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Comparison between Developing and Nondeveloping Disturbances for Tropical Cyclogenesis in Different Large-Scale Flow Patterns over the Western North Pacific

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Contents

Previous work and the key question

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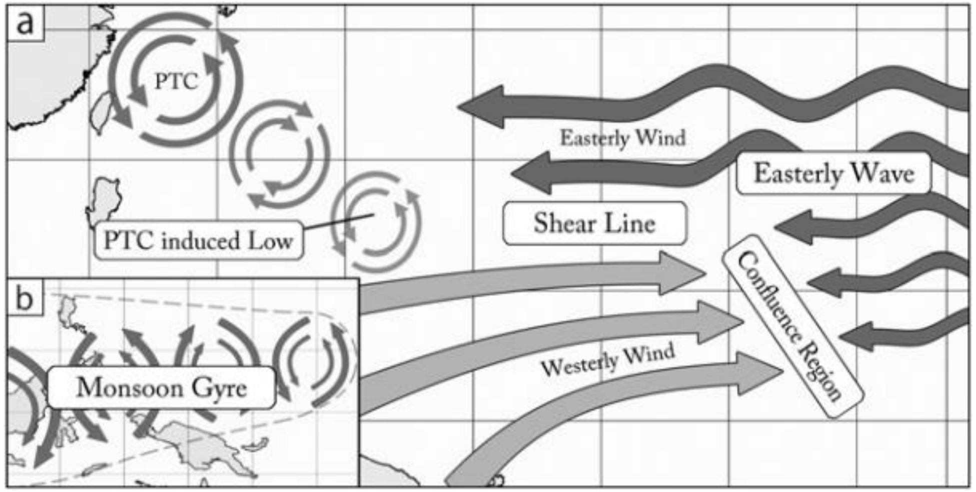
Tropical cyclogenesis is particularly susceptible to the large-scale circulation.

Zehr (1992): Monsoon-E, Monsoon-Stg, Monsoon-Wk, easterly pattern

Ritchie and Holland (1999): Rossby wave energy dispersion, Monsoon shear line (MS), Monsoon confluence (MC), Monsoon gyre (MG), Easterly wave

Feng et al. (2014): MS, MC, MG, reverse-oriented monsoon trough, trade easterly wind

Most disturbances still failed to develop into a tropical depression (TD).



A schematic image of the five flow patterns over the western North Pacific (Yoshida and Ishikawa, 2013)

How to distinguish developing disturbances from nondeveloping ones in different large-scale circulation patterns?

Data

International Best Track Archive for Climate Stewardship (IBTrACS)

- **genesis time and location for developing disturbances**
- The TC genesis time is defined as the time when the maximum sustained surface wind first reaches **11 m/s** and persists for **at least 24 hr**.

European Centre for Medium-Range Weather Forecasts' (ECMWF's) next-generation reanalysis ERA5

- **0.25°×0.25°, 6-hourly, from June to November in 2000-2019**
- **disturbance identification, large-scale environmental parameters**

GridSat-B1 infrared brightness temperature

- **0.07°×0.07°, 3-hourly**
- **MCS information**

Classification of large-scale circulation patterns

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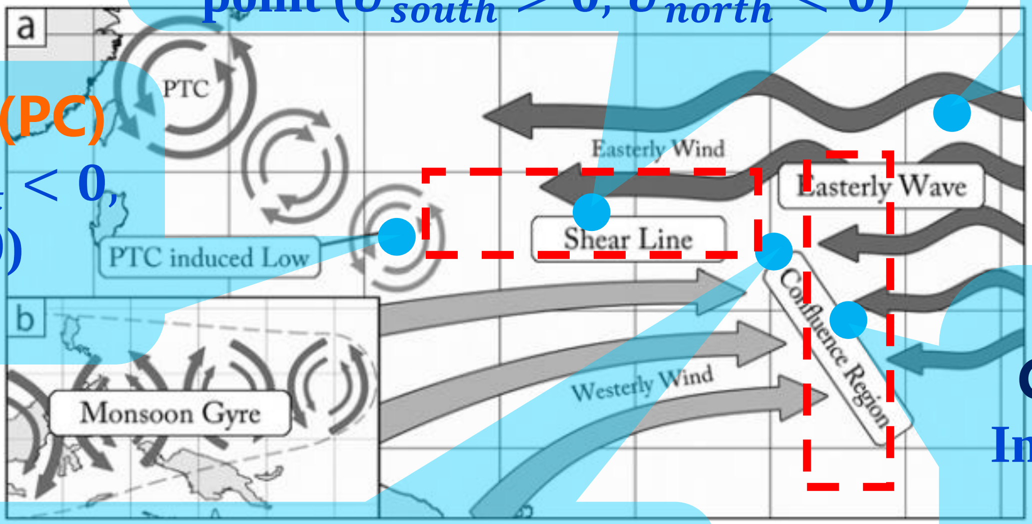
A new set of criteria for five large-scale patterns

Zonal Wind Shear Line (SL)
In a 30°×7.5° west-east band, at least 50% longitudes have a shear point ($U_{south} > 0, U_{north} < 0$)

Easterly Wave (EW)
easterly wind ($U < 0$)
area radius ≥ 500 km

Pre-existing Cyclone (PC)
cyclone ($U_{south} > 0, V_{west} < 0, U_{north} < 0, V_{east} > 0$)
radius ≥ 400 km



Zonal Wind Convergence (CON)
In a 7.5°×30° north-south band, at least 12.5% latitudes have a convergence point ($U_{west} > 0, U_{east} < 0$)

Mixed Zonal Wind Convergence and Shear Line (CON-SL)

Classification of large-scale circulation patterns

Disturbance detection

- **cyclonic circulation radius ≥ 400 km**
- **maximum relative vorticity ≥ $3 \times 10^{-6} s^{-1}$**
- **displacement velocity ≤ 1000 km/day**

(e.g., Kerns et al., 2008; Peng et al., 2012; Gao et al., 2019)

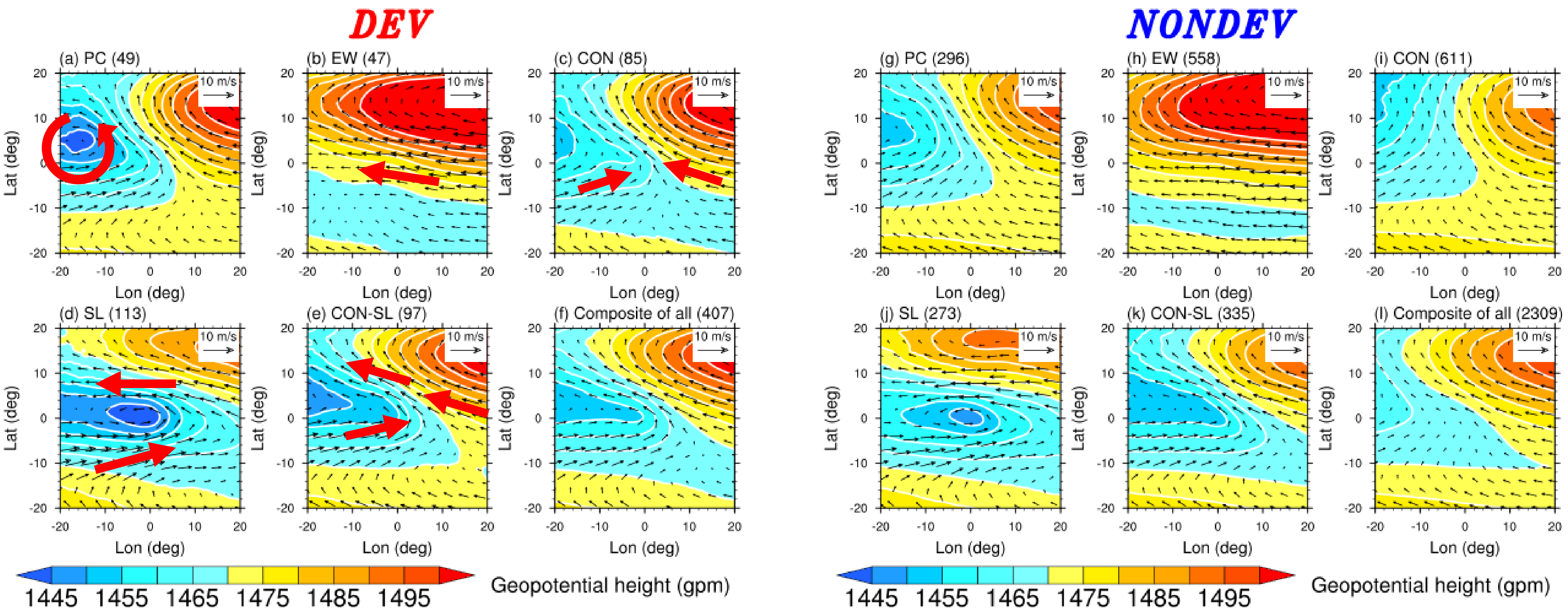
→ Develop into a TD?
Yes → Developing (DEV)
No → Nondeveloping (NONDEV)

Flow pattern	Number of disturbances		TC yield
	DEV	NONDEV	
PC	49 (12.0%)	296 (12.8%)	14.2%
EW	47 (11.5%)	558 (24.2%)	7.8%
CON	85 (20.9%)	611 (26.5%)	12.2%
SL	113 (27.8%)	273 (11.8%)	29.3%
CON-SL	97 (23.8%)	335 (14.5%)	22.5%
Unclear	16 (3.9%)	236 (10.2%)	6.3%
Total	407	2309	15.0%

least favorable pattern (EW)

most favorable patterns (SL, CON-SL)

Classification of large-scale circulation patterns



20-day low-pass filtered 850-hPa wind and height for the five patterns at 0 h

DEV and NONDEV in different large-scale patterns

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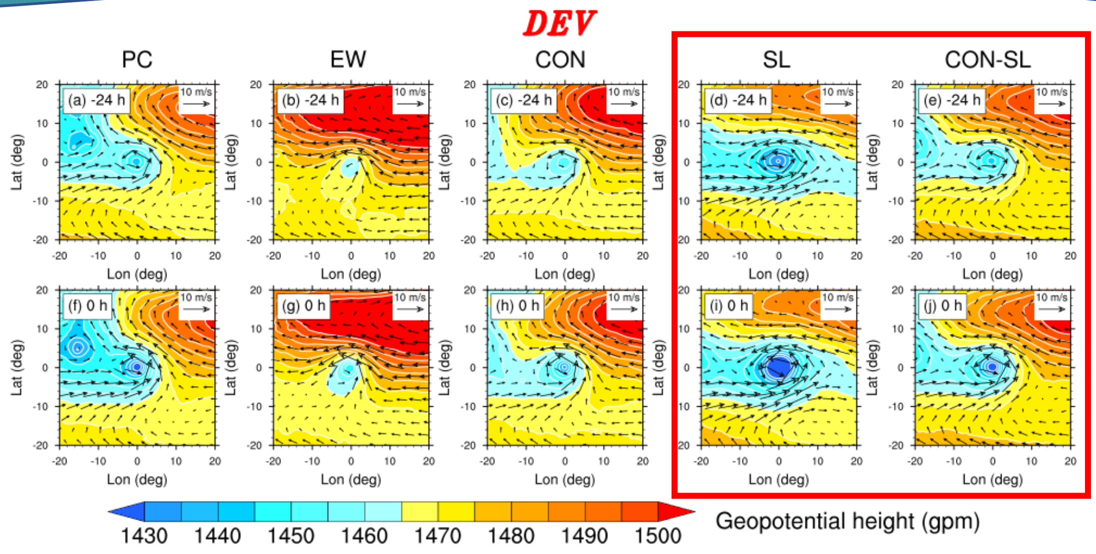
DEV intensifies rapidly approaching genesis

-24h

0h

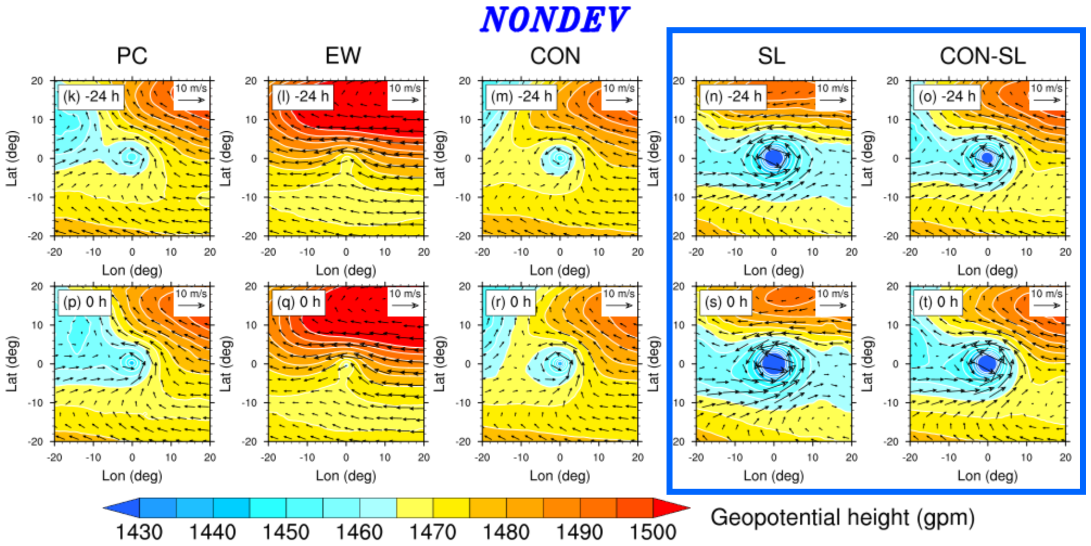


Rapid development

NONDEV remains nearly unchanged approaching its maximum strength

-24h

0h



Even stronger at -24 h, but develop slowly

Unfiltered 850-hPa wind and height evolution

DEV and NONDEV in different large-scale patterns

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A box difference index (BDI)

by Peng et al (2012)

$$BDI_D = \frac{m_{DEV} - m_{NONDEV}}{s_{DEV} + s_{NONDEV}}$$

m: mean
s: standard deviation

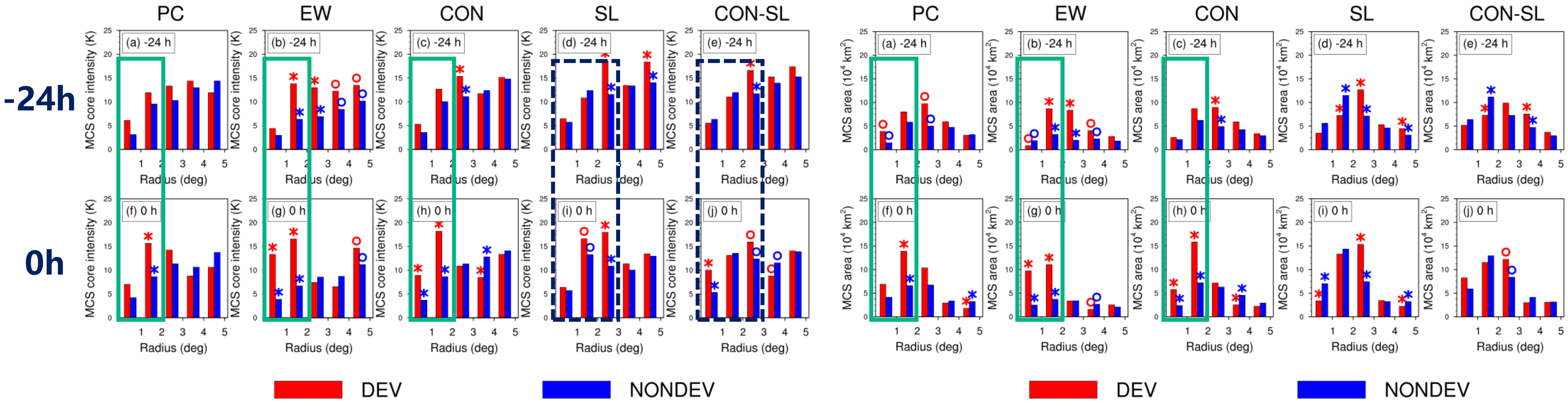
Variable	BDI_D				
	PC	EW	CON	SL	CON-SL
Dynamic variables					
200-hPa divergence	**0.42***	**0.65***	**0.42***	**0.20***	**0.22***
850-hPa convergence	0.02	**0.28***	0.11	0.01	0.05
850-hPa vorticity	**0.37***	**0.48***	**0.30***	0.05	-0.01
850-hPa vorticity growth	0.06	0.05	0.11	**0.17***	**0.13***
500-hPa vorticity	**0.33***	**0.46***	**0.29***	0.03	-0.01
500-hPa vorticity growth	0.06	0.04	**0.18***	**0.16***	**0.14***
850-200-hPa VWS	0.02	**-0.15***	-0.04	0.03	-0.01
Thermodynamic variables					
500-hPa relative humidity	**0.26***	**0.45***	**0.24***	**0.15***	**0.16***
Surface heat flux (SHF)	**0.26***	0.06	**0.17***	-0.04	0.01
SHF growth	**0.20***	**0.17***	**0.23***	**0.15***	**0.12***

The values are in bold with * when the difference between **developing and nondeveloping** disturbances is significant at a 95% confidence level.

DEV and NONDEV in different large-scale patterns

Roles of mesoscale convective systems (MCSs)

Criteria for MCSs within 500 km from the disturbance center, BT < 233 K, area ≥ 5000 km²



MCS intensity

Total area of MCSs

- **PC, EW and CON: DEV has stronger MCSs close to the disturbance center**
- **SL and CON-SL: DEV has deeper convection approaching genesis.**

DEV and NONDEV in different large-scale patterns

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Secondary circulation

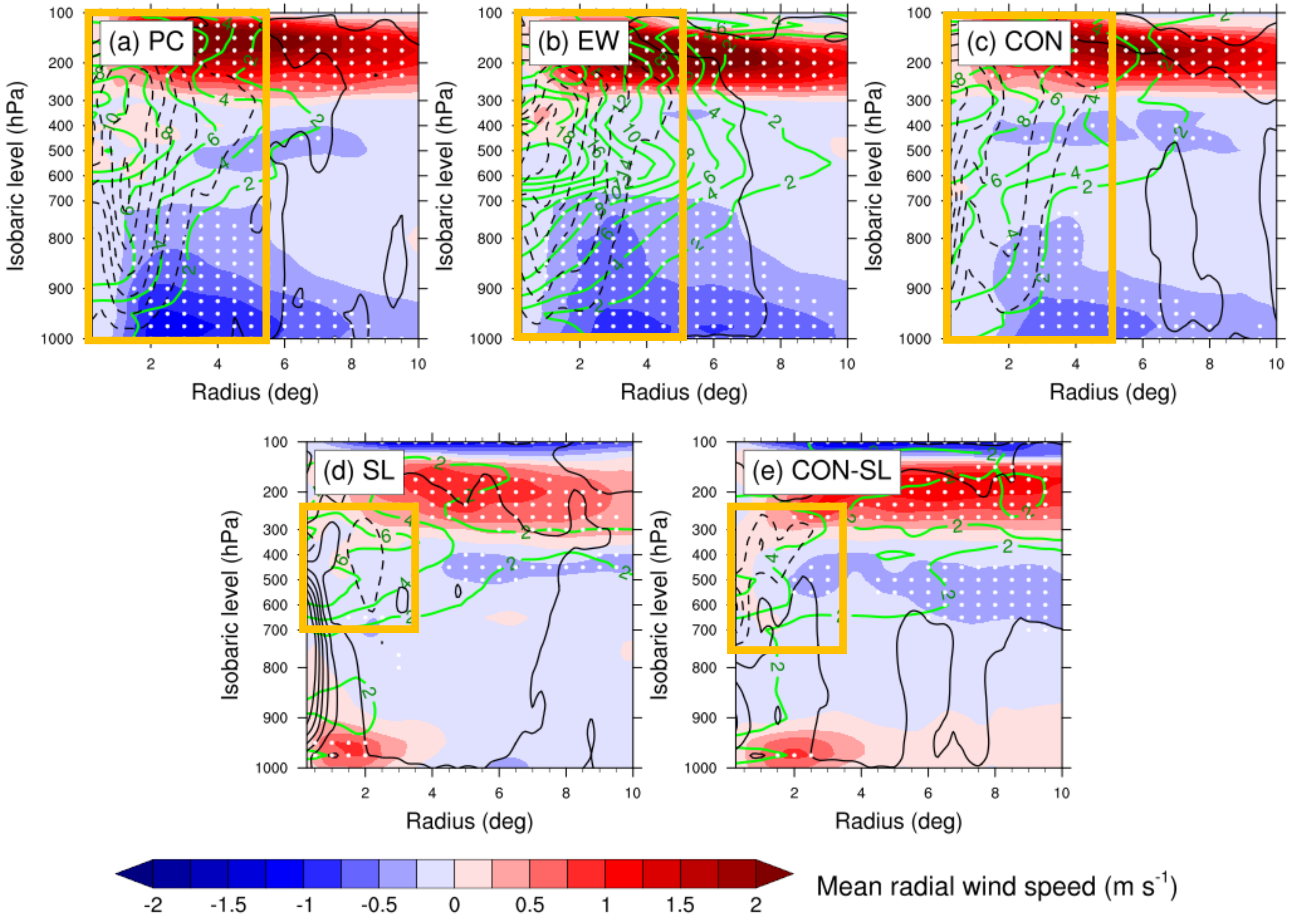
DEV has **stronger upper-level outflow**

PC, EW and CON

- **stronger boundary-layer inflow and whole-layer updrafts with DEV**

SL and CON-SL

- **NONDEV** has stronger boundary-layer inflow and updrafts but **less mid to upper-level moisture** and **weaker upper-level suction**



Azimuthally-averaged radial wind, vertical velocity (black) and relative humidity (green) difference between DEV and NONDEV

DEV and NONDEV in different large-scale patterns

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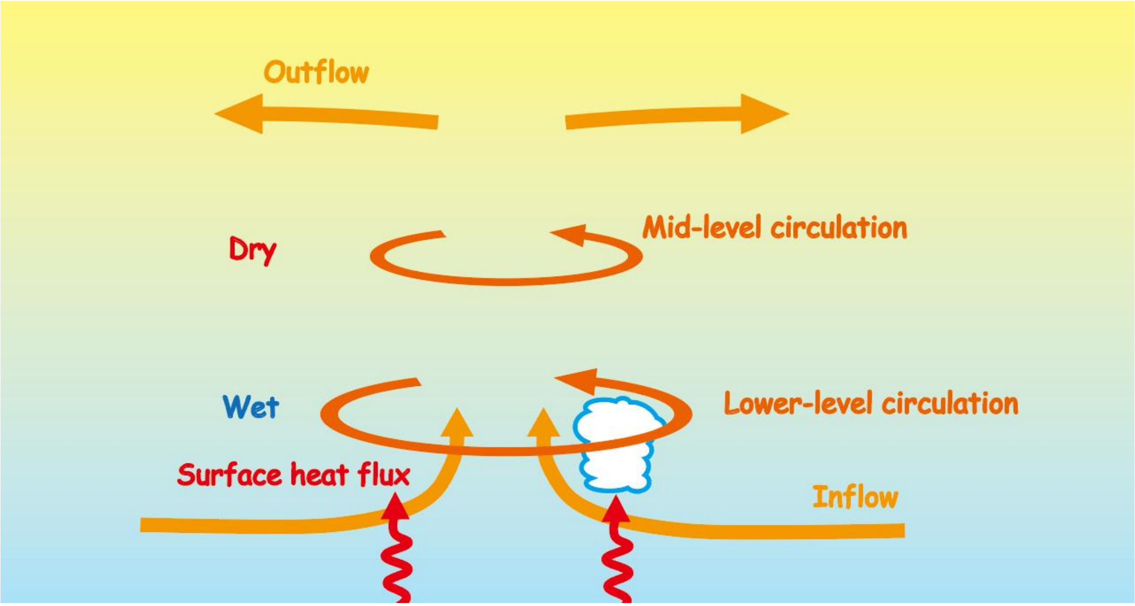
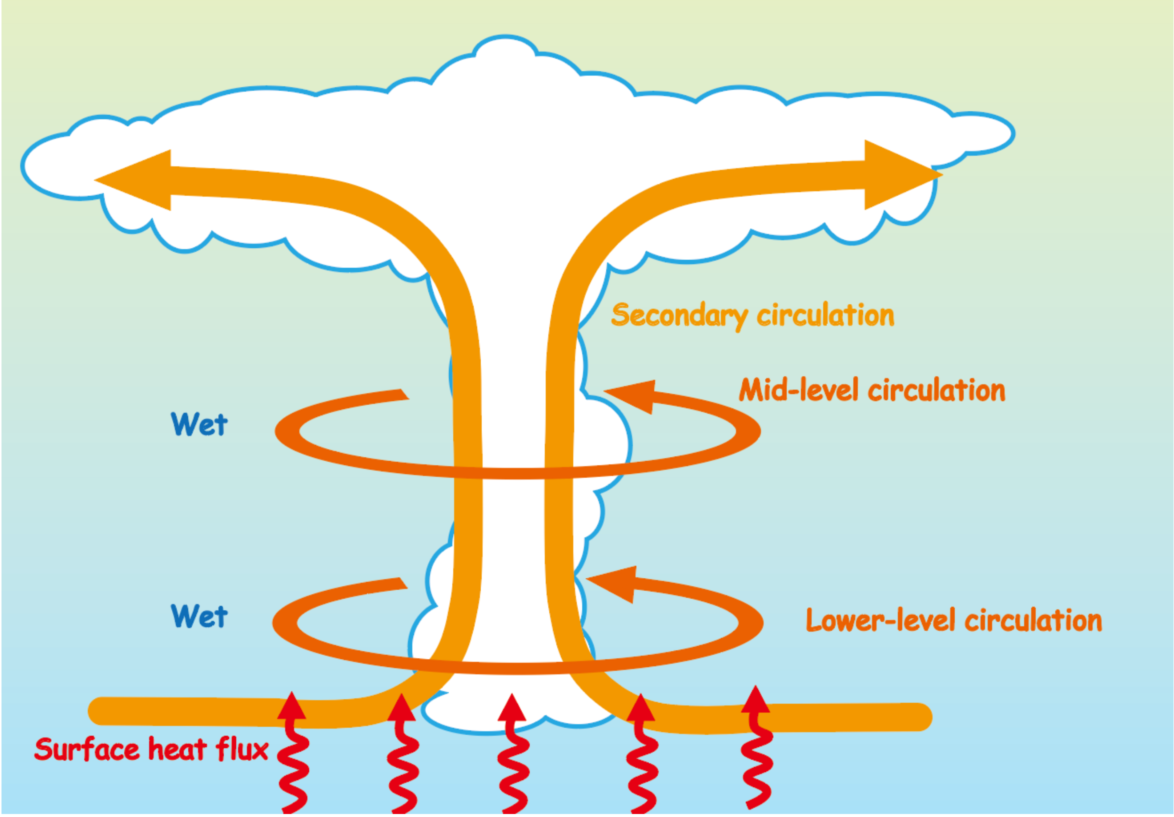
Key factors for disturbance development

- Active MCS close to the center
- Mature primary circulation
- Whole-layer moisture and updrafts



NONDEV in the PC, EW and CON pattern



DEV in the PC, EW and CON pattern

DEV and NONDEV in different large-scale patterns

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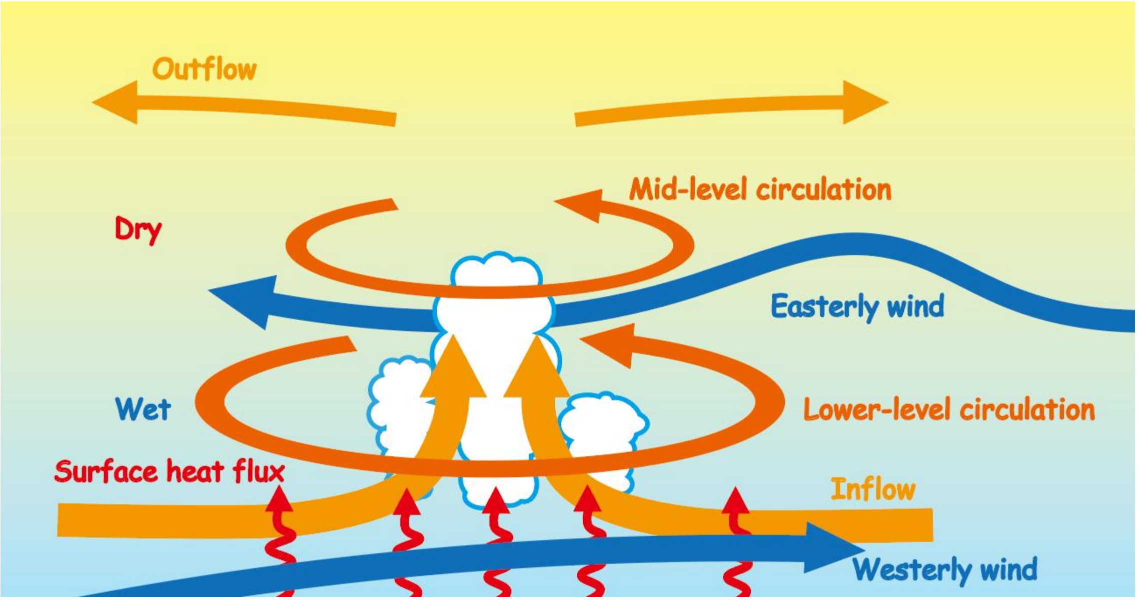
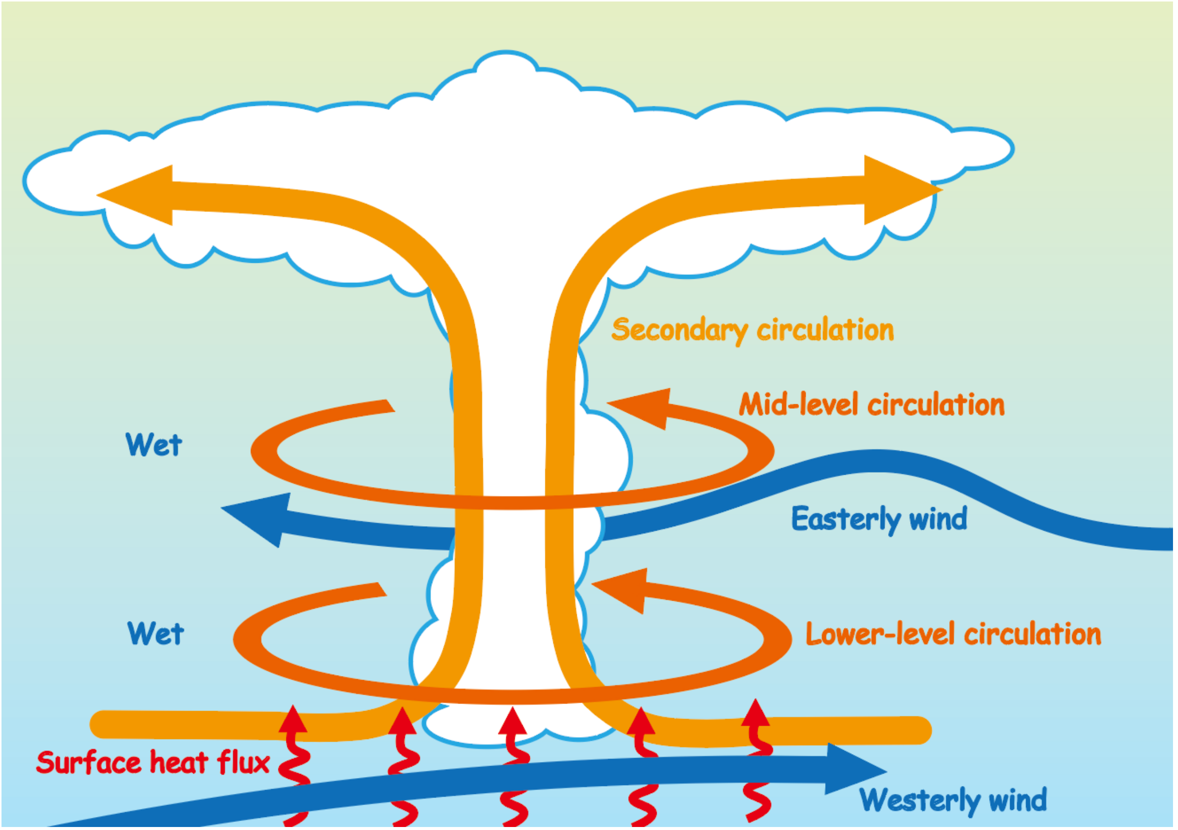
Key factors for disturbance development

- mid-level moisture
- sufficient upper-level suction



NONDEV in the SL and CON-SL pattern



DEV in the SL and CON-SL pattern

Conclusions

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- Over the WNP, large-scale **zonal wind shear line (SL and CON-SL)** remarkably **facilitates** TC genesis, while the **easterly wave (EW)** is the **least favorable** among canonical patterns.
- DEV benefits from **larger background westerly flows** in the south, and **intensifies more rapidly** approaching genesis time.
- In **PC, EW and CON**, **whole-layer moisture** is important, and **strong, large-area MCS close to the center** are crucial to disturbance development.
- In **SL and CON-SL**, both DEV and NONDEV usually have active MCS close to the center, with strong primary circulation, probably because of relatively **high environmental vorticity**. However, **drier mid layer in the NONDEV inhibits deep convection**, which may explain its **shallow secondary circulation** and therefore poor potential to develop further.

Thanks for your attention!

Wang, Z. and G. H. Chen*, 2023: Comparison between developing and nondeveloping disturbances for tropical cyclogenesis in different large-scale flow patterns over the western North Pacific. *J. Climate*, 37, 655–672, https://doi.org/10.1175/JCLI-D-23-0401.1.

DEV and NONDEV in different large-scale patterns

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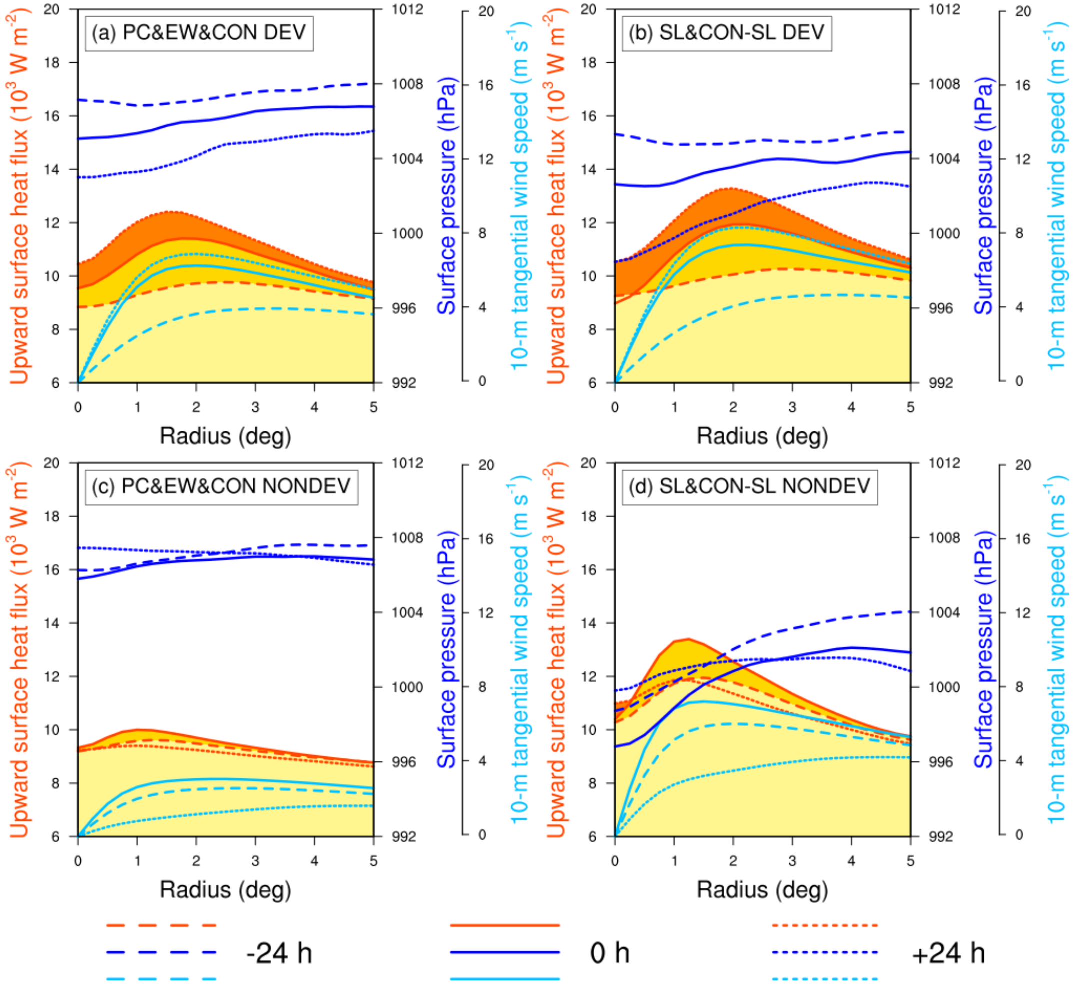
PC, EW and CON
DEV

PC, EW and CON
NONDEV
quite weak
from -24 h to +24 h



SL and CON-SL
DEV

SL and CON-SL
NONDEV
stronger at -24 h
weakened by +24 h

Composite azimuthally-averaged profile of
10-m tangential wind, surface pressure and SHF