Sea Surface temperature control on the brightness of marine clouds over the North Atlantic Ocean

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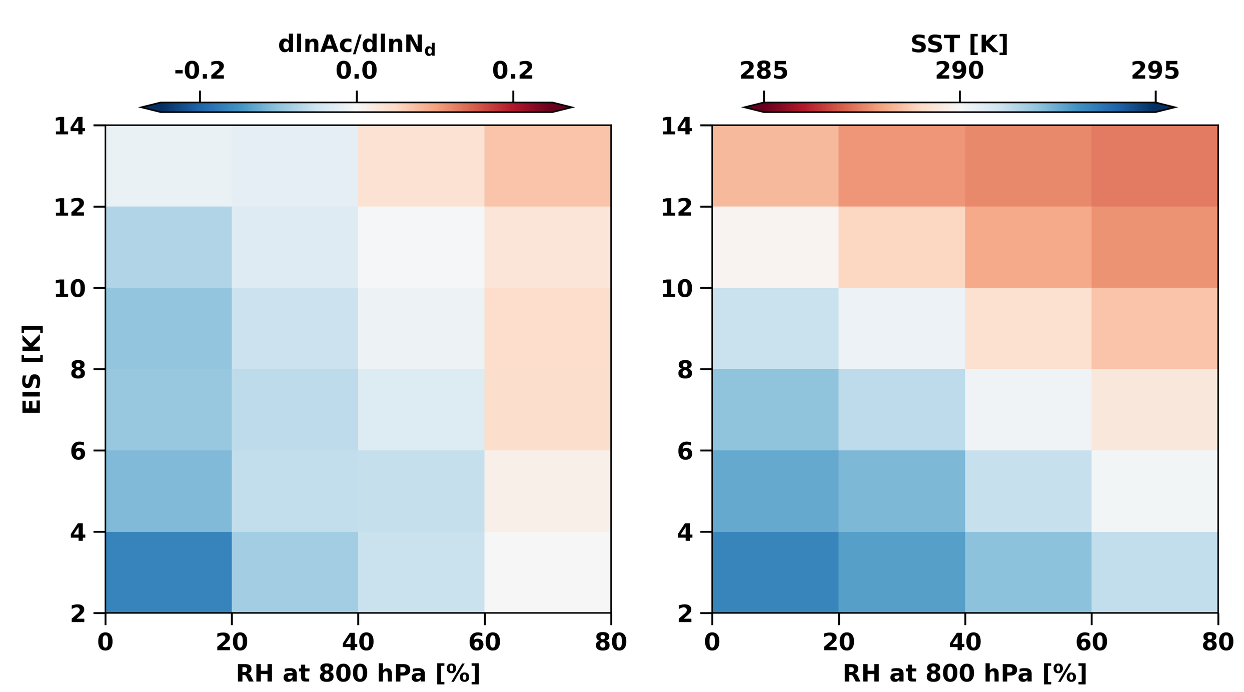
Introduction

- The effect of anthropogenic atmospheric aerosols on global cloud radiative forcing through changes in cloud amount and brightness is a major uncertainty in climate projection.
- Previous studies have identified lower tropospheric stability and humidity in the free troposphere as important controls on the cloud water adjustment to aerosol-induced perturbations.
  -- Relatively unstable troposphere facilitates cloud-top entrainment
  -- Entrainment of dry air from above the cloud accelerates evaporation of cloud liquid in response to higher aerosol conditions.

- Here we present the control of sea surface temperature (SST) on tropospheric stability and cloud-top humidity, and therefore on the relative occurrence of aerosol-induced brightening and darkening of clouds.

Dataset

- 8 years (2003-2011) of A-Train satellite measurements and ERA5 reanalysis over the North Atlantic Ocean (25ºN~55ºN; 50ºW~15ºW) for single-layer warm (liquid phase) clouds.
- Cloud properties and cloud albedo susceptibility are computed in each 2ºx2º box where cloud fraction is greater than 0.25.
- The North Atlantic region does not have a large variability of cloud droplet number concentrations, allowing us to examine the environmental control on cloud albedo susceptibility.

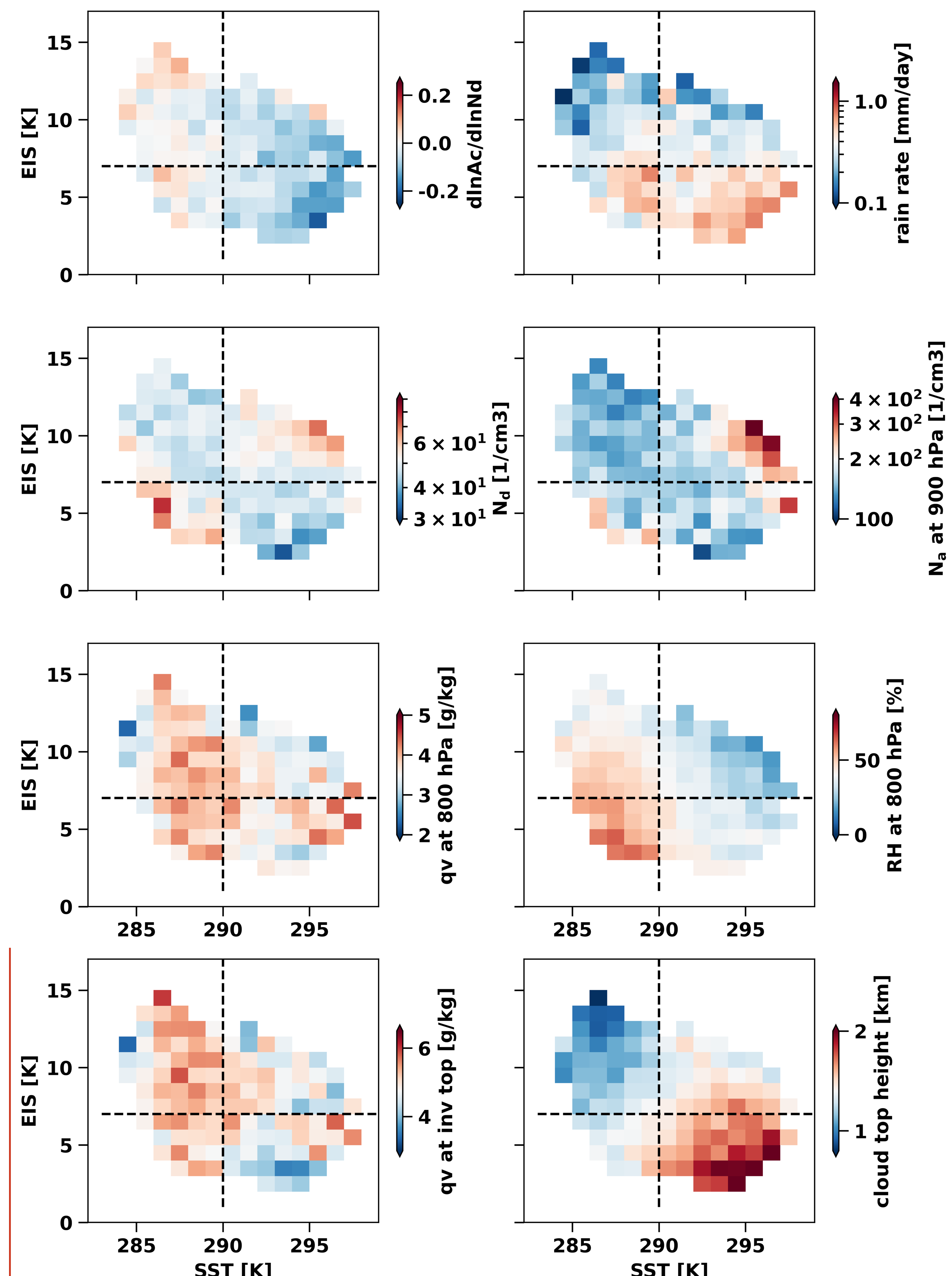


- Left: Darkening clouds prefer low relative humidity at 800 hPa (RH_{800hPa}) and low estimated inversion strength (EIS), consistent with previous studies.
- Right: Favorable regions of darkening clouds are with high local SST.

High local SST favors cloud darkening

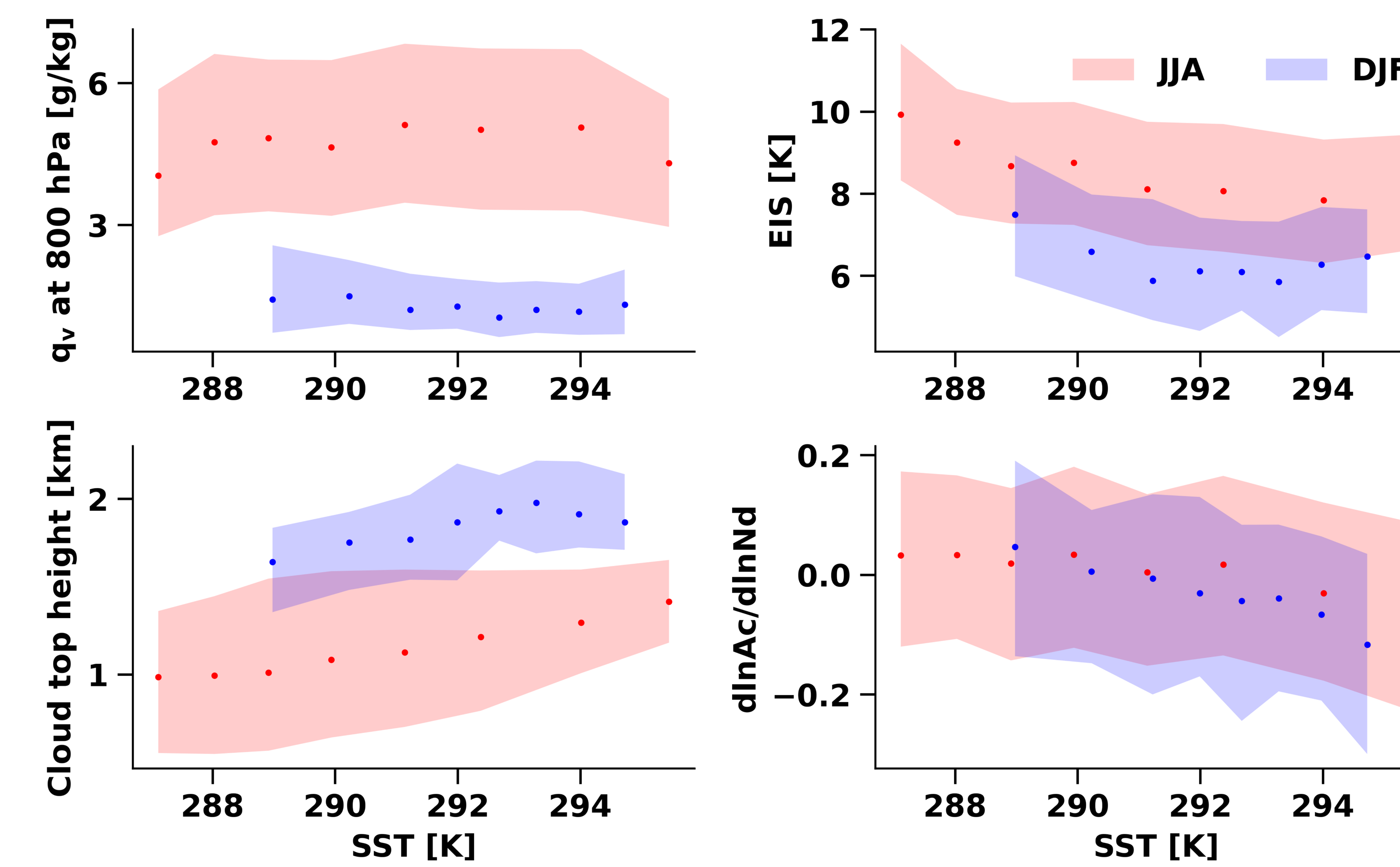
- **Scenario I: Higher local SST; Unchanged remote SST**
  All else being equal, higher local SST deepens boundary layer by reducing EIS. Relatively unstable lower troposphere favors cloud-top entrainment; deeper boundary layer is associated with drier cloud-top air.

- **Scenario II: Higher local SST; higher remote SST**
  Assuming a fixed EIS of 10 K (i.e., remote SST increases with local SST), increasing local SST from 285K to 295K reduces RH_{800hPa} by ~50% for a given water vapor mixing ratio at 800 hPa (q_{800hPa}), as per the Clausius-Clapeyron relation.



More darkening clouds in winter

- Top left: Free troposphere over the North Atlantic is drier in winter than in summer, likely due to the seasonal variation of Hadley circulation.
- Top right: Free troposphere temperature remains low in winter.
- Bottom left: Dry free troposphere and low EIS (relatively unstable lower troposphere) facilitates deep boundary layer in winter.
- Bottom right: A more frequent occurrence of darkening clouds in winter (as indicated by the close spacing between dots and the negative shift of the shading) due to stronger and more efficient entrainment drying.



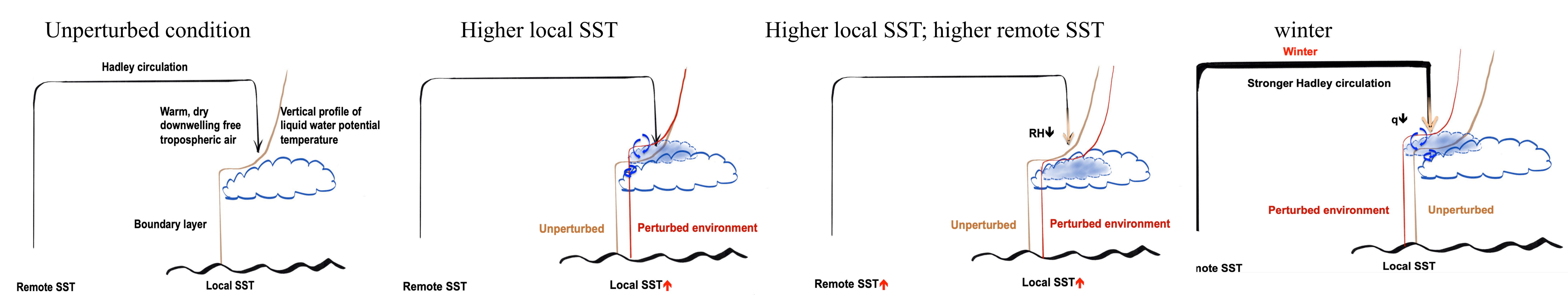
Shading: Interquartile range; dots: mean value within SST quartile bins (10%).

Discussion

- Seasonal variability of Hadley circulation can modulate cloud albedo susceptibility by directly changing the free troposphere water vapor mixing ratio and lower tropospheric stability.
- Change of local and remote SST can modulate cloud albedo susceptibility by modifying free troposphere temperature and lower tropospheric stability.

Implications

- A more frequent occurrence of less reflective clouds (warming effect) over the North Atlantic with global warming or with the strengthening phase of the Atlantic meridional overturning circulation.
- The synoptic interference appears less important in determining cloud albedo susceptibility compared to the large scale environmental conditions (e.g., seasonal variability; SST).



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