Response of convectively coupled Kelvin waves under warming scenarios in a global storm-resolving model

Xianpu Ji[1,2]*, Hans Mikhail Segura Cajachagua[2], Ortega Arango Sebastián[2], Tao Feng[1]

[1] College of Oceanography, Hohai University, Nanjing, China
[2] Max Planck Institute for Meteorology, Hamburg, Germany

MAX-PLANCK-INSTITUT FÜR METEOROLOGIE

Motivation

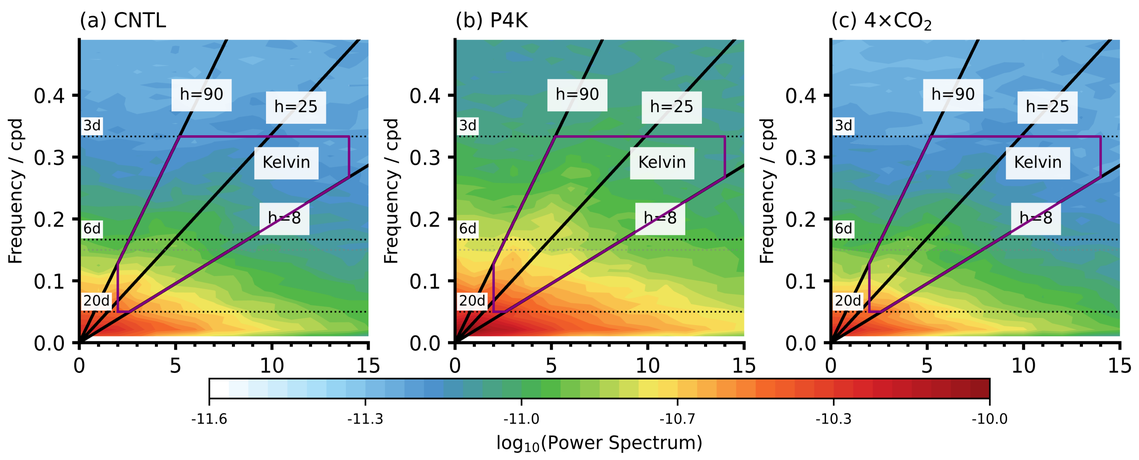
Response of convectively coupled Kelvin waves (CCKWs) under warming scenarios and the driving mechanism remains unclear.

Experiment Design

CNTL	P4K	$4CO_2$
SST hist	SST +4K	CO_2 × 4
CO_2 base	CO_2 base	SST Fixed

- ICON global storm-resolving atmosphere ~10 km, without cumulus parameterization.

Fig .1 Power spectrum of CCKWs in different experiments



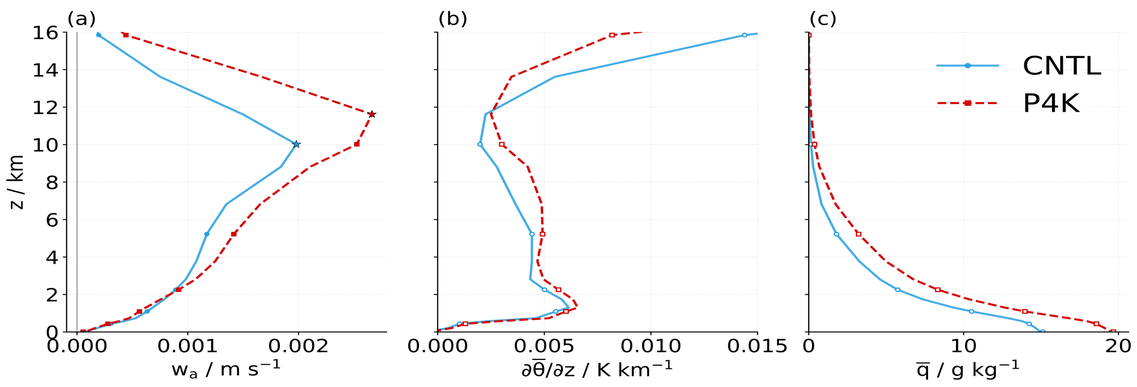
✓ Kelvin-band spectral power increases and moves to deeper equivalent depth markedly in P4 K, while negligible changes occur in 4×CO2.

1. Why are the CCKWs more faster in response to SST warming?

Phase speed of Kelvin wave: $c = \sqrt{gH_{eq}} \approx \frac{N}{m}$

H_{eq}: equivalent depth; N: static stability; m: vertical wavenumber

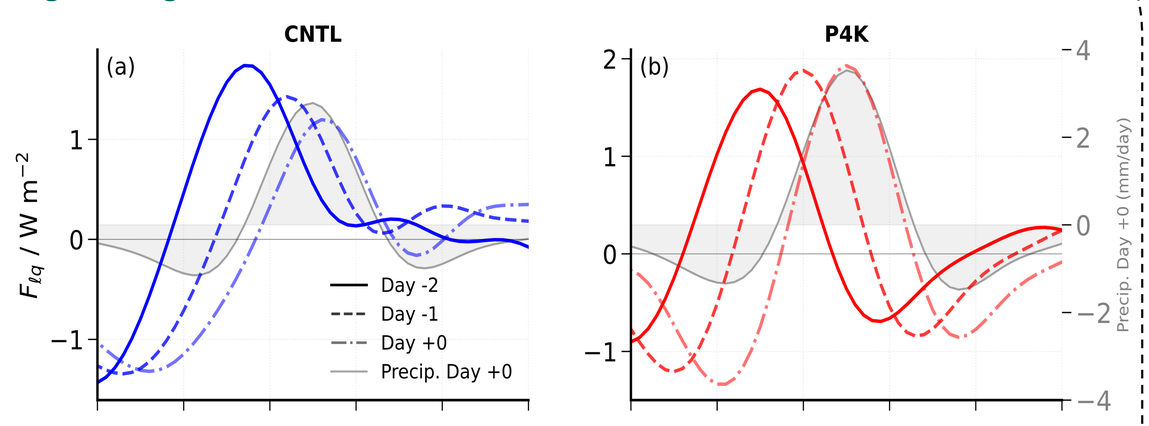
Fig .2 Background state between CNTL and P4K



✓ P4K exhibits **increased atmospheric stability**, implying an increase in the equivalent depth (faster CCKW propagation).

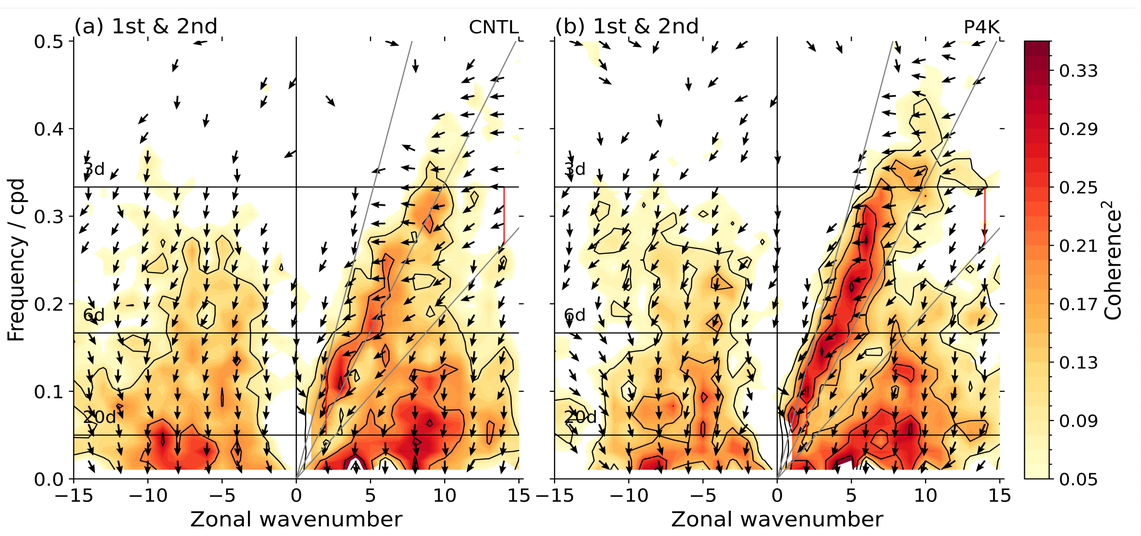
2. Why are the CCKWs more intensified in response to SST warming?

Fig .3 Longitude of wave-related anomalies in CNTL and P4k



✓ **Surface-flux and energy input enhancement before CCKW Passage.**

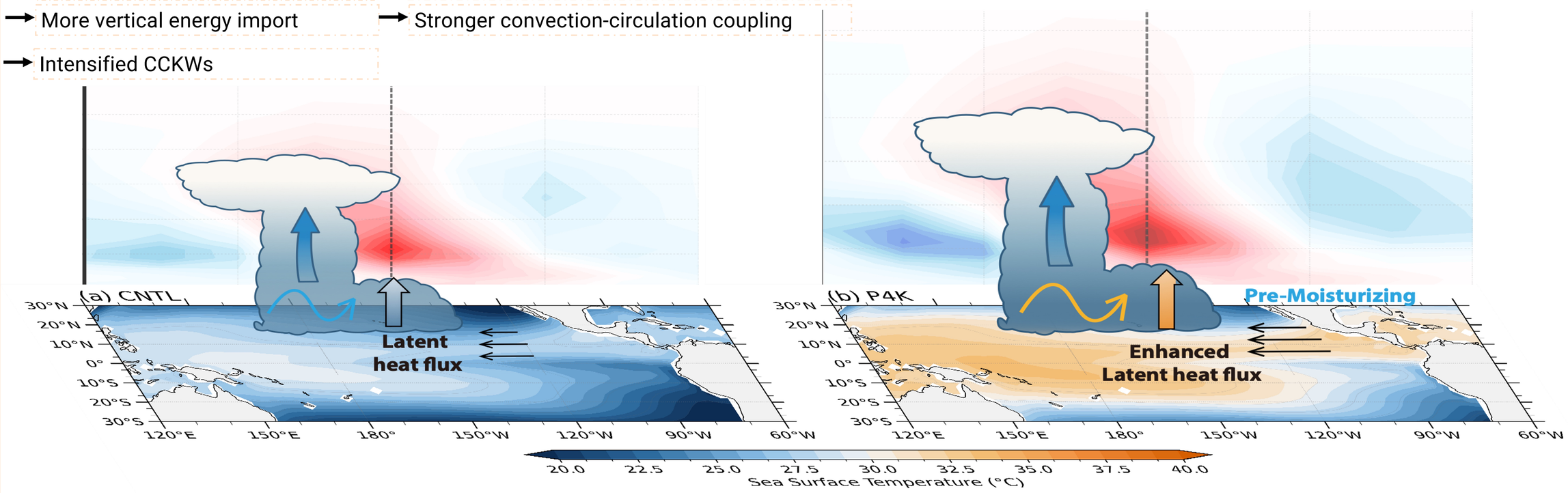
Fig .4 Cross-spectrum of the first and second modes of vertical velocity



✓ **Stronger coherence** between the first and second modes of convection in the Kelvin band under P4K.

3. Mechanism: enhanced Wind-Induced Surface Heat Exchange (WISHE; Emanuel,1987) feedback links surface warming

Surface warming background
→ Increased wave-related zonal wind → Enhanced pre-moistening and latent heat flux
→ More vertical energy import → Stronger convection-circulation coupling
→ Intensified CCKWs



KEY NOTES

CCKWs are intensified primarily in response to SST warming rather than directly to CO_2 forcing.

Faster: increased equivalent depth

Stronger: enhanced convection-circulation coupling

Mechanism: strengthened surface-flux feedback

Connect: xianpuji@hhu.edu.cn