# Observational estimate of stratocumulus susceptibility across timescales

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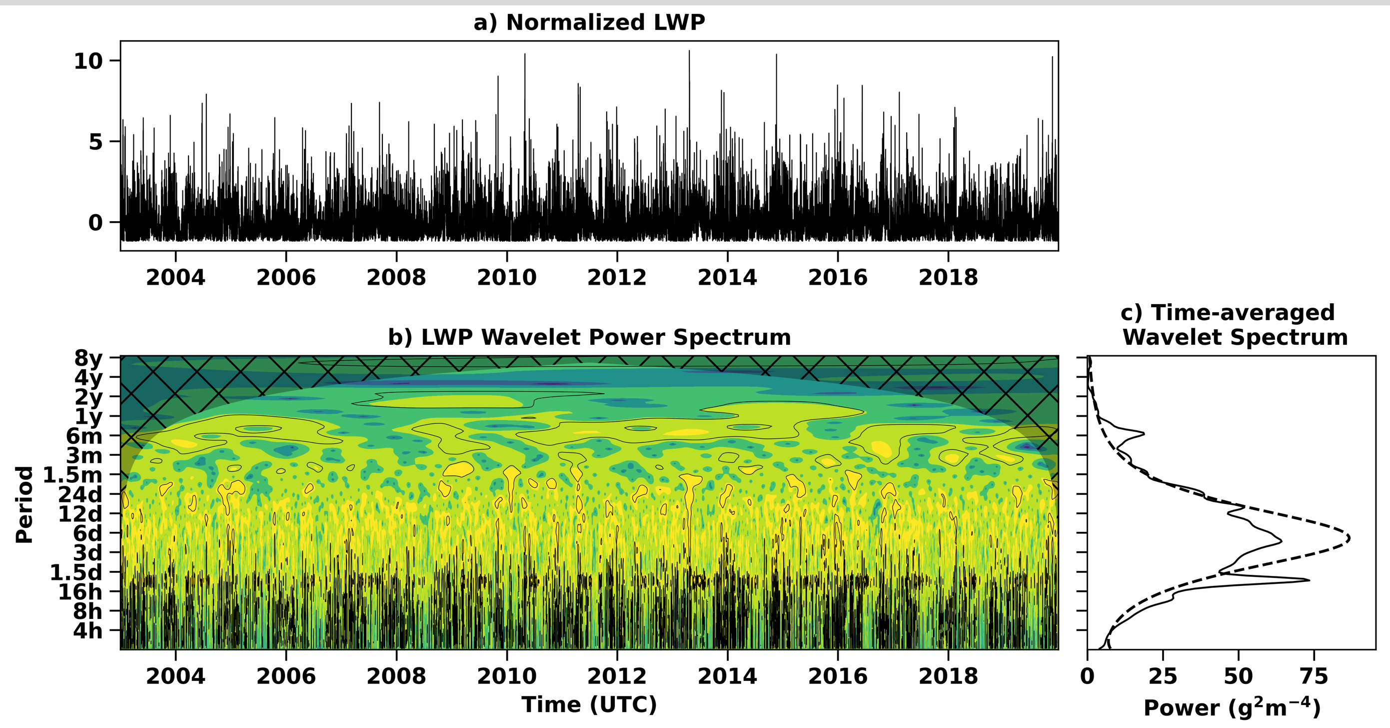
## Introduction

- 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.
- A robust quantification of cloud susceptibility requires a better understanding of the interactions between fast and slow aerosol-related processes.
- So far there is no observational estimate of cloud susceptibility across timescales, mainly due to the difficulty of isolating the causal relationship between cloud water path (LWP) and cloud droplet number ($N_d$) in the context of other natural co-variabilities between meteorological conditions, aerosols, and cloud water.
- Here we perform wavelet analysis to quantify the magnitude and trend of the LWP adjustment to perturbations in aerosol number concentrations across timescales.

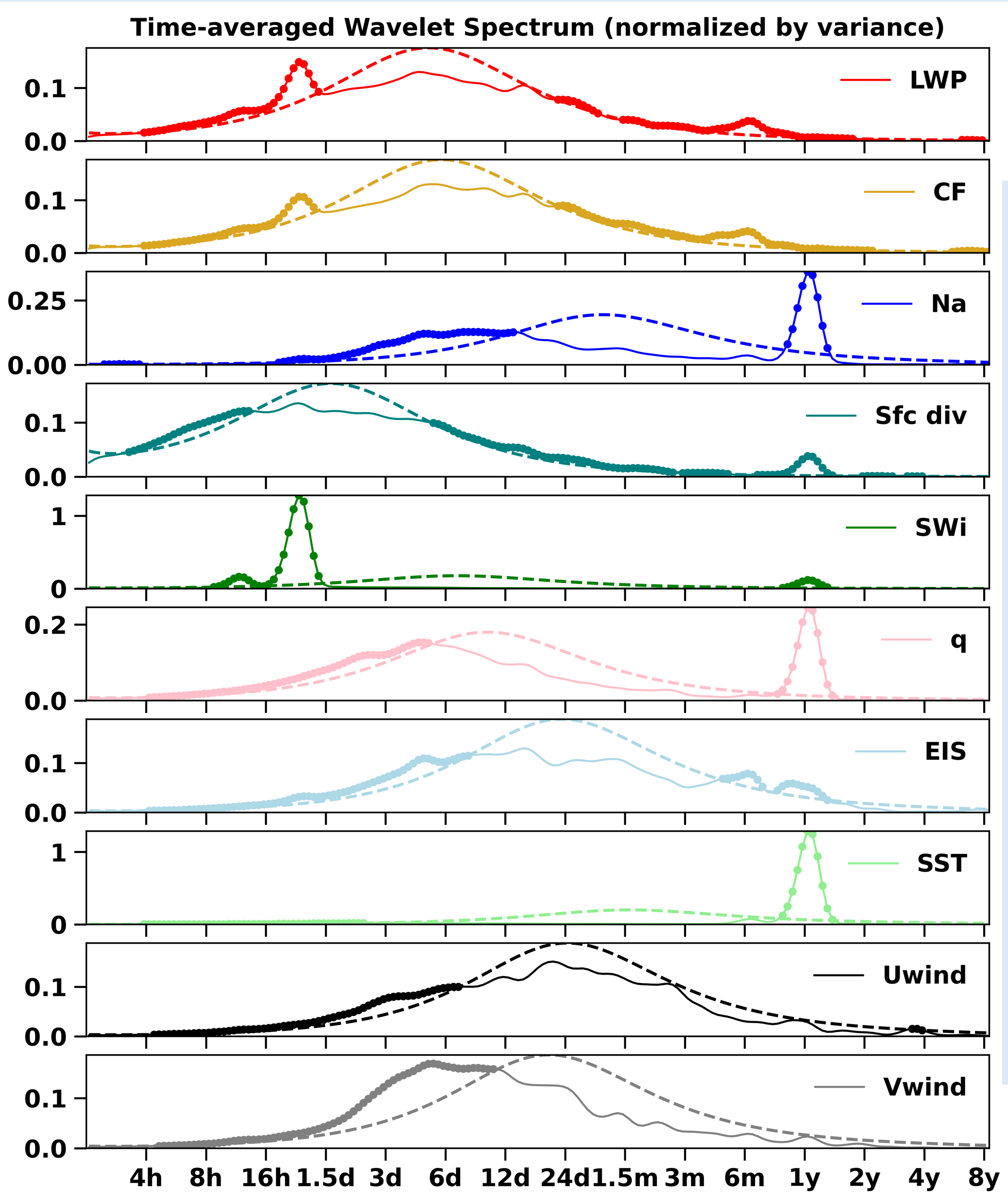
## Dataset

- 17 years (2003-2019) of hourly cloud properties and meteorological data from ERA5 reanalysis, and aerosol properties from CAMS
- Hourly data averaged in the 8ºx8º box over the Eastern North Atlantic Ocean (35ºN~43ºN; 32ºW~24ºW) for single-layer warm (liquid phase) clouds
- Will incorporate ground-based measurements and retrievals at the DOE/ARM ENA site, and geostationary satellite retrievals

## Temporal variabilities of clouds, aerosols, and meteorology

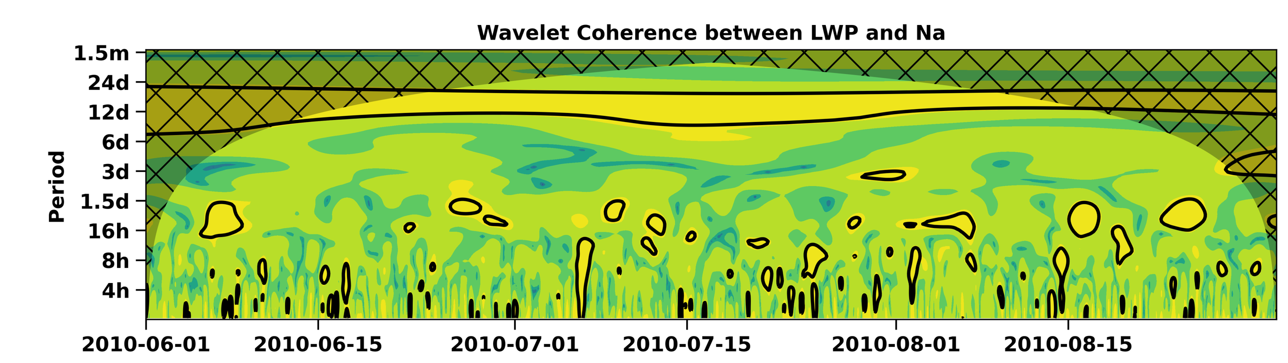



a) Normalized LWP used for the wavelet analysis. b) The wavelet power spectrum of LWP using the Morlet wavelet. The black contour encloses regions of greater than 95% confidence for a red-noise process with a lag-1 coefficient of 0.94. Cross-hatched regions on either end indicate the "cone of influence", where edge effects become important. c) Time-averaged wavelet power spectrum of LWP. The dashed line is the 95% confidence spectrum.

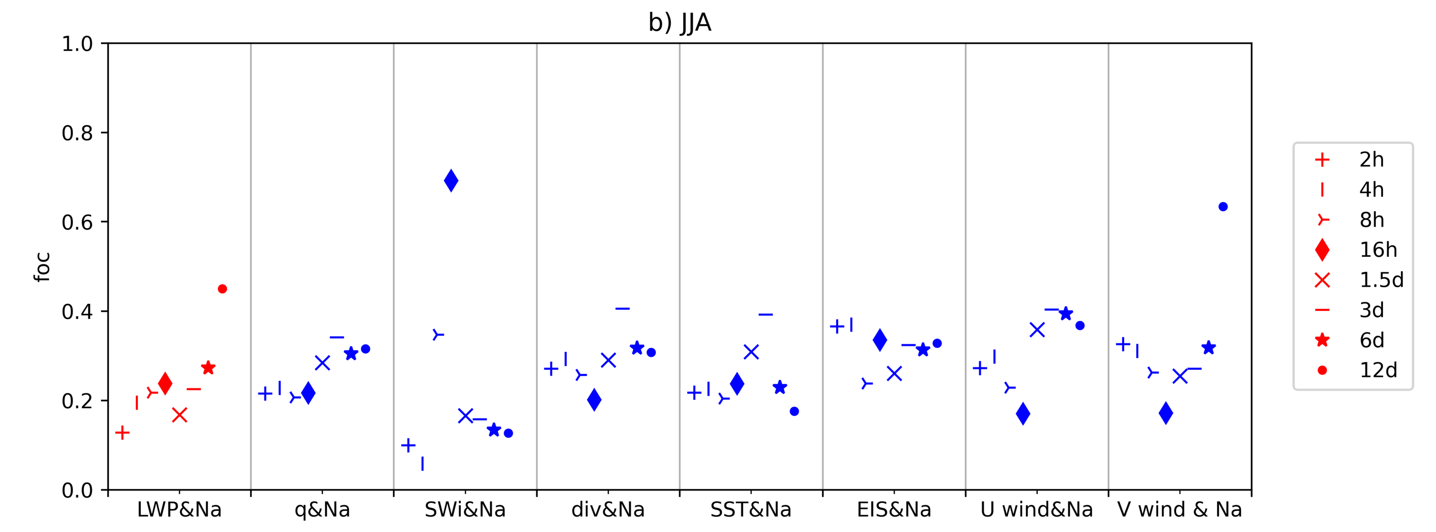



Time-averaged wavelet power spectrum of LWP, cloud fraction (CF), aerosol number concentration at 900 hPa ($N_a$), surface divergence (Sfc div), incoming solar irradiance (SWi), absolute humidity at 500 hPa (q), estimated inversion strength (EIS), sea surface temperature (SST), U wind at 100 m (Uwind), V wind at 100 m (Vwind). The power is normalized by variance. Dashed lines are the 95% confidence spectrums. Dots indicate powers passing the confidence level.

## How often are LWP and $N_a$ coherent and at what scale?




Wavelet coherence between LWP and Na during June, July, and August (JJA) in 2010. The black contour encloses regions of greater than 95% Monte Carlo confidence level.

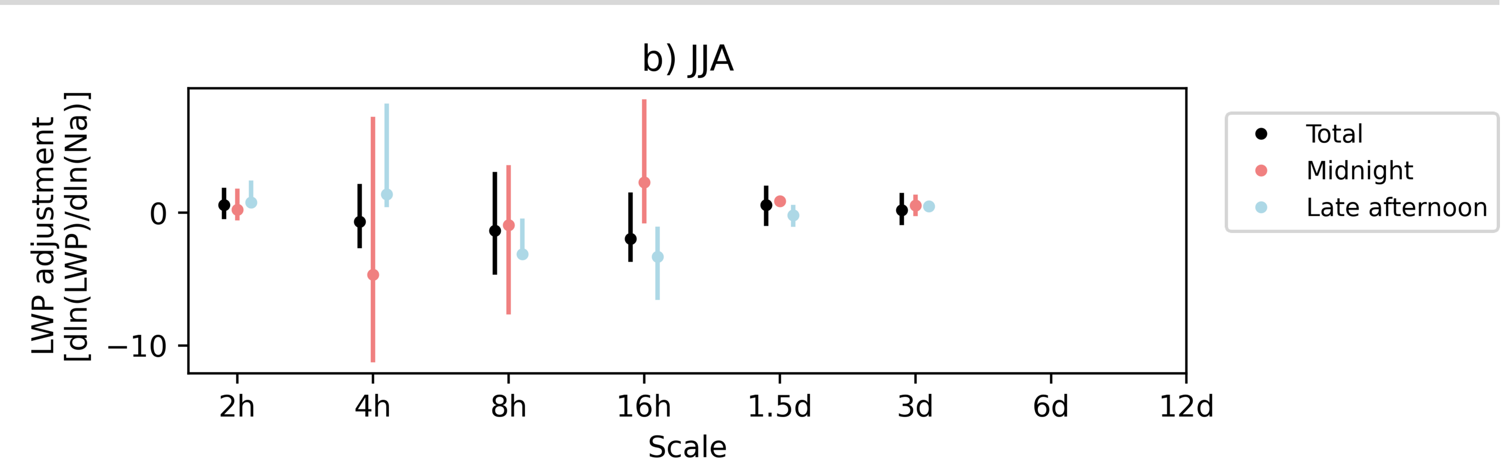



Red: Frequency of occurrence of significant coherence between LWP and $N_a$ across scales in JJA. Blue: frequency of occurrence of significant coherence between $N_a$ and meteorological conditions across scales during the period when LWP and $N_a$ are significantly coherent.

## Compute LWP adjustment across timescales

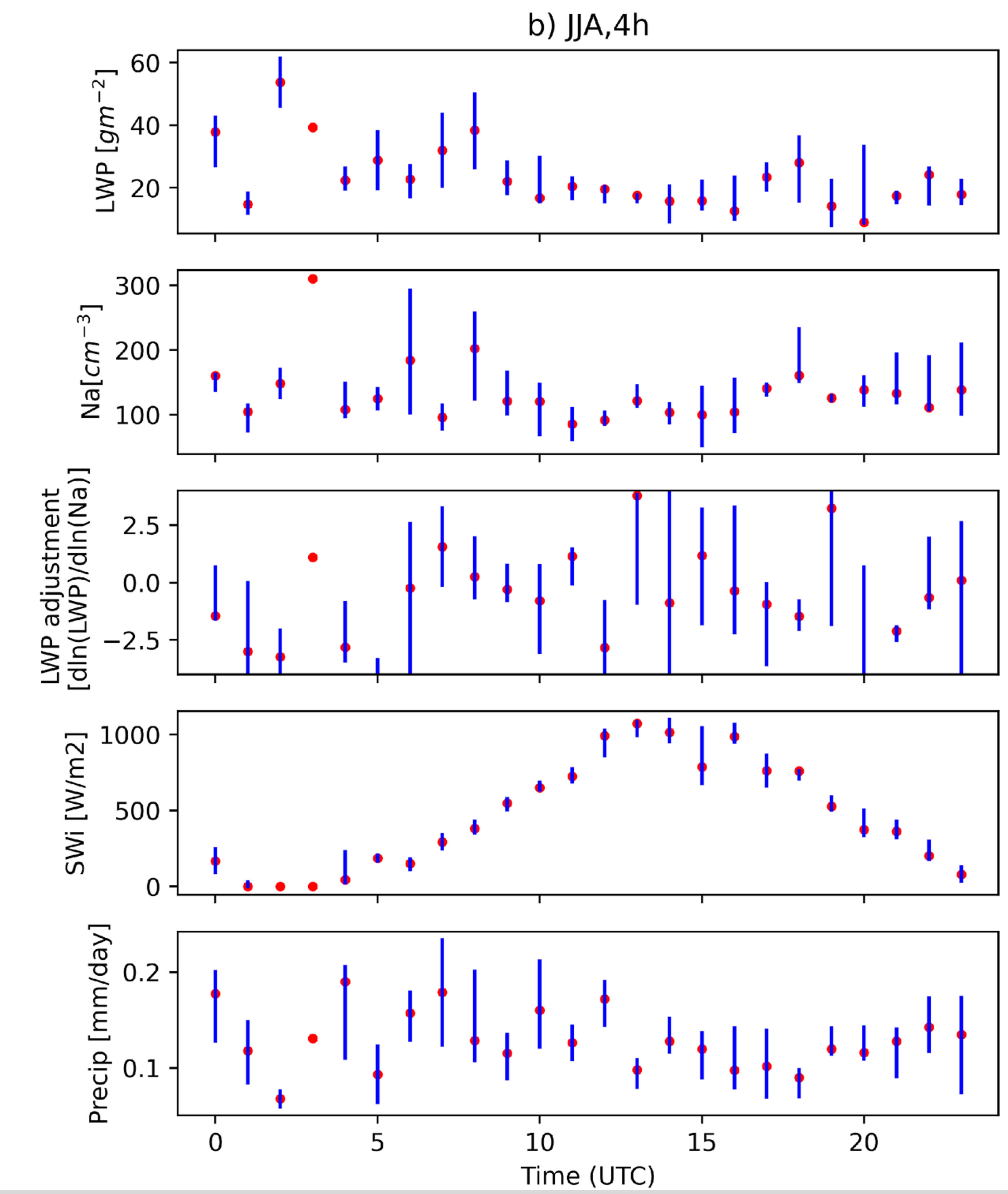
- At each scale, we identify continuous time periods (>5 hours) when cloud water and aerosols are significantly coherent in the absence of the co-variabilities between aerosols and meteorological conditions.
- Within each selected time period, we compute LWP adjustment (dln(LWP')/dln($N_a$')), where LWP' and $N_a$' are fluctuations at the specified scale decomposed using discrete wavelet analysis.

## Time dependence of LWP adjustments



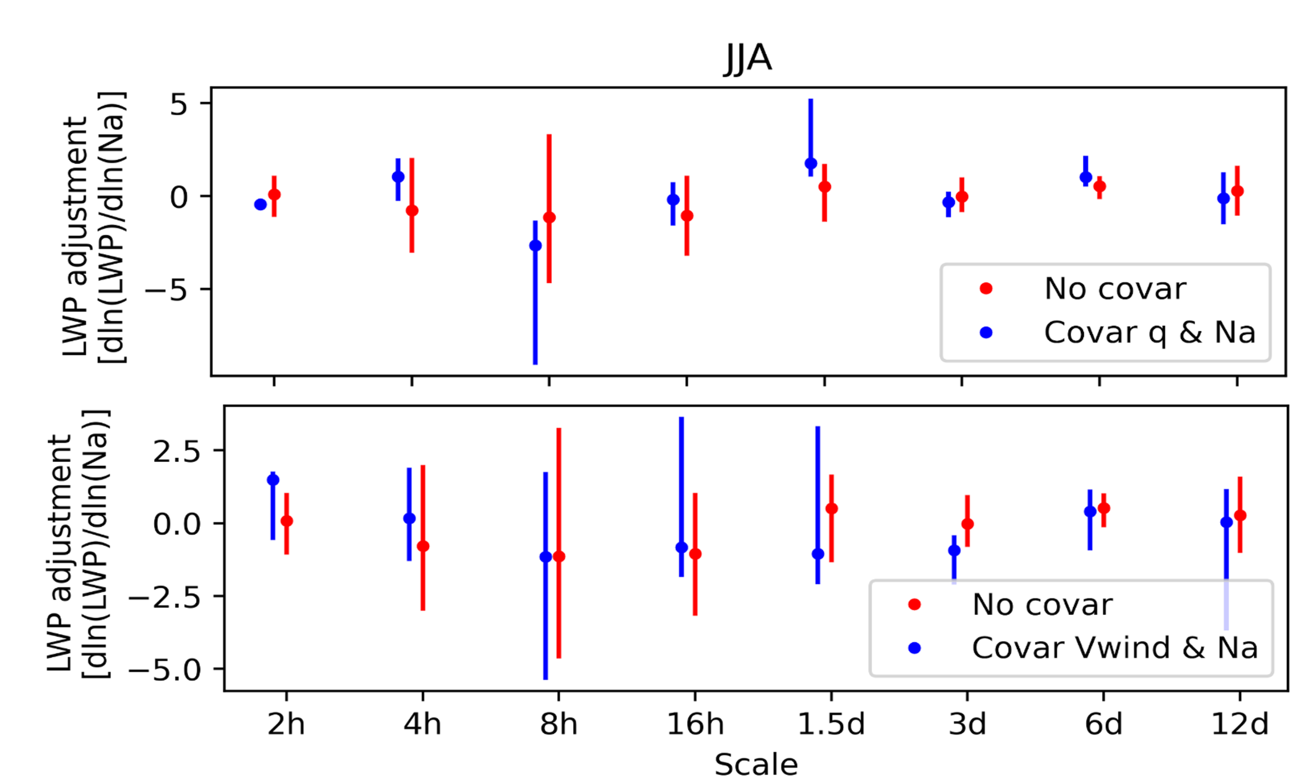

- Overall strongest negative cloud adjustment occurs at ~16 h timescale.
- Adjustment is faster at night (stronger entrainment), slower in the daytime (weaker entrainment). Nighttime adjustment timescale is much shorter than predicted by nocturnal large eddy simulations.

## Diurnal variability of LWP adjustment (4h timescale)




- Strong diurnal cycle of LWP adjustment: positive adjustment in late afternoon and negative adjustment at night
- Precipitation mediation: relatively strong precipitation at dawn and midnight increases the LWP adjustment

## LWP adjustments in the context of other natural co-variabilities (ongoing work)

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