Insights from Ex-Typhoon Halong (2025) – An Arctic Cyclone of Tropical Origin

Zhuo Wang

Department of Climate, Meteorology & Atmospheric Sciences (CLiMAS)

University of Illinois Urbana-Champaign, Urbana, Illinois

Yang, M., Z. Wang, J. Walsh, J. Doyle, R. Thoman, and A. DuVivier, 2026: Insights from Ex-Typhoon Halong (2025) – An Arctic Cyclone of Tropical Origin, Bull. Amer. Meteor. Soc., under review.

Mingshi Yang

Introduction

- Ex-Halong originated as a typhoon in the western North Pacific.

- Ex-Halong propagated over regions of warm SST anomalies and re-intensified south of Alaska, causing severe wind, storm surge, and flooding.

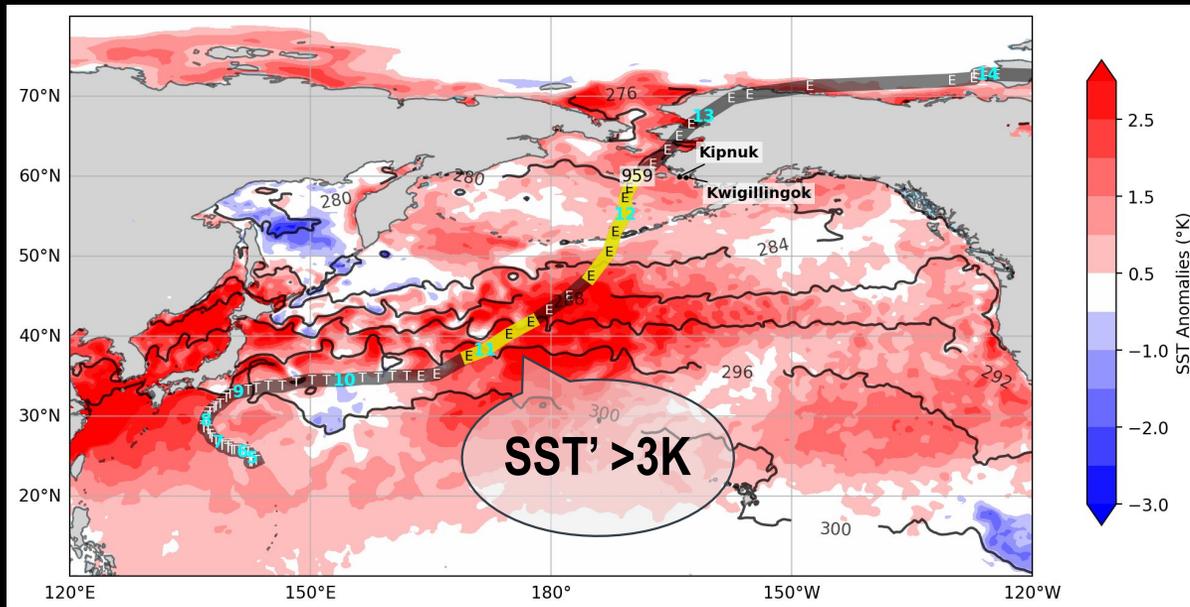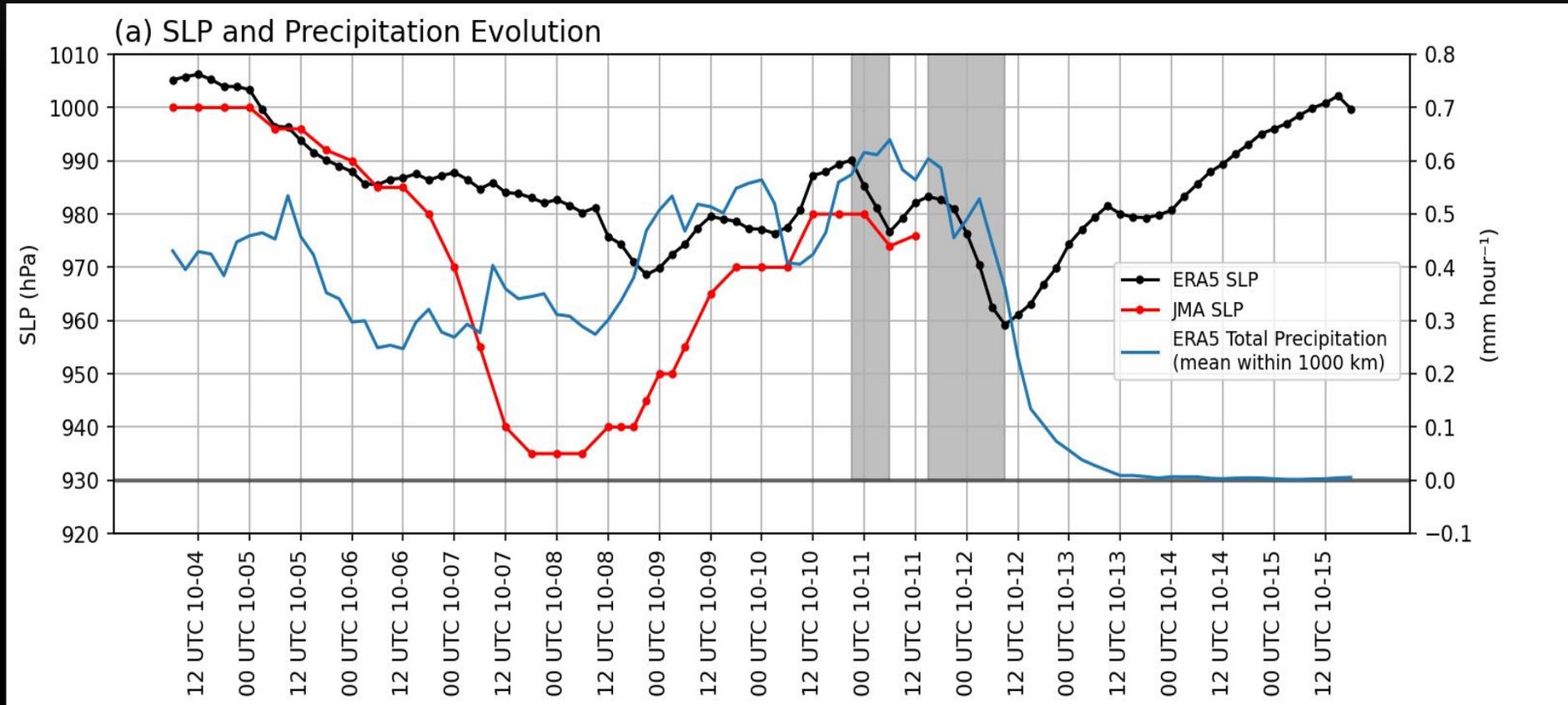- Native villages near the coast were especially hard hit.

Figure source: https://alaskabeacon.com/

Re-intensification of Ex-Halong

(a) SLP and Precipitation Evolution

SLP: black (ERA5) and red (JMA)
Precipitation: blue; Shaded: re-intensification

Questions and Outline

- Questions:
  - *What processes or factors contributed to the extratropical re-intensification of ex-Halong?*
  - *How does ex-Halong compare to other Arctic cyclones near the Bering Sea?*
- Outline:
  1. The role of upper-level forcing (QG analysis)
  2. The role of warm SST (WRF model simulation)
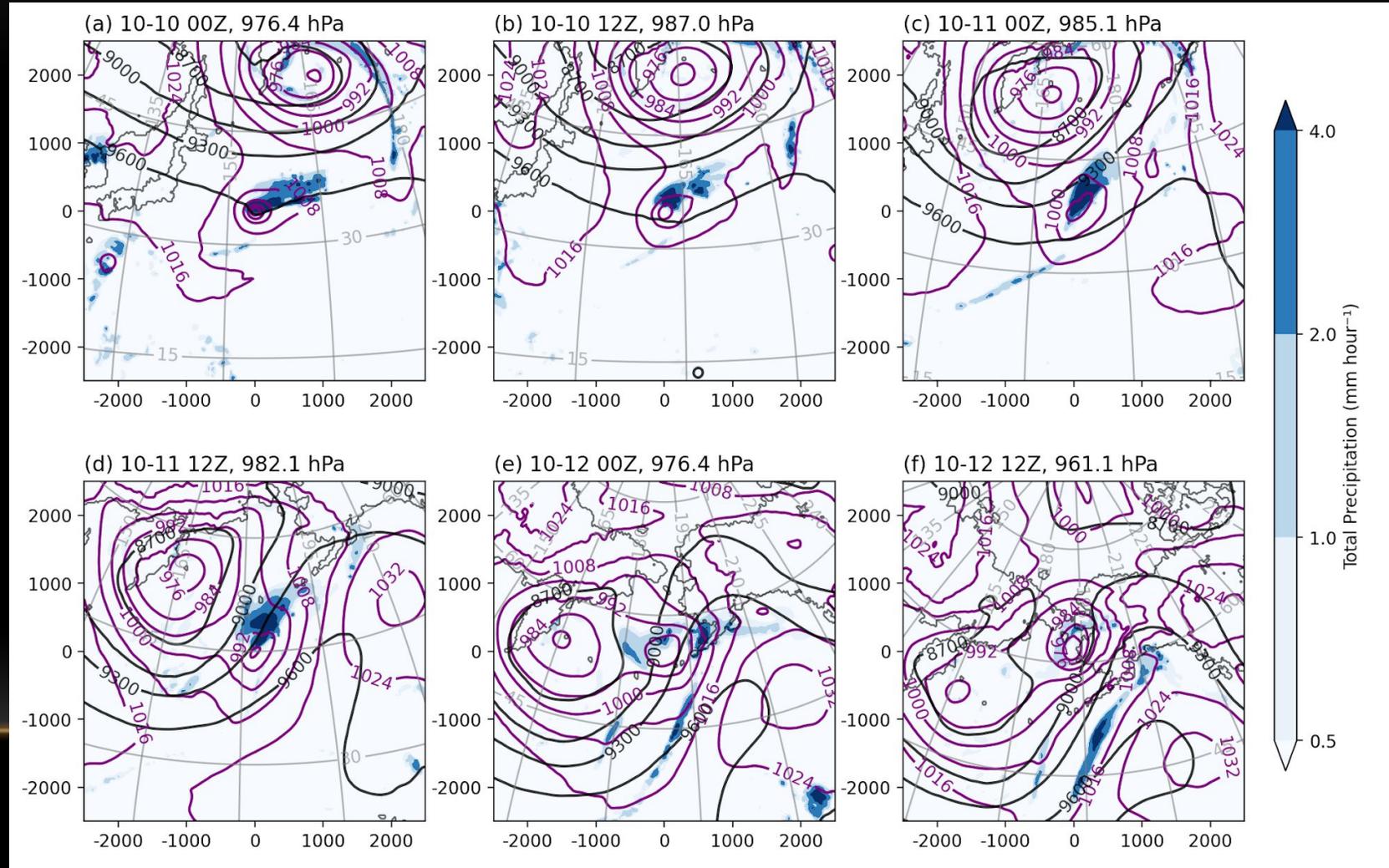 3. Climatology of Arctic cyclones of tropical origin in the North Pacific

Role of Upper-level Forcing during Ex-Halong's Re-intensification

Ex-Halong's evolution: SLP, H300, and Precip

- A quasi-stationary ETC with a deep circulation is located north/northwest of ex-Halong and steers Ex-Halong cyclonically around it.

- Ex-Halong develops a comma-shaped precipitation pattern after ET.

SLP: --------- purple
H300: --------- back
Precip: shading

(a) 10-10 00Z, 976.4 hPa
(b) 10-10 12Z, 987.0 hPa
(c) 10-11 00Z, 985.1 hPa
(d) 10-11 12Z, 982.1 hPa
(e) 10-12 00Z, 976.4 hPa
(f) 10-12 12Z, 961.1 hPa

Omega

$$\left(\nabla_p^2 + \frac{f_0^2}{\sigma}\frac{\partial^2}{\partial_p^2}\right)\omega = -2\nabla_p \cdot \boldsymbol{Q} + \frac{f_0\beta}{\sigma}\frac{\partial v_g}{\partial p} - \frac{\kappa}{\sigma p}\nabla_p^2 J$$

Omega from ERA5   Adiabatic QG Omega   Diabatic QG Omega

1st intensification period:
heating dominant
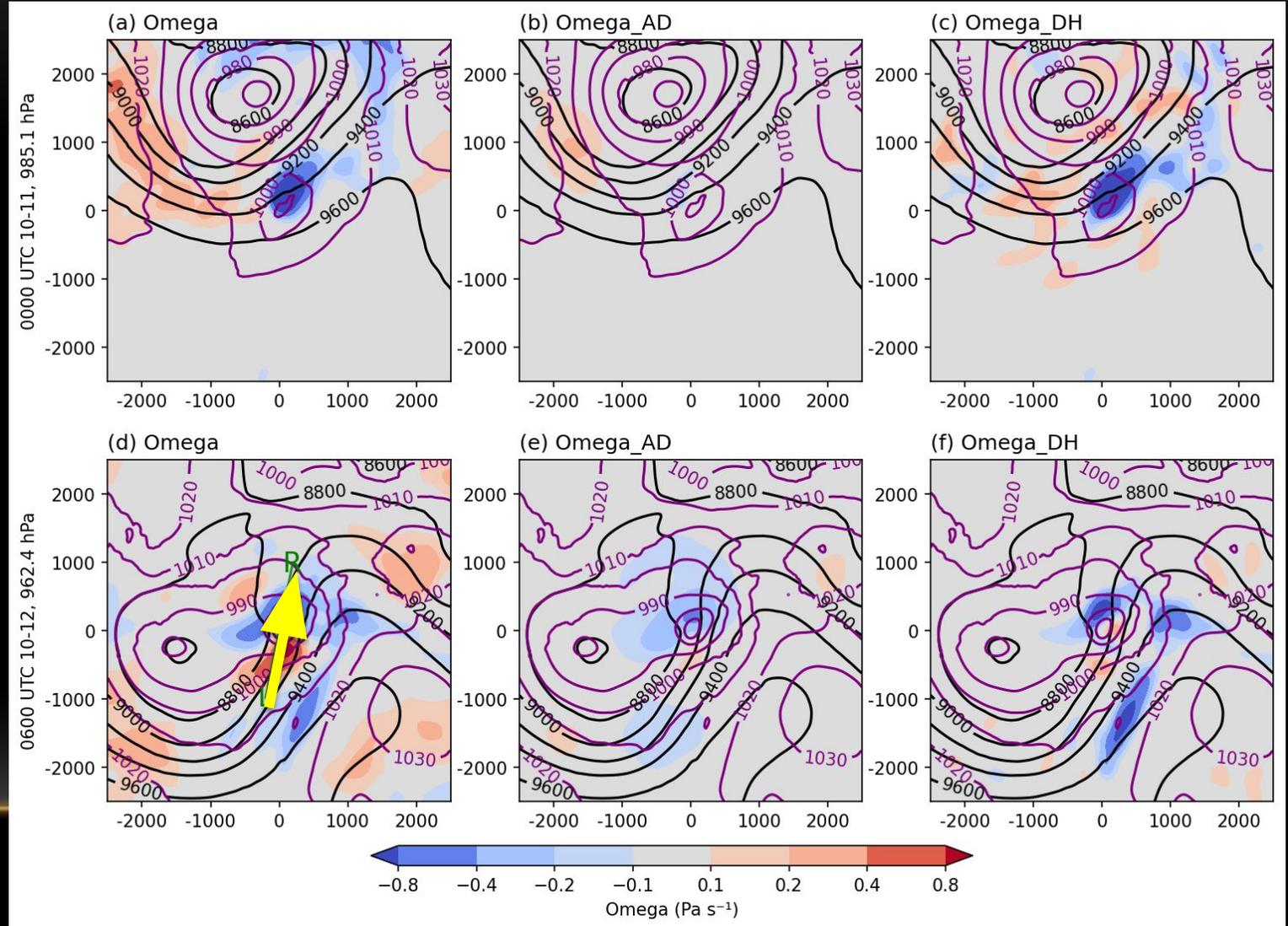
2nd intensification period:
Q vector convergence + heating

SLP: --------- purple
H300: --------- back
Omega: shading

(a) Omega   (b) Omega_AD   (c) Omega_DH
(d) Omega   (e) Omega_AD   (f) Omega_DH

Omega (Pa s⁻¹)
−0.8 −0.4 −0.2 −0.1 0.1 0.2 0.4 0.8

Vertical cross section

- Q vector convergence dominates ahead of the surface cyclone center of Ex-Halong.

- Consistent with vorticity advection by the thermal wind.

- QG forcing associated with the upper-level jet promotes ascent, which is further amplified by latent heat release
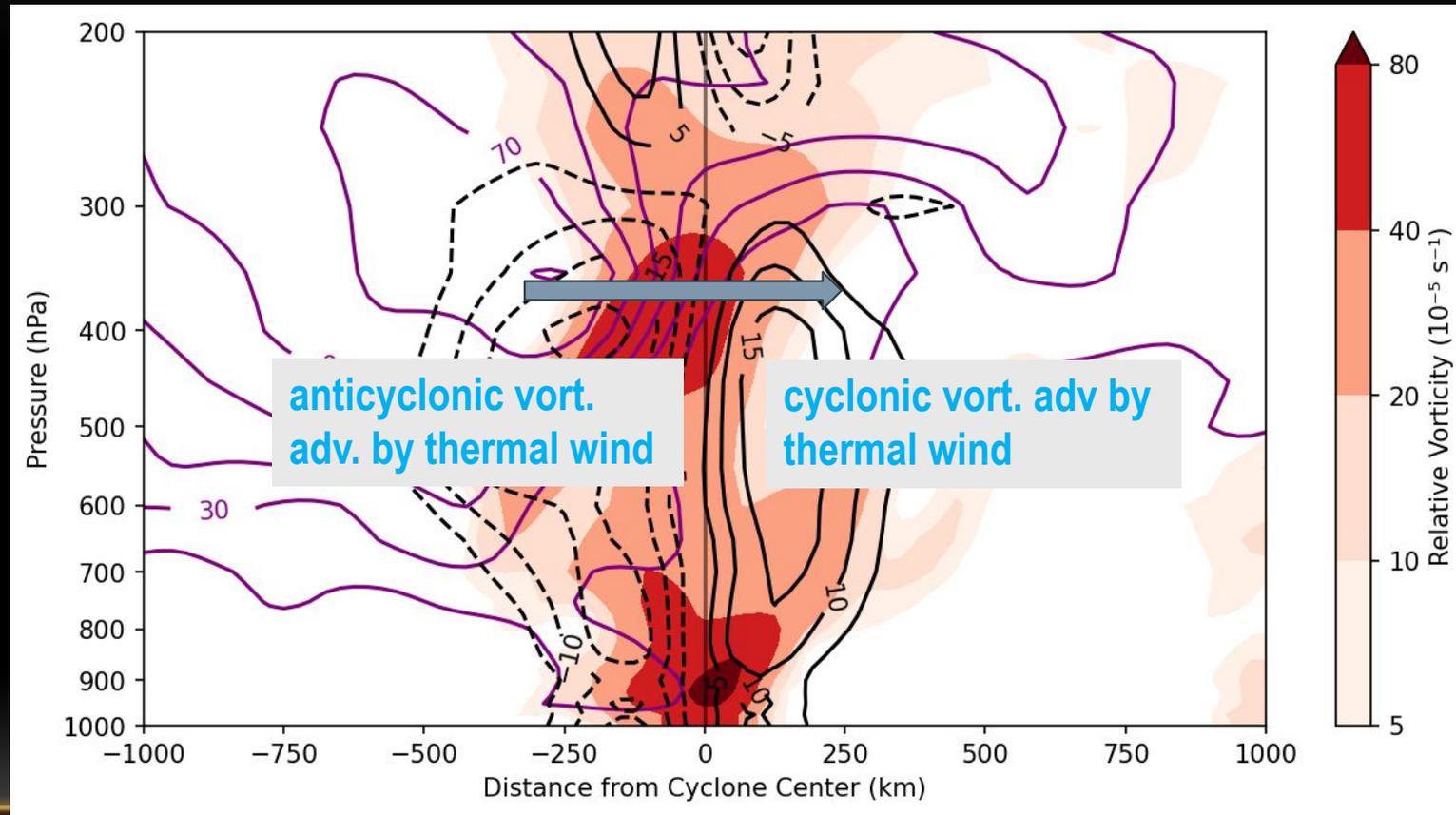
wind: --------- purple
QG: --------- back
vorticity: shading

Role of SST during Ex-Halong's Re-intensification

WRF Simulation configurations

- Three sets of experiments using WRF v4.2.2:

  - Control experiment (CTRL): SST from ERA5.

  - Long term mean SST (LTM): long term mean SST during 1940-2025

  - Detrended SST experiment (**DSST**): linear trend **removed**

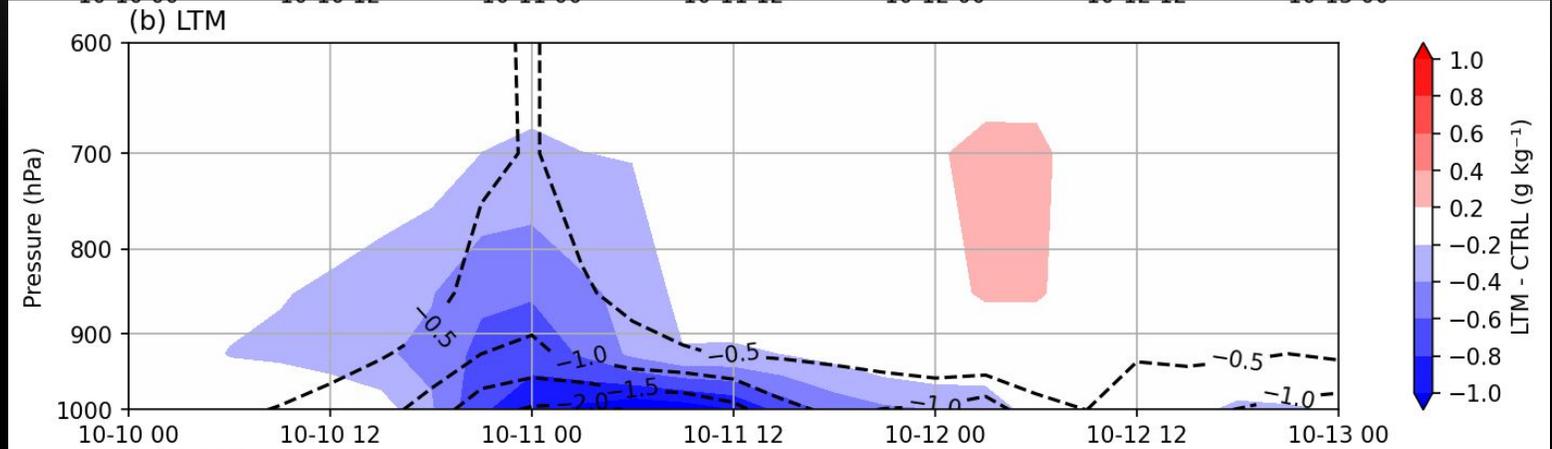- 18 ensemble simulations for each experiment (diff. physics options)
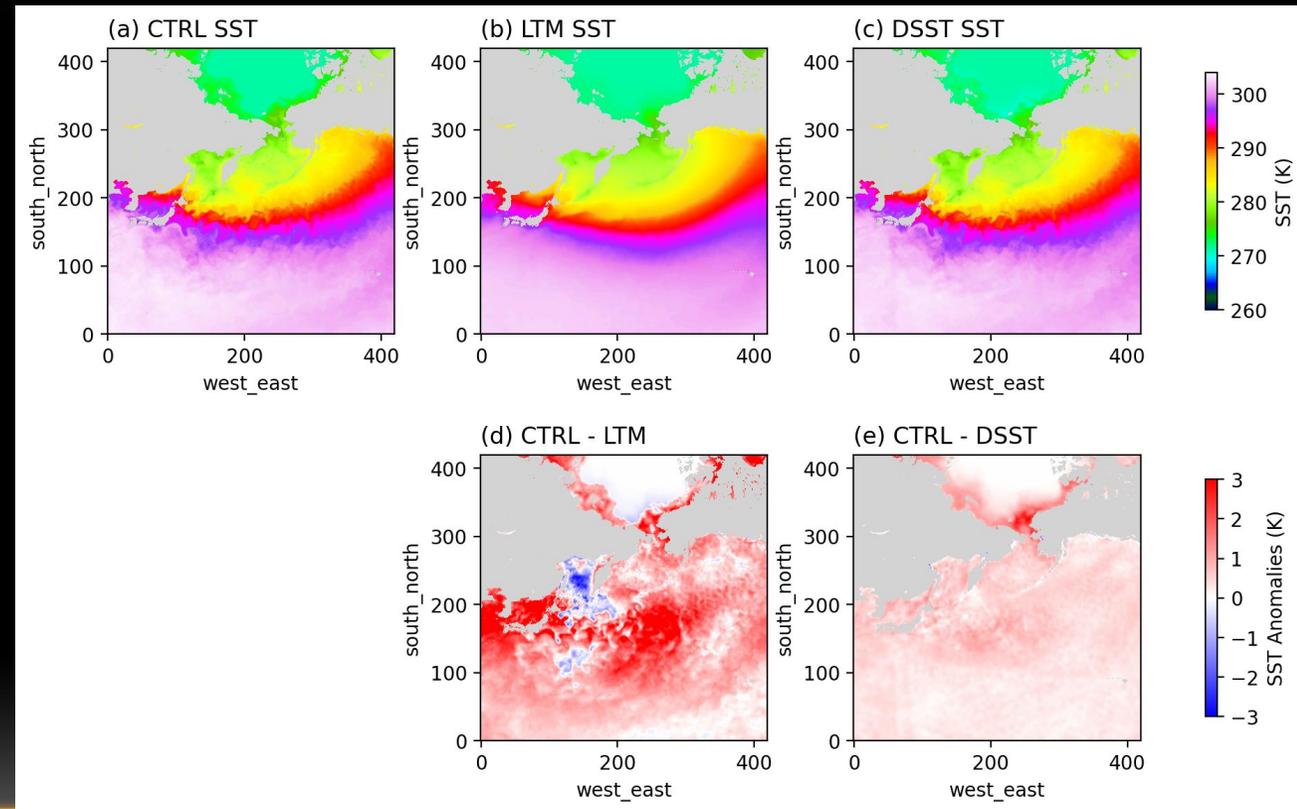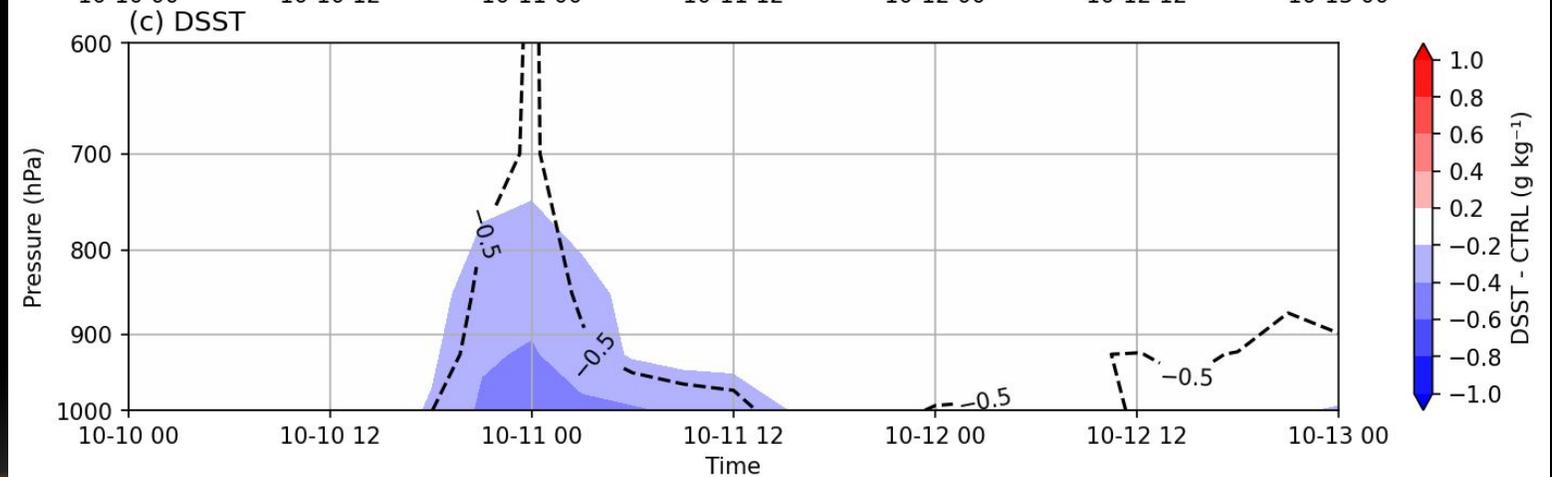
Track and Intensity Evolution

Track

SLP
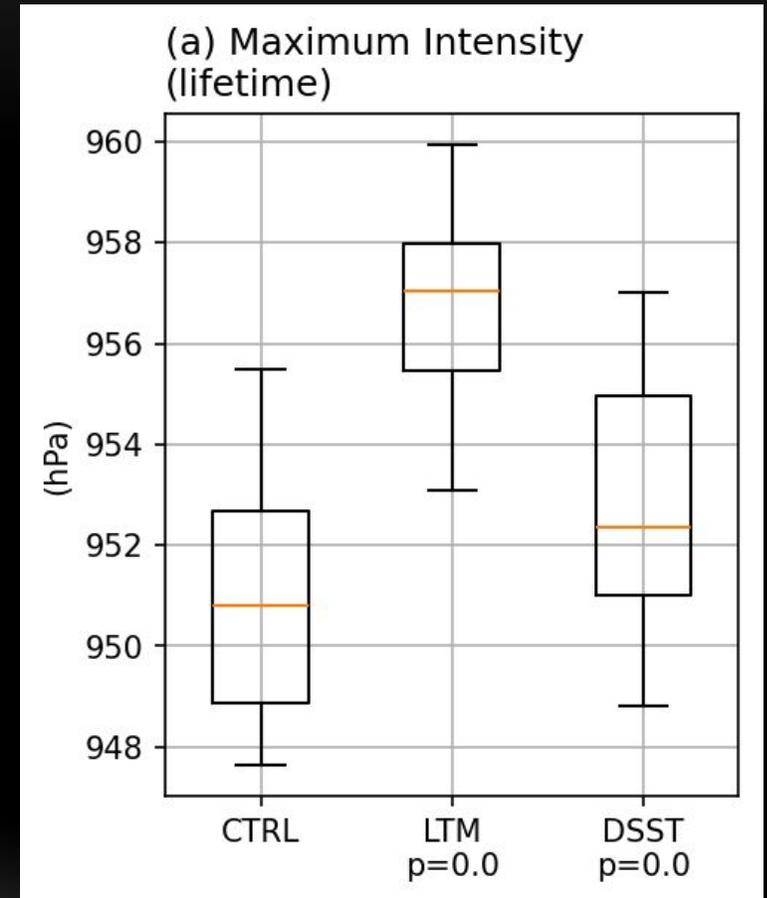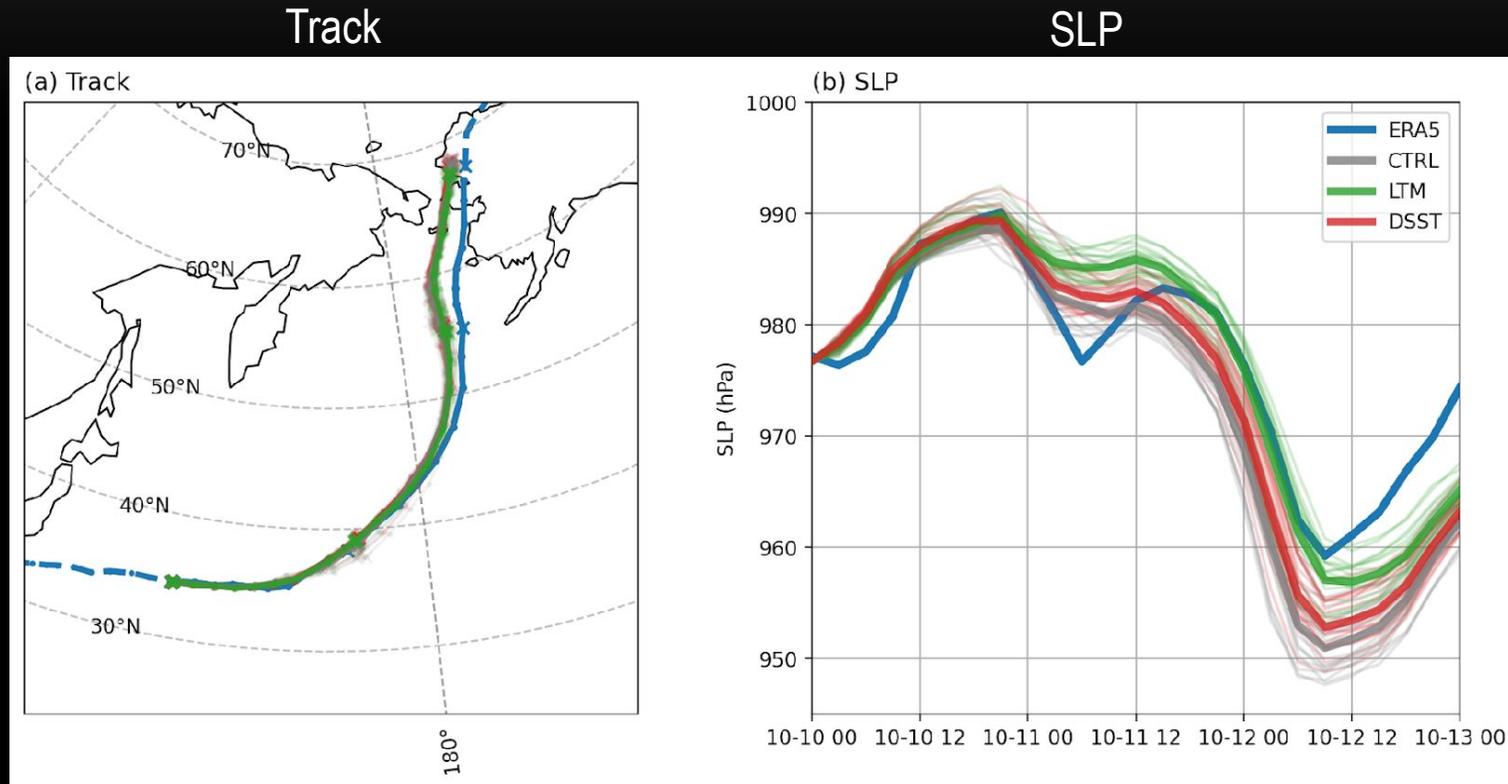
- SST modifications do not strongly alter the trajectory of ex-Halong

- Both LTM and DSST experiments produce weaker Ex-Halong.

Time-pressure Evolution of T and SH Diff w.r.t. CTRL

LTM

DSST

T: --------- back
SH: shading

Warm SST preconditions ex-Halong's re-intensification by enhancing CWV and reducing static stability
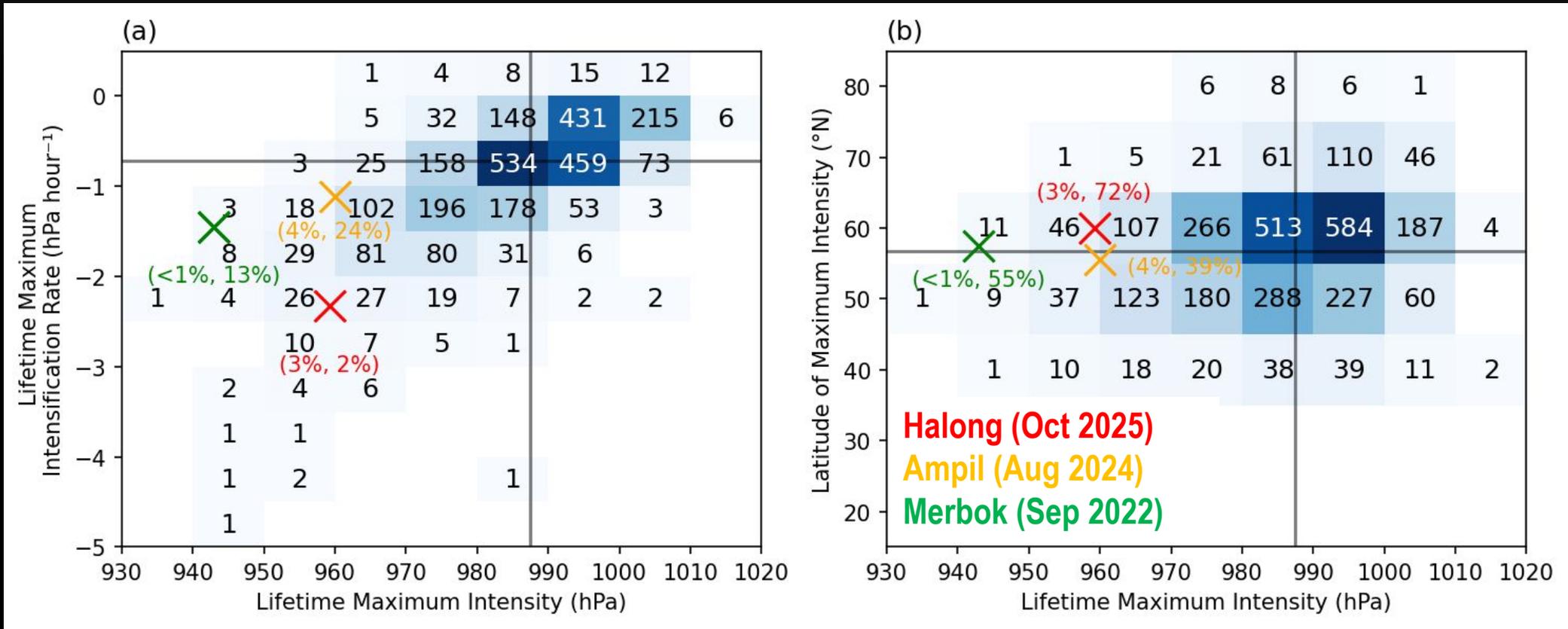
Ex-Halong in the Climatological Context

Arctic Cyclones in the North Pacific

Max Intensification rate vs. Intensity

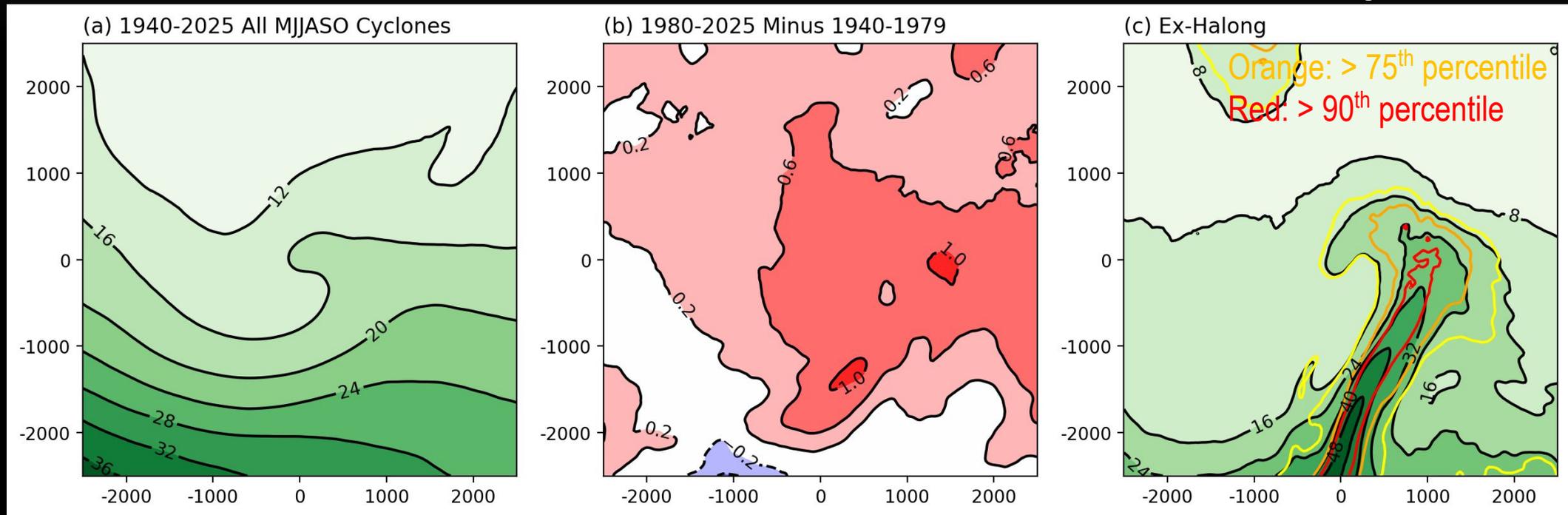Lat. Of Max Intensity vs. Intensity

Ex-Halong is characterized by rapid intensification and high intensity at high latitudes.

Cyclone-Centric CWV

1940-2025   1980-2025 minus 1940-1979   Ex-Halong

- CWV has increased in recent decades, consistent with a warmer atmosphere.

- Ex-Halong features a pronounced moist tongue to its east, resembling a warm conveyor belt or AR.

Seasonality of Arctic Cyclone of Tropical Origin (ACT)

- In the long-term mean (1940-2025), ACTs occurred less than once per decade in Oct.

- ACT frequency strongly increased in Aug-Sep in recent decades, leading to more warm-season ACTs.

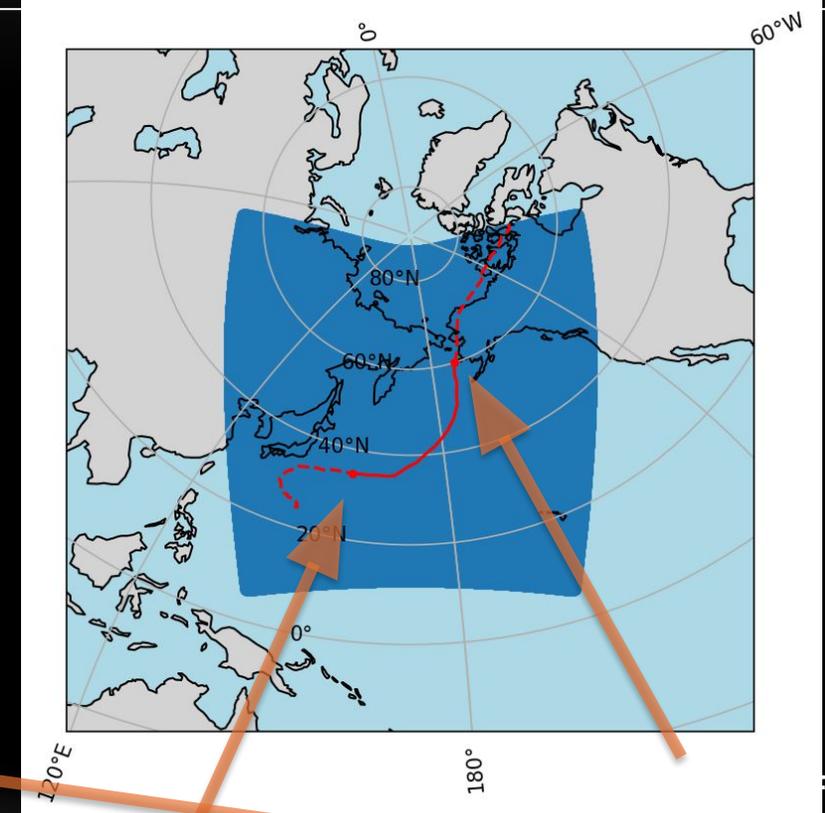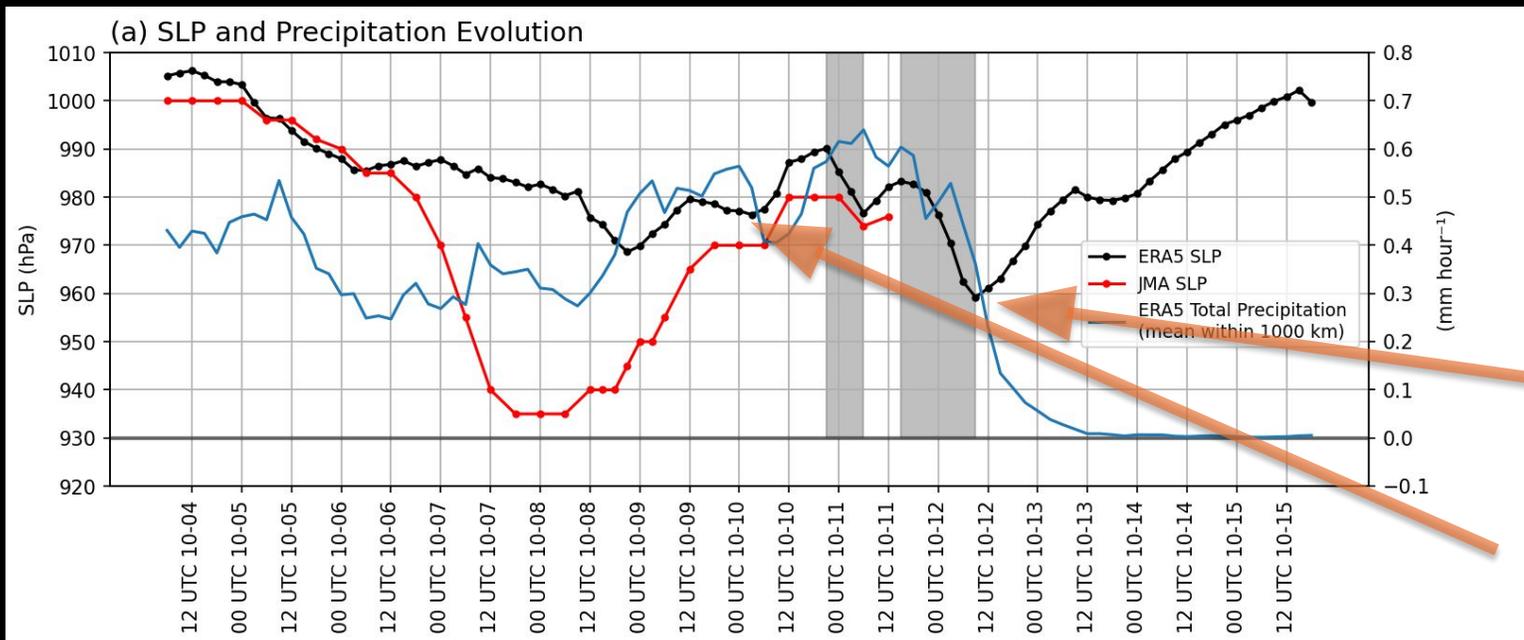- The low sea ice extent in fall implies strong impacts of ACTs.
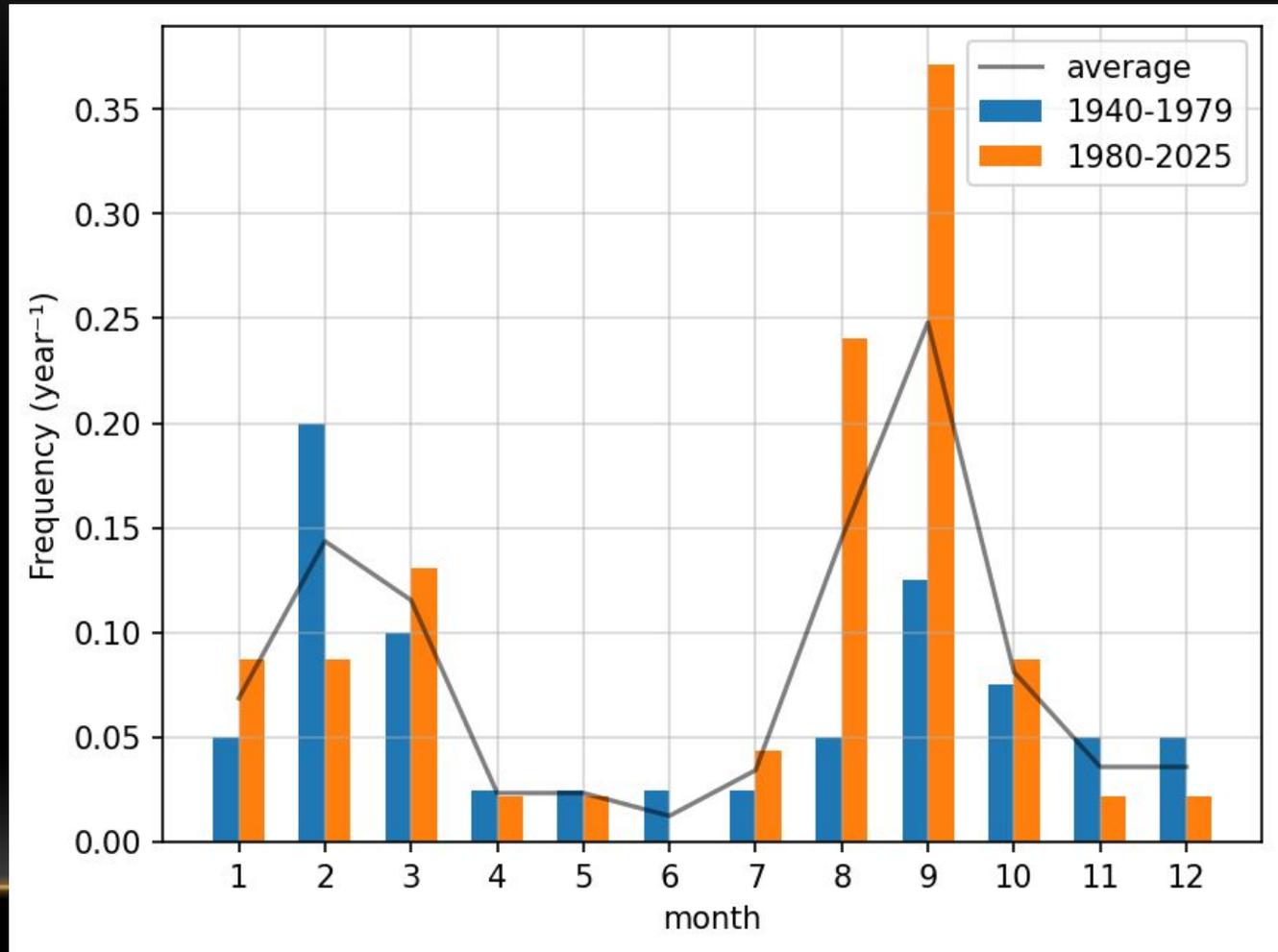
Summary

- Warm SST anomalies preconditioned ex-Halong's re-intensification by increasing CWV and reducing static stability. Quasi-geostrophic lifting associated with a subsequent interaction with another extratropical cyclone led to the rapid deepening of ex-Halong south of the Bering Sea.

- The frequency of Arctic cyclones of tropical origin increased by a factor of four in August and by a factor of three in September during 1980–2025 compared with 1940–1979.
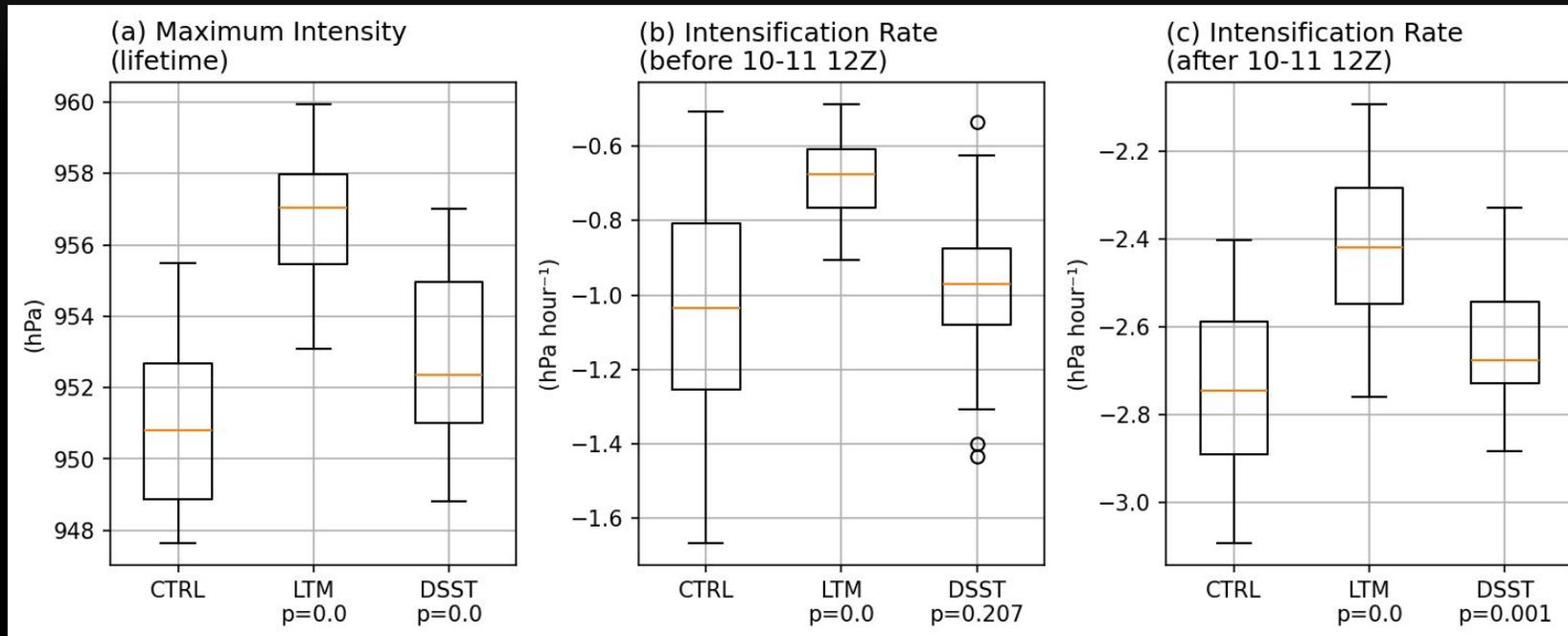
WRF simulations

Simulation domain (blue) and ERA5 track (red)
Domain is 420*420 20 km Lambert grid

- Simulation start time: 10-10 00Z

  - Near the end of Typhoon stage, and ERA5 SLP bias is reduced and is closer to the JMA analysis.

- Simulation period: 10-10 00Z to 10-13 00Z

  - Covering re-intensification and peak intensity.

(a) SLP and Precipitation Evolution

ERA5 SLP
JMA SLP
ERA5 Total Precipitation (mean within 1000 km)
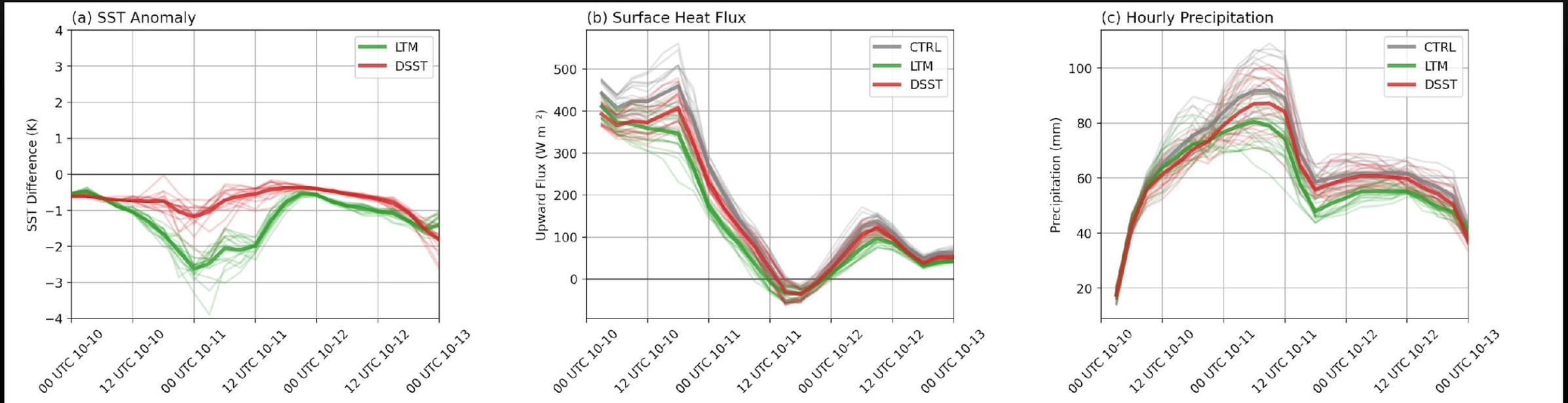
Ex-Halong in ERA5

Simulation starts

Lifetime maximum intensity and intensification rate

Boxes show interquartile range with median (orange); whiskers extend to 1.5×IQR, with dots indicating outliers. p values denote Student's t-test significance relative to CTRL (pairwise).

- First period (b): LTM shows significantly weaker deepening than CTRL, indicating a dominant role of regional SST anomalies, while SST trend has a weak and insignificant impact.

- Second period (c): Both SST modifications significantly weaken re-intensification.

Cyclone characteristics

(a) SST Anomaly — LTM, DSST

(b) Surface Heat Flux — CTRL, LTM, DSST

(c) Hourly Precipitation — CTRL, LTM, DSST

- Under cooler SSTs, both LTM and DSST experiments produced ex-Halong with weaker surface heat flux and precipitation.

- LTM's stronger response is related to its stronger regional SST anomalies experienced by ex-Halong.