# Spiderweb Structure of Stratocumulus


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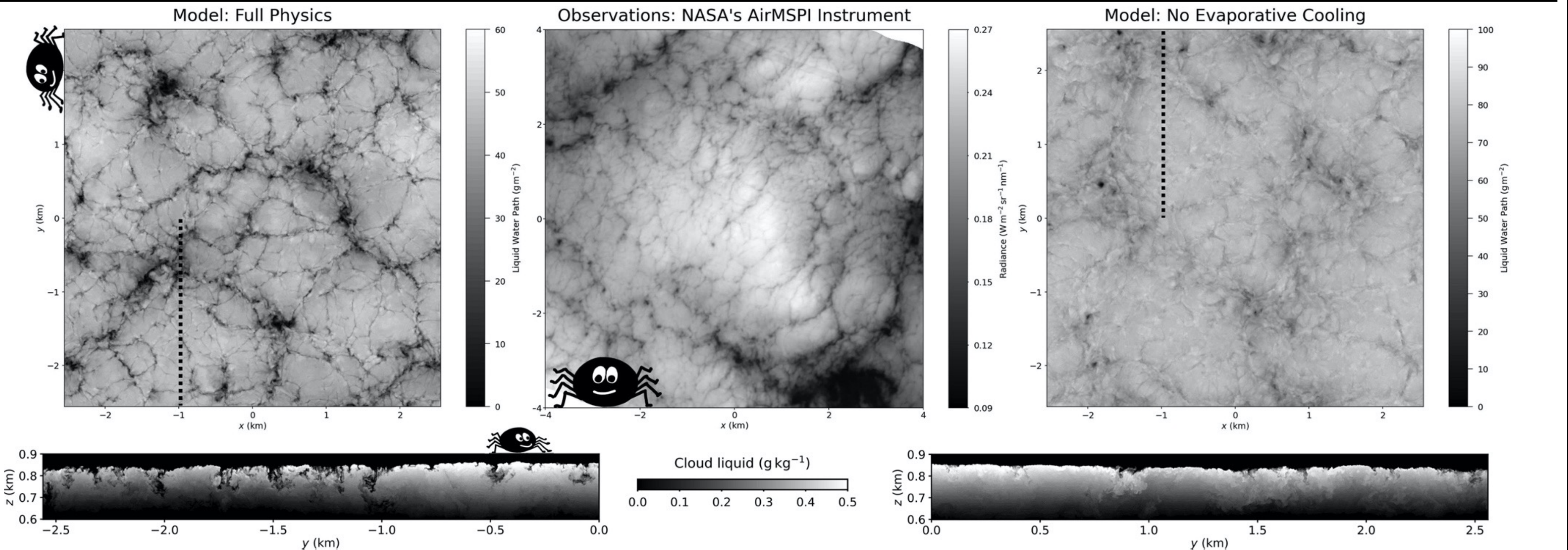


**Large-Eddy Simulation (LES) models can be used to pin down micro-physical processes that cause key macro-physical phenomena, here, turbulent entrainment of dry air at the top of marine stratocumulus (Sc). The observed "spiderweb" structure of entrainment events in these climatically important clouds can be reproduced only if evaporative cooling is included in the LES cloud physics package.**

**Significance:** Our finding will inform the design and implementation of future parameterizations of sub-grid processes in global climate models (GCMs).


G. Matheou, A.B. Davis, and J.P. Teixeira, The Spiderweb Structure of Stratocumulus Clouds, *Atmosphere*, ***1***, 730- (2020).



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**Science or Technology Question:** Extensive and persistent Sc layers often cap marine boundary layers. To better model the radiative balance and thermal structure of the atmosphere, we need to better understand the turbulent dynamics unfolding near cloud top.

**Data & Results:** JPL LES model output and JPL AirMSPI data show that the critical microphysical process that sustains cloud top entrainment dynamics is evaporative cooling.

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**Data Sources:**
Most of the data used here were simulated with the evolved version of the JPL Large-Eddy-Simulation (LES) model used at U. Conn. That said, for direct visual comparison of the LES clouds with real-world counterparts, the authors used nadir views of the 450 nm channel acquired by the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI) on 22 September 2016 off the coast of Namibia, during the ORACLES campaign. These data are readily available from the LaRC DAAC.

**Technical Description of Figure:**
The left and right panels are LES outcomes, respectively with and without the inclusion of evaporative cooling in the cloud physics. Top panels show the column-integrated liquid water path (LWP) in g/m$^2$ over the entire computational domain, which is 5.12 x 5.12 km$^2$ with 1.25 x 1.25 m$^2$ resolution (4096 x 4096 horizontal grids). Bottom panels show liquid water content (LWC) in g/m$^3$ for the transects indicated with dotted lines in the top panels. The top middle panel shows an AirMSPI nadir image (20 m pixels) of a stratocumulus capping the oceanic boundary layer; see details in the above entry on Data Sources.  Both the “full physics” and real-world clouds display an intricate pattern of cloud-top entrainment instabilities, which we describe as “spiderwebs,” but not when evaporative cooling is left out. This positively identifies the cloud microphysical process that causes the cloud-top dynamical process that vigorously mixes above-cloud dry air with in-cloud saturated air. The exquisite spatial resolution of 1.25 m used in the LES runs was key to gaining this insight. Previously, it was widely believed that radiative (rather than evaporative) cooling was the only process that mattered for marine Sc cloud layers, and LES runs at coarser resolutions did not contradict this conventional wisdom.

**Scientific significance, societal relevance, and relationships to future missions:**
Modeling clouds with LES has many purposes. An important one is to provide cloud scientists with a computational laboratory where they can ask “what if” questions that cannot be addressed with real-world observations. The example here is: What if the marine stratocumulus deck did not cool off when droplets evaporated? The answer is that these climatologically important clouds would not have the widely observed property of filamentary cloud-top entrainment instabilities structured as “spiderwebs.” In turn, the inhibition of entrainment has deep ramifications for the thermal structure and radiative properties of the clouds that have a major influence on the Earth’s climate system. In conclusion, we need to model and observe the turbulent dynamics of clouds down to the ~1 m scale to get the entire climate right.