorophyll summed over depths 0-100 meters. For each of these four variables, we average over the red polygons from Figure 1 to give a single index for each variable in each basin for each month.

In order to distinguish alongshore from cross-shore wind, It will be convenient to consider a rotated coordinate system: instead of the usual x- and y-coordinates, we will define, for each region, a t-coordinate in the alongshore direction (defined by a linear least-squares regression fit to the coastline) and an n-coordinate normal to this. The positive t-direction is roughly to the north or northeast, and the positive n-direction is roughly to the east or southeast, toward land.

To verify the expected links between variables, we calculate the correlations shown in Figure S1. Note that we show the correlations between the t-component of wind stress (TAUT) and the n-component of surface current (CURN). The reason is that the 0-10 meter layer of water, over which the “surface” current is defined, is deep enough to include a substantial fraction of the Ekman layer, and the wind-driven current in this layer is somewhat to the right of the direction of the wind itself.

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**Figure S1.** Correlations (blue numbers) among upwelling-related variables, including surface wind stress in the alongshore direction (TAUT) surface current in the cross-shore direction (CURN) upwelling at 50-60 meters (WVEL), and chlorophyll at 0-100 meters (CHL). Each variable is averaged over one of the red polygons in Figure 1, using de-seasonalized JJA-season data from the first 500 years of the CESM fully-coupled control run. Chlorophyll is lagged by 1 month for the California Current region only (see methods). The alongshore direction is defined by a linear least-squares regression fit to the coastline within the red polygon, with the positive direction being roughly north or northeast, and the cross-shore direction is perpendicular to this, with the positive direction being roughly east or southeast.

**Figure S2**. Regression of 10-meter wind to the NPSH indices **(top row)** and NASH indices **(bottom row)**.All data are de-seasonalized and de-trended monthly means from the JJA seasons of ERA-Interim data, using years 1980-2016. The bold arrow in the corner represents a regression of 4 (m/s)/sigma, for scale, where sigma represents the standard deviation of the index. **Note that the scale cannot be directly compared with Figure 2.**

**Figure S3.** As in Figure 4, but for the Northern Hemisphere Hadley cell width and strength instead of the subtropical high indices. Chlorophyll is lagged by 1 month in the Pacific only (left panel).



**Table S1.** Correlations among subtropical high indices (lon: longitude, lat: latitude, and str: strength), using monthly de-seasonalized JJA-season data from the full 1800 years of the CESM coupled control run. Due to the long time series, all correlations larger than 0.03 are statistically significant at the 𝑝<0.01 level.



**Table S2.** Correlations between subtropical high indices and upwelling-related indices, using de-seasonalized JJA-season data from the first 500 years of the CESM fully-coupled control run. Chlorophyll (Chl) and wind stress (TAUX, TAUY) are averaged over the red polygons from Figure 1. Chlorophyll is lagged by 1 month for the California Current only (see text). Due to the long time series of 1500 months, all correlations with absolute value greater than or equal to 0.06 are statistically significant at the 𝑝<0.05 level. (The cutoff is 0.07 for Pacific chlorophyll, where only 1000 months are used due to the lag).



**Table S3.** Correlations between 2006-2100 trends of upwelling-related indices for the California Current and trends of subtropical high indices across ensemble members of CESM-LENS (RCP 8.5 scenario). Bold values are statistically significant at the 𝑝<0.05 level. Note that since the anticipated sign of each correlation is known from Figure 2, we use a one-tailed t-test. Also note that since only 34 of the 40 ensemble members include chlorophyll, the threshold for statistical significance is slightly higher for first row. All data are monthly means from the JJA season.