Abstract

We evaluated the ¼° model NorESM1.3 and noticed that the well-known “double-ITCZ problem” is likely solved. However, excessive precipitation is produced in the northern branch of the ITCZ. The excessive precipitation is consistent with overevaluated latent heat flux in the tropical ocean. Further analysis shows that in NorESM1.3, the latent heat flux is too sensitive to the surface wind. The increased sensitivity in the ¼° model is partly contributed by small-scale air-sea interaction. The sensitivity of latent heat flux to surface wind, with the scale finer than 2.5°, is up to 40 (Wm-2 / ms-1), which is almost twice of that with scale coarser than 2.5°. This study helps to understand extra air-sea interaction resolved by higher-resolution models, and helps to tune and correct the related model bias.

Introduction

The oceans impact weather and climate by heating (and cooling) the lower atmosphere. In particular, as seawater evaporates, the ocean surface cools; and when the moisture later condenses into cloud droplets, this heat is released, warming the atmosphere. This moistening, and then warming, makes the air buoyant, driving low-level baroclinicity and atmospheric convection, causing wind convergence at the surface and divergence aloft. At the equator, ocean heating of the atmosphere can result in towering convective clouds that reach the top of the troposphere. These disturbances in turn drive teleconnections in the atmosphere, affecting weather and climate remotely. Most dramatically, every 2–7 years, zonal shifts in the surface heating patterns along the equatorial Pacific, associated with El Niño Southern Oscillation (ENSO), lead to climate extremes across the world.

Patterns of surface heat fluxes (**Figures 1**, **2**) also affect large-scale atmospheric circulation patterns, with deep convection over the thermal equator forming the upward branch of the “Hadley Cell” that drives trade winds. Westerly jet streams in both hemispheres are likewise associated with vertical-meridional cells in the midlatitude and high latitudes.

As discussed in this paper, quantifying these air-sea fluxes, which represent the direct communication between the ocean and atmosphere, is challenging.

Reducing inaccuracies (both biases and random uncertainty) in air-sea fluxes is important for improving long-term weather and climate predictions. Because the ocean’s capacity to store heat is about 1000 times greater than that of the atmosphere, long-term weather and climate predictability has its origins in the oceans. Heat storage and release occurs on a range of time scales (**Figure 2** and **Supplementary Table S1**) and can provide predictability out to 10–100 days (e.g., Madden-Julian Oscillation, Asian/Indian Monsoon), on seasonal-interannual time scales (e.g., ENSO), and out to decades (e.g., Pacific Decadal Oscillation, Atlantic Multidecadal Oscillation). Predictions of weather and climate on these time scales have great economic benefits for agriculture, water resource management, energy management, human and ecosystem health among others. Thus, to achieve useful predictions we must be able to quantify where, when and how much heat is released to the atmosphere.

Surface latent heat flux, *Qlat* , is the heat extracted from the ocean when seawater evaporates. This heat is released to the atmosphere when and where this vapor condenses, forming clouds. Likewise, sensible heat flux, *Qsen*, is the heat extracted from the ocean associated with an air-sea temperature difference.